

# PLANNING FOR VV&A: AN EXAMPLE

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## 1. INTRODUCTION

### 1.1. PURPOSE

This paper describes the development of Verification, Validation, and Accreditation (VV&A) Program Plans for the Extended Air Defense Test Bed (EADTB). The strategies, techniques, and methods presented herein may be used as guidance to develop similar Program Plans for a wide variety of simulation and test bed systems.

### 1.2. OVERVIEW

This paper addresses a systematic approach to the VV&A of complex models and simulations (M&S), simulation test beds, and distributed interactive simulations (DIS). Definitions of terms and the current state-of-the art are discussed. Department of Defense (DoD) policies and practices are reviewed. A few critical concepts are introduced which are fundamental to establishing a tailored V&V program. These notions are considered valuable not only for their utility in underlying the EADTB VV&A program definition, but for their potential application in other related contexts. The process by which VV&A Program Plans may be developed methodically is delineated, and the typical results of such a process in terms of VV&A Program activities, schedule, resources, and products are indicated. Issues characteristic of VV&A for test beds and distributed simulations are identified and ameliorative strategies are proposed. Finally, application of the VV&A program planning process and tailoring all VV&A programs in response to characteristics of particular simulations and test beds and to the needs of the user communities are addressed. The results of employing the recommended planning process are described. Finally, the proposed approach is demonstrated to be very general and readily applicable to other models and simulations.

## 2. DISCUSSION

In the discussion which follows, we address briefly the background of the current research in the context of VV&A state-of-practice in industry and in DoD in particular. Next a few particular concepts and strategies which are fundamental to EADTB's VV&A program planning are introduced. Problematic issues associated with the EADTB VV&A program planning and execution are identified and solutions are suggested which may have wider application to test beds and distributed simulation architectures.

### 2.1. BACKGROUND

The context and motivation of the subject research is discussed briefly in the sections which follow.

#### 2.1.1 Extended Air Defense Test Bed (EADTB)

EADTB development is managed by the Test Bed Product Office (TPO) of the U.S. Army Space and Strategic Defense Command (SSDC). The EADTB Program entails active coordination with Army, Navy, Air Force and North Atlantic Treaty Organization (NATO) agencies as well as with United Kingdom and Israeli collateral test bed components. With recent delivery of initial operational capability, the EADTB product will support material developer, combat developer, and operational commander user-communities. It will provide the capability to define, execute, and analyze digital analytical (i.e., construction) and, eventually, Man-in-the-Loop (MIL) / Hardware-in-the-Loop (HWIL) / Software-in-the-Loop (SWIL) (i.e., virtual) simulation experiments of a wide range of military systems and operations. The scope of simulation representation for extended air-defense includes anti-tactical ballistic missile defense (including active defense, passive defense, and counterforce operations); air-breathing threat; satellite-, ground-, and air-based sensors; land-based and sea-based air operations; electronic countermeasure (ECM); explicit

adaptive command, control; communications; pertinent weapons effects environments; and terrain and atmospheric phenomena. This scope of phenomena is modeled in a simulation environment which is object-based, data-driven, open-ended, symmetric, and interactive. The full EADTB system includes test bed experiment definition, execution, and analysis tools; and distributed nodes are currently planned for Fort Bliss, NATO's SHAPE Technical Centre, Kirtland Air Force Base, the National Test Facility, and a Navy site to be determined.

### 2.1.2. Need for Explicit VV&A

The need for explicit verification, validation, and accreditation of models and simulations, particularly in the DoD environment, is becoming increasingly clear. Declining budgets are forcing decision makers to rely less on expensive testing and more on the results of simulation-based systems analyses. This is true at all phases of the system life-cycle. In response, many new M&S are being developed. Some of these employ virtual environments, distributed architectures, or other new technologies. While

these new M&S offer improved capabilities for system analysis and evaluation, they require substantial investment for development and for operation and maintenance. The expense of these assets and the importance of the decisions they will influence, demands that their capabilities and limitations be clearly understood and their credibility firmly established. The EADTB is a good example. Not only is it the result of a major system development program, but its use will influence many important decisions in the future. It will have an impact in System designs and architectures, military tactics, and operations.

The essence of verification, validation, and accreditation is to establish the degree to which decision-makers may have confidence in the results of studies and analyses conducted using the M&S tool. The scope of evidence which is pertinent to that determination is indicated in the illustration of Figure 2.1.2-1 in which the domain of M&S verification and validation activities is highlighted. Much of the V&V process will be seen to consist of generating, organizing, and reporting in auditable form the evidence by which an accreditation decision may be predicated.

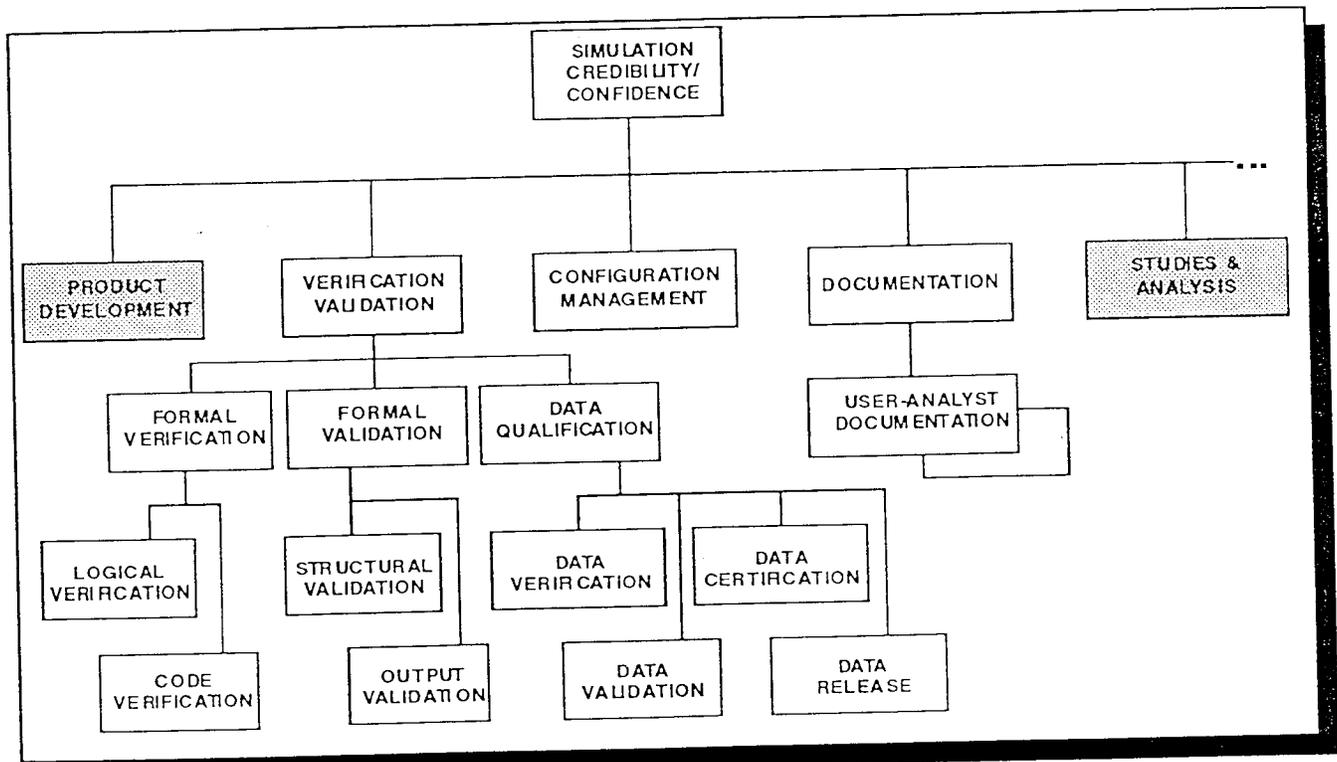


Figure 2.1.2-1 M&S Confidence Assessment Scope-of-Evidence

### 2.1.3. State of Practice

In recent years there has been significant activity in the area of VV&A of M&S within the DoD. As a result, VV&A in

this community has evolved to a relatively stable and self-consistent state-of-practice. The EADTB VV&A Program Plans have been developed to be consistent with this current state-of-practice. Definitions of terms are provided below<sup>1</sup>

which are widely accepted and consistently (and literally) employed in developing EADTB VV&A program activities:

**VERIFICATION** - the process of determining that the models and simulations accurately represent the developer's conceptual description and specification (...is it what I intended?)

**VALIDATION** - the process of determining the extent to which models and simulations accurately represent the real-world from the perspective of their intended use (...how well does it represent what I care about?)

**ACCREDITATION** - an official determination that the model / simulation is acceptable for its intended purpose (...should my organization endorse this simulation?)

Formal directives and points-of-contact are being established for DoD simulation VV&A. These are indicated in the table of Figure 2.1.3-1 and are cited in the endnotes.<sup>234567</sup>

AGENCY	DIRECTIVE	POCs
DOD	DOD 5000.29 (draft)	DMSO
ARMY	AR 5-11 and PAM 5-11	DUSA-OR
NAVY / MARINE	SECNAV Instruction (draft)	N81
AIR FORCE	DRAFT Plan (draft)	Director M&S (XOM)
BMDO	BMDO 5002 (draft)	BMDO/AQT

Figure 2.1.3-1 VV&A Guidance

Complementary guidance is available via individual memoranda of agreement (MOA's), distributed interactive simulation (DIS) standards and publications of technical societies (IEEE, SCS, etc.). This guidance is adequately defined for implementing a reasonable program, and the EADTB VV&A Program Plan is intended to be materially compliant to this set of directives.

### 2.1.4. EADTB Program Plan

Notwithstanding the recent visibility of VV&A and the publication of guidance for the practice of simulation verification and validation, detailed practical procedures for VV&A are not generally available and exemplative applications are rare. The TPO is committed to the deliberate development and implementation of a plan for verification, validation, and accreditation which is reasonably integrated into the overall EADTB Program Plan. Effort reported in this paper is intended to establish a program of VV&A activity which is: 1) compliant with evolving guidance (Multi-Service and DoD) and state of practice, 2)

tailored to the circumstances of EADTB development process and test bed product characteristics, and 3) pro-active in building the audit trail to provide evidence necessary and sufficient for confidence in EADTB simulation results.

## 2.2. EADTB VV&A CONCEPTS AND STRATEGIES

There are four elements which comprise the foundation of the EADTB VV&A Program. This set of concepts and operational strategies is neither completely original nor necessarily exhaustive of prospective standard practice; and they are in any case more honored in the breach than in the observance - but at best they reflect conceptual paradigms which are particularly effective in this context.

### 2.2.1 Requirements-Driven Program

Requirements for the EADTB V&V Program are driven from the top-down, while design is built from the bottom-up. This chestnut of systems engineering is novel only insofar as its implementation is taken seriously. Since the goal of VV&A activity is to achieve the appropriately qualified accreditation of a given tool for a given purpose, it makes sense to start by identifying the basis of such a judgmental decision, infer the forms of evidence sufficient to support a positive outcome, and further derive the means to generate and prepare for review and deliberation such evidence as is necessary and sufficient. This process is indicated in the illustration of Figure 2.2.1-1, where requirements flow downward and implementation is imagined to be the inverse traverse. Particular steps in the ladder-down of requirements are discussed in detail below.

Difficulties exist, of course, in anticipating the accreditation agent's criteria, and preferences for evidentiary support. Still, the expedience of assuming those positions and then building a program of action while preserving the audit trail of requirements traceability to serve as a ready basis of possible tailoring is a practical, effective, and reasonably low-risk strategy.

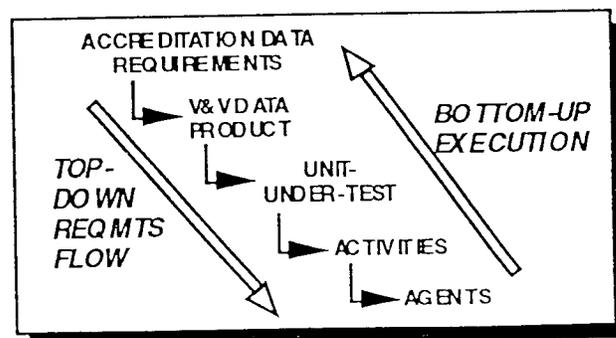


Figure 2.2.1-1 VV&A Requirements Flow-Down

### 2.2.2. Test Bed Evaluation Space

The second significant concept used in EADTB VV&A program definition is also a familiar one - it is the systems engineer's multi-dimensional manifold whose dimensions exhaust the important attributes of his conceptual space. Here we posit an 'evaluation space' whose (relatively orthogonal) dimensions consist of: 1) V&V activities, 2) V&V agents, and 3) units-under-test. The points or cells in this evaluation space represent the V&V data products which are produced when a V&V agent carries out a V&V activity to evaluate a particular unit-under-test. This space is indicated (imperfectly) in the diagram of Figure 2.2.2-1.

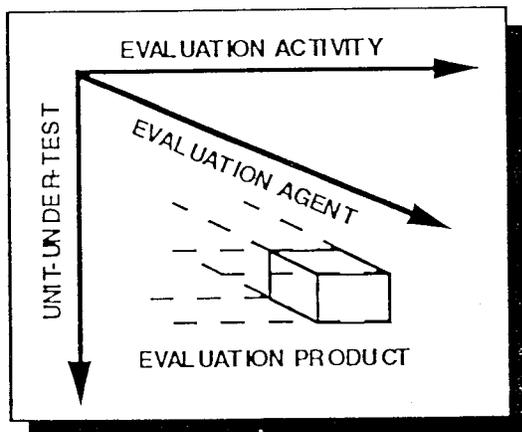


Figure 2.2.2-1 EADTB V&V Evaluation Space

Each dimension is described in detail in the paragraphs which follow, after which the use of this construct in mapping-out and populating a practical plan-of-action is indicated.

EADTB V&V Program products comprise the evidence for accreditation decisions. Evaluation product requirements are implied by needs of users and accreditors. Classes of V&V Program products include: 1) V&V administrative documentation (Accreditation Plan and Report, Software V&V Plan, etc.), 2) system documentation (System Specifications, System Designs, CM Plan, User's Guide, Training Materials, etc.), 3) system evaluation documentation (CDR; TRR; Test Plans, Descriptions, Results, Reports, etc.), and 4) reports generated by other evaluations (Requirements Analyses, CM Reviews, Subject Matter Expert Evaluations, IV&V Analysis Reports, etc.).

**Units-under-test** are those components of the EADTB to which V&V evaluation activities apply and upon which judgments are made. Because the EADTB is at once a simulation tool kit and a set of system specific models, several entities exist which need to be verified / validated to establish user confidence and product credibility. Several

candidate components or facets of the EADTB are indicated by the items enumerated in Figure 2.2.2-2.

Naturally, the design of verification / validation exercise activities depends on the nature of the UUT (for example, we may validate analytical models, verify code, validate system models, certify (validate) data, etc.). Because the variety of entities which comprise EADTB is so large and because the items are themselves so disparate and require such a variety of evaluation procedures, explicit identification of UUT's is imperative.

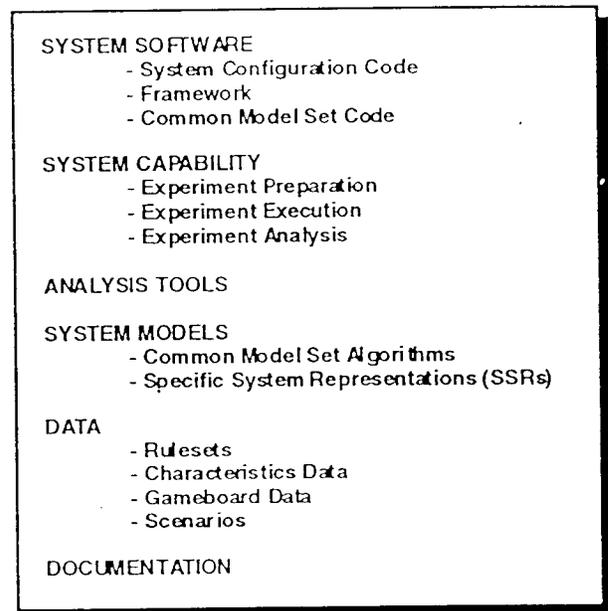


Figure 2.2.2-2 EADTB V&V UUT Candidates

Classes of potential EADTB V&V activities include those indicated in the list of Figure 2.2.2-3.

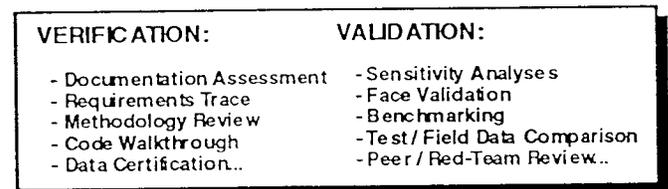


Figure 2.2.2-3 VV&A Activity Classes

Several considerations are pertinent to V&V activities planning. First, activities definition requires careful specification of evaluation procedures and criteria. Second, details of activity specification effectively defines the V&V program - activity flow and duration determine program schedule and the choice of V&V activities determines level-of-effort resource requirements. Finally, every V&V activity should be required to yield a valuable data product.

A wide variety of agents are available to contribute to the execution of activities which comprise the EADTB V&V Program. Each has its own role and is the appropriate executor of one of more activities. The TPO is responsible for program strategy and oversight. The Prime Contractor provides systematic product development, system / software / model verification, testing, and documentation. The SETA contractor conducts document reviews, subject-matter-expert (SME) reviews, and engineering analysis. AMSAA contributes to the development of V&V program strategy, conducts data certification and provides SME support. The IV&V Contractor conducts a wide range of independent reviews. Nodes custodians / users are expected to conduct documentation review, provide SME support to simulation-to-simulation comparisons, and conduct peer reviews, and hands-on operational evaluation. Weapon system product offices will provide SME support for specific system simulation representations, certify characteristics data, and evaluate simulation prediction of system performance / effectiveness. Other agents within the joint service community will provide SME support, specialized analyses, and senior reviews. Coordination among a diverse set of V&V agents is required to execute a balanced, comprehensive program.

For EADTB, a crosswalk of activities versus UUT's was prepared as an Excel spreadsheet, in which the cells contained comments on designated agents and expected data products. Definitions-of-terms for the matrix entries were developed and published to facilitate coordination and to establish common terms of reference among the V&V team. This representation of the evaluation space (i.e., the space projected onto the activities-UUT plane) has been a valuable representation of V&V program activity, a convenient medium to support the balancing of 'investment' in V&V activity, and a simple form from which to generate estimates required for execution of the proposed program. Such a representation assures a systematic, complete (not exhaustive) basis for description and revision of the proposed V&V Program.

### 2.2.3. Evaluation Kernel Process-Model

Verification and validation are forms of evaluation or judgment of the merit of a model and simulation tool with respect to some specific application or class of application. It entails evaluation of components or facets of the tool, and eventually a net assessment of the entire tool. The ultimate result is a management judgment, suitably constrained or qualified, on the suitability for use of the tool (i.e. accreditation). A generic evaluation process model is indicated in the diagram of Figure 2.2.3-1.

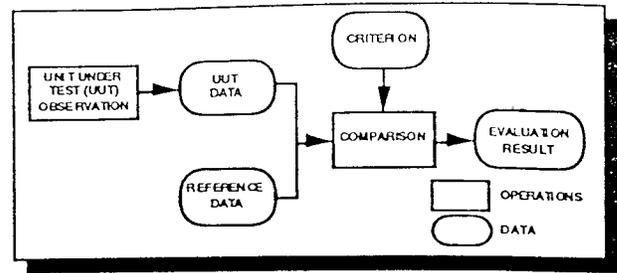


Figure 2.2.3-1 Generic Evaluation Process Model

This activity / data flow diagram illustrates the components of a generic evaluation process which is applicable to any evaluation enterprise, but particularly pertinent to V&V evaluation. This generic model includes operations of 'observation' of a UUT item, and 'comparison' of UUT characteristics data with suitable reference data under the constraint of *a priori* criteria. A simple (model validation) example application of this generic process is to execute the EADTB ballistic missile move model, observe resulting trajectory, and compare it to real-world trajectories, expecting similarity to within 500m. This V&V evaluation paradigm is simple, flexible and powerful. It is universally applicable and can serve as the template of each and every V&V evaluation activity. Finally, it serves as a sanity check on V&V activity specification insofar as each of the elements of the paradigm must be explicit before any activity can be considered well-defined.

### 2.2.4. Accreditation Process

The first issue for accreditation is scope of application. Current direction all reflects that accreditation is contingent on application scope, that application domain must be specified explicitly, and that a given simulation tool may be incrementally accredited for a progressively wider scope of application. Army guidance recognizes that accreditation may be conferred for either a particular study or for a 'class of applications'. While study managers will be responsible for conducting study-specific accreditation, accreditation for classes-of-application is managed by the developing agent here, the TPO. Typical classes of application for EADTB are expected eventually to include those indicated in the table of Figure 2.2.4-1.

- ANALYSIS
- TEST AND EVALUATION
- EDUCATION AND TRAINING
- PRODUCTION AND LOGISTICS
- RESEARCH AND DEVELOPMENT

Figure 2.2.4-1 EADTB Accreditation Class-of-Application Goals

Plans exist to initially accredit EADTB as a simulation and analysis tool for carrying out theater level effectiveness evaluations of extended air defense and related C3I. The applicable classes of analysis applications are shown in the table of Figure 2.2.4-2.

- **FORCE CAPABILITY AND REQUIREMENTS**
  - Requirements Analysis
  - Cost and Operational Effectiveness Analysis
  - Force Mix Studies
  - Architecture Studies/Tradeoff Analyses
- **COMBAT DEVELOPMENT**
  - Doctrinal Studies
  - Employment Strategies

Figure 2.2.4-2 EADTB Initial Class-of-Application Scope

A second consideration in specifying M&S accreditation is to establish the level and span of authority of the accrediting agent. In the case of EADTB, a joint-service accreditation at the level of the Director, BMDO is considered appropriate, notwithstanding the additional difficulty in coordinating joint-service determinations. The management mechanism for EADTB joint-service accreditation for specified class-of-applications use is indicated in the activity / data flow diagram of Figure 2.2.4-3.

As indicated in the figure, the TPO and users execute the VV&A plan, generating records of original entry and preparing reports and abstracts. These materials are made available to the Accreditation Review Team which is appointed by the accreditation authority. The EADTB Model Advisory Group (EMAG) is a high level group with joint membership. The EMAG periodically reviews and provides comments and suggestions throughout the planning and execution of the VV&A process. The Joint Accreditation Panel, under the leadership of BMDO, makes the accreditation decision and provides notification to the EXCIMS/DMSO.

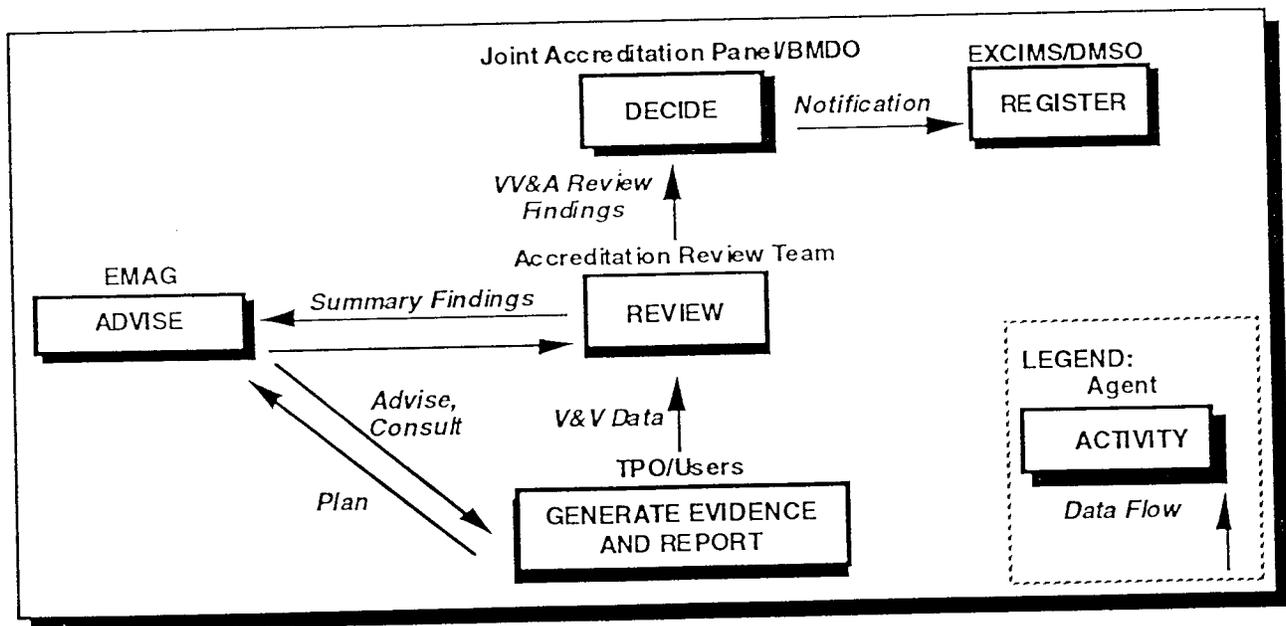


Figure 2.2.4-3 EADTB Joint-Service Accreditation Process

### 2.3. VV&A ISSUES FOR EADTB

Several issues are associated with VV&A for EADTB. These are, in fact, endemic to the class of models and simulation which share EADTB's attributes, including typically, distributed interactive simulations (DIS) ensembles. In the paragraphs which follow, each of several issues is identified, and plausible strategies for dealing with them are indicated.

#### 2.3.1. Validation of Generic Models

The EADTB consists of a 'simulation framework' and a set of generic 'common models' as well as a variety of 'specific systems representations' (SSR's) of real-world systems. The common models are coded algorithms which provide the 'methods' to generic object classes (e.g., guided\_missile\_move) from which representations of real-world systems are composed. These SSR's are comprised of

the inherited common models, their associated 'characteristics' (parametric) and 'instance' (initial condition) data, and decision processor 'rulesets'. V&V must confirm both that the generic model methods are correct, and that the SSRs composed from them represent real-world systems adequately. The approach selected to address this concern includes: 1) distribution of V&V effort across EADTB entities, 2) careful identification of UUT's and explicit qualification of results, and 3) acknowledgment that user defined systems will require their own V&V.

### 2.3.2. Tool Kit vs. Application

It is necessary that VV&A encompass both: 1) the EADTB M&S development environment and common models (i.e., the test bed 'tool kit') and 2) those application-specific models, scenarios, and data generated in the M&S environment by the node-owner / analyst-user (i.e., specific application SSR's and study scenarios). In response to this set of responsibilities, it is planned that the TPO will develop an overall VV&A strategy and process which: 1) accredits the tool kit for classes of applications, and 2) delegates specific application accreditation to node-owners / analyst-user or to other appropriate authority.

### 2.3.3. Variety of UUT Entities

There exists in EADTB (as in DIS) a wide variety of entities which need to be verified and validated. This circumstance requires, as a minimum, a disciplined development and V&V process and adequate documentation. In particular, ameliorative actions by the TPO during VV&A program planning include the following: 1) clearly identify UUT entity for each evaluation exercise, 2) identify procedures, sufficiency criteria, and expected products before expending effort, and 3) allocate effort to critical evaluation efforts first, then establish balanced coverage of V&V evaluation. Finally, it must be recognized that The EADTB V&V effort will be systematic, but cannot be exhaustive; and careful allocation of resources onto high-return-on-investment activities is critical.

### 2.3.4. Variance in Service Policies

Although the Services have similar practices and strategies for simulation verification and validation, their evolving formal policies stand at differing levels of maturity and they include a variety of guidance and procedures. Some tailoring of the EADTB VV&A Program was necessary to accommodate this variance. It is certainly necessary to understand evolving Service and DoD policies and practice, to select EADTB V&V strategies and activities which will

be generally acceptable, and to coordinate through user's group and EADTB Model Advisory Group to establish multi-service consensus on the EADTB V&V program.

### 2.3.5. Configuration Management

Configuration management is a natural concern for verification and validation of any complex simulation system insofar as the unambiguous identity and stability of the system which is the object of the V&V evaluation is imperative. Confidence in EADTB and credibility of study results depends on configuration management of accredited components even though variation in EADTB configuration among multiple nodes is inevitable and to some degree desirable. EADTB CM practice is intended to support confidence in the tool and includes management of the framework at the base node, and logical delegation of CM activities as appropriate (e.g., Node-specific SSR's, data, and scenarios, and study-specific entities may be managed on-site).

### 2.3.6. Range of Applications

The EADTB will be employed over a very wide range of applications. Exhaustive *a priori* qualification is impossible; and convincing VV&A qualification sampling is difficult. Finally, VV&A UUT's, activity, and criteria may be sensitive to choice of application class. On this account, the EADTB VV&A Program has been designed for 'mainstream' applications. And, there has been a careful, conservative specification of 'class-of-use' for which accreditation is requested, pending progressive qualification for other classes-of-use as test bed matures.

## 2.4. PROGRAM PLAN

The process of composing a VV&A Program Plan consists in executing the activities indicated in the activity flow diagram of Figure 2.4-1.

A particularly significant issue is the iterative balancing of the program scope to ensure that the investment in V&V activity provides the best possible marginal return on investment.

The results of VV&A program definition includes the complete, explicit specification of the activities, UUT, agents, required resources (data and level of effort), schedule, and products of an integrated program. Such Program Plan components are indicated in the illustration of Figure 2.4-2.

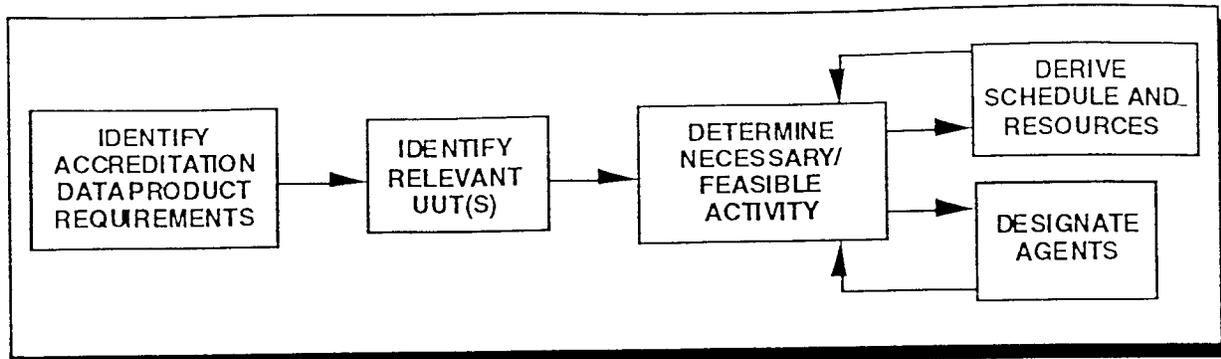


Figure 2.4-1 VV&A Program Definition Process

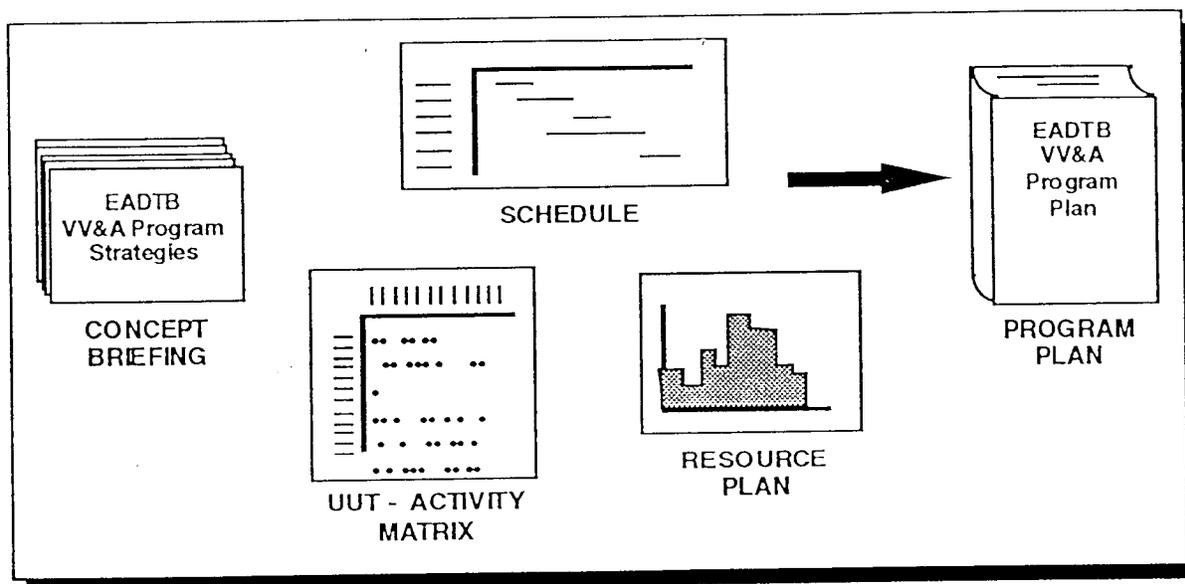


Figure 2.4-2 VV&A Program Plan Components

A standard set of VV&A program definition documents facilitates program definition, description, review, and acceptance.

UUT, activities, schedule, evaluation criteria, data products, and agents. The special challenges of VV&A for EADTB and similar M&S resources are coming to be appreciated and to be addressed constructively.

### 3. CONCLUSION

#### 3.1. OBSERVATIONS

Several observations are supported by the experience of EADTB VV&A program planning. Certainly, systematic VV&A is required for the EADTB and for many similar tools. The technology and management of VV&A programmatics is generally understood. Based on this understanding, at least one approach to deliberate development of VV&A programs has been derived which is illustrated by EADTB VV&A experience. In that environment, accreditation data requirements were successfully allowed to drive the identification of V&V:

#### 3.2. RECOMMENDATIONS

Some recommendations are implicit in the EADTB VV&A experience. In many cases, generalization of strategies and techniques and their employment in domains such as BMDO modeling and simulation management and DIS standards environments are appropriate. First, the V&V Evaluation Space paradigm and the Evaluation Kernel Process-Model might reasonably be adopted and employed in a wide variety of VV&A program definition circumstances, and they could be included in evolving guidance and standards. An explicit requirements flow-down strategy and a VV&A Program Definition Process Model for program development are

equally applicable. Dimensions of a desirable program should include at least specification of: 1) evaluation products, 2) unit under test, 3) evaluation activities, and 4) V&V Agents. It is certainly prudent to establish baseline taxonomies for classification of unit under test (UUT) entities and V&V activity types. Compilation of guidance on issues, providing: identification of significant issues, potential pejorative consequences, approaches to remediation, and guidance on applicability of solutions is possible in any of several M&S domains. Finally, it is desirable to identify components of a preferred set of VV&A program defining documentation.

## ENDNOTES

<sup>1</sup> Note that these definitions are those which are tailored to modeling and simulation practice and differ in some significant ways from those cited in references dedicated to software development.

<sup>2</sup> Department of Defense Directive 5000.29, DoD Directive on Modeling and Simulation (Draft) (Washington, DC: August 1992).

<sup>3</sup> Department of the Army Regulation 5-11, Army Model and Simulation Management Program (Washington, DC: 10 July 1992).

<sup>4</sup> Department of the Army Pamphlet 5-11, Verification, Validation, and Accreditation of Army Models and Simulations (Washington, DC: 15 October 1993).

<sup>5</sup> Secretary of the Navy Instruction, Principles for Verification, Validation and Accreditation of Navy Managed Modeling and Simulation (15 December 1993).

<sup>6</sup> Department of the Air Force, Air Force Instruction 16-102, Verification, Validation, and Accreditation.

<sup>7</sup> Ballistic Missile Defense Organization Directive No. 5002, Test and Evaluation Verification, Validation, and Accreditation Policy for Ballistic Missile Defense Organization, (Washington, DC: August 1993).