

VERIFICATION, VALIDATION, AND ACCREDITATION OF HIGH LEVEL ARCHITECTURE FEDERATES AND FEDERATIONS

- A VV&A STRATEGY FOR LEGACY MODELS, SIMULATIONS, ALGORITHMS AND SOFTWARE COMPONENTS -

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ABSTRACT

A formidable task in the development, test, acceptance, and ultimately, accreditation of High Level Architecture (HLA) Federates and Federations is obtaining community consensus on appropriate verification, validation, and accreditation (VV&A) strategies for legacy models and simulations (M&S), including legacy code, which may be embedded. However, the verification and validation (V&V) of legacy components is essential to ensuring timely accreditation decisions for HLA Federates and Federations by DOD and Service Accreditation Authorities. AEgis Research proposes a VV&A strategy for legacy M&S, algorithms and software code components used in the development, test and acceptance for use of HLA Federates and Federations.

1.0 INTRODUCTION

The technical difficulties and costs associated with ensuring adequate V&V of legacy M&S are major challenges in successfully executing the HLA enterprise within the Department of Defense (DoD).

AEgis Research has successfully addressed VV&A of legacy M&S and software components in DoD simulation programs through execution of a rigorous assessment strategy which is focused and adaptable to the particular simulation object, or unit-under-test (UUT). We believe incorporation of an overall V&V evaluation activity identification process which considers each legacy M&S component in the context of its impact on the accreditation decision is the best means for ensuring program success. Our proposed VV&A strategy for legacy components includes:

- consideration of each M&S component in the context of its impact on the accreditation decision;
- a consistent process for identify a tailored set of V&V activities based upon the pedigree of the legacy entity, and
- explicit linkage of the nature and extent of V&V activities to the information data requirements of

the government's potential accreditation authorities.

2.0 BACKGROUND

The DoD has provided direction for M&S management and VV&A activities through promulgation of DoD Directive 5000.59, DoD Directive 5000.61, and the new DoD VV&A Recommended Practices Guide developed by the Defense Modeling and Simulation Office (DMSO). A review of these directives and the individual service component VV&A policies and directives indicates a growing consensus within DoD on the necessity to subject all M&S, especially those supporting materiel acquisition decisions, to a formal, structured program of V&V activities.

2.1 DoD Consensus on M&S VV&A

There exists a fair degree of commonality across all the DoD components in V&V strategies and methodologies. Of interest to the VV&A practitioner are not just these VV&A areas in common, but those special V&V areas of interest resident within only a specific Service or agency. A convenient paradigm to view the entire DoD set of VV&A guidance is provided in the Venn relational diagram in Figure 2.0-1, below.

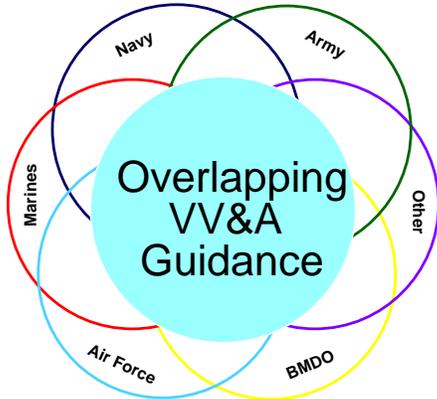


Figure 2.0-1. DoD M&S VV&A Paradigm.

Accordingly, any universal VV&A strategy proposed for legacy M&S utilized in HLA federates and federations must be effective across the wide range of DoD components and M&S programs and be accommodative to overlapping, and Service specific VV&A guidance domains.

2.2 M&S VV&A Policy Requirements

The DoD Directive 5000.59 instructed all DoD service components to establish VV&A policies and procedures for M&S applications managed by each service component. The individual services complied; formal M&S management and VV&A directives and points-of-contact (POCs) have been established across the DoD M&S community. These agencies develop and provide policy guidance regarding the adequacy and efficacy of verification and validation (V&V) programs. Key DoD and Service VV&A policy guidance available is identified in Table 2.2-1, below.

3.0 PROPOSED VV&A STRATEGY FOR LEGACY COMPONENTS

The VV&A of legacy components is essential to ensuring timely accreditation decisions for HLA Federates and Federations by DOD and Service Accreditation Authorities.

3.1 Central Concepts Applicable to HLA VV&A Programs

A few pivotal concepts, paradigms and representations which can be of assistance in defining and executing an HLA VV&A practice are introduced here [1].

Determinants of Confidence - Confidence in the use of an HLA Federation and Federates is the ‘bottom-line’ for accreditation. Several factors contribute to confidence in re-used legacy M&S components in HLA, including those related to included data, degree of demonstrated compliance to requirements, and degree of demonstrated ability to ‘predict’ real-world systems, processes, and phenomena. The accrual of V&V evidence and the preparation of accreditation recommendations for particular uses which preserve the audit traceability to the detailed V&V evidence can improve confidence in the HLA Federation and improve the prospects of successful accreditation(s). Any activities which improve a priori confidence in the use of an HLA Federation are properly part of the HLA VV&A program.

Dimensions of the Problem - The explicit indemnification of a VV&A problem domain or ‘analysis space’ will facilitate both the definition of a VV&A program for an HLA Federation and the exposition of accreditation recommendations. Views or dimensions essential to VV&A Program definition include:

- 1) V&V data products,
- 2) Unit-under test (UUT) or evaluation,
- 3) Evaluation activities,
- 4) VV&A Program resources, and,
- 5) V&V evaluation activity execution agent.

Object-Oriented Analysis -There is considerable value in a point-of-view which is essential object-oriented in planning any HLA V&V Program. UUTs are effectively objects and HLA Federations are a

AGENCY	M&S VV&A POLICY GUIDANCE	POCs
Department of Defense	<ul style="list-style-type: none"> • Department of Defense Directive (DoDD) 5000.59 • DoDD 5000.61 • DoD VV&A Recommended Practices Guide 	Defense Modeling and Simulation Office (DMSO)
Joint Chiefs of Staff	<ul style="list-style-type: none"> • Joint Staff Instruction (JSI) 8104.01 	J-8
US Army	<ul style="list-style-type: none"> • Army Regulation 5-11 • DA Pamphlet 5-11 	DUSA(Operations Research)
US Navy	<ul style="list-style-type: none"> • Secretary of Navy Instruction (SECNAVINST) 5200.38 	N81
US Air Force	<ul style="list-style-type: none"> • Air Force Instruction 16-1001 	XOM
BMDO	<ul style="list-style-type: none"> • Ballistic Missile Defense Organization (BMDO) Directive 5002 • BMDO Directive 5011 	BMDO - AQT BMDO - AQM

Table 2.2-1. DoD M&S VV&A Guidance.

composite object entity. From this point of view, it is useful to consider the characterization of HLA M&S in terms of object (or component) attributes, and how evaluation of the HLA Federation (or components) consists of the determination of the degree of correctness or acceptability of the values of such attributes taken singly and together.

Evaluation Activity - Establishment of an 'evaluation kernel' process-model suitable as a template V&V evaluation activity planning is expected to have the following particular advantages:

- 1) being able to completely populate the template demonstrates the soundness (completeness and consistency) of VV&A activities,
- 2) using the model clarifies the identification of the UUT of the subject evaluation,
- 3) using the model clarifies the identification of an explicit reference data baseline and comparison process, and
- 4) the model clarifies the necessity and use of goodness of fit criteria for evaluation comparison.

Obviously, the identification of attributes to be evaluated and the determination of evaluation criteria from the needs of accreditation is critically important. Such an 'evaluation kernel' provides a convenient framework for describing V&V activities and how the alternative formulations of the evaluation hypothesis (how good vs. good enough) may be accommodated.

Requirements Flow-Down - A clear process for flow-down of accreditation needs into V&V data products and findings, UUT, activities, resources and agents respectively is required for accreditation. Despite the mitigating circumstance of uncertainty in identification of the accreditation agent(s), intended use(s) and consequent accreditation information needs, such explicit requirements flow-down is worth attention. Practically, coping with such uncertainty by means of 'estimating' basic accreditation needs, documenting those requirements, and proceeding to work the problem, improving estimates incrementally, and preserving auditability of needs-to-results, is profitable.

Managed Investment - Considerable opportunities exist for managed, marginal investment in V&V activity by way of making deliberate progress toward accreditation goals. The V&V analysis space (and particularly an UUT-evaluation activity cross-walk

matrix) can serve as a tool in identifying an optimal managed investment program for executing activity and accumulating V&V evidence toward scheduled accreditation decision(s).

Development of an Audit Trail - Establishing an audit trail from accreditation needs / requirements to the designed evidence and to the details of V&V evaluation (manifest as UUT, reference information, evaluation comparison process, and evaluation goodness-of-fit criteria) will be particularly valuable for M&S VV&A. Contingent program planning may be promptly converged when a clear audit trail exists. Also, unanticipated extension of intended use and consequent accreditation needs may be best accommodated when a clear audit trail exists.

Compliance to Guidance - HLA V&V will be conducted in such a way as to be compliant simultaneously with alternative, somewhat ambiguous guidance. Also, M&S V&V will be planned and conducted in such a way that it is linked clearly to the accreditation authority for the intended use(s).

Integrated Product Team (IPT) Utilization - An IPT strategy, wherein the HLA VV&A program is planned and executed in such a way that the participation of the entire HLA community of interest is facilitated, shall be implemented. Particularly weapon-system and HLA M&S developers, user-analysts, and HLA-information-using decision-makers will cooperate, providing the best-focused and quickest-converging VV&A program possible.

Progressive Execution / Accumulation of Evidence - An explicit strategy of progressive definition and execution of HLA V&V and the time-distributed accumulation of V&V evidence pertinent to specific intended uses and associated accreditation(s) is expected. This approach is consistent with the circumstance of phased system development, alternative intended uses, and the strategy of marginal / managed investment introduced above.

3.2 VV&A Strategy for Legacy M&S

Any overarching VV&A strategy proposed for legacy M&S must be effective across the wide range of DoD components and M&S programs and should satisfy all, or most of the objectives outlined below. First and foremost, the VV&A strategy must support the standardization of M&S assessment activities and associated data, and the archiving of VV&A data into a standardized relational database structure consistent with DoD guidance, policies, and procedures. Satisfying this key objective will facilitate M&S re-use

and, over time, will reduce the costs associated with “stove pipe” M&S development and maintenance.

Secondary objectives for any proposed VV&A strategy should also include:

- 1) being responsive to the information needs of the Accreditation Authorities,
- 2) supporting an accreditation decision which allows the use of HLA generated data to be used in support of materiel acquisition decisions; and
- 3) complying with VV&A guidance applicable to M&S used to support acquisition decisions for Major Defense Acquisition Programs (MDAPs).

3.3 Proposed Legacy VV&A Methodology

AEgis Research has successfully addressed VV&A of legacy M&S and software components in DoD simulation programs through execution of a rigorous assessment strategy which is focused and adaptable to the particular simulation object, or unit-under-test (UUT). We believe incorporation of an overall V&V evaluation activity identification process which considers each legacy M&S component in the context

of its impact on the accreditation decision is the best means for ensuring success.

The VV&A strategy proposed for legacy M&S components is based on an initial assessment of the entity’s previous VV&A status which then provides alternative paths leading to their re-use and accreditation within HLA federates and federations. Based upon the entity’s prior VV&A status, the execution of additional V&V activities required due to changes in the M&S component’s “intended use”, and, or changes in the M&S code made that were made by the developer for it to successfully function within the HLA, can be identified and conducted.

To establish the pertinent regimen for VV&A of a particular M&S, or component, an analyst should consider the VV&A status of the object and identify previous V&V activities in order to minimize cost, and eliminate redundancy in the VV&A program. The accreditation decision process flow for legacy M&S components which can be derived from this initial assessment are illustrated in Figure 3.3-1, below.

Generally, a legacy simulation or model component may be assigned to one of four “states” for the purpose of identifying the extent of required V&V activities anticipated to meet an accreditation decision:

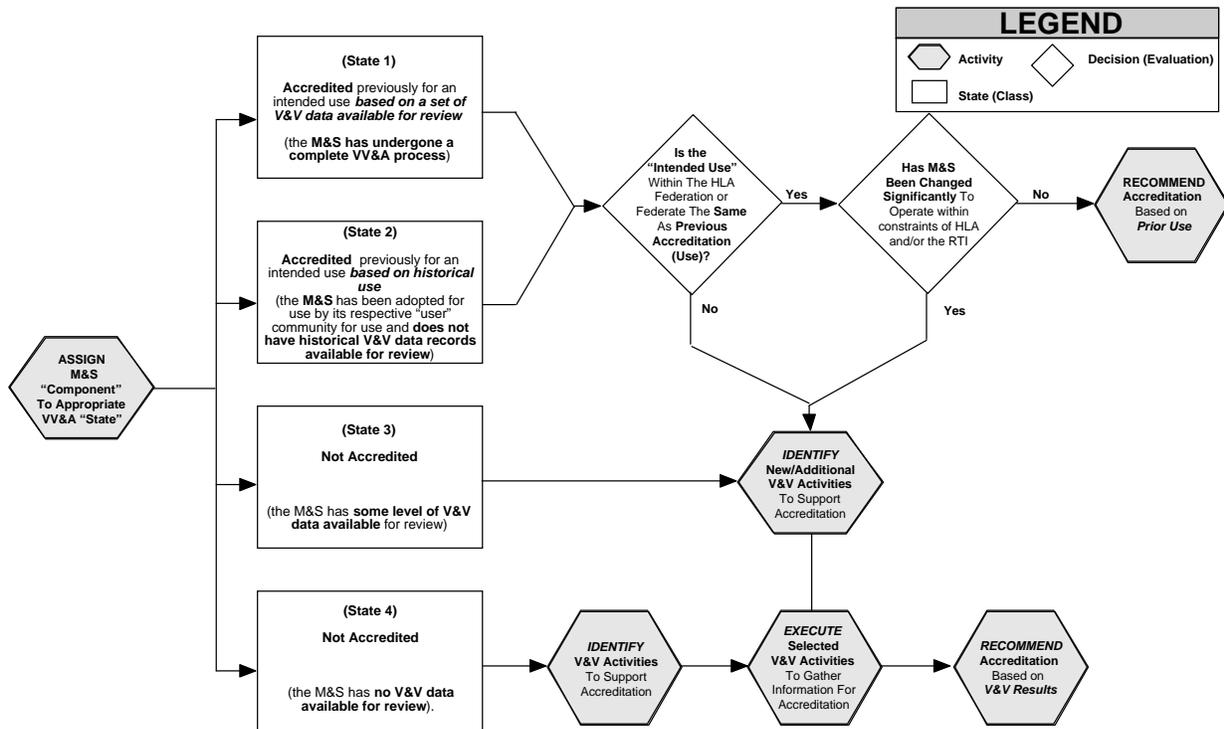


Figure 3.3-1. VV&A Program Definition Process Flow For Legacy M&S Components

- 1) *Accredited previously* for an intended use *based on a set of V&V data available for review* (the M&S has undergone a complete VV&A process);
- 2) *Accredited previously* for an intended use *based on historical use* (the M&S has been adopted for use by its respective “user” community for use and does not have historical V&V data records available for review);
- 3) *Not Accredited*, but *some level of V&V data available for review*; and
- 4) *Not Accredited*, with *no V&V data* available for review.

The development of a particular V&V program of activities is built on this initial assessment of the legacy M&S component by providing alternative paths leading to its use and accreditation within an HLA Federation or Federate.

Once a component is assigned to a specific “state”, then from that flows an accreditation strategy that complies with Service guidance and determines the scope of V&V activities required to support the evaluation process. However, this inchoate assessment and assignment of GE M&S components to a particular class is not necessarily as easy, or direct, as this functional flow diagram may indicate.

AN EXAMPLE CASE

The employment of these alternative accreditation paths can be depicted through an example case. For this paper, a model for rain induced attenuation of radio frequency (RF) signals will be used as an example to illustrate this strategy. Using an example will demonstrate its utility in determining the type and extent of V&V program activities which may be required for accreditation.

The first step in the process requires assignment of the model to the appropriate VV&A state. This initial decision is based upon available model documentation provided by the M&S proponent or developer. Review of the documentation for the model provides key information which bears on its assignment to the appropriate VV&A state.

For example, the model development documentation available indicates that the model for rain induced attenuation RF signals is based on the community accepted Crane algorithm [2]. The Crane algorithm determines the RF signal attenuation based on a

statistical rain model for which the yearly rain rate percentage is the primary input.

As a function of system location, this yearly rain rate percentage is used to define the absolute 1 minute average point rain rate, in millimeters per hour. The rain rate, signal frequency, and propagation path geometry are then used to compute one-way RF signal attenuation. The model is applicable to radar operations, and ground-to-space communications and space-to-ground communication link performance for which the attenuation will be a function of propagation path elevation angle.

In this example, a *community accepted algorithm* was selected and used by the M&S proponent or developer as the basis for *developing a model*. This leads to a set of questions that are generally applicable to any M&S software component:

- 1) What software V&V was performed by the developer, and what documentation exists to report the results?
- 2) What software V&V was performed independently of the developer [independent software verification and validation, or IVV], and what documentation exists to report the results?
- 3) Based upon the overall environment model and intended use of the Federation or Federate, what additional tests may be prudent from an M&S VV&A perspective; i.e., making the judgment that its is acceptable for use in the intended application? Examples of additional evaluation methods which may be appropriate include comparisons to actual field tests and exercise results.
- 4) Are the limits or constraints of the model or simulation known and documented? Will its use within the Federation or Federate be outside these recognized boundaries?

Legacy M&S Assignment To A VV&A “State” - In this example, let’s assume the M&S developer documented development of this particular model in several reports. Collectively, these reports document the development of the Crane RF Rain Attenuation Model and provide answers to some of the above questions, but not all. For example, the first report provides complete descriptions and listings for the original source code for the FORTRAN routines,

including purpose, inputs, outputs, methodology, and limitations. However, it does not provide the code to which these routines were converted for subsequent implementation in HLA, nor identify what CASE tool or method was used to perform this conversion. This begs the question, “What software tests were performed after the model’s conversion to ensure that no errors were introduced in the process?” For purposes of illustrating the process flow, assume no reports provide information to answer that question.

Let us also assume that this documentation offers no evidence that the model has been independently accredited for use by any accreditation authority, or previously used or accredited for any other program. Consequently, the model, lacking any additional supporting documentation, *would be assigned to the third state* defined in Figure 3.3-1, above, “**Not accredited, but some level of VV&A data available for review**”.

Identification Of Additional VV&A Activities - The proposed accreditation path then indicates the next step is identifying the additional M&S V&V activities which will provide information to support the accreditation decision. To make this determination, further review of the developer’s documentation is required to identify potential shortfalls, or issues, which need to be addressed; and to ensure data is available to answer challenges to the model that may arise during the accreditation process.

Leveraging Lessons-Learned - This VV&A strategy strongly leverages existing process models, previously conducted V&V efforts, and findings for: concepts, strategic and tactical approaches, procedures, and reporting formats.

Needs-Driven V&V - The V&V activities identified for execution and formal documentation in the M&S

V&V Plans should be selected with the goal of satisfying the fundamental data needed for accreditation decisions. The V&V activities definition will be driven by data requirements which will support BMDO and other government agency accreditation decisions. The accreditation decision data requirements are expected to influence the identification and selection of V&V data products during the V&V activity definition / design process (see Figure 3.3-2, below).

The V&V data products are subsequently flowed down to entities to be evaluated (units-under-test), then to pertinent V&V activities (with associated procedures and evaluation criteria), and finally to the agents or staff resources necessary to execute the activities. Identification of the accreditation data requirements, V&V data products, associated UUTs, applicable V&V activities, and V&V agents comprise the V&V Plan.

Execution of Selected V&V Activities - The proposed accreditation path’s next step is executing these additional M&S V&V activities to gather the information needed to support the accreditation decision. The V&V planning for the legacy M&S components can be defined in terms of a generic evaluation process which is applied within a V&V “evaluation activity space” (see Figure 3.3-3). Dimensions of the evaluation space consist of: a) a Unit Under Test (UUT), b) an evaluation *activity*, c) an evaluation *agent*, and d) a data *product*. These dimensions define the cells of the V&V candidate evaluation activity space.

From this candidate space, a subset of actual evaluation activities can be selected using an incremental and managed investment strategy. The V&V evaluation products can be further defined in terms of this evaluation activity space. The V&V evaluation product is a function of the V&V evaluation agent executing a pertinent evaluation activity on a UUT of interest.

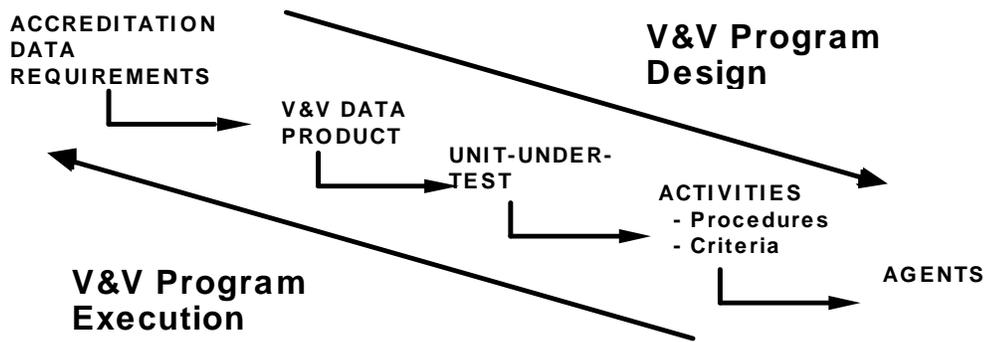


Figure 3.3-2. Needs-Driven V&V Activity Design And Execution.

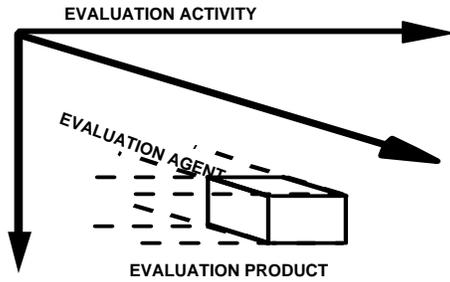


Figure 3.3-3. V&V Evaluation Activity Space.

Identifying such an explicit V&V domain-of-interest assures a complete and systematic consideration of the evaluation opportunities of the test resource and pertinent M&S. It provides a synoptic view of V&V evaluation activities so that the most cost-effective of the activities may be elected for execution as needs dictate and as resources permit.

UUT Decomposition - Units-under-test (UUTs), are the specific components of the legacy M&S that are evaluated using applicable V&V evaluation activities and making judgments about their adequacy.

Managed Investment - Managed investment is the execution, from all the possible, candidate V&V activities, of a carefully selected subset of V&V activities. This is graphically illustrated in Figure 3.3-4:

- 1) offering the “best return on investment” by providing the essential information necessary for V&V reports findings, and
- 2) providing the evidence required to support the accreditation decisions of Service and DoD agencies and activities.

As a consequence, cost as an independent variable is considered during the selection and execution of the V&V activities for the legacy M&S component.

The V&V activities subset is chosen based upon the:

- 1) accreditation data needs,
- 2) realities of the M&S program, and
- 3) fixed resources available for V&V.

As the most cost-effective set of cells within the space of possible activities, the actual V&V evaluation suite subset of V&V activities constitutes an optimal investment in V&V. The next cell implemented will be one that provides the best marginal return on investment for the expended resources in terms of the value associated with the accreditation data product developed.

This managed investment strategy addresses the problem of specifying scope and detail of V&V activities and allows near-optimal investment in V&V activities and products for an economically constrained environment. This investment strategy provides for a deliberate and progressive outlay of resources that garners the information necessary to support accreditation decisions. Thus, an actual V&V evaluation suite can be identified which is the most cost-effective within the space of possible candidate activities. This sub-domain constitutes an optimal investment within program resource constraints.

Accreditation Recommendation - Finally, the last step in the process is recommending accreditation of the model based upon the information gathered.

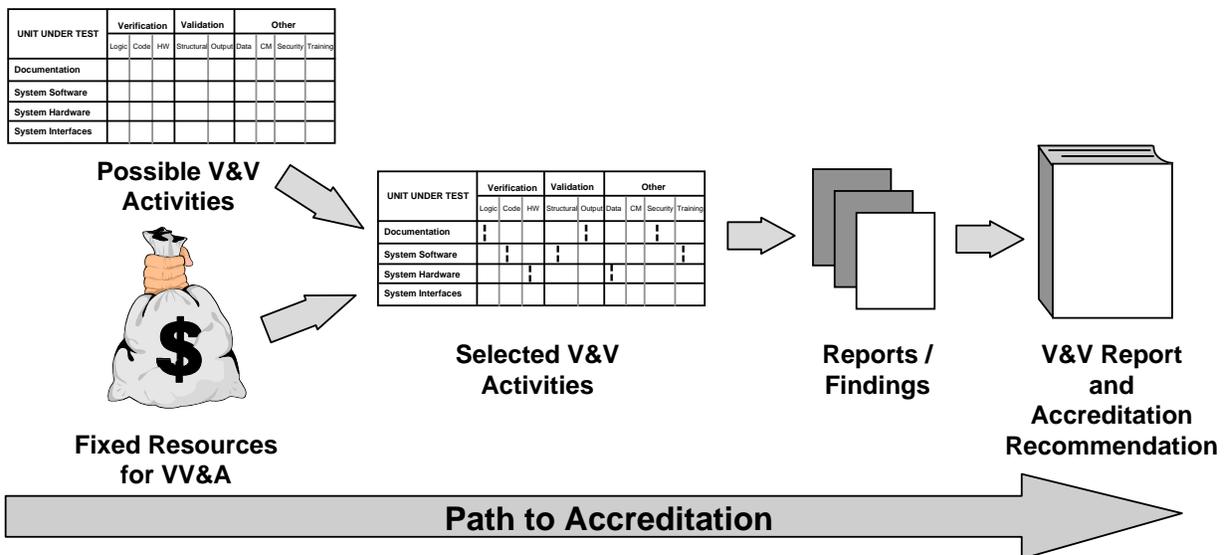


Figure 3.3-4. Managed Investment of Resources Supports VV&A Program Definition.

This is but one example, but it serves to illustrate the process and difficulties in determining the magnitude and type of V&V required for a particular model within an HLA Federation or Federate.

4.0 SUMMARY

There is *broad guidance* available upon which to structure a VV&A Program Plan for legacy M&S components used in HLA Federations and Federates. However, there is no one, single path which leads to their accreditation.

For each Federation or Federate, legacy M&S components will need to be reviewed initially and categorized with respect to current VV&A state in order to derive an appropriate VV&A regimen. The expectation is that, even though M&S legacy models may be based on community accepted algorithms or data, most are not previously accredited models that can be used with little or no associated VV&A activity. Even when a legacy M&S component is obtained from another government program, or agency, this same basic methodology applies: *establish its current VV&A status to derive an acceptable accreditation path.*

5.0 REFERENCES

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6.0 ABOUT THE AUTHORS

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