Joint Accreditation Support Activity

Credible Models for Credible Analysis . . .

"VV&A FROM A TO Z"

***A** SMART approach to VV&A*
for Acquisition M&S

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EXECUTIVE SUMMARY

As acquisition programs continue to expand the use of modeling and simulation (M&S) to reduce time, resources and risk in the acquisition process, there is a growing need to ensure that the simulations are sufficiently credible for their intended uses. Toward this end, Department of Defense (DoD) policy requires that simulations be accredited for each major application. The purpose of this document is to describe in detail a set of recommended steps that lead to a logically sound and justifiable accreditation decision for simulations used in acquisition applications. These steps are grouped into four major phases: a preparation phase, a planning phase, a verification and validation (V&V) phase, and an accreditation assessment phase.

- The preparation phase consists of a clear description of the acquisition problem; the decision(s) to be made; and identification of M&S requirements based on an analysis of the problem. The focus of this component is on clearly identifying the modeling requirements, describing the application and how the models are going to be used.

- The planning component consists of identifying the credibility requirements dictated by the application, and the minimum V&V requirements that will satisfy these credibility requirements. The focus of this component is on establishing minimum V&V tasks that must be done to supplement existing V&V data and provide sufficient information to support an accreditation decision.

- The V&V phase consists of producing of detailed information about M&S capability and credibility so that a reasonable comparison can be made with the modeling requirements for the application. The specific V&V techniques included in the process described in this document are particularly applicable to legacy models, and were selected based on a comprehensive survey of verification, validation and accreditation (VV&A) policy and practice for acquisition applications of M&S across the Services. Where a new model is being developed for a particular acquisition program, V&V techniques that are essentially the same as those described herein would still be applicable, but they should be incorporated into the model development process.

- The accreditation assessment phase consists of comparing of information about the model's capabilities and characteristics (generated through V&V tasks) with the M&S requirements to determine model suitability for the application, and identifying any critical deficiencies. It also includes an analysis of those critical deficiencies to identify potential work-arounds and associated risks.

The VV&A methodology is presented in a Work Breakdown Structure (WBS) format. This format permits VV&A planners to integrate VV&A plans and activities into larger M&S objectives within a program. Each WBS element is defined in terms of required tasking, relevance to the VV&A process, and the contributions of each element to the credibility of the model(s). This structure facilitates employment by acquisition program officials.

The Defense Modeling and Simulation Office (DMSO) has prepared a draft Recommended Practices Guide (RPG) for VV&A. All aspects of the VV&A process presented here are consistent with the RPG. Attention was also paid to making the process consistent with recent DoD and Service directives and instructions regarding M&S management and VV&A, in particular: DoDD 5000.59 and DoDI 5000.61; AR 5-11 (and its relative, DA PAM 5-11); draft SECNAVINST 5200.38; and AFI 16-1001. The format and content of VV&A described herein have also been standardized. This was done not only to facilitate direct comparison with M&S acceptance criteria derived from analysis of the application, but also to facilitate the integration of summary results into the M&S Resource Repository (MSRR) sponsored by DMSO. Thus, this process, in its entirety, reflects a particularization of the best DoD and Service thinking about VV&A at the levels of both policy and practice for model(s) used to support weapons systems acquisition.

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TABLE OF ACRONYMS

ACRONYM	MEANING
ALARM	Advanced Low Altitude Radar Model
ASD	Accreditation Support Database
ASP	Accreditation Support Package
CASE	Computer Aided Software Engineering
CM	Configuration Management
CMS	Conceptual Model Specification
COEA	Cost and Operational Effectiveness Analysis
DID	Data Item Description
DMSO	Defense Modeling and Simulation Office
DTIC	Defense Technical Information Center
ECM	Electronic Countermeasures
ESAMS	Enhanced Surface to Air Missile Simulation
EXCIMS	Executive Council on Modeling and Simulation
FA	Functional Area
FAC	Functional Area Council
FAT	Functional Area Template
FE	Functional Element
FEAP	Functional Element Assessment Plan
I/O	Input/Output
IAC	Information Analysis Center
IR	Infrared
JASA	Joint Accreditation Support Activity
JCS	Joint Chiefs of Staff
M&S	Modeling & Simulation
MDR	Model Deficiency Report
MOE	Measures of Effectiveness
MOM	Measure of Merit
MOP	Measures of Performance
MSRR	Model & Simulation Resource Repository
MTI	Moving Target Indicator
NTP	Notional Test Plan
PDDD	Post Development Design Document
PRF	Pulse Repetition Frequency
RADGUNS	Radar-Directed Gun System Simulation
RPG	Recommended Practices Guide
S&TI	Science and Technology Initiative
SA	Sensitivity Analysis
SALE	Summary of Assumptions, Limitations, & Errors
SAM	Software Analysts' Manual
SDD	Software Design Document
SMART	Suceptibility Model Assessment and Range Test
SME	Subject Matter Expert
SOW	Statement of Work
SPM	Software Programmers' Manual
SQA	Software Quality Assessment
SUM	Software Users' Manual
SURVIAC	Survivability Information Analysis Center
T&E	Test and Evaluation
TP	Test Plan

TPS	Test Plan Supplement
TR	Test Report
TRS	Test Report Supplement
V&V	Verification and Validation
VSR	Verification Source Report
VV&A	Verification, Validation, & Accreditation
WBS	Work Breakdown Structure

1. INTRODUCTION

The following sections provide an introduction to the intended purpose, scope and audience of this document. This information should be sufficient for you to determine the applicability of this document to your particular need for guidance in the areas of verification, validation and accreditation (VV&A) for models and simulations (M&S) typically used to support acquisition decisions.

1.1 Purpose

The purpose of this document is to amplify and particularize, for acquisition related applications the guidance contained in the Defense Modeling and Simulation Office (DMSO) Recommended Practices Guide (RPG). This document describes in technical detail a cost-effective process for developing the information necessary to support an M&S accreditation decision. The information necessary to support accreditation includes an analysis of the problem being addressed, and elements of verification, validation and configuration management of the M&S under consideration.

1.2 Scope

This document covers all activities normally associated with planning, executing and documenting comprehensive VV&A efforts for single or multiple model(s).

1.3 Applicability

The top-level VV&A process template presented here (see Section 2) was intentionally designed and constructed to have generic applicability based on the most recent DoD guidance on VV&A policy and practice (see sections 1.5 and 2.2). It describes in greater detail the accreditation process that is summarized in section 3.4 of the DMSO RPG. However, the specific V&V techniques that are discussed in sections 3.3 and 3.4 of this document were selected for inclusion on the basis of a study of tri-Service VV&A policy and practice[1] that was focused on legacy[2] model(s) used primarily to make or support acquisition decisions.[3] Because of the emphasis on legacy models, the V&V techniques selected were less focused on techniques typically used during software development, and more focused on techniques normally used to evaluate operational software. Finally, although earlier versions[4] of the VV&A process described here focused on engagement level models, the process has since been expanded and successfully applied to engineering and mission level models.[5] The process is equally applicable to new model developments.

1. See “Accreditation Requirements Study Report” dated Feburary 1994; [reference 6].

2. Legacy models are those built before the advent of detailed software design specifications and standards such as MIL-STD 2167A, and others. Despite recent emphasis on the development of new models architectures incorporating these standards, legacy models still form the mainstay of M&S used to support acquisition decisions across the DoD.

3. E.g., models used in Cost and Operational Effectiveness Analyses (COEA’s, a.k.a. Analysis of Alternatives, or AOA), force structure analyses, and Test and Evaluation (T&E).

4. See “An Accreditation Support Framework for DoD M&S”, dtd September 1995; [reference 29].

5. See the EADSIM Accreditation Support Packages I & II and unpublished AEDC training seminar notes [references 21, 22 and 32, respectively].

This document will be most useful to those needing to structure and implement cost-effective, policy-compliant VV&A programs for engineering, engagement and mission level models used in making or supporting acquisition decisions.

1.4 Terminology

This document uses standard modeling terminology as defined in JCS Pub 1, wherein the definitions and explanations for the terms "*verification*", "*validation*", "*accreditation*", "*configuration management*" and other terms will be found.[6] There are exceptions, however to standard teminology found here.

The term "model" will be used throughout this document in place of "M&S". The term "M&S" actually has two meanings: "modeling and simulation", which is one approach to problem solving; and "model and simulation" (actually a misnomer for "model or simulation"), which refers to an actual executable piece of software. Most people use the term "model" when referring to well-defined software entities that perform certain functions.[7] We also will follow this convention. The term M&S will only be used to mean "modeling and simulation".

Two terms that will be used frequently in section 3 that are not defined in JCS Pub 1 are "*problem*" and "*application*". A "*problem*" is "a question raised for inquiry, consideration, or solution." Problems are typically solved by establishing problem solution requirements and approaches, collecting and analyzing necessary information or data, integrating results, and deciding on an answer to the problem. A conceptual diagram of the problem solving process is shown in Figure 1–1: The Problem Solving Process.[8] It should be apparent that the term "problem" in this diagram refers to the basic issue or question that is to be resolved. In contrast, an "*application*" is "a use to which something is put." In the context of problem solving, models are typically used to generate data as part of the overall problem-solving approach. In Figure 1–1: The Problem Solving Process the box labeled "Plan and Conduct M&S Analysis" is the M&S application within the overall problem solving process.

In some cases, M&S might be the only approach that is used in the problem solving process. It should be remembered, however, that *problem* still refers to the question to be answered and *application* refers to the use of the model or simulation. Consider the example of a program manager who might be responsible for recommending one of two alternatives in a competitive procurement. The problem would be "which alternative is best under certain criteria" (typically performance and cost). A probable M&S application within this problem might be "to predict the performance of each system under certain conditions". From this example and the definitions provided, it should be obvious that *problem* encompasses the *application* but is not synonymous with it.

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6. A clear and detailed explanation of these terms is found in chapter 1 of the DMSO RPG.

7. E.g., the Enhanced Surface to Air Missile Simulation (ESAMS) is frequently referred to as a "model".

8. This figure is a simplification of figure 5-1 found in Chapter 5 (Accreditation) of the DMSO VV&A RPG.

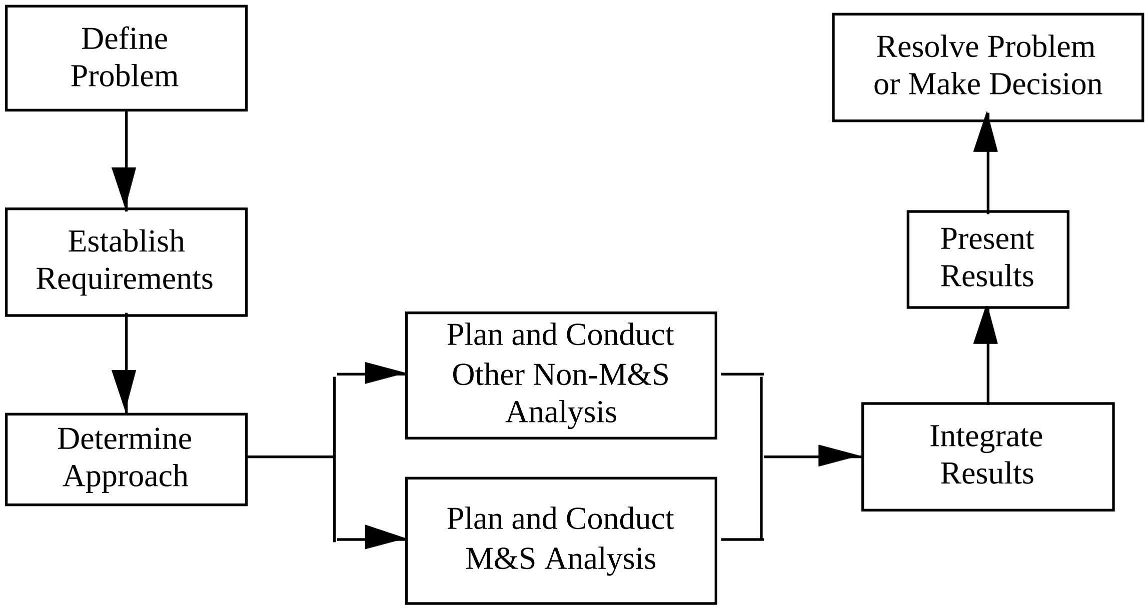

Figure 1–1: The Problem Solving Process

1.5 Relation to Official Guidance

The VV&A process described here has been structured to be consistent with the Recommended Practices Guide for VV&A published by DMSO (November 1996 edition), as well as with the most recent DoD policy guidance on M&S management and VV&A (i.e., DoDD 5000.59 dated 4 January 1994, and DoDI 5000.61 dated 29 April 1996). It is also completely consistent with both policies and procedures called out in Army Regulation 5-11 (and its companion DA PAM 5-11), the draft SECNAVINST 5200.38, and Air Force Instruction 16-1001. As such, it reflects a particularization of the best DoD and Service thinking about VV&A at the levels of both policy and practice for models used in acquisition.

1.6 Context

As a consequence of the attempt to make the VV&A process compliant with DoD guidance, this document makes certain assumptions about the context of VV&A activities within the larger context of analytical problem solving in support of acquisition related decisions. It assumes that the general approach to problem solving can be described by Figure 1–1: The Problem Solving Process and that the use of M&S within the problem solving process is represented by the steps shown in Figure 1–2: VV&A in the Scheme of Problem Solving.[9] In this figure, VV&A activities take place within the context of the M&S Life Cycle, which in turn, takes place within the larger context of other (non-M&S) approaches to problem solving. Thus, VV&A activities are only a

9. This figure is a combination of figures 5-1 and 5-2 found in Chapter 5 (Accreditation) of the DMSO VV&A RPG.

part of the entire spectrum of M&S activities, while M&S activities themselves constitute only one approach to problem solving. These contextual assumptions mean that this document will provide the reader with enough detail to structure and implement a cost-effective VV&A program within the context of M&S activities (and within the constraints stated in section 1.3), but it will provide only the most general guidance about how to integrate M&S activities into the larger context of problem solving.[10]

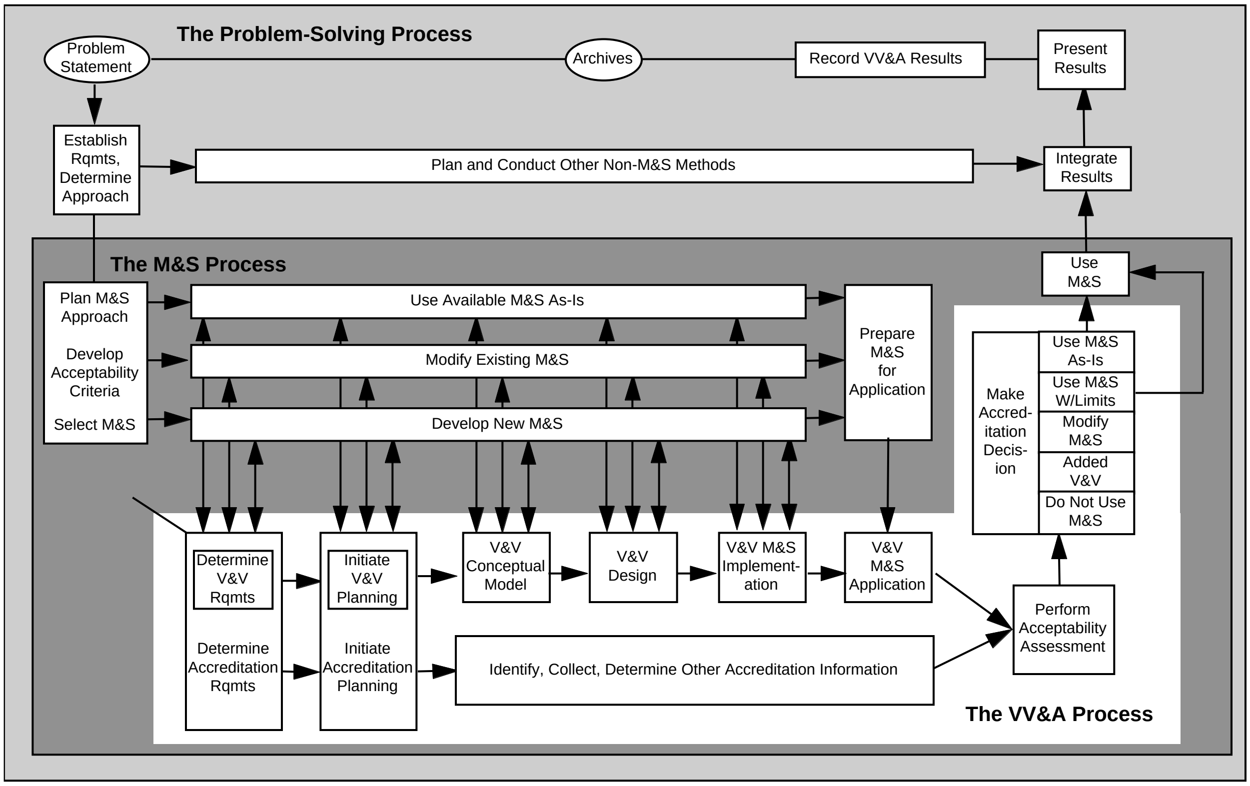

Figure 1–2: VV&A in the Scheme of Problem Solving

1.7 Document Structure

A detailed description of the VV&A process begins in section 2 with an explanation of Work Breakdown Structure (WBS) modeling of complex tasks, and an overview of the WBS for VV&A. Section 3 provides detailed descriptions of each of the VV&A WBS elements. Section 4 provides and discusses flow charts which integrate WBS elements into coherent verification, validation and accreditation processes. Section 5 discusses documentation requirements and specifications for VV&A tasks. Section 6 provides information on where to go for more help in applying the principles and techniques discussed in this document. It includes a table of annotated references.

This document is also supported by a number of Appendices that amplify or supplement material found in the text. Appendix A is a compilation of the VV&A WBS charts discussed throughout

10. For example, this document does not discuss tradeoffs between modeling and testing, or make recommendations as to which should be used when.

the text. Appendix B provides guidance on preparation of key VV&A documents. Appendix C contains suggestions for preparing work packages to execute various VV&A tasks.

1.8 Intended Audience

This document should have interest primarily to Accreditation Agents and V&V Agents as defined in DoDD 5000.59 and DoDI 5000.61. It should also be of interest to V&V practitioners who wish to broaden their understanding of VV&A practice by reviewing lessons learned from practical experience in applying the techniques presented here. Accreditation authorities may also benefit from a review of the accreditation planning and accreditation analysis concepts that are the logical basis for the entire process.

1.9 How to Use This Document

It is recommended that accreditation agents read and digest the sections describing the following WBS elements: 1.0 accreditation precursors, 2.0 accreditation planning, and 3.0 accreditation, which are sections 3.1, 3.2 and 3.5, respectively, in this document. They, along with the accreditation authorities, should also review and understand the accreditation related flow charts in section 4 and the documentation requirements in section 5.

V&V agents should review the accreditation process flow charts in section 4 and clearly understand the WBS descriptions and flow charts for the verification and validation processes. In addition, they should review and understand the configuration management tasks as well as the V&V documentation processes in sections 3 and 5 respectively.

2. THE VV&A WORK BREAKDOWN STRUCTURE (WBS)

Appendix A contains the complete WBS for VV&A. The following sections provide a discussion of what a WBS is, how this one was created, and how it should be used. Section 2.4 identifies which portions of this particular WBS have generic applicability and which are tailored specifically to acquisition applications of M&S.

2.1 What Is A "WBS"?

A WBS is a project management tool that specifies how complex tasks are broken down into smaller, more manageable pieces. A WBS identifies the "building blocks" that make up a project. These "blocks" can be defined either in terms of system components (e.g. airframe, engine, flight controls) or project tasks (e.g. design, testing, production, management). Since VV&A is a process and not a system, this WBS is structured along task lines.

A WBS specifies both what is to be accomplished, and what is the necessary hierarchical relationship of the various tasks that comprise the overall work effort. A good WBS partitions a large, complex task into manageable elements of work for which costs, budgets and schedules can more readily be established. The purpose of developing a WBS for VV&A is to provide a conveniently pre-packaged hierarchy of tasks that can easily be correlated with larger M&S objectives and integrated into overall M&S employment plans and program management plans.

2.2 How Was This WBS Created?

The development of a WBS begins by subdividing the top level objective (in this case, "Perform VV&A") into successively smaller work blocks until the lowest level to be reported on or controlled is reached. At each level of this WBS, care was taken to ensure that the identified tasks were comprehensive. Although the management function or task is normally included in a WBS, this WBS for VV&A does not include it. It is assumed that this WBS will be integrated into the overall program structure, and that management tasks are part of the higher level program-specific WBS.

Figure 2-1 illustrates the top level WBS for VV&A. The overall (level-one) goal is to "Perform VV&A". This goal is supported by five level-two activities: Precursors, Planning, Verification, Validation and Accreditation. Each of these, in turn, is supported by several level-three activities. The level-two task, "Precursors", for example, consists of Define Application, Develop M&S Requirements and Select Candidate M&S.

2.3 How Should This WBS Be Used?

This WBS is structured down to subtasks at the fourth level (X.X.X.X). At the fourth level some of the entries are actual subtasks and others are meant only as checklists. Checklist items were included to aid the practitioner in understanding the scope of the third level task. Those fourth level entries that are actual subtasks are identified by the typical "box" around the entry similar to that used for higher level tasks. In contrast, "checklist" items are not marked with a box, and in that case the lowest task-related level of that branch of the WBS is the third level.

At the lowest level of each branch of the WBS, a "Work Package" is prepared, which specifies the work to be performed, the deliverables to be produced, the expected duration of the task, the relationship with other tasks, and other information essential to task management. Work Packages lead directly to well-defined products that are crucial to the completion of either some higher level task, or to the overall project objective directly.

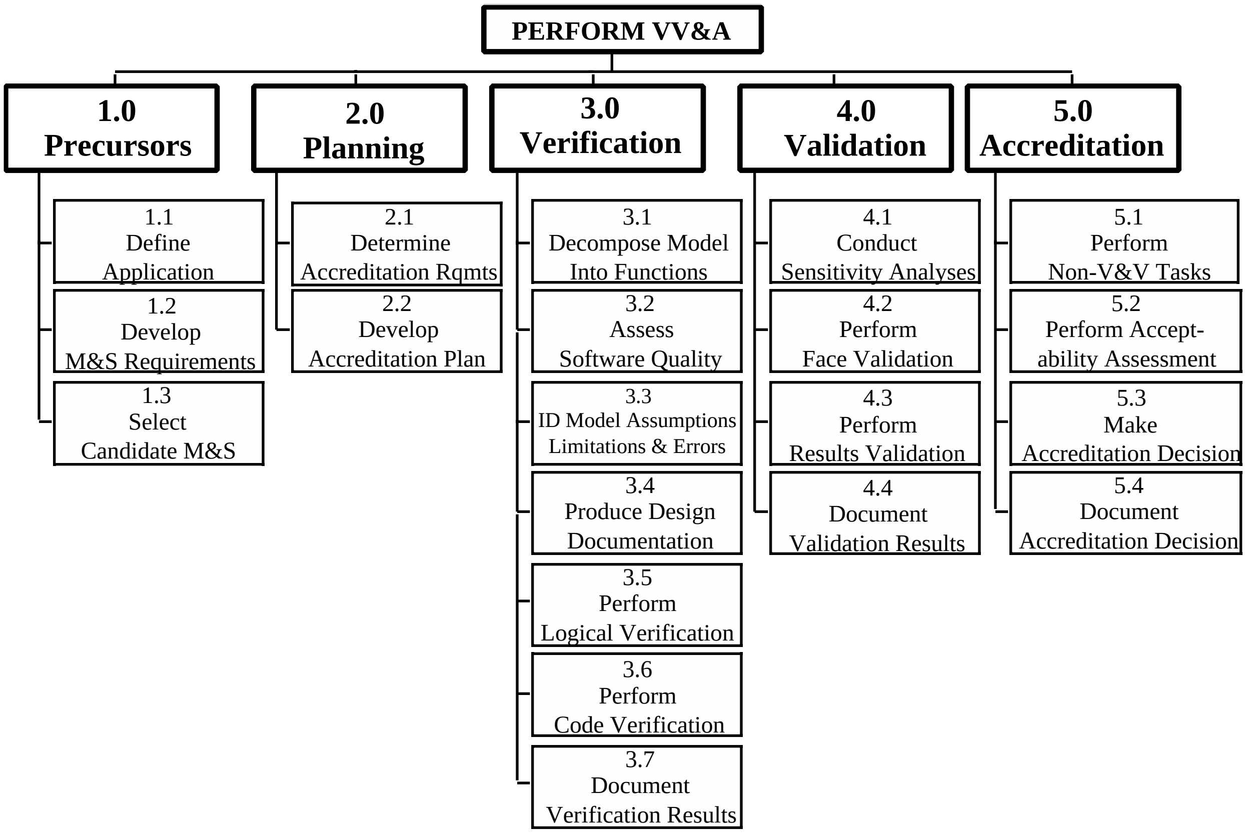

Figure 2–1: WBS for "Perform VV&A"

For example, referring to Figure 2–2: Sample WBS (Develop M&S Requirements), completion of the task labeled "Define & Prioritize Functional Requirements" would require the preparation and completion of Work Packages for both of the two listed subtasks. On the other hand, the task "Define & Prioritize Operating Requirements" would be accomplished as a single task. Essential things to consider in performing this task are the five items shown. These five items are not necessarily all that needs to be done and each is not significant enough to be considered a separate task.

Although WBS elements are typically used as the basis for a contractor's statement of work, some of the WBS tasks are not suitable for "contracting out". As a matter of fact, tasks such as defining the problem, developing M&S requirements, and selecting the model(s) should be performed by the accreditation agent or someone at an equivalent level who has a good understanding of the overal application.

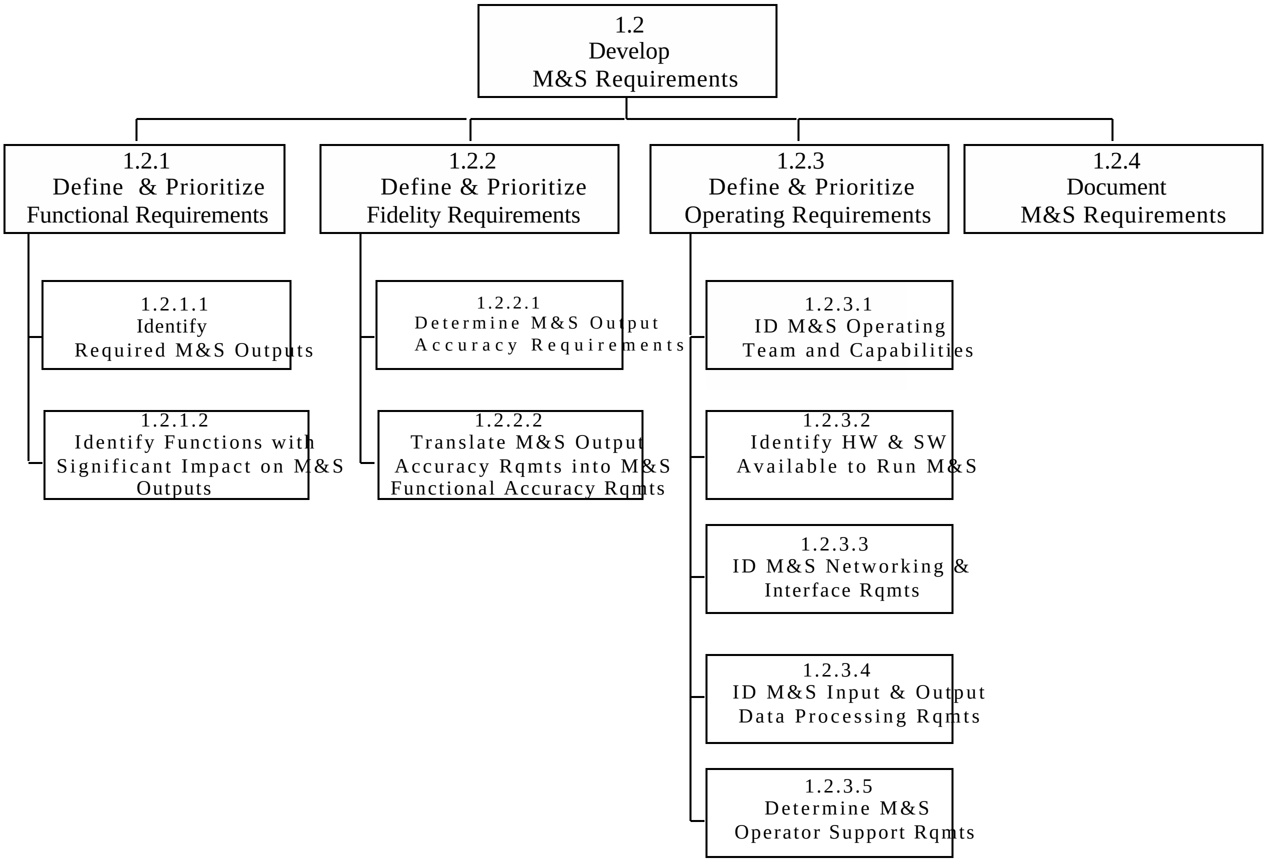

Figure 2–2: Sample WBS (Develop M&S Requirements)

2.4 Applicability Of This WBS

The WBS for VV&A described in this document is completely generic down to the first level, and continues to be generic at all levels below WBS elements 1.0 (Precursors), 2.0 (Planning) and 5.0 (Accreditation). As stated in section 1.3, however, the third level WBS elements below 3.0 (Verification) and 4.0 (Validation) are tailored specifically to acquisition applications of M&S. This does NOT mean that the V&V techniques listed are inapplicable to other types of M&S or M&S applications. In fact, many of the specific techniques listed are described in chapter 4 of the DMSO RPG, and are applicable to most model(s) and M&S applications. The techniques selected for inclusion under these categories were selected on the basis of a review of VV&A practice and policy within the Services for acquisition applications of M&S,[11] and a consensus derived therefrom about which V&V techniques were most suitable and useful to these M&S and M&S applications. It is, true, however, that the most direct applicability of WBS elements 3.0 and 4.0 will be for engineering, engagement and mission level M&S used to support acquisition decisions.

11. See “Accreditation Requirements Study Report” dated Feburary 1994; [reference 7].

3. WBS DETAILS

The following sections provide a detailed description of the tasking required to execute each element of the WBS for VV&A. Most of the tasks are written as though they are logically sequential, but it should be remembered that each task is a separate entity. Some tasks may not require the completion of any of the other tasks; actual task relationships are specified by Work Packages developed specifically for a given application. Section 4 provides details on how to integrate the individual task elements of the WBS into a coherent VV&A process.

3.1 Precursors

According to Figure 1–2: VV&A in the Scheme of Problem Solving, the nature, depth and breadth of VV&A activities depend on information developed outside the VV&A process itself. In particular, the basis for the M&S application, which is the part of the problem that is being analyzed using models, is a problem statement and a set of problem requirements. It is necessary to define the problem in sufficient detail to be able to specify (with reasonable accuracy) the M&S requirements appropriate to it[12]. These M&S requirements are needed for model selection and accreditation. Before actually planning and executing a VV&A program, suitable model candidates must be screened, and the best model suite identified. If no suitable models exist (either those which can be used as-is, or those whose deficiencies can be addressed by minor modifications and/or additional V&V), it may be necessary to develop new models to address the M&S requirements specified for the problem. This brief explanation shows the importance of developing a comprehensive description of the application based on a clear understanding of the problem. Along with this application description a set of M&S requirements tailored to the application are also necessary. The following sections describe those tasks that lead to a clear set of M&S requirements which are the basis for specific VV&A activities.

3.1.1 Define Application

Before being able to specify particular requirements for accreditation, it is necessary to have a thorough understanding of the M&S application. Absent such understanding, requirements for accreditation (if they can be stated at all) will tend to be subjective and arbitrary, and any requirements that are specified may add little or no objective weight to the actual credibility of the models under consideration. Where VV&A efforts fail, it is generally due to a failure to define adequately the overall problem and how the model(s) will be used in resolving all or part of the problem. Put in more colloquial terms, "If you can't define what you're going to be using model outputs for, you can't determine whether or not they're good enough." A careful, complete and well documented analysis of the problem is the key to understanding the M&S application and to developing and executing a cost-effective VV&A program for the model(s) that will be used in that application. Figure 3-1 shows the three principal tasks and associated subtasks that are required to generate a comprehensive definition of the application, from which objective require-

12. The application definition process parallels the initial steps in a model development outlined in chapter 3 of the DMSO RPG [reference 45]

ments for modeling (and model accreditation) can be derived. These tasks are essential to determining VV&A requirements and to ensuring acceptability of M&S results.[13]

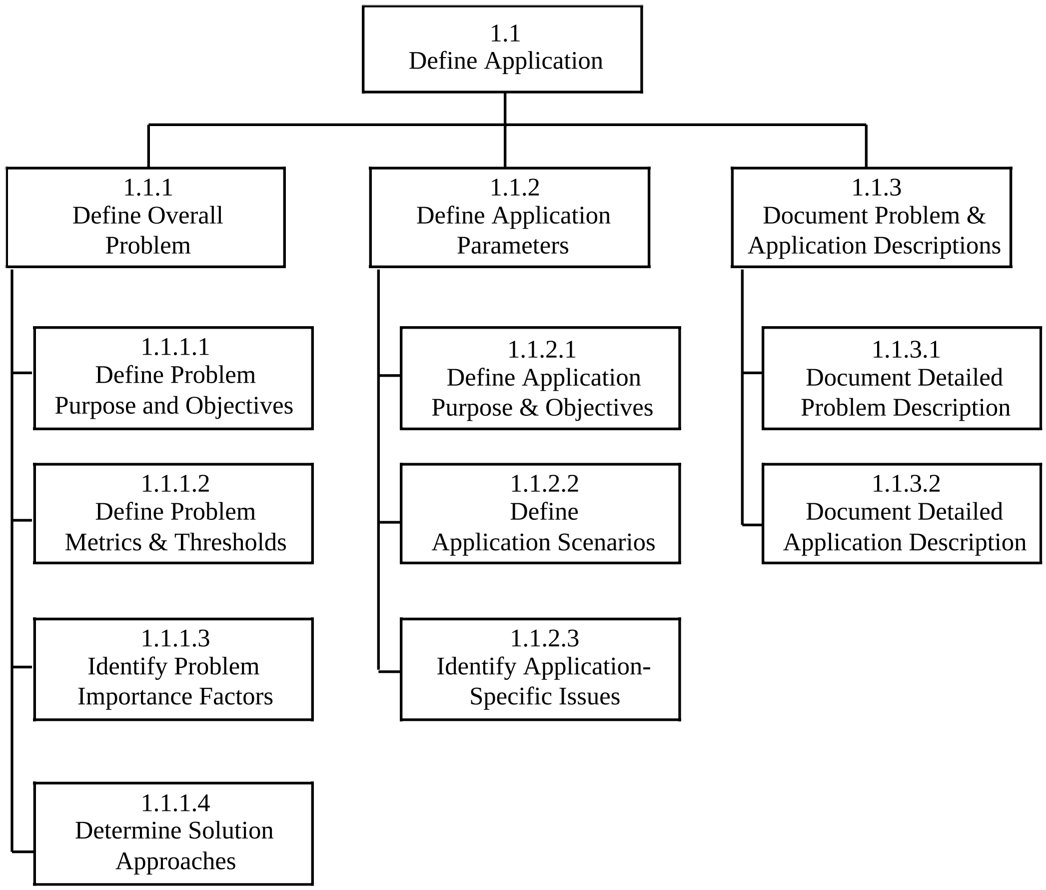

Figure 3–1: WBS for "Define Application Problem"

3.1.1.1 Define Overall Problem

The basic difficulty usually encountered in planning VV&A activities is that the problem being addressed with M&S has not been fully defined. This is not to say that the program managers have not defined their objectives; rather, they have usually not defined them in terms that can be readily applied to the question of M&S credibility: "How good do the M&S need to be to resolve my problem?" Very often the problem definition has not been documented, nor has the use of M&S outputs been rigorously correlated with the metrics that are used in evaluating and addressing the questions to be answered.

Preparing a problem statement appears almost trivial. However, in trying to prepare such a document, the most difficult aspect is often determining that it is complete and comprehensive. The

13. See principle #3 in chapter 2 of the DMSO RPG [reference 45]

traditional, and apparently the "best" approach to defining the problem statement is to use some sort of checklist that lists numerous different types of factors that should be addressed when preparing the problem statement.

As shown in Figure 3–1: WBS for "Define Application Problem", a detailed and comprehensive problem definition includes at least four factors. In particular, the specific purpose and objectives of the overall problem must be defined, as well as the metrics and thresholds that govern all expected decisions. The factors that affect problem importance must also be determined and specified. These factors evolve from the effects of the ultimate decision or problem outcome and are only indirectly related to the model outputs. (These importance factors are essentially the potential risks and benefits that might result from one decision or the other.) Finally, the approaches to generating information are identified. The use of M&S is only one approach. Other means of collecting data include testing, gathering historical data, using questionnaires or surveys, and/or data estimating.

3.1.1.1.1 Define Problem Purpose and Objectives

Recall that the definition given in section 1 for the term *problem* was "a question raised for inquiry, consideration, or solution." The purpose and objectives of the problem include a statement of the question as well as the goals or objectives that are to be achieved by developing an appropriate answer. For example, a typical acquisition problem might be "which alternative should be selected for development or procurement?". The goals or objectives to be achieved would typically include achieving best performance at minimum cost (acquisition and/or life cycle). These goals would drive the criteria used for making the choice between alternatives. A statement of the problem purpose and objectives in this example would include:

- a specific statement of the question, identification of alternatives and any specific issues to be resolved

- the goals that are to be achieved or the criteria to be used in making a decision

The description of the problem purpose and its objectives serves as the touchstone against which objective statements of model capabilities and model accreditation requirements can be defined. Poorly defined problems lead to poorly defined (or, at least, objectively unjustifiable) requirements for accreditation.

3.1.1.1.2 Define Problem Metrics and Thresholds

The next major part of a problem definition is a set of metrics that are used to quantify the pertinent information, the threshold values that will control decisions or actions, and the critical parameters that must be calculated or estimated as a basis for solving the problem. These factors have immediate impact on selecting a model or some other tool for analysis.

Most acquisition problems deal with making a choice between competing alternatives based on the tradeoff between some measure of cost, risk, and benefit. In this context, metrics are used to quantify the costs, risks, and benefits and to provide some means of ranking the different alternatives. The ultimate decision or choice between different alternatives is usually determined by the specific values of critical metric(s). If the value of a particular decision metric is above a predetermined level, one choice is made. If it is below that level, a different choice is made. This predetermined level is referred to as a "threshold".

Depending on the particular problem, thresholds may be more or less rigid. Analyses of Alternatives (AoA) associated with acquisition programs tend to have rigid thresholds for selected performance parameters (e.g., weight, range, life cycle cost, etc.). Other problems (such as evaluation of alternative strategies or tactics) might have less rigid thresholds. In some cases, a choice might hinge on the relative size of a parameter rather than on its absolute value. Thus, there is usually an acceptable "tolerance" in the value of each metric about the threshold that will not cause the final answer to the problem to change. Acceptable tolerances in a problem's metrics should be defined based on a judgment of how much error is acceptable without affecting the final (or intermediate) decision(s). In some cases there might not be any threshold. Instead, alternatives might be compared on the basis of their relative ordering in terms of one or more metric values.[14] The only requirement on the tolerance would be that the metric sensitivity to its constituent parameters was the same for both alternatives.

3.1.1.1.3 Identify Problem Importance Factors

In addition to the problem purpose, objectives, metrics, and thresholds, the importance of the problem must be clearly articulated. The term *problem importance* refers to the potential impacts attached to the problem outcome or decision. It does not refer to the importance of the model outputs that are used to support the problem decision.

Problem importance can usually be defined in terms of importance factors. These factors include the benefits that might be expected from a "good" decision or outcome, how widespread these benefits will be felt, the potential impacts or effects of erroneous decisions or outcomes, and the breadth of any "bad" effects. Another importance factor is the scope of the effects or how widespread the effects will be felt and who or what will be impacted (a segment of society, individuals, equipment, and/or the environment). Other factors that should be addressed when defining importance are concerns of the problem sponsor or higher level officials and potential public reactions to either a positive problem outcome or to the consequences of an erroneous outcome.

The particular importance factors defined above should be integrated with an assessment of specific risks in order to prioritize them. There may be several risks related to a given application. As an example, consider a hypothetical missile acquisition program where some analysis must be

14. For example, in comparing two different tactics for employment of an on-board radar jammer, one metric might be the miss distance of a threat missile. Evaluation of the different tactics would then be evaluated on the basis of which tactic yielded the greatest miss distance.

done to select the most appropriate sets of test conditions from the entire conceptual missile operating envelope. If a particular simulation has been selected for use in planning the tests, the risk elements that might result from an inadequate simulation include: 1) potential safety violations that could result in equipment damage, equipment loss, environmental damage, personnel injury, or even death; 2) wasted time and money if the test outcome is a "no test" due to improper selection of test parameters; and 3) possible increased test costs if inefficient test conditions and procedures are specified in the test plans (a secondary effect). The relative importance of these risks will be determined by an analysis of the contributing importance factors discussed above. The prioritized risk assessment that results is used to adjudicate conflicts between the need for increased M&S credibility and the availability of fiscal, human and schedule resources.

Understanding problem importance is necessary because it provides a critical basis for any risk analyses that ultimately determine the necessary level of V&V to be done (see section 3.5.2.3). For example, if V&V activities identify what appear to be serious deficiencies in a model, it would be helpful to know how to assess the relative importance of those deficiencies with respect to concrete criteria related to the overall importance of the problem.

3.1.1.1.4 Determine Solution Approaches

The final step in defining the overall problem is really a transition step leading to the definition of the M&S application. Once the problem is fully defined, the analysts who are responsible for developing the information that is needed to make an informed decision must determine how they will generate that information.

There are several common approaches that might be used either singly or in combination. In some cases, there may be historical data available, or it may be possible to go into the field during operations and actually collect operational data. In other cases, it may be possible and desirable to actually run tests under controlled conditions to collect data that is representative of real operations. In still other cases, data might be collected through surveys or questionnaires sent to knowledgeable personnel. These surveys can obtain data that reflects expert opinion or that represents perceptions of real world outcomes by those who participated in real operations. Finally, the last common approach is the use of models, representing real world operations, to generate data on such operations.

This last approach is the one that is of interest in this discussion, since it is the M&S application for this problem. If this last approach is selected for use, either alone or in conjunction with other solution approaches, the specific data that are to be generated by models must be identified as a starting point to define each of the application parameters.

The whole purpose of explicitly defining the problem is to provide a common, well-understood starting point for the analysts who must next define the application parameters, accredit and run the model, and analyze the resulting data to arrive at a problem recommendation. Without such an explicit statement, there is a significant possibility that analysts, in a sincere attempt to avoid errors, will make conservative assumptions that can lead to gold plating the model or unnecessary V&V. A clear problem definition and explicit M&S requirements are the manager's best tools for controlling M&S (and V&V) costs.

3.1.1.2 Define Application Parameters

The application description consists of a set of clearly identified parameters or factors. These parameters are common to every application and include the specific purpose and objectives of the application (that part of the problem being addressed with M&S), a complete description of all the scenarios that are applicable, the boundary conditions or assumed limitations placed on these scenarios, and a description of any and all issues that have been explicitly identified for special or specific consideration and resolution.

3.1.1.2.1 Define Application Purpose and Objectives

The first step in defining the application purpose is to identify the broad application type because the requirements for M&S credibility and level of detail vary from one application type to the next.[15] Knowing the application type is also important because each is supported by a different Functional Area Council (FAC) within the EXCIMS/DMSO infrastructure.[16] The role of the FACs is to coordinate and advise DMSO on M&S activities within their respective areas of expertise. They also have the authority to levy certain requirements on programs using models within these application areas.

The application type will typically fall into one of the three major M&S application categories defined by DMSO. These are acquisition, analysis, and training.

- Acquisition applications of M&S include representations of proposed systems (virtual prototypes) to be embedded in realistic synthetic environments to support simulation-based design, support of development and operational testing, support of production and manufacturing, and acquisition of logistics. Test and Evaluation (T&E) support can be subdivided into three major types: test planning (including pre-test performance predictions), test hazard/safety predictions, and test data extrapolation and analysis.

- Analysis applications of M&S are used to assess issues relating to DoD policies, plans, programs, and budgets. These analyses include studies of alternative investment strategies, analyses of warfighting alternatives, and development of combat strategies and tactics.

- Training applications include individual training (e.g. flight simulators), specialized group or

15. For example, the size of a missile footprint is important in determining test safety whereas it may be immaterial in extrapolating test performance data to areas of the envelope where the missile was not tested.

16. More information on DMSO and the Executive Council on Modeling and Simulation (EXCIMS) can be obtained at the DMSO Home Page at http://www.dmso.mil.

crew training (e.g. communications or logistics exercises using simulations of real world activities), or integrated staff training (e.g. large, integrated wargames).

Having identified the type application, the detailed purpose and objectives can be defined. These detailed statements explicitly define what is to be achieved through the use of M&S. For example, the specific objectives of the test planning example mentioned previously might be: (1) to ensure that the test parameters will not violate any test range safety rules; (2) to determine if certain test conditions will result in test failure or a "no test"; and (3) to predict the conditions of missile intercept with the target to ensure that photo instrumentation is properly oriented. Each of these objectives specifies with greater clarity the goals inherent in the overall purpose of the M&S application. The accuracy with which application objectives can be specified will determine the accuracy with which requirements for models (and their accreditation) can be specified later (see sections 3.1.2 and 3.2.1).

3.1.1.2.2 Define Application Scenarios

Included in the application description are the specific conditions or scenarios imposed by the larger problem that are being addressed. A comprehensive scenario definition requires that the participating organizations, forces, systems, environments, and boundary conditions be identified. The environments include both the physical environment and the operating environment. In addition to these elements, all simplifying assumptions and critical combinations of scenario conditions that are important to the problem should be identified. A comprehensive definition of the scenarios and accompanying conditions are key factors: that influence the functional and fidelity requirements for the model, affect impact and risk assessments, and contribute to the basis for overall model assessments.

3.1.1.2.3 Identify Application-Specific Issues, Concerns

This last parameter in the application definition is a catch-all for the issues and concerns, either explicit or implicit, which are not addressed elsewhere in the application description but which may impact the problem outcomes, and therefore, can impact the requirements for accreditation of any models used to support the application. Continuing with the test planning example used in the previous paragraphs, one issue might be whether the missile can be successfully tracked in flight by the range tracking radars. A determination of the maximum range (for different aspect angles) that the missile can be tracked could be a special issue in the application description.

3.1.1.3 Document Problem and Application Descriptions

Depending on the documentation requirements specified for the accreditation of a model (see section 3.2.1.3), it is very useful to document both the problem and application descriptions using the tasks described under 3.1.1.1 and 3.1.1.2 as an outline. Such documentation can serve as the touchstone for the adjudication of competing models, V&V and non-V&V requirements (see sections 3.1.2, 3.2.1.1 and 3.2.1.2, respectively) in cases where budget constraints force a reduction in the scope and/or depth of the VV&A effort. A good application description, coupled with a clear understanding of the problem, can provide the basis to identify areas where requirements can be relaxed objectively without risk to the credibility of the problem answer. Even in cases where it has been determined that a detailed description of the application and problem is not a requirement for model accreditation, serious consideration should be given to documenting them in some way, even if only in synoptic form.

3.1.2 Develop M&S Requirements

M&S requirements are, in simple terms, statements of what the model or simulation is expected to do and what is needed to run the model. A clear statement of M&S requirements is essential to forming an objective basis for model accreditation. Modeling requirements can be stated in terms of criteria that candidate models must meet in order to be considered acceptable for use in an application. Comparing these requirements with the information available about a model identifies model deficiencies, and specifies requirements for additional V&V that will lead to a better understanding of the model's strengths and weaknesses.

M&S requirements are derived based on an analysis of the problem, its objectives, importance, and criteria for any decisions to be made. These requirements are unique to each application and must be developed anew each time the model is to be used for a different purpose. This is not to say that similar applications might not have the same modeling requirements. However, if requirements from a previous application are used, they should be reviewed to ensure that they completely reflect the needs of the current or intended application.

M&S requirements can be grouped into three categories: Functional Requirements, Fidelity Requirements and Operating Requirements. Figure 3-2 is the detailed WBS for "Develop M&S Requirements", and the following sections describe in greater detail the tasks necessary to specify these requirements.

3.1.2.1 Define and Prioritize Functional Requirements

Functional requirements are system features or functions, physical phenomena, political or environmental conditions, and personnel or unit actions that have an important impact on the ultimate solution of the problem and, therefore, must be represented in a simulation. In all probability, the interactions between these represented entities must also be simulated by the model or simulation. These entities and their interactions, presented as a hierarchical list, are the functional requirements for a model or simulation. Some sample functional requirements might be:

- capability to model certain types of Electronic Countermeasures (ECM)
- capability to model C^3I effects
- capability to model human decision making processes
- capability to represent specific terrain features
- capability to model different Infrared (IR) backgrounds

The functional requirements proper to individual applications will be influenced heavily by the nature, depth and breadth of the application scenario (see section 3.1.1.2), as well as the purpose and objectives of the application (see section 3.1.1.2.1). For example, if M&S are being used to evaluate the aggregate effects of ECM on the forward movement of a FEBA[17], the detailed functional requirements for ECM will probably be very minimal. On the other hand, if M&S are used to evaluate the ability of a particular jammer waveform to defeat a particular threat missile system, the detailed functional requirements for ECM will probably be very stringent.

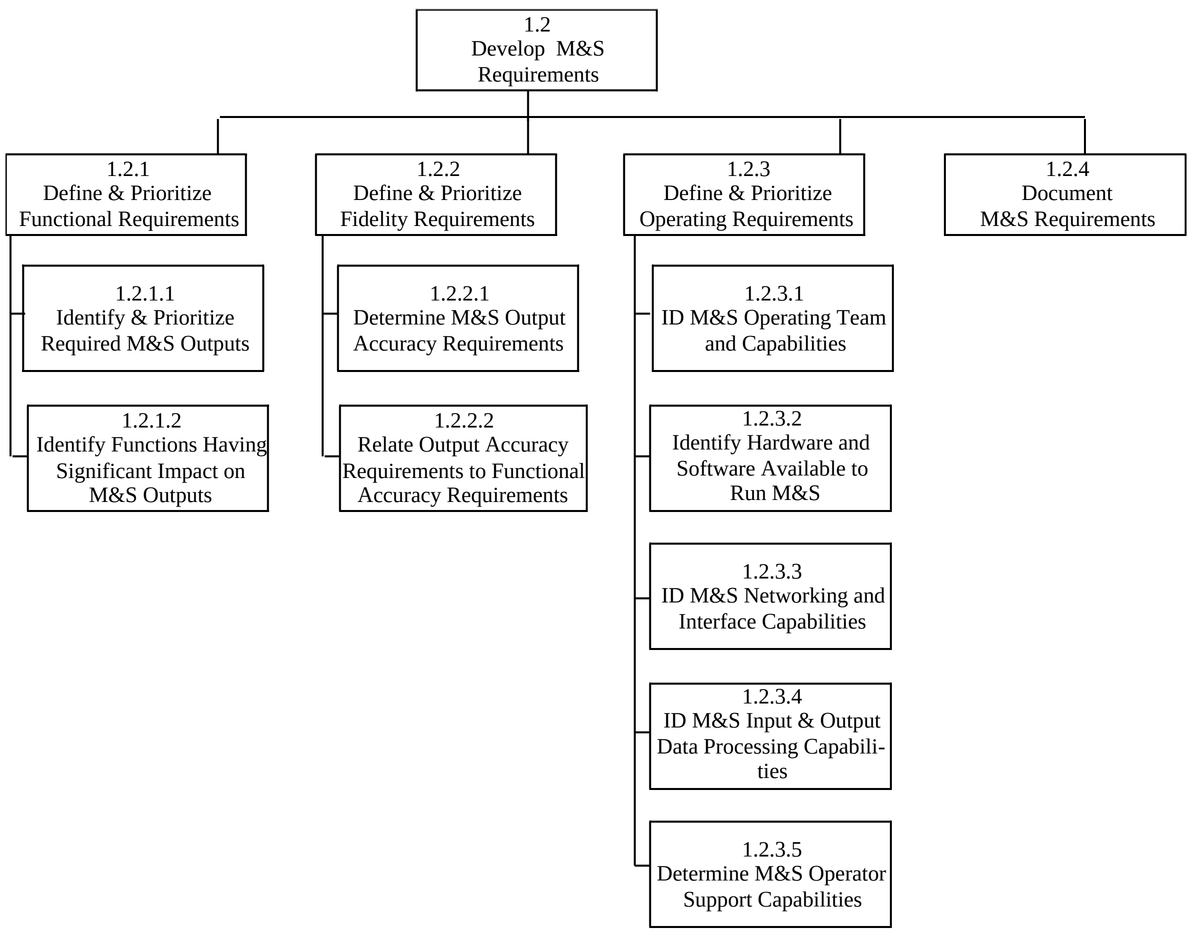

Figure 3–2: WBS for "Develop M&S Requirements"

Defining functional requirements begins with identifying those model outputs that are required to calculate the key metrics identified in section 3.1.1.1.2. Once model outputs have been identified, a user can identify contributing functions which are likely to have a direct impact on model outputs, and then prioritize them in terms of their potential impact on MOM values and problem outcomes. There are three different techniques for defining functional requirements depending on the complexity of the application[18]. All the techniques embody the two essential steps described in

17. Forward Edge of the Battle Area

the following sections.

3.1.2.1.1 Identify and Prioritize Required M&S Outputs

The relationship between metrics that are critical to the problem resolution (see section 3.1.1.1.2) and model outputs needs to be determined. Some metrics may be related to model outputs directly. In other cases, it may be necessary to integrate a number of outputs from a single model (or from multiple models) to calculate the desired measure of merit (MOM) upon which a final decision will be made. (For example, “loss ratios” might be important. A form of loss ratio would be the number of targets destroyed per aircraft lost. The number of targets destroyed might be the output of one model and the number of aircraft lost the output of another.) In all cases the required model outputs must be identified and related to individual Measures of Merit (MOMs). Based on the importance of different MOMs to the overall problem outcome, the list of required model outputs should be prioritized. If a specific priority ranking is not possible, the model outputs should, at least, be grouped into more important and less important outputs, based on their potential impact on program decisions.

For reasons of increased cost and complexity, it is prudent to minimize the number of required model outputs wherever possible. Each requirement for a model output can add to the number of required models, or to the number of required model functions, or to the amount of validation work that must be done to ascertain the credibility of model outputs. All of these factors can significantly increase the cost of accreditation by increasing the cost of V&V.

In those problems where the MOM hierarchy necessitates the integration of multiple models (e.g., engineering, engagement, mission, etc.) to address all problem metrics, or where a single MOM requires the use of multiple, integrated models, it is essential to define the relationships between the MOMs and the models’ outputs, so that the impact of model deficiencies on problem outcomes can be evaluated. A logic tree detailing the flow of data between different models, and showing the relationship between model outputs and problem MOMs, is most useful in this regard. Such a diagram permits a direct comparison of model outputs with problem metrics, which helps to ensure that the selected suite of models will be adequate to address all problem MOMs, and to identify exactly which MOMs will be affected by model deficiencies. This mapping of the information flow will aid in determining the most important model outputs and thus in prioritizing them. The mapping of models to metrics also greatly facilitates risk and impact analysis (see section 3.5.2.3).

3.1.2.1.2 Identify Functions Having Significant Impact on M&S Outputs

After a comprehensive and prioritized list of model outputs has been identified, it is necessary to identify contributing functions which have a primary impact on the value of those outputs. The

18. For additional information on these techniques see section 3.1.1 of the SMART VV&A Lessons Learned Document [reference 34].

purpose of this is to develop a comprehensive list of the most important functional drivers of model outputs. This list, in turn, forms a checklist of critical functions against which the capabilities of candidate models can be evaluated. (For example, in an application where an aircraft's probability of survival in a dense threat environment is an important model output, functions that would have a significant impact on this output might include: radar cross section, aircraft maneuvering, ECM effects, etc. Each of these primary functions may be significantly influenced by other lower level functions. For example, ECM effects would probably be influenced by the effects of atmospheric propagation, antenna patterns, etc..) This list of significant functions for each model output should be prioritized based on the prioritized list of problem MOMs developed above.

3.1.2.2 Define and Prioritize Fidelity Requirements

Fidelity requirements can be defined as the degree of correlation between model outputs and real world phenomena that is necessary for credible use of a model for a particular problem. They can also be looked upon as the acceptable error that can be tolerated in model outputs before problem outcomes will be grossly affected, or problem decisions will change from one state to another (e.g., from "yes" to "no"). Fidelity requirements are generally determined through sensitivity analyses performed on the problem MOMs. The sensitivity of problem outcomes to changes in MOM parameters determines the degree of accuracy for their associated model outputs. Sensitivity analysis on problem MOMs determines how far off model results can be while still allowing the right program decision to be made.

Definition of fidelity requirements begins by establishing the necessary degree of accuracy that model outputs must have in order not to exceed an error tolerance threshold defined for those MOMs to which they are related. Once this degree of accuracy is defined for each model output, it is necessary to relate it to the degree of accuracy required in those functions which significantly contribute to each model output. The following sections describe these two tasks in greater detail.

3.1.2.2.1 Determine M&S Output Accuracy Requirements

Once MOM values are related to model outputs (see section 3.1.2.1.1), defining an acceptable tolerance in a MOM will lead to a corresponding tolerance in the associated outputs of the models to which the MOM is related. These tolerances form the basis for model fidelity requirements. MOM tolerances can be estimated by analyzing the sensitivity of application outcomes to changes in the parameters by which the MOM will be calculated or evaluated (defined in section 3.1.1.1.2). Since these parameters have been related to model outputs (see section 3.1.2.1.1), MOM parameter sensitivities can be related to model output tolerances.

For example, assume that MOM #1 is completely parameterized by two variables (say x and y), and that it is determined that a 10% change in x or y (or x and y in combination) does not change the problem outcome. Let us further assume that x and y come directly from the output of a single model. The 10% tolerance about x and y implies that the model's predictions of x and y must be accurate to within 10% of the "real world" value in order for the model to of predictive use to the problem. If the model cannot predict *x* and *y* to within 10% of their actual values, then the tolerance of MOM #1 will be exceeded, and problem outcomes based on MOM #1 will be adversely affected.

The preceding discussion would seem to imply that tolerances about MOM values, MOM parameters, and their associated model outputs are easy to define, and have a closed-form analytical solution in every case. Nothing could be further from the truth. In fact, most MOM sensitivity analysis is done on the basis of Subject Matter Expert (SME) opinion and experience[19]. The insights gained by investigating application sensitivity to MOM values, however, far outweigh the pitfalls inherent in the subjectivity of this approach.

3.1.2.2.2 Relate Output Accuracy Requirements to Functional Accuracy Requirements

Once the model output fidelity requirements are determined for a model, they are further allocated to functions within the model. This is done through a sensitivity analysis on model functions, which determines how any variability in the individual functions affects the model outputs. This analysis should be performed one function at a time, keeping other parameters fixed at representative values characteristic of the application as a whole. If a great deal of variability is expected in other parameters, the sensitivity analysis is done with constants fixed at both extremes of the range of variability. Through this type of sensitivity analysis, the overall model tolerances can be further allocated to individual functions. These allocations form the fidelity criteria for the functions and are used as a basis for comparison with existing validation results.

For example, assume that target detection range is the model output that is of interest to a problem. A sensitivity analysis of different functions in the radar model being considered shows that this model output is sensitive to two parameters in the Multipath and Diffraction function. The analysis shows that a 20% change in the refractivity factor results in a 6% change in target detection range. Based on these results, a fidelity requirement of 5% on target detection range would require that the refractivity index be calculated to an accuracy of about 17%.

This process is not always an exact science. It is most directly applicable when a single model will be used to resolve a single MOM characterized by only a few parameters. In more complex cases, heavy reliance on SME opinion and experience is still necessary, and may be the only practical way to define fidelity requirements.

3.1.2.3 Define and Prioritize Operating Requirements

Operating requirements address practical issues surrounding the operation of software for use in the intended application. The goal is to characterize the computational environment in which a model must be used so that the resources and capabilities available to the model user can be com-

19. For additional information on these techniques see section 3.1.1 of the SMART VV&A Lessons Learned Document [reference 34].

pared with actual model usage requirements as defined, for example, in a User's Manual or other model documentation (see section 5.1.4). This comparison leads to the identification of unmet operating requirements (such as new hardware, software or interface capabilities) that must be addressed before the model can be properly and effectively used.

It is rare that unmet operating requirements alone will derail an accreditation effort. However, in situations where model use will require a significant investment in computational or analytical resources, it is possible that a tradeoff against other requirements for accreditation (e.g., V&V work) will need to be made. In cases where the VV&A budget is small, and the need for a credible model is high, such considerations can mitigate against the use (or development) of a new model, no matter how highly functional it may be.

Operating requirements can be parameterized in a number of ways, and no single list of characteristics can cover all situations. Based on the experience defined in section 1, however, we suggest the following five factors as sufficiently robust to characterize most modeling environments: definition of the operating team, its capabilities and expertise; definition of the hardware and software available across the operating team to support the use of models; identification of networking and interface capabilities across the modeling team; identification of input and output data processing capabilities and resources; and identification of modeling support resources. The following sections describe these factors in more detail.

3.1.2.3.1 Identify M&S Operating Team and Capabilities

It is necessary to identify who will actually run the models that may be chosen for use. It is also necessary to specify the modeling experience of each team member, which should include such information as area of modeling and analysis expertise, as well as a listing of experience with particular models and analyses. The goal is to characterize the modeling team in terms of an experience "pedigree" that can be compared to the level of experience needed to operate effectively the models that will be used in the application. Differences between modeling expertise requirements and team capabilities will be indicative of a need for modeling support services such as training.

3.1.2.3.2 Identify Hardware & Software Available to Run Models

It is also necessary to specify the computational resources available to the team that will use the models. Computational resources include such items as available hardware and software at each team site, the ability to network on-site or with other sites, availability of dedicated support for computational facilities and resources, etc. The goal is to specify the modeling team's hardware and software environment in sufficient detail to allow easy identification of upgrade requirements when team capabilities are compared to the requirements of the models chosen for use.

3.1.2.3.3 Identify M&S Networking and Interface Capabilities

In this task, the networking and interface capabilities of each member of the modeling team are specified in terms of the specific equipment and physical locations that can be networked (on-site and off-site), the interface protocols available (or necessary) for networking, and any hardware or software available to establish the required linkages. Other factors should be included as necessary to characterize as completely as possible the modeling team's network and interface environment, so deficiencies can be easily specified when the environment is compared to the requirements imposed by the selection of specific models.

3.1.2.3.4 Identify M&S Input and Output Data Processing Capabilities

The modeling team's ability to pre- and post-process data of any kind should be defined. Some models require the development and maintenance of sizable input databases; some models generate sizable output databases that may have to be processed for input to other models, or to generate final results. The ability of the modeling team to handle such tasks should be characterized in terms of available hardware, software, expertise, experience, and other factors that can be compared to requirements for such capabilities that might be imposed by the models selected.

3.1.2.3.5 Determine M&S Support Capabilities

Here, the modeling team's access to support services should be identified. Modeling support services are items such as access to training, the availability of dedicated support personnel (e.g., system administrators), repair and maintenance contracts on equipment, upgrade agreements on software, etc.. The characterization of modeling support capabilities should be structured to provide an indication of how robust and responsive the modeling environment is to demands that might be placed on it (for example, by the selection of new models).

3.1.2.4 Document M&S Requirements

Depending on the documentation requirements specified for the accreditation of a model (see section 3.2.1.3), it is very useful to document the M&S requirements developed via execution of the tasks described under 3.1.2.1 through 3.1.2.3. These formally documented M&S Requirements serve as the basis for comparison with model characteristics as defined by VV&A and other data. A good description of modeling requirements can substantially reduce the subjectivity of an accreditation decision, because such requirements are derived from the specifics of the problem, not the specifics of any particular model. Even in cases where it has been determined that a detailed description of modeling requirements is not necessary for model accreditation, serious consideration should be given to documenting these requirements in some way, even if only in synoptic form.

3.1.3 Select Candidate Models

The selection of models that totally comply with all problem requirements is usually not feasible except in the case of very simple problems. In most studies, the available models will have some functional limitations that must be addressed with model changes or work-arounds. Data on model capabilities and limitations is typically found in the accompanying model documentation and in the results of V&V activities. If a model has had previous V&V performed on it, the model's assumptions and limitations might be explained.[20] Figure 3–3: WBS for "Select Candidate M&S” shows the basic steps that are essential for model selection.

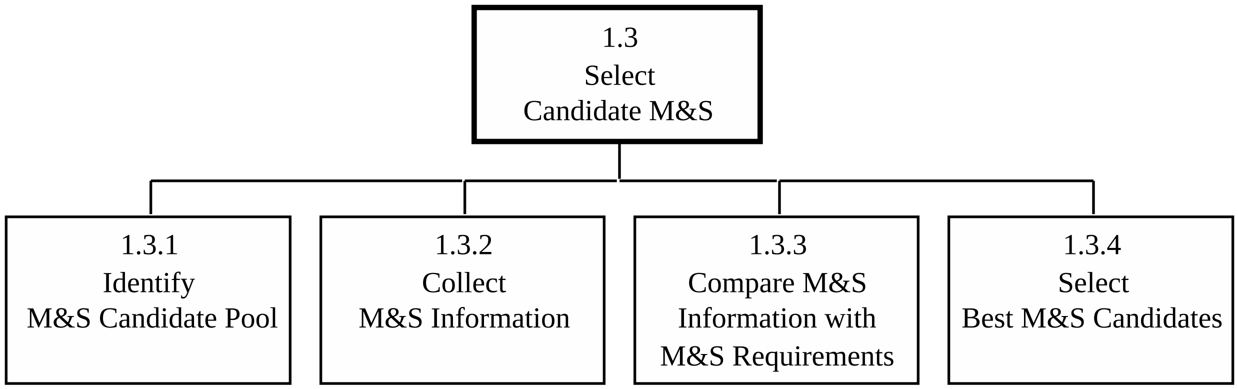

Figure 3–3: WBS for “Select Candidate M&S”

Currently each of the military services and major DoD activities maintain data repositories for selected models. Access to (and use of) these data repositories varies, and is limited by the lack of a common architecture and representation of the data. The Defense Modeling and Simulation Office (DMSO) has undertaken an initiative to establish a Modeling and Simulation Resource Repository (MSRR). The MSRR is a structured framework to allow DoD M&S community members to link resources they own into an organized architecture that permits easy data location and access by all M&S users. The MSRR is planned to be a distributed client-server network of repositories. Its resources are a subset of the future DoD repository system and include models and simulations, data, metadata, algorithms and tools. The SMART Accreditation Support Database (ASD) metadata are being included in the MSRR planned structure for M&S.[21]

3.1.3.1 Identify Model Candidate Pool

Once the application analysis is complete to the point that the functional and operating requirements are defined, a set of models that best satisfies the basic application requirements can be selected. It is important to understand the data flow hierarchy so that the proper models may be identified for each level in the hierarchy. Model outputs must be compared to study metrics to ensure that the MOMs are completely addressed.

3.1.3.2 Collect Model Information

Information about each of the models in the candidate pool is assembled. This information is obtained from basic model documentation, previous V&V reports, and inputs from model manag-

20. Summary V&V information for a number of models is available in the Accreditation Support Database (ASD) which is maintained by the Joint Accreditation Support Activity (JASA). The ASD can be accessed via the JASA Home Page at http://www.nawcwpns.navy.mil/~jasa/

21. For more information on the MSRR, visit the DMSO Home Page at http://www.dmso.mil/.

ers, developers, and previous users. Often the development and usage history provides additional insights into the intended uses of the model, as well as applications in which the model was successfully used. It is important to note that the information collected on each model in the candidate pool should, in some way or other, provide information about the model's strengths and weaknesses.

3.1.3.3 Compare Model Information with M&S Requirements

A compendium of all the available information on each model in the candidate pool permits a comparison of the capabilities and limitations of each model with the M&S requirements developed in accordance with the steps in 3.1.2. This comparison should result in a determination of three different types of results for each model: M&S requirements that appear to be satisfied by the particular model; M&S requirements that are not satisfied; and M&S requirements for which there are insufficient data to make a determination. These results lead to a determination of what model improvements might be required for each model and what additional V&V information will be required if the model is selected.

Model improvements are typically required and made when some limitation of the model negatively impacts the application or problem outcome, and no reasonable work-around exists. In many cases the model user will choose to modify the model to eliminate or reduce the limitation, if it can be accomplished within the program's budget and schedule constraints. This change to the model results in a version that is unique to the program, but the model's configuration manager may choose to incorporate the change into an authorized future version of the model. If the user of the model has a number of limitations that need to be reduced or eliminated, the user needs to prioritize the changes. Those changes that have the most impact to the decisions should be ranked the highest in priority. Any changes to the model should also become the object of additional V&V.

3.1.3.4 Select Best Model Candidates

Having determined the changes needed or the additional V&V needed to make each model acceptable for use in the application, the best model suite can be selected. This selection is based on the cost and schedule impacts of making the changes or performing the necessary V&V efforts. In all likelihood, after the comparison is made for each model candidate, there will be one model or set of models that are clearly the best for the application. The problem then becomes one of determining how best to make the necessary changes and/or perform the additional V&V tasks.

3.2 Planning

The object of accreditation planning is to ensure that all V&V efforts are focused on justifying the accreditation decision. Careful planning will minimize the chance that any V&V activities will be undertaken without a specific justifying requirement. As noted in principle #10 of the DMSO RPG, VV&A activities must be planned and documented.[22]

Before discussing accreditation planning, the difference between modeling requirements and accreditation requirements should be noted. M&S requirements are defined in the problem definition phase of the VV&A process (see Section 3.1), and detail the requirements and attributes that candidate models should possess to be of use in the application. Accreditation requirements detail the type and depth of information that is needed about candidate models to ensure that they satisfy the modeling requirements.

Accreditation requirements are derived from three sources: the level of credibility required by the application; unique requirements specified by the accreditation authority; and requirements specified by DoD and service policies. Determining these accreditation requirements is the first step in the planning process. The second step is doing the actual planning of the V&V and other data collection efforts. This planning typically involves laying out the responsibilities and schedules for individual tasks, and determining resource requirements to carry out the tasks. The schedule and resource requirements for V&V tasks must then be reconciled with the master program schedule and resource constraints.

3.2.1 Determine Accreditation Requirements

Accreditation requirements fall into three categories: V&V data requirements, non-V&V data requirements, and documentation requirements. V&V data requirements are derived from the credibility requirements of the application. Non-V&V data requirements and documentation requirements depend primarily on the nature of the application, and the specified requirements of both the accreditation authority and higher level authorities. The output of this series of steps is a consolidated VV&A task list and a set of VV&A documentation requirements. Figure 3–4: WBS for "Determine Accreditation Requirements" shows the WBS for this set of tasks.

3.2.1.1 Identify V&V Requirements and Tasking

The goal of V&V planning is to identify and fill in application-specific gaps in the existing body of V&V data for the models being used in the particular application. Additional V&V need only be performed when insufficient information is available to justify an accreditation decision.

V&V information is used for two purposes within the context of accreditation. Along with basic model documentation, V&V data provides information on model functionality and serves as the basis for determining if a model satisfies the functional requirements for a given application. V&V information is also used to evaluate the fidelity of the model's functions and outputs vis-à-vis the application's fidelity requirements.

The task of determining V&V requirements can be broken down into a series of sub-tasks. The starting point is a determination of what types of V&V or other information are needed to justify

22. See chapter 2 of the DMSO RPG [reference 45]

an accreditation decision. Existing data that match these requirements are collected and used to evaluate whether the M&S requirements are satisfied. This comparison leads to identification of information voids. The voids are analyzed to determine which ones are critical, after which the appropriate V&V tasks to fill critical voids are identified and added to a consolidated task list. This process is used for each M&S requirement.

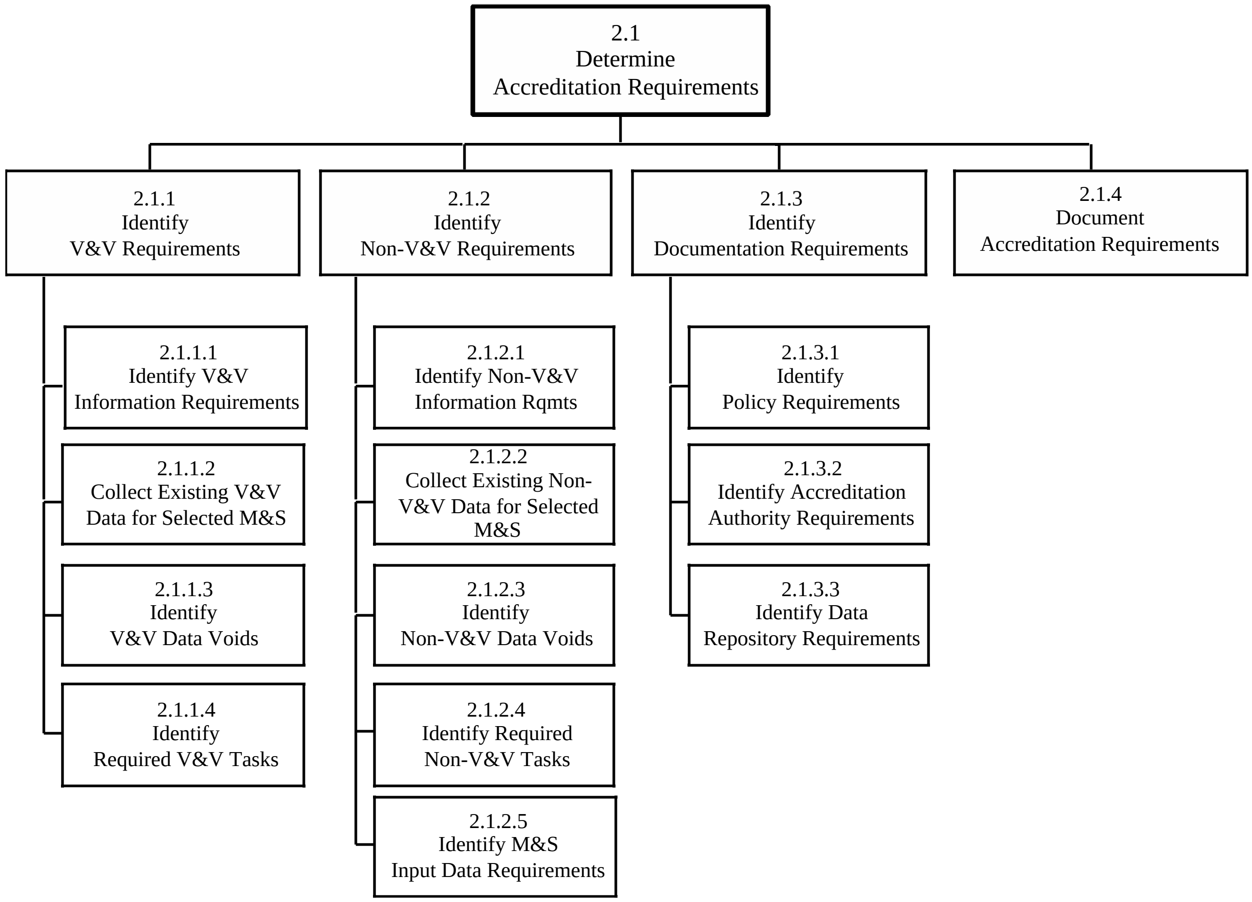

Figure 3–4: WBS for "Determine Accreditation Requirements"

3.2.1.1.1 Identify V&V Information Requirements

The scope and depth of V&V information that is necessary and sufficient to support an accreditation decision can be specified in terms of different V&V tasks, since each task produces a unique type of information. These pieces of information are generally complementary and, when taken together, yield an ever broader picture of the model's capabilities and limitations.

The minimum V&V data sufficient to support accreditation for an application depends on the level of credibility required. The higher the credibility requirement, the greater the need for more detailed V&V data. A V&V task menu has been developed which is organized into a sequence that proceeds from the macro-level to the very detailed level. This sequence is meant to aid the model user in selecting the appropriate levels of V&V data needed for an application.

Figure 3–5: V&V Data Selection Guide shows suggested V&V data for different credibility requirements. The information elements listed in the figure are defined in sections 3.3 and 3.4. The credibility levels identified in the figure are determined through analysis of the risks and benefits associated with the application outcome or the intended decision that is the object of the entire analysis. A detailed description of this risk/benefit analysis is contained in the SMART VV&A lessons learned document

3.2.1.1.2 Collect Existing V&V Data for Selected Models

Once M&S acceptance criteria are established and candidate models selected, the V&V results for these models are collected. Lists of previous users are obtained from the model manager or the appropriate Information Analysis Center.[23] Existing databases may contain some V&V results or provide pointers to sources of past V&V documentation. Because there has not been a formal requirement to document V&V results in the past, V&V data from previous users is sometimes a hit or miss proposition.

For those models that have been assessed using the process described in this report, the V&V results are available in a series of three Accreditation Support Packages (ASPs) that are organized according to the types of information most frequently used to support accreditation. ASP-I contains data that characterizes the model, summarizes the VV&A and usage history of the model, provides an assessment of model documentation and software quality, summarizes the configuration management process, and lists all the known assumptions and limitations for the model.[24] ASP-II provides the results of sensitivity analyses of the model at both the functional and overall levels, the conceptual model specification, logical verification, and any previous face validation. ASP-III provides the results of input data verification and validation, detailed code verification at the functional level, as well as the results of any validation done on either functional elements or the overall model. The validation reported in this section is validation done by comparing model or functional element outputs to real world test data.

3.2.1.1.3 Identify V&V Data Voids

At this point in the process the analyst has a set of functional and fidelity requirements, an understanding of what types of V&V information are necessary for the application, and prior V&V data. For each functional or fidelity requirement, the V&V information requirements are compared with the prior V&V data. If these data are not sufficient to satisfy the requirement (e.g., V&V historical data are incomplete, of unknown validity, or were not obtained), a V&V data void exists. After the functional and fidelity requirements have been evaluated with this process, all of

23. For example, the Survivability and Vulnerability Information Analysis Center (SURVIAC), in the case of survivability models.

24. Although treated as V&V information here, some of this data (specifically the VV&A and usage history, the model documentation, and the configuration baseline information) is referred to as non-V&V information in the DMSO Recommended Practices Guide.

the data voids must be documented and considered for possible additional V&V.

V&V MENU	Needed Credibility					
	Model Level			Functional Level		
	Nominal	Better	High	Nominal	Better	High
Baseline Definition	X	X	X	X	X	X
Determine C/M Attributes	X	X	X	X	X	X
Assess M&S Documentation	X	X	X	X	X	X
Est. VV&A and Usage History	X	X	X	X	X	X
S/W Quality Ass'mt			X			X
ID Assump & Limits	X	X	X	X	X	X
Produce Design Documentation		X	X		X	X
Perform Logical Ver.		X	X		X	X
Detailed Code Ver.			X			X
Sensitivity Analysis-Model Level		X	X		X	X
Sensitivity Analysis-Function Level					X	X
Face Validation		X			X	
Model Level Results Validation			X			X
Function Level Results Validation						X

Figure 3–5: V&V Data Selection Guide

These data voids also need to be prioritized. Those model functions that have little or no historical V&V data and that have a significant impact on the application outcome(s) are at the top of the list for supplemental V&V. By doing this prioritization of V&V requirements, resources can be efficiently allocated to the V&V effort.

3.2.1.1.4 Identify Required V&V Tasks

In most applications, efforts are constrained by limited budgets and requirements to meet deadlines. Therefore, the impact that V&V data voids have on the application or problem outcome should be examined before a decision is made to perform additional V&V to fill the voids. The impact can be assessed by assuming a worst case, that is that those parts of the model about which there is missing information do not provide reliable information. The question to ask under this assumption is "what impact will this unreliable data have on the application or problem outcome and what, if any, work-arounds can be used to minimize these impacts?" If the impacts are acceptable, or if there are acceptable work-arounds, the data void need not generate a V&V requirement, but it should still be noted and documented. The list of unacceptable data voids for which there are no suitable work-arounds becomes the list of required V&V tasks.

3.2.1.2 Identify Non-V&V Requirements and Tasking

Non-V&V requirements encompass needs for information that is not obtained through traditional V&V activities. This "other" information includes basic information about the model normally found in model documentation or other documentation produced by the model manager or configuration manager. Non-V&V requirements also include the identification and collection of information that addresses model input data.

3.2.1.2.1 Identify Non-V&V Information Requirements

Non-V&V information is typically needed to determine how well the model fulfills operating requirements associated with the application. These information needs typically include lists of hardware and software with which the model is compatible, information on the availability of training or other user support designed to assist users in operating the model, model documentation explaining the meaning and interpretation of model outputs, and information on the configuration management policies and practices. New users of the model will also need to know how to obtain the executable code and supporting documentation, if there are any costs for obtaining the model, and where assistance can be obtained for possible model changes. Some non-V&V information, including the users manuals, design specification or other similar documents, and a model description, is needed to help determine if the model satisfies the functional requirements of the application.

3.2.1.2.2 Collect Existing Non-V&V Data on Selected Models

Armed with the knowledge of what non-V&V information is needed, the prospective user must search out any existing information about the model. The sources for this information include the model manager, model developer, other users, and/or the appropriate Information Analysis Center (IAC).[25]

3.2.1.2.3 Identify Non-V&V Data Voids

As with V&V information, voids in non-V&V information are identified by comparing the information requirements with the information available. Any mismatches become data voids. Typically, there is sufficient information available to determine if the operating requirements can be satisfied. If this information is not documented, it may available through the model developer or the model manager. Data voids will most likely be in documentation of the model or its design.

3.2.1.2.4 Identify Required Non-V&V Tasks

The non-V&V data voids will usually lead directly to specific tasks to collect or to generate the necessary information. The approach used in identifying V&V tasks, namely assessing the

25. SURVIAC manages aircraft survivability models. A list of the different IACs and their spheres of responsibility can be obtained from the Defense Technical Information Center (DTIC).

impacts and finding work-arounds to avoid additional V&V, will generally not be useful in this case. Non-V&V data is needed to assess the fundamental functionality of the model as well as its operational attributes. This information is essential and usually cannot be bypassed or "worked around". Therefore, in most cases, each data void will equate to a specific task to collect the necessary information.

3.2.1.2.5 Identify M&S Input Data Requirements

Model inputs that are necessary to generate the required outputs for the problem must be specifically identified. Accuracy requirements for each input element should be identified using model sensitivity analysis results (see Section 3.4.1). If a sensitivity analysis has not been (or will not be) done, the maximum and minimum values of each input parameter can be used in the model to determine how much effect these variations have on the outputs. These results combined with SME opinion(s) should be used to estimate accuracy requirements.

In addition to the accuracy requirements, the requirements regarding data pedigree and source validity should be specified. Such requirements give assurance that the data truly represent the system or is an average value for all systems. If the data concern foreign systems, the source requirements give assurance that it conforms to the best intelligence estimates about the system which the data represents.

3.2.1.3 Identify Documentation Requirements

Requirements for accreditation documentation include the specification of which documents must be prepared, as well as the format and content requirements for each. The sources of these requirements are service or DoD policies, accreditation authority requirements, and any special requirements due to archiving compatibility.

3.2.1.3.1 Identify Policy Requirements

Most of the services or DoD components have published instructions that specify accreditation documentation requirements. These requirements typically specify whether a V&V plan, an accreditation plan, a V&V report, and/or an accreditation report is necessary. These instructions typically give some guidance on the content of each of these documents. Therefore, as part of the requirements determination process, it is important to review the pertinent service or component instructions to identify the minimum documentation that is needed to conform to the requirements.[26]

3.2.1.3.2 Identify Accreditation Authority Requirements

In addition to the service policy requirements, the accreditation authority may have some unique requirements for accreditation documentation. These requirements can be identified through a review of program documentation and/or direct inquiries to the accreditation authority. Where the

26. See references 39 through 44.

accreditation authority is in a command position, there may be command instructions governing these requirements.

3.2.1.3.3 Identify Data Repository Requirements

As the emphasis on model credibility grows, there is a growing recognition of the need to archive V&V results for the benefit of future model users[27]. Archiving systems are being established at various levels from DoD to the local command. During the requirements definition process, the accreditation agent who is determining the requirements should determine which system(s) will be used to archive the V&V results. The archive system administrator(s) should be contacted to determine if there are any unique requirements on the accreditation documentation to make it compatible with the archiving system. These unique requirements are incorporated into the documentation requirements.[28]

3.2.1.4 Document Accreditation Requirements

All of the accreditation requirements should be succinctly summarized and recorded as the basis for eventual accreditation. This summarized list of accreditation requirements will serve as a checklist of items to be reviewed as part of the accreditation assessment. These accreditation requirements should be documented in the accreditation plan.

3.2.2 Develop Accreditation Plan

An accreditation plan includes plans for performing V&V tasks, collecting non-V&V data, assessing the results in light of the accreditation requirements, and documenting both the V&V and assessment results. Accreditation planning also includes documentation of the plan itself. Figure 3–6: WBS for "Develop Accreditation Plan" shows the WBS for accreditation planning. The following paragraphs describe the steps necessary to develop an accreditation plan.

3.2.2.1 Plan V&V Tasks

The V&V plan defines the V&V tasks that are to be performed, identifies which functions of the model will receive priority consideration, and identifies the responsibilities for each step in the V&V process.

In most applications V&V efforts are constrained by limited budgets and requirements to meet deadlines. In some applications, personnel who are sufficiently knowledgeable to perform V&V on selected models may not be available. Each of these limitations must be identified so that a

27. See chapter 6 of the DMSO RPG for a discussion of documentation and archiving principles [reference 45]. Also see chapter 5 of the SMART VV&A Lessons Learned document for a discussion of the benefits of using standardized documentation [reference 34].

28. JASA performs this V&V data repository function for a number of M&S categories; it is recommended that any new V&V data generated by this process be made available to the JASA in order to update V&V documentation for the benefit of future users.

reasonable accommodation can be made to get the most work done as possible. Unless schedules can be slipped and/or additional resources found, the amount and type of V&V will be constrained. In these cases, the priority listing of requirements and a clear understanding of the different types of V&V activities is most important to maximize the benefit within the imposed limitations.

The nature of the expected results from the V&V activities should be defined in the plan as a guide to the V&V practitioner. Wherever possible, existing sources of test or operational data should be cited for use in performing validation on either the model as a whole or on specific functional elements within the model. Inclusion of these details in the V&V plan will reduce costs by front-loading the effort with the results of good planning.

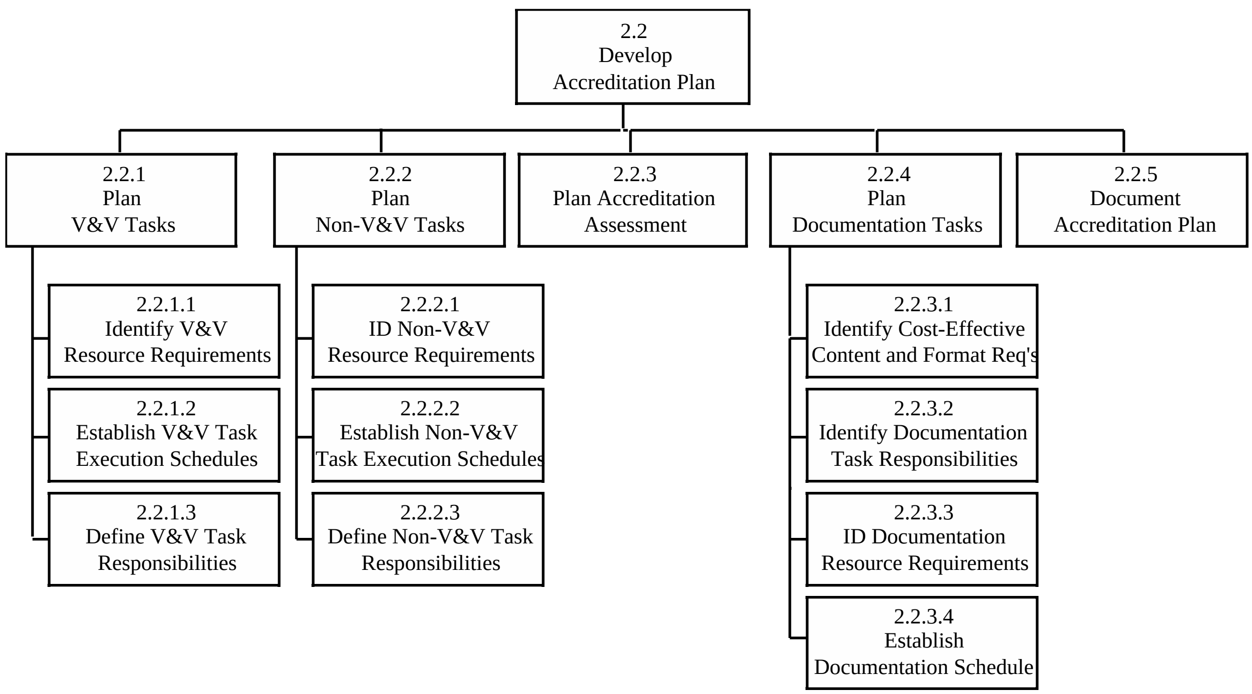

Figure 3–6: WBS for “Develop Accreditation Plan”

3.2.2.1.1 Identify V&V Task Resource Requirements

The comprehensive list of V&V tasks is the starting point for the VV&A planning effort. The planning effort follows a typical sequence for any planning effort. The first step is to identify resources needed to perform each of the identified V&V tasks. Since funding is likely to be the critical factor, funding requirements are the primary focus of this step. The funding requirements are reconciled with the program budget and adjustments made to the plans or the budget. Note that requirements for accreditation are not adjusted in this step, but may have to go unfulfilled based on budget or schedule considerations. The risk associated with these unfulfilled requirements is assessed later in the process.

The second part of this step is to identify the personnel requirements (numbers and qualifications) to perform the identified V&V tasks and estimate if these requirements can be met. A final determination and iteration of these personnel requirements is done after the task assignments have been made (see paragraph 3.2.2.1.3).

3.2.2.1.2 Establish V&V Task Execution Schedules

Once the financial requirements have been reconciled with the budget, estimated schedules are developed for each task. These task schedules are reconciled with the overall program or application schedule and adjustments made as necessary. If the required tasks cannot be completed in time to meet an accreditation deadline dictated by the program master schedule, the accreditation authority should be consulted. The options are to leave some V&V requirements unfilled or to accomplish the most critical V&V tasks and use those results to support a provisional accreditation. The remaining V&V tasks might then be programmed for completion at later time to support final accreditation.

3.2.2.1.3 Define V&V Task Responsibilities

Once the resources and schedules are tentatively agreed upon by the application manager(s), task responsibilities are defined. The organizations with primary and supporting responsibility for each task are identified, and preliminary negotiations undertaken to confirm that the resource and schedule estimates are essentially correct. If a major adjustment to either the budget or schedule is required, the prior planning steps must be redone and the plan iterated.

3.2.2.2 Plan Non-V&V Tasks

The first step in planning non-V&V tasks (after identifying what information is needed) is to determine how the information can best be collected. The most common non-V&V data voids are documentation deficiencies. For many models, adequate design documents were not prepared when the model was developed, and model manuals are either not complete or not updated as the model is modified. Preparation of model documentation (users', analysts', and programmers' manuals) is normally supported by the model manager.

Preparation of the design documents should also be done by the model manager as part of model development or upgrades. However, if sufficient time and resources exist, the V&V agent can reverse engineer the model's design requirements to develop a pseudo-design document conceptual model specification. This is normally a preliminary task to logical verification and detailed verification for those models that do not have a design specification. If other non-V&V data voids exist, the V&V agent can usually find sufficient information through contacts with the model developer, model manager, or other previous model users. If sufficient information cannot be developed, the data deficiency could be the basis for non-accreditation of the model, in which case the risks and impacts to the program need to be assessed using techniques similar to those used in assessing the impact of model deficiencies. (see Section 3.5.2.4).

3.2.2.2.1 Identify Non-V&V Task Resource Requirements

Having identified what tasks are necessary, the amount of work to accomplish these tasks is estimated. Costs for equipment or special support must also be factored into the overall resource requirements. These requirements are then added to the resource requirements for V&V tasks, so that the total resource requirements can be reconciled with the budget. If the budget is insufficient to allow all the requirements to be met, the plans for collecting accreditation data must be adjusted. Again, the requirements for accreditation are not changed but the planned tasks are curtailed so that only the highest priority tasks are performed. The probable need for this type of budget reconciliation is the primary reason that accreditation requirements should be prioritized in terms of required model functions and credibility levels.

3.2.2.2.2 Establish Non-V&V Task Execution Schedules

After the prioritized non-V&V tasks have been determined and reconciled with the budget, an estimated schedule for these tasks is prepared. This schedule is compared with the program master schedule and the schedule for the V&V tasks to make sure that the planned date for accreditation fits with the program requirements. If the accreditation schedule is not acceptable, adjustments to the schedule or provisions for a provisional accreditation must be made, just as was done in planning the V&V tasks.

3.2.2.2.3 Define Non V&V Task Responsibilities

Having established and reconciled the resources and schedule for the non-V&V tasks, the final step in planning them is to identify the organization or individual that will perform each task. For those tasks that will be funded by someone other than the accreditation authority (e.g., the model manager) appropriate coordination will be necessary to ensure that the final results will fulfill the requirements and will be provided in sufficient time to satisfy schedule requirements. For accreditation authority funded tasks, the products and schedule can be directed by the sponsor.

3.2.2.3 Plan Accreditation Assessment

A necessary element of the planning process is to develop plans for assessing the suitability of the model for the intended application. There are two commonly used approaches to performing an accreditation assessment. The first is to place the responsibility on the primary analyst who obtains and interprets the model results. If this approach is used, the plans for accreditation assessment should address issues such as: ensuring that specific criteria for evaluating the model's suitability are clearly documented and utilized; determining what actions will be taken if criteria are not specific; identifying what steps will be taken if the model does not fit the criteria; identifying the reviews that will be done on the analyst's findings; and identifying sources of assistance if other problems arise beyond the assessor's technical capability.

The second commonly used approach for performing an accreditation assessment is the use of an expert review team. If this approach is used, there is significantly more planning that is necessary to make such a team assessment effective. Planning for an expert team assessment must address team composition, team leader selection, assessment criteria, methods for resolving differences of opinion, the mechanics of running and supporting the assessment meetings, financial support for team members, and documenting the team findings. If these issues cannot be definitively planned during the planning phase, which often takes place several months before the assessment actually is done, the assessment plans must at least identify who will do the detailed planning, when it will be done, and who will be responsible for implementation. Additional considerations and suggestions for effective assessment planning are contained in the SMART Lessons Learned document[29].

3.2.2.4 Plan Documentation Tasks

Having identified the documentation requirements and planned the various data collection tasks, the last planning task is to define a documentation scheme or plan that fulfills all the requirements and yet will require a minimum amount of resources to implement. Different documentation techniques are possible, and one that is appropriate for each application depends on local operations and needs. The selected approach should fulfill all of the identified documentation requirements and should be applicable to all documentation tasks within the application. The important factor, according to the DMSO RPG is that the plans are documented[30].

3.2.2.4.1 Identify Cost-Effective Content and Format Requirements

In developing a documentation plan, the local operating methods or the accreditation authority's requirements may suggest a particular approach that will require a minimal amount of resources. A bound, formal, traditional set of plans and reports may not be needed or cost-effective. With the advent of the paperless office and networked facilities, innovative methods for recording plans and results should be used wherever the requirements can be met with a less costly approach. Since there will probably be a number of different documents for different aspects of the VV&A effort, there may also be different documentation formats for these different aspects. If so the various different formats should be identified.[31]

3.2.2.4.2 Identify Documentation Task Responsibilities

Since there will probably be separate documents to record accreditation requirements, V&V plans, data collection plans, V&V results, other data, and accreditation assessment results, each product will probably be the responsibility of a different individual or organization. Part of documentation planning requires that the appropriate group or individual be identified to assemble and record the necessary information for each document or product. A simple list of documents or products and the responsible party will often suffice to record the results of this planning task. In most cases the party that actually performs each task will be responsible for documenting its

29. See section 3.5.2 of reference 34.

30. See Principle #10 in chapter 2 [reference 45].

31. As an example, one accreditation authority requires that the V&V results and accreditation recommendations be explained in a formal briefing. In this case the briefing includes all the topics required by service instruction and an annotated copy of the briefing charts is used as the accreditation report.

results.

3.2.2.4.3 Identify Documentation Task Resource Requirements

Since documentation is specified as a separate task, the associated costs may be of interest to the accreditation authority who typically sponsors these efforts. Cost estimates for each documentation effort are prepared as part of the planning process and consolidated into a total documentation cost. During budget reconciliation these costs are reviewed and, if they seem excessive, form a basis for reviewing the documentation planning. The ultimate purpose is to make the documentation effort as cost-effective as possible.

Another part of this task is to identify any other equipment or support that might be required. Possible equipment requirements might include work station upgrades, desktop publishing improvements, and/or electronic storage improvements. Other support might be needed from centralized activities such as an IAC or the Defense Technical Information Center (DTIC).

3.2.2.4.4 Establish Documentation Task Schedule

The schedule for the documentation tasks will normally be driven by the schedule for the VV&A tasks that are the subject of each respective document. Information to support documentation will normally be collected during each task and then assembled into a final document at the end of the task. Documentation can normally be completed within a month following the completion of a task, assuming that interim documentation has been produced in accordance with a documentation outline developed prior to the task. In some cases the documentation can be done in less time, especially for relatively short tasks such as the accreditation assessment. The schedule should also allow time for any draft reviews that are necessary prior to completion of a final version.

3.2.2.5 Document Accreditation Plan

Once all the planning has been completed, the plans must normally be documented. These plans will serve as a guide to those who are charged with implementing them and also provide information to the accreditation authority about how the credibility of the selected models will be quantified and justified. This accreditation plan allows the accreditation authority a chance to modify the planning and also serves as a justification for resource expenditures. The accreditation plan should be documented according to the requirements (format and content) specified in the documentation requirements.

3.3 Verification

Verification is defined in Joint Pub 1-02 as "...the process of determining that a model implementation accurately represents the developer's conceptual description and specifications."[32] Verifi-

32. Department of Defense. Department of Defense Dictionary of Military and Associated Terms, Washington D.C., DoD, 23 March 1994 (Joint Publication 1-02)

cation activities support model credibility by evaluating the confidence a user should have in the software as written. Verification can be labor intensive , especially if it was not planned for and accomplished during software development. Consequently, it is very important to identify and prioritize carefully those verification tasks which must be done to support accreditation, and to ensure that the maximum benefit is realized from each verification dollar spent. This may best be done by identifying and prioritizing those functions within the model that most impact the user's problem area, or application. In order to identify those functions, the model must first be decomposed into functional elements.

3.3.1 Decompose Model Into Functions

Model decomposition identifies and describes the major functional capabilities of a model, as well as the functional elements (FEs) that implement each capability. An FE is defined by that collection of software modules (or, sometimes, a single module) in a model that implements a functional capability and that would be a candidate for V&V. Examples of FEs would be the clutter, multipath and diffraction subroutines of a detailed radar analysis model like ALARM. Identification of a model's functional capabilities at different levels of detail serves to parse the model into manageable pieces against which detailed verification (and validation) can be applied. After a model's major functional areas and supporting FEs are identified, the capabilities of each are defined with descriptive material that documents the purpose of each function, its role in the overall model, the theory behind its operation, and its implementation in the code.

Model decomposition is a straightforward task if associated documentation is adequate, and most model functions can be characterized by a hierarchy of only a few levels. These levels usually suggest areas where verification (and validation) is essential to credible use of the model, as well as areas for which they may be inappropriate (e.g., random number generators or trigonometric functions). Most important, if the functional hierarchy shows that functions required for an intended application are not addressed by the model, further V&V efforts may be unnecessary (although model development may be called for, instead).

If more than one model is being examined at the same time, further benefits can be derived from the decomposition effort if areas or elements of common functionality can be identified in more than one model. For example, ESAMS, ALARM, and RADGUNS[33] all contain a radar detection function, but only one simulates missile flyout, and only one simulates ballistic trajectories. Identification of functional redundancies across M&S, as shown in Table 3-1, can help streamline V&V efforts by permitting parallel execution of V&V tasks on the same FEs for different models.

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33. ESAMS stands for Enhanced Surface to Air Missile Simulation; ALARM for Advanced Low Altitude Radar Model; and RADGUNS for Radar Directed Gun System Simulation. All are joint-Service models used to support current acquisition programs.

Table 3-1 Top Level Functional Areas for Three Models

MODEL	FUNCTIONAL AREAS		
ALARM	RF Sensor		
ESAMS	RF Sensor	Missile Flyout	
RADGUNS	RF Sensor	AAA Gun System	AAA System Operator

After decomposing the model into FEs, a hierarchical template that links functional elements together into successively higher order functions is constructed, thus characterizing the functionality of the entire model. The resulting functional area templates (FATs) provide a structural framework that can be used to prioritize verification efforts, as well as to guide data collection and validation efforts for a model. Comparison of FATs between models also permits a top-level comparison of their functional capabilities directly, without the need for in-depth documentation review, or even detailed familiarity with each model.

One of the FATs developed for RADGUNS is shown in Figure 3-7. The hierarchy of FE designators below each FA is apparent, and the numbering system shown can be used as a guide for the development of V&V tasking and documentation associated with each FE. FATs such as this can also be color coded, or shaded, to track plans and progress of V&V efforts.

The idea that V&V should be conducted at the functional level vice the subroutine (or module) level, or overall model level, is an essential element of cost-effective V&V. Commonality of functions across models, for example, permits a single data collection effort to be used for validation of the same FEs of different models. In addition, this data can be used to validate models with similar functions at a later time.

Most important for accreditation is the fact that all model functions at some level of detail are represented by the FAT, providing a prospective user with an indication of where (and at what level of detail) a particular function is implemented in the model. This can be important in situations where several models are being examined as possible candidates for accreditation and the FATs indicate significantly different implementations of the functions of interest. FATs can then be used as evaluation elements in criteria for selecting one model over another. They can also be used to direct the development of notional and detailed test plans (see section 3.4.3.1) for acquisition of the data required to validate the various FEs, as well as to guide the subsequent analysis efforts associated with validation.

For verification purposes, the FAT provides a breakdown that individual software modules can be collected under so that implementation of critical or application-specific code can be examined with respect to what was intended or what may be required. It also helps prevent redundant efforts that could be applied to similar functions controlled by executive or manager modules that normally don't need to be verified. A potential problem for verification, however, is that FATs provide no indication of MAIN source code modules which facilitate understanding of the code from the top-down perspective shared by most independent verification agents.

Another approach to FAT development that is perhaps more appropriate for newer M&S is the decomposition of objects that have unique attributes and function associated with them. In the case of the anti-aircraft threat simulation used above, a decomposition of the RADGUNS model by object platforms, attributes and functions is shown in Figure 3-8. In this template, the target aircraft platform and the threat system platform are disaggregated and represented by separate objects having the same general form. Note that in this representation functions not modeled (as indicated by the italicized shadow typeface) appear in the aircraft sensor and decision-making element (DME) areas and that propagation functions are not included in either platform template, but rather in a separate template that encompasses functions that occur between the platforms. In a distributed simulation, these would be considered disaggregated players, or entities, that may be assigned to different processors or network nodes. When planning for V&V of these types of M&S, the FAT heirarchy becomes increasingly important in developing an understanding of where critical functions are performed both physically and within the software itself.

RF Sensor

1.0 Target Characteristics

- 1.1 Flight Path
- 1.2 Signature
  - 1.2.1 RCS
    - 1.2.1.1 Static
    - 1.2.1.2 Dynamic
  - 1.2.2 Fluctuations
- 1.3 ECM
  - 1.3.1 Noise
    - 1.3.1.1 On-Board
    - 1.3.1.2 Off-Board
    - 1.3.1.3 Standoff
  - 1.3.2 Deception
    - 1.3.2.1 On-Board
    - 1.3.2.2 Off-board
    - 1.3.2.3 Standoff

2.0 Propagation

- 2.1 Masking
- 2.2 Clutter
- 2.3 Multipath/Diffraction
- 2.4 Atmospheric Attenuation

3.0 Transmitter

- 3.1 Waveform Generator

4.0 Receiver

- 4.1 Thermal Noise
- 4.2 AGC
- 4.3 Detector
- 4.4 Blanking

5.0 Antenna

- 5.1 Gain

6.0 Signal Processing

- 6.1 Threshold
- 6.2 Clutter Rejection
  - 6.2.1 MTI
  - 6.2.2 Doppler Filters
- 6.3 Integration
- 6.4 Pulse Compression

7.0 Target Tracking

- 7.1 Angle
- 7.2 Range
- 7.3 Doppler
- 7.4 Antenna Scan

AAA Gun System

8.0 Fire Control Computer

- 8.1 Aiming Solution
- 8.2 Gun Movement
- 8.3 Fire Enable/Disable

9.0 Guns/Ammunition

- 9.1 Fire Rate (Burst) Control
- 9.2 Ballistics

10.0 End Game

- 10.1 Probability of Hit
- 10.2 Probability of Kill

AAA Systems Operator

11.0 Radar Control

- 11.1 Search Modes

12.0 Reactions

- 12.1 Reacquisition
- 12.2 Optical/Manual Tracking

Figure 3-7: Functional Area Template for RADGUNS

I AAA SYSTEM PLATFORM

- 1.0 Attributes
  - 1.1 Configuration
  - 1.2 Movement
- 2.0 Sensors
  - 2.1 Acoustic
  - 2.2 Electro-optical
  - 2.3 IR
  - 2.4 RF
    - 2.4.1 Transmitter
      - 2.4.1.1 Waveform Generator
    - 2.4.2 Antenna
      - 2.4.2.1 Gain Pattern
    - 2.4.3 Receiver
      - 2.4.3.1 Thermal Noise
      - 2.4.3.2 AGC
      - 2.4.3.3 Detector
      - 2.4.3.4 Blanking
    - 2.4.4 Signal Processing
      - 2.4.4.1 Threshold
      - 2.4.4.2 Clutter Rejection
        - MTI
        - Doppler Filters
      - 2.4.3.3 Integration
    - 2.4.5 Target Tracking
      - 2.4.5.1 Angle
      - 2.4.5.2 Range
      - 2.4.5.3 Doppler
- 3.0 Weapons
  - 3.1 Guns
    - 3.1.1 Fire Rate/Burst Control
    - 3.1.2 Ammunition Ballistics
    - 3.1.3 Lethality - P_h/P_k
- 4.0 Comm Devices
- 5.0 CM/CCM
  - 5.1 EO Tracking
- 6.0 DME
  - 6.1 Operator
  - 6.2 Fire Control Computer

II AIRCRAFT TARGET PLATFORM

- 1.0 Attributes
  - 1.1 Configuration
  - 1.2 Movement
    - 1.2.1 Propulsion
    - 1.2.2 Aero/Kinematics
      - 3 DOF
      - Blue Max
  - 1.3 Signatures
    - 1.3.1 EO
    - 1.3.2 IR
    - 1.3.3 RF
      - Static
      - Dynamic
      - Fluctuations
  - 1.4 Vulnerability
- 2.0 Sensors
- 3.0 Weapons
- 4.0 Comm Devices
- 5.0 ECM
  - 5.1 Noise
    - 5.1.1 On-Board
    - 5.1.2 Off-Board
  - 5.2 Deceptive
    - 5.2.1 On-Board
    - 5.2.2 Off-Board
- 6.0 DME

III ENVIRONMENT

- 1.0 Atmospheric
  - 1.1 Attenuation
  - 1.2 Refraction/Ducting
  - 1.3 Radiance/Transmittance
- 2.0 Topographic
  - 2.1 Clutter (Terrain/Sea/Culture)
  - 2.2 Multipath/Diffraction
  - 2.3 Masking

Figure 3-8: Object Oriented Template for RADGUNS

3.3.2 Assess Software Quality

Software quality assessment (SQA) provides the prospective model user with an indication of the conformance of model code to accepted (standardized) software development and documentation practices. The structure of the source code of the model is analyzed from a software engineering perspective in at least three major areas: use of programming standards; computational efficiency; and resource (e.g., memory or disk) utilization. Within each of these major areas are several contributing factors which are individually evaluated and aggregated into a "score" representing an overall evaluation of source code quality. This process yields consistent results as long as the subjective evaluation criteria remain constant, and scores are produced by the same analyst. The subjective nature of the evaluation, combined with personal preferences, will likely result in different assessments from different analysts, however. The documentation of objective assessment criteria and scoring mechanisms can mitigate against gross subjectivity.

A typical set of software quality factors is shown in Table 3-2. The contributing factors within each major area of software quality may be a function of other requirements, and the list provided is intended to be neither exhaustive nor prescriptive.

Table 3-2 Factors Contributing to Software Quality Assessments

Programming Conventions	Computational Efficiency	Memory Utilization
Use of Comments	Modularity	Local Memory
Use of Formatted Headers	Memory Allocation	Global Memory
Formatting of Source Code	Variable Allocation	Shared Memory
Variable Naming Conventions	Algorithm Development	Control of Memory
Logical File Processing	Use of Subroutines and Functions	
Undeclared Variables		
Programming Logic		

Software quality assessments of the type described above can be combined with, and benefit from, an analysis of the software using Computer Aided Software Engineering (CASE) tools. CASE tools are designed to automate and document various facets of the software development process, but can also be used in a "reverse engineering" examination of existing code. Static CASE tools provide detailed information about a model's size, structure, and complexity. These can be significant quality factors that may affect plans and resources required for further V&V. Some static CASE tools generate detailed software flow charts, but these most likely will need to be reduced into a more usable form, because the volume of flow chart output for a large model quickly becomes unmanageable.

Much of what can be learned from software analysis with CASE tools, however, can also be provided by the developer of the model, who has most likely already produced logical flow and structure charts, and who is familiar with its computer resource and I/O requirements. This is a cost-effectiveness issue in which the time required to learn enough about the model using CASE tools must be weighed against the cost of obtaining the information more quickly from the model developer.

If run-time performance (i.e., speed of execution), and I/O requirements are the limiting quality factors, a set of dynamic CASE tools can be used to determine exactly how and where the model spends its time and uses computational resources. Depending upon the experience level one has with a model, the resources available for allocation to CASE tool analyses, and the relative importance of code structure and performance factors, this type of quality assessment could precede, or even replace the static type of analysis previously described.

Software quality assessment is no substitute for actual model experience and application as developed in a user community by individual users. It does, however, focus both on clearly identifiable software problems in a structured way, and gives a prospective model user a feeling for the tradeoff between software maturity and credible model use. For those considering in-depth V&V of an existing model, SQA is also a risk-reduction tool, identifying the potential for failure in verification or validation due to poorly designed, structured and documented code. The importance of a software quality assessment will depend upon the intended application and the degree of software modification required to tailor the model to address the application properly. Any amount of software development or modification required to tailor the model to the application will be accompanied by risk factors that could negate the utility of software quality assessment or prevent the achievement of other V&V objectives.

Table 3-3 illustrates the results of a typical software quality assessment. The approach taken was a straightforward comparison of existing source code against published coding standards (ANSI FORTRAN 77 in this case) and against what is generally considered good practice in the software development community. Software modules were selected randomly, and scoring points were assigned according to evaluations as unacceptable, poor practice, acceptable, or excellent. Ratios of maximum possible scores were averaged into an overall assessment value that could be used to compare or rank the modules with respect to software quality. Results were positive in most areas, even though deficiencies and examples of bad practice were found in each.

3.3.3 Identify Model Assumptions, Limitations and Errors

Different users typically have different applications for the same model, applications which require that the model have certain characteristics. This V&V activity helps the user determine, at an early stage, whether or not the model's assumptions, limitations and errors place it outside the realm of acceptability to the problem at hand. Coupled with the model's usage and VV&A histories (see section 3.5.1.2), a Summary of Assumptions, Limitations and Errors (SALE) can be a powerful model selection and evaluation tool in the case where multiple models appear to be suitable for the same application. The SALE also provides a format for integrating any assumptions, limitations, and errors discovered during prior and ongoing V&V efforts, and for incorporating any that may be discovered in future V&V efforts by other users.

Table 3-3 Software Analysis Worksheet for Module GUN23.for in RADGUNS 1.8

CRITERIA	*Unacceptable*	*Poor Practice*	*Acceptable*	*Excellent*
MOE #1 - Use of Standards:				
Criterion #1: Readability			**x**	
Criterion #2: Modifiability			**x**	
Criterion #3: ANSI standards				**x**
MOE #2 - Programming Conventions:				
Criterion #1: Use of comments and headers.			**x**	
Criterion #2: Use of variables.			**x**	
Criterion #3: Use of formatted statements.				**x**
Criterion #4: Logical I/O devices.				**x**
Criterion #5: Variable declarations.				**x**
Criterion #6: Variable initialization.				**x**
Criterion #7: Variable naming conventions.				**x**
Criterion #8: Algorithm logic.				**x**
MOE #3 - Computational Efficiency:				
Criterion #1: Mixed mode calculations.				**x**
Criterion #2: Use of library functions.				**x**
Criterion #3: Nested computations.				**x**
MOE #4 - Memory Utilization:				
Criterion #1: Dynamic allocation.				**x**
Criterion #2: Re-utilization of variables.				**x**
Criterion #3: Memory management.				**x**
Criterion #4: Use of COMMON blocks.				**x**
Criterion #5: Use of EQUIVALENCE.				**x**

Using the methodology described in this document, much of the information relating to assumptions, limitations and errors comes from the production of the Conceptual Model Specification (CMS) that is required for more detailed verification efforts (see section 3.3.4). When new models are undergoing verification in parallel with the development process (as they should be), a summary of assumptions and limitations can be prepared based on an analysis of the conceptual model and the model design specification. For new model developments, of course, the discovery of errors will only come from extensive testing and inspection of the software.

The purpose of the CMS is to specify and reference the design criteria to which the model's software was developed, thereby documenting essential information relating to the implicit and explicit design assumptions and limitations.[34] In addition, a preliminary code review performed during final preparation of these documents can frequently result in the discovery of heretofore unknown or unsuspected errors. Other sources of information are equally valuable, however. Configuration management change requests and error reports, as well as user group meeting minutes and model documentation, all provide important supplementary information about a model's assumptions, limitations and errors, and all such sources should be considered when compiling such data for review.

34. See [9] for a detailed description of technical requirements for design documentation.

While the SALE report provides valuable information to support accreditation decisions, it also provides an indication of the probable scope of required verification efforts. A model that is based upon few assumptions and a well-defined scope of application will be less likely to have subtle errors and more likely to withstand intensive verification scrutiny than one designed to address a broad range of conditions, each requiring several assumptions. Large, complex models are also more prone to coding errors that may not be easily identified or corrected, further complicating the verification problem. Ultimately, the SALE provides a top-level description of the underlying assumptions and limitations of the model. It is often easy to determine the applicability of a model to an application by understanding the intent for which the model was built. If the model was intended for a given purpose but is being considered to serve a different one, the SALE will help the user understand the possible ramifications of such usage.

3.3.4 Produce Design Documentation

For legacy M&S, which (by definition) were developed before the advent of detailed software design specifications and standards, design documentation is almost always absent. In order to be able to conduct detailed code verification, however, it is necessary to have such documentation because it describes the implementation against which code is verified. To address the lack of design documentation (currently provided in Software Design Documents (SDDs) during the development of new models), SMART developed a reverse-engineering approach to defining and documenting design requirements and criteria for legacy M&S. The post-development substitute for the SDD documents the developer’s conceptual design and approach to modeling the systems, physical phenomena and interactions included in the simulation.

The development of the CMS begins with production of a detailed descriptions of the implementation of each FE that can be used to establish design requirements and design elements. This information should be produced by the model developer, or other sources with a detailed knowledge of the model. The verification team then uses this information, along with references, model documentation, and code associated with each FE to define design elements and requirements, and compiles these requirements into the CMS. Where necessary, requests for clarification are written directly in a draft CMS in the form of “Notes to the Developer”, for which specific feedback of further information may be required. Additional PDDD revisions may be generated during the actual verification process if errors not previously noticed are discovered.

Final versions of this documentation should appear in a Conceptual Model Specification (CMS) report, or section of ASP-II. The information contained in the CMS can provide valuable inputs to an expert review team about assumptions, limitations, and errors associated with the design of FEs, as well as about the model at a top level. The process of CMS production is illustrated by the flowcharts in Figure 3-9.

To get the most value from dollars spent on development of design documentation, a prioritized list of FEs should be developed, based on the functional modeling requirements of the application at hand. Design documentation should only be produced for those FEs that have a critical bearing on application requirements. The actual priority of FEs to be verified will, of course, depend upon the intended application and the available resources that can be applied. Development of design documentation may not be necessary for simple functions for which intended designs are obvious (e.g., trigonometric or random number routines), or for functions that will not be subjected to code verification activities. However, an understanding of any assumptions and limitations inherent in the software design will still be necessary to complete an expert review and document a logical verification effort (see section 3.3.5).

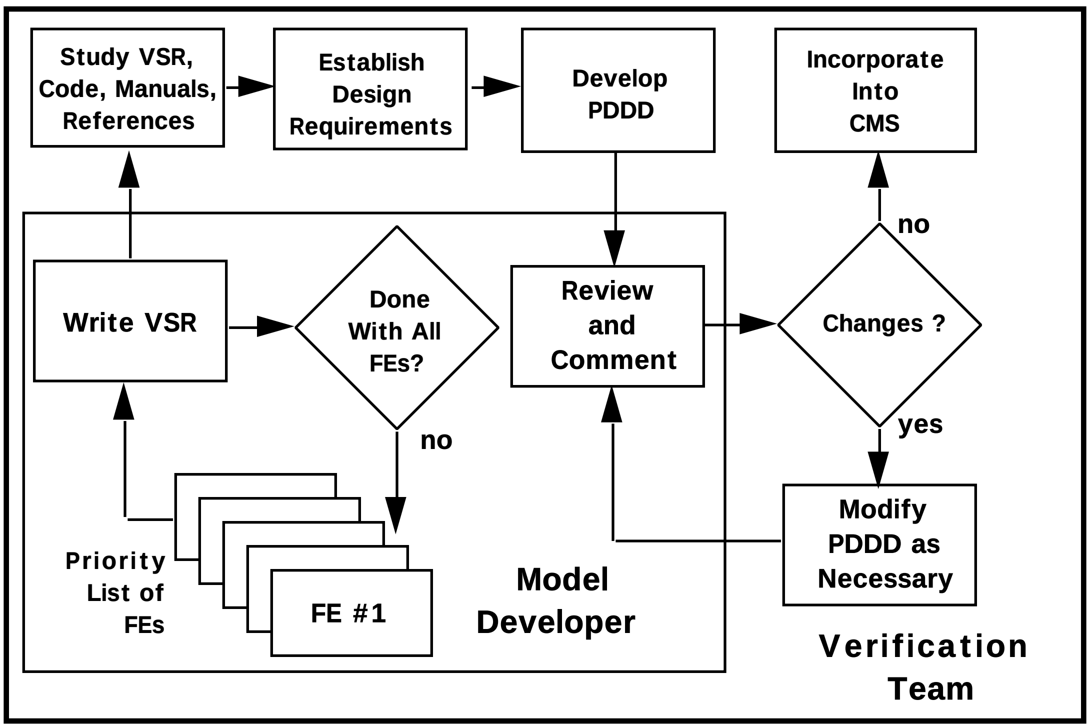

Figure 3-9: CMS Development Process

3.3.5 Perform Logical Verification

Modeling assumptions and/or approximations can easily lead to gross oversimplifications of physical phenomena, system capabilities or interactions between systems that may be critical for a particular application. When M&S acceptance criteria and requirements are defined, a summary of assumptions, limitations and errors, as well as design documentation, can be used to determine the degree of applicability of the model to the desired application. This review should result in a logical verification of the model implementation.

The purpose of logical verification is to compare a model's assumptions, limitations, known errors, and approximations with the modeling requirements of the problem at hand to determine whether the model can reasonably be expected to produce results realistic enough to be of use in the application. Logical verification ensures that the basic equations and algorithms comprising a model are correct, and helps to determine its appropriateness for a particular application.

Logical Verification is most useful when it consists of an expert review of a model's design (e.g., in the form of an SDD, or a CMS for legacy M&S; see section 3.3.4), it's documentation (see section 3.5.1.3), and it's SALE (see section 3.3.3). Of particular interest will be areas where expected model results might lead users to erroneous or false conclusions due to interdependent (or heretofore unknown) assumptions.

<u>3.3.6 Perform Code Verification</u>

The purpose of code verification is to provide a detailed examination of the code to ensure that design requirements have been satisfied, and that the algorithms and equations being used are properly implemented in the software. A secondary objective is to ensure that appropriate coding practices are being used, and that the software can actually be executed as implemented. In most software development efforts, code verification is accomplished by examining individual software modules one by one until the software has been examined in its entirety. For legacy M&S, however, it is more cost-effective to verify by FE than by software module. This is because the credibility of critical model functions is more important to accreditation decisions than is the credibility of individual software routines (except in the rare cases where they happen to be the same).

The verification process described here for legacy M&S differs from classical model verification in that each FE is verified as a unit. This contrasts with the classical approach of structuring the process according to the software call hierarchy, or top-down approach. However, the methods used within this approach are the same as the classical methods described in [2, 4, and 7]. Activities are grouped into areas that address code examination, software testing, and documentation of findings. Results of these tasks are reported in the form of individual FE verification reports, or sections of ASP-III. A process flowchart depicting the procedural steps employed in the verification process is shown in Figure 3-10.

Code verification consists of four major activities:

a) correlating design requirements and specifications with cited references;
b) correlating code implementation with the design specifications;
c) auditing the code for correctness of implementation;
d) testing of all executable statements.

Correlating design specification with cited references is done simply by examining the CMS design descriptions and verifying that the described equations and algorithms accurately represent (or can be derived from) references accepted as credible by a knowledgeable source (in this case, the model developer or author of the CMS). Sometimes this cannot be done because the only reference available is another model (code), or an incomplete document provided by the model developer. In such cases, it may be necessary to document a verification deficiency.

Correlating software design with actual code includes checking that the code follows the flow diagrams provided in theCMS . CASE tools could be used here to produce flow charts derived directly from the code to be compared to those in the CMS. This part of the process is performed on all lines of code within each software module that comprises a given FE. For each software module, the following steps are performed:

1. Ensure that subroutine input and output reflect those specified by the design specification .

2. Associate sections of code with design elements described in the design approach section of the CMS. (Design elements are self-contained entities that perform a single function; i.e., an equation or an algorithm.)

3. Check that the code accurately implements the design element. This includes a check of equations, logical algorithms, and units of measure.

4. Check that the routines implemented in the code match any applicable flow charts that appear in the CMS .

5. Review existing Model Deficiency Reports (MDRs) (see Appendix C, Configuration Management) to determine if any previously reported errors apply to this FE. If so, check whether or not they have been corrected.

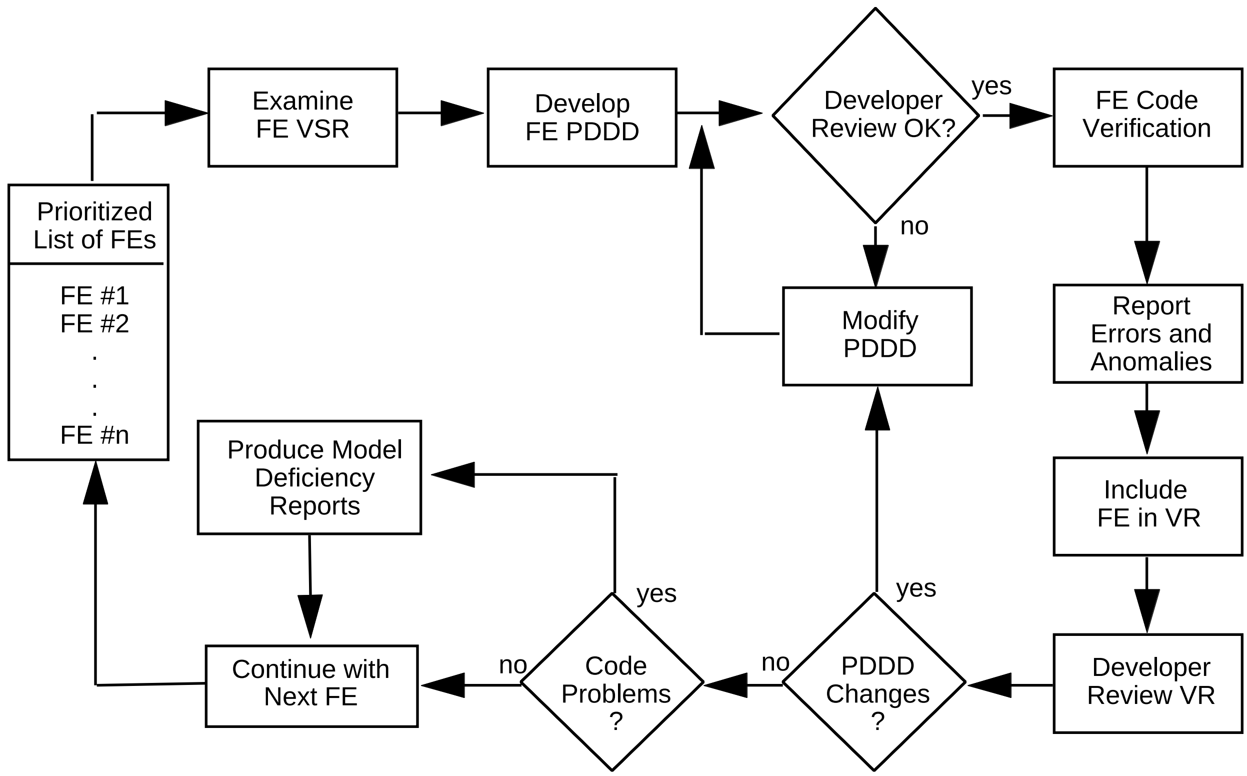

Figure 3-10: Verification Process Overview

Code auditing consists of checking for errors introduced in the coding process. Procedures used in this part of the task include the following:

1. Check whether internal code documentation (prologues, comment lines) are accurate and adequate to describe the purpose and functioning of the software.

2. Identify potential overflow and underflow conditions.

3. Identify potential array bound overwrite conditions.

4. Examine conditional structures for logical branch accessibility.

5. Check for errors such as interface mismatches and typographical errors.

6. Check code quality characteristics such as code structure and variable usage.

CASE tools could be useful in performing some of these steps. Many static CASE tools give information about the type of problems mentioned in Steps 5 and 6. CASE tool functions associated with compilers may also be available for some languages and operating system combinations to assist with Steps 2-4.

The initial step in software testing is to develop a set of software test cases. Some test cases are designed to exercise the code during run-time to verify that the design elements implemented in the code are performing the required calculations correctly. The values produced by the code are compared to values produced from the mathematical algorithms by hand, or by independent (verified) software. Some test cases are designed to verify that system-specific and user-specified input data arrive correctly at a routine and affect the design element as expected. Other test cases are designed to determine how any potential conditions for overflow, underflow, array bound violations, and inaccessible code discovered during desk checking affect model execution and output results.

If the test cases described above have not exercised all lines of code, additional tests are designed to do so. This reduces the chance that errors in programming logic have been overlooked. The flow diagrams in the CMS are consulted during this effort to determine if all logical branches are accessible.

The final software test step is to execute the software test cases and analyze and record the results. These tests are performed in three ways: (1) using an off-line driver, (2) executing the entire model in debug mode, or (3) executing the entire model using instrumented code (i.e., diagnostic output statements). A process flowchart for FE level verification is shown in Figure 3-11.

Dynamic CASE tools can be used during software testing to instrument the code and provide variable values for examination. They also can help keep track of which lines of code have been executed and which logical branches have been accessed.

3.3.7 Document Verification Results

The verification report for each FE should include an FE overview, a description of which verification techniques were applied, a summary of results, recommendations for the resolution of any deficiencies encountered, and a description of how verification results impact credible use of the model. Section 5 provides more detailed format and content guidelines for verification documentation that are tailored to support accreditation decisions directly.

3.4 Validation

Validation is defined in Joint Pub 1-02 as "...the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model." In other words, validation is an assessment of how well the model does what you think it's supposed to do.

It should be noted that under this definition, validation is not an absolute end in itself; rather, it is a process of determining the degree to which the model represents those aspects of reality that are critical to solving the problem at hand. For simple models, this degree of correlation may be accomplished through evaluation of a single test result, especially when the testing can be performed under repeatable laboratory conditions. For complex models that perform many functions, it is more likely that any degree of correlation with reality will be established incrementally over time as individual FEs are subjected to comparisons with test results focused on specific functional areas.

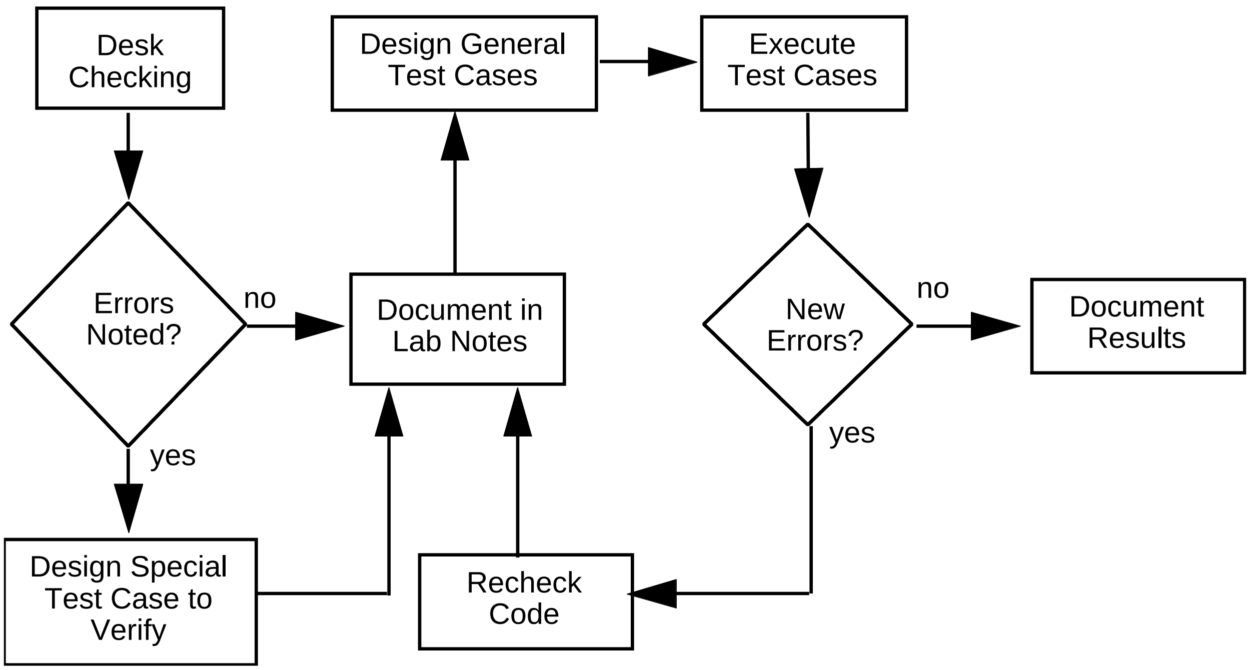

Figure 3-11: FE Code Verification Details

The validation of a model typically takes two forms: validation by expert review (sometimes called "Face Validation"), and validation by comparison with test data (sometimes called "Results Validation"). Although there are a variety of techniques appropriate to each of these two broad classes of validation activities, the collection of tasks that follows is based on extensive validation experience for M&S used in acquisition (see figure 3-12).

One component of validation activities that is frequently overlooked is sensitivity analysis (SA). SA can be used not only to characterize and assess the validity of trends in model outputs as a function of changes in model inputs, but can also be used to specify and refine the data collection parameters (such as accuracy and sampling rates) necessary for meaningful comparisons of test data with model outputs. It may also be possible to show through SA that some functions need no further validation. This would be true, for example, for functions that do not have a significant impact on the model outputs that are important to the problem at hand. Because of the relevance of SA to both Face Validation and Results Validation, we discuss it first.

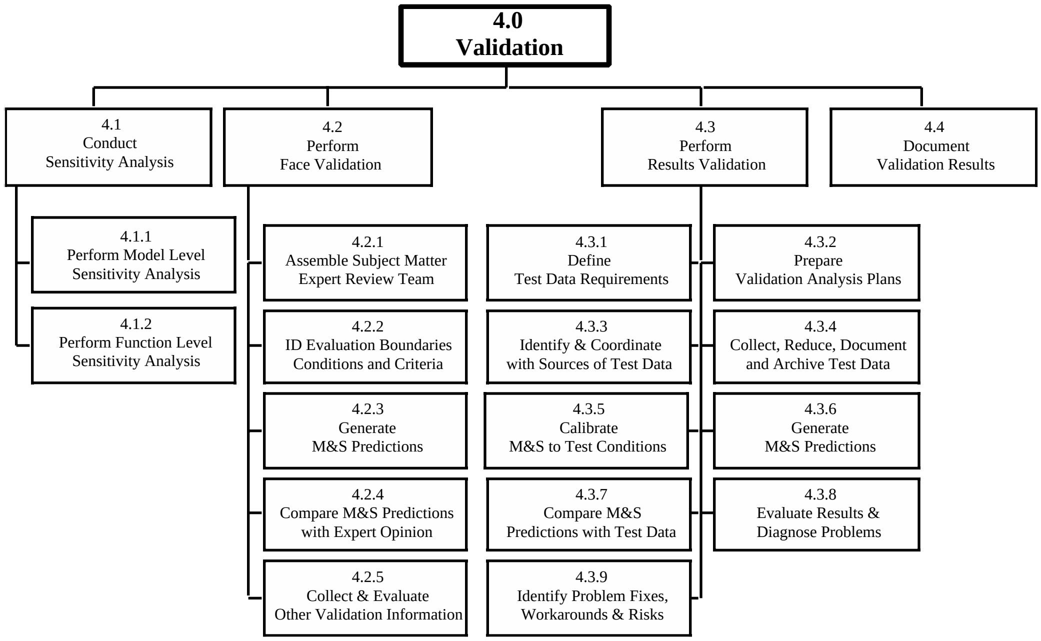

Figure 3-12: WBS for “Validation”

3.4.1 Conduct Sensitivity Analyses

Sensitivity analysis has three major purposes:

1. to establish the reasonableness of changes to FE (and model) outputs relative to changes in FE (and model) inputs;

2. to identify critical model functions with the ultimate aim of prioritizing verification and validation efforts among them, and;

3. to specify data collection parameters for validation of each prioritized function.

Performance of sensitivity analyses requires that model FEs be well defined during model decomposition (see section 3.3.1) so that the code for each FE can be identified and extracted. This may involve the extraction of several related modules that contribute to the calculations of the function. For each function so extracted, inputs and outputs are identified, both internal to the model and external (user input). A test matrix for each FE that stresses the full range of input combinations and variable values over their anticipated dynamic range is then constructed. Engineering analysis is then applied to reduce the matrix of possible input/output combinations that need to be tested to determine function level sensitivities. Response curves resulting from variation of function level inputs are then plotted for the various input combinations, and the impact of the resultant function-level variability on overall model results is also evaluated .

It frequently occurs that a function that is very sensitive at the detailed level may have only marginal impact on the outcome of overall model results. For example, a change in the pulse repetition frequency (PRF) of the Moving Target Indicator (MTI) function in a radar model can alter the MTI response curve significantly, while having negligible impact on maximum detection range. Functions whose outputs have a large impact on overall model results are ranked higher in importance for V&V than those whose impact on overall model results is marginal.

For the higher priority model functions, sensitivity analysis response curves help establish critical data collection parameters, such as the accuracies and sampling rates required for good statistical comparison between test data and model predictions. For the lower priority model functions, sensitivity analysis results, coupled with engineering analysis and expert opinion, can eliminate the need to validate a function explicitly against test data (see section 3.4.2). Thus, sensitivity analysis serves to focus verification and validation efforts on the highest priority model functions by identifying those functions that do not have a large impact on overall model results, and helps to identify critical data collection parameters for those functions that do.

SA can also be used to refine data collection requirements for validation. Functions that are highly sensitive to changes in input data may require higher sampling rates or greater accuracy of test data to ensure meaningful comparisons for validation purposes. Data accuracy and sampling rates, in turn, can greatly affect the cost of collecting, processing, and analyzing data used in comparisons with model outputs. Although it is not uncommon for a model to be infinitely sensitive to input variations (i.e., the “model as a calculator” problem), reasonable limits must be placed on data collection requirements, and FE sensitivities must be compared to what can be resolved and recorded during a test. How much sensitivity can be tolerated is a function of the criticality of the model’s output to the outcome of the overall problem or application. These tolerances are derived from problem analysis (see section 3.1).

Sensitivity analysis has two important byproducts. First, the exercise of model software at the function level flushes out errors and anomalies previously unknown or unsuspected, especially when boundary conditions are investigated. Early error identification of this type saves much guesswork in later phases of validation, when actual test data may not correlate well with function level or model level results.

Secondly, SA can also assist with verification by providing a characterization of function-level behavior that is suitable as an input to logical verification activities; and SA can supplement the software testing portion of code verification. Hidden limitations, constraints and assumptions become obvious when model functions are tested separately from the main model and then re-integrated to assess their impact at the model level. Sensitivity analysis thus becomes a model characterization tool that provides the user with important function-level and overall model response characterizations.

3.4.1.1 Perform Model Level Sensitivity Analyses

Sensitivity analysis at the model level entails varying the outputs of critical FEs (singly or in combination) over their expected dynamic range of operation in the application being considered. Curves that represent the model output response to variations in FE outputs (singly or in combination) are generated. This process is repeated for all FEs (and associated input parameters) determined to be significant on the basis of problem definition (see sections 3.1 and 3.2). This information provides guidance for prioritizing detailed validation work. Those functions having the greatest impact on model outputs related to problem MOMs are those for which validation with test data should be a high priority. Those model functions with less impact on problem MOMs should be considered as candidates for Face Validation.

3.4.1.2 Perform Function Level Sensitivity Analyses

At the function level, sensitivity analysis usually begins by extracting the software modules associated with the function from the model, and running them separately using an "off-line" driver that “feeds” the function all its required inputs. These inputs are then varied (singly or in combination) over their expected dynamic range of operation in the application being considered. Response curves are drawn representing function level sensitivities to changes in input parameter combinations, providing a measure of how much the output of the functional element changes with variations in input parameters. Those parameters that cause large variations will typically require accurate measurement at high sampling rates. Those that have little effect on the functional element response will typically not require as accurate a measurement; they may not require measurement for validation purposes at all. Depending on the importance of the function outputs to the problem MOMs, sensitivity analysis results can be used to identify candidates for Face Validation vice more detailed Results Validation.

3.4.2 Validate M&S Outputs with Expert Review

Validation with an expert review (or “Face Validation”) is a subjective evaluation of a model’s outputs against the expectations of a group of Subject Matter Experts (SME). Conducted properly, it provides reasonable assurance that the model behavior in specific situations or under specific conditions is realistic enough for use in the problem or application at hand. It does not provide any specific information about how well the model represents specific functions that are a part of the overall problem. Neither does it provide any means of quantifying the goodness or realism of the model for other, dissimilar applications. The primary benefit of using this technique is that it can be accomplished with far fewer resources than are required for detailed validation of the whole model and its critical internal functions.

The review is conducted by SMEs who have a good real-world understanding of the phenomena being modeled and the fidelity requirements of the application at hand. The model developer should also be included to aid the group in understanding particular modeling techniques, but should not be involved in the evaluation of the model per se. In some cases, where model runtime requirements for a face validation are prohibitive, or the number of scenario conditions to be evaluated is large, face validations might take on the character of a design review, wherein the design features rather than model outputs are analyzed. This is less effective than an SME review of model outputs under application-specific conditions, however. The goal is for people familiar with the phenomena involved to judge whether the model accurately represents the real world within the context of a well-defined application.

Face Validation gives the user confidence that the outputs of a model are realistic for a given set of input conditions. Where feasible, these input conditions are chosen to match or fall within the bounds of input conditions for the intended application. Matching of input conditions in this manner lends even greater credibility to the use of the model in the intended application. The following paragraphs describe several important aspects of Face Validation in more detail.

3.4.2.1 Assemble Subject Matter Expert (SME) Review Team

The quality of the judgments made by an SME team is heavily dependent on the technical expertise of the team members and how well they can work together to form a judgment. The team's composition should be balanced between experts in the subject being modeled, modeling experts from the developer's organization that have a detailed familiarity with the model, and analysts from the user organization who are familiar with the application and who will be required to use the model. Representatives from the model developer (or anyone who has a vested interest in the model itself) should not participate in evaluative decision making, but should be available to answer questions about M&S details. All participants must be given the opportunity to become familiar with the problem overall, the specific application and its conditions, and the model prior to the actual review. The group should understand the detailed acceptance criteria that were established during VV&A planning, as well as the conditions under which the model will be run. Their task is to determine whether or not the candidate model adequately represents the intended system(s) operations and interactions for the given application. Clear statements of the review objectives and intended product should be prepared and be provided to review team members well in advance of the review. It is also important to clearly identify the focus of the review or analytical process: a comparison of model outputs to their expert judgment of what the real world outcomes would be under well-defined input conditions.

Another major consideration in selecting team members is an assurance of their availability and commitment to the effort. It is important that all team members be present for all meetings and discussions so that everyone has a common basis for discussion of conclusions. They should also be available to participate in documenting the review results. Their presence at all team planning sessions is highly desirable. They should help determine how the review will be conducted and what evaluation techniques will be used. They should also be encouraged to contribute to the agenda.

For reporting purposes, it is important to identify the SME team members and to record the background and experience of each. This information provides the accreditation authority and any other subsequent reviewers or model users with a means of evaluating the quality and credibility of the team findings.

3.4.2.2 Identify Evaluation Boundaries, Conditions and Criteria

In order to generate the model outputs necessary to conduct a Face Validation, a set of inputs are needed that are derived from the conditions under which the model will be used. Therefore it is necessary to identify all the conditions and boundaries that represent those found in the intended application, which are derived from the nature of the problem overall (see sections 3.1 and 3.2). In some cases, especially those problems where the model may be used for different applications under a multiplicity of conditions, multiple sets of conditions and boundaries may need to be identified. Sets of conditions and boundaries need not be exhaustive, but should be selected to include the extreme limits of the operating envelope.

In addition to the operating conditions and boundaries, a set of criteria should be developed. These criteria will serve as guides for determining whether the model outputs, when judged against the expert opinion, are good enough to be of predictive use in the intended application. The nature of these criteria will be application (and problem) specific and cannot be described generically. The only guidance that can be given is that the SME team should review the problem and the application, identify the criteria for judging the model's suitability for use in the application, and develop a written set of criteria that conveys to the accreditation authority how the model was evaluated.

3.4.2.3 Generate M&S Predictions

The next step is to run the model and generate outputs which are the basis for judging model validity with respect to the requirements of the application. To be most useful, these model predictions are generated using inputs that are within the limits or boundaries of the problem for which the model will be used. In some cases, input parameters may include boundary conditions, so that the SME review team can evaluate model performance under extreme conditions which might be of importance to problem resolution. The SME team must be fully aware of the input conditions, so that it can adequately assess model performance within that context. The input conditions should be documented in some form and passed to the review team as part of the preparatory material.

3.4.2.4 Compare M&S Predictions with Expert Opinion

The comparison of model predictions with expert opinion is the essence of the Face Validation process. The scope and depth of this evaluation typically goes beyond a simple comparison of predictions with expected outcomes, however. If model predictions are not as expected, the SME team will probably choose to review and analyze major parts of the model to determine reasons for the unexpected or unrealistic outputs. In those cases where model predictions are not used as part of the evaluation, and the Face Validation takes on the character of a design review, the analysis will tend to focus on the design of major model functions to assess how well they might be expected to represent reality.

To make this review effective it is important to streamline the proceedings. A well planned agenda will help minimize haggling over the mechanics of the meeting and focus attention on the actual evaluation exercise. The actual review agenda should be established prior to beginning the review, and should be agreed upon by the team members in advance. The team needs to understand what the objective of the review is, and what products they will be expected to produce. Everyone should agree on the criteria that are used to determine model acceptability.

The actual comparison of model capabilities with acceptance criteria can be organized in any manner that is acceptable to the team. Too often the team becomes engaged in evaluating the model performance and discussing its weak features and how it can be improved. This type of discussion does little to support a decision on M&S acceptability for use in the application at hand. Team focus must be maintained on the critical issues that relate to the model's acceptability for this application.

3.4.2.5 Collect and Evaluate Other Validation Information

Face validation should also include evaluation of other information that can help establish model acceptability for use in the specified application. The team should collect all available information that describes the model functionality and performance, review that information, and assess it in light of application-specific requirements. A prime example of useful information is sensitivity analysis results. An expert panel can review the degree to which model outputs are affected by changes in input parameters, and assess whether the magnitude and direction of the changes are what would be expected under similar real world variations. Other types of information that might also be useful to review would include the summary of assumptions, limitations and errors; model descriptive information contained in design documents or produced by the use of CASE tools; and the descriptions of model changes. All of this information, when combined with the results of an assessment of model outputs under well-specified conditions, provides a well-rounded evaluation of the model's overall adequacy for use in an application.

3.4.3 Validate M&S Outputs with Test Data

The scope, depth and complexity of results validation activities will vary both with the function or phenomenon being validated, and the fidelity with which that function or phenomenon is represented in the model. At the FE level, bench test data in the form of characteristic response curves and single point measurements can often be used to assess the representation of a single function (e.g., a missile guidance servo) within a model. At the model level, several or all of the functions are usually exercised together, in an attempt to correlate model outputs with data collected from an open air range (or other) test. Comparison of model predictions with test observations (measurements) usually requires the use of some form of statistical correlation method, whose results are then used to assess the validity of the model or the function for the scenario under which the data were collected. An overview of the Results Validation process is shown in figure 3-13, and is described in more detail in the following sections.

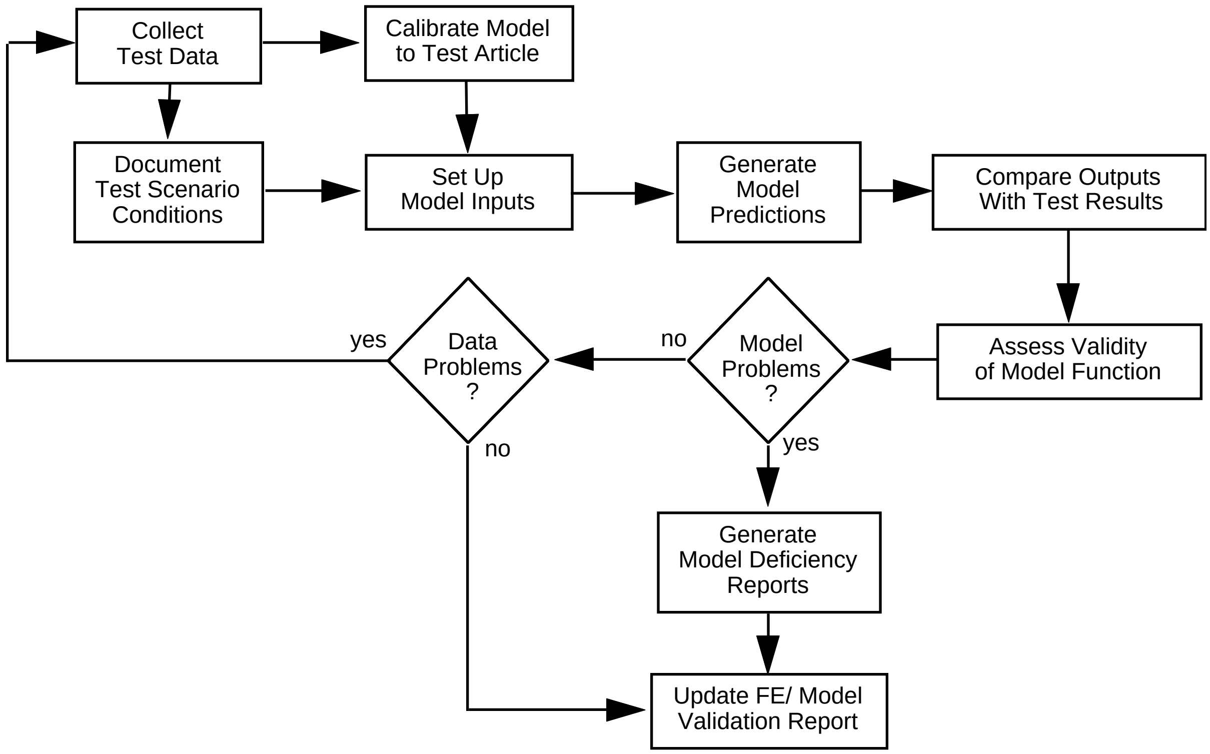

Figure 3-13: Validation Process Overview

3.4.3.1 Define Test Data Requirements

Validation of model functions at a detailed level will require data collected from "real world" situations for comparison with function-level outputs. Using the FAT as a checklist, the software comprising each FE of interest is examined to identify its input data requirements and output data listings. These parameters are then cast in the form of data collection requirements for test range or laboratory tests. These requirements constitute a "wish list" that can be compared with data collection plans for ongoing service testing programs. They can also be used to construct test plans for dedicated tests aimed at independent collection of the required data, although this is usually a considerably more expensive alternative. Although required accuracy and resolution requirements for the data cannot be specified in detail until a sensitivity analysis is conducted (see section 3.4.1), preliminary requirements based on test range capabilities and actual experience can be specified. The purpose of this activity is to identify, at the earliest possible stage, what the validation data requirements are likely to be. In this way, special data collection requirements can be anticipated, and data requirements for similar FEs from different models can be combined into a single collection plan. This is perhaps the most difficult step in the results validation process, and should only be initiated when there is a clear indication that results validation will be necessary to support model accreditation.[35]

Data requirements are initially specified during the model decomposition process (see section 3.1.1) and usually revised during the sensitivity analysis (SA) process (see section 3.4.1). SA is also used to establish requirements for accuracy and sample rates of certain data. Once data requirements for validation are well specified, a Notional Test Plan (NTP) should be developed. The NTP describes a theoretical test that could be used to measure the actual parameters required to validate a particular FE. The NTP is a useful tool to bridge the gap between modelers and testers. It tells test personnel how detailed the implementation of the FE is in the model, as well as a type of test scenario that could be used to collect data needed to assess FE validity.[36]

3.4.3.2 Prepare Validation Analysis Plans

Planning the assessment of each FE requires the analyst, or team, to identify and describe the MOEs or MOPs that should determine the degree to which the model function represents reality. An FE assessment plan should be prepared to describe how the data collected from testing would be used to compare with values produced by the model, and what statistical parameters would be used to evaluate correlation of model outputs with the test data. It should also identify the conditions to be applied to model runs (if possible), the steps to be followed in analyzing model outputs and comparing them with the test data, and any specific success or failure criteria that can be described beforehand. These plans are often changed when data are actually obtained, due to deviations from what was described in the NTP or TPS, but they serve an important purpose by aiding in the preparation of detailed validation efforts.

Model assessment plans are similar, but tend to be more model-specific as to top-level objectives, as well as the test procedures required to produce data for them. (Even though each of the first three models examined by SMART simulated radar sensors, there was little similarity between test data or procedure requirements for each of them due to their individual treatments of the detection and target tracking problems.) Nevertheless, assessment at the model level is perhaps

35. Many of the data requirements for the models examined by SMART were identical for the same FEs in different models. Accuracy requirements differed between the models, but much of the data collected from ongoing tests satisfied requirements for more than one model. This is a natural benefit of the decomposition and functional element approach to validation. Not only can more than one model be validated simultaneously, but test and data collection plans can take advantage of functional commonality among them. Furthermore, if two identical functions with different implementations in two separate models are assessed using the same data, and one model produces a better correlation with test data, a case for replacement of the less valid software can then be made. This will have the beneficial tendency to focus modeling efforts on those techniques and algorithms that have proved themselves valid, thereby reducing duplication of modeling effort and encouraging modeling community consensus about which techniques work best for which applications. In this way, the better parts of several models can be integrated.

36. The SMART Project employed a Test and Evaluation (T&E) team of contractors and consultants, who used NTPs to prepare detailed Test Plan Supplements (TPS's) that could be appended to the test plans of tests already in progress. TPS's were used to identify specific data requirements and test procedures necessary to address validation objectives defined in the NTP for each particular model or FE. Another important aspect of the TPS was identification of the products, formats, and media that would be used to record the data collected from the range test, as well as any documentation associated with the data or conduct of the testing. An important aspect of NTP and TPS documents is their historical significance in providing users of the test data with information about the test long after the test was planned and conducted. SMART developed a library of these documents that can be used to address validation requirements as new testing opportunities arise.

the most important aspect of validation to the end user of the model, so attention to proper and thorough assessment procedures is one of the most important aspects of planning for model level validation.

3.4.3.3 Identify and Coordinate with Sources of Test Data

Once data collection objectives are specified, it is necessary to identify potential sources of test data. Identification of (and continuous coordination with) ongoing test programs and other data collection efforts can ensure that validation data can be obtained at the least cost using the data collection systems planned for a specific test. If viable sources of validation data are identified and source managers are willing to cooperate, data collection plans must be developed to guide the collection, reduction, and analysis processes that will be applied to the data. If not, plans must be made to conduct dedicated tests.

3.4.3.4 Collect, Reduce, Document and Archive Test Data

The overall scope of the validation data collection process is presented in Figure 3-14. Based on the NTPs, the test engineers and modelers determine whether test data for a given FE or model can best be obtained by using existing test data, piggybacking on current or planned tests, or by conducting their own dedicated test. One of the basic premises of M&S results validation is that it is best to obtain test data that can be leveraged from on-going tests that have already been planned, because considerable cost savings can be realized. Experience has shown that data for many FEs can be obtained by piggybacking; however, there usually are some FEs with special data requirements that can only be met through dedicated testing.

The purpose of the Test Plan or the Test Plan Supplement (TPS) is to define the plans and performance objectives of system testing that will provide the M&S validator with specific test data that can be used for M&S validation. TPs are generated for dedicated tests while TPSs are used when the test host's TP describes the basic test but does not include FE/model validation specific requirements. The TPS describes requirements for additional tests, equipment, or instrumentation needed to generate useful validation information. These additions to the test would probably require additional funding from the validation agent. The information that should be recorded in the plans includes the test concept, objectives and requirements to be satisfied; test methods and functional elements involved; responsible activities associated with the test; and data collection methods to be used.

NTPs should reflect real-world parameter values rather than theoretical values of interest to the modeler. Some categories of data are known or measured crudely because of lack of intelligence information or lack of ability to measure what is needed. Also, unit-to-unit variations can mask some of the data accuracies of interest. The test plans have to be derived in light of the instrumentation that is available at the test range. If the instrumentation is not available, then cost, schedule, and effort estimates need to be developed to determine if development of special instrumentation is cost-effective.

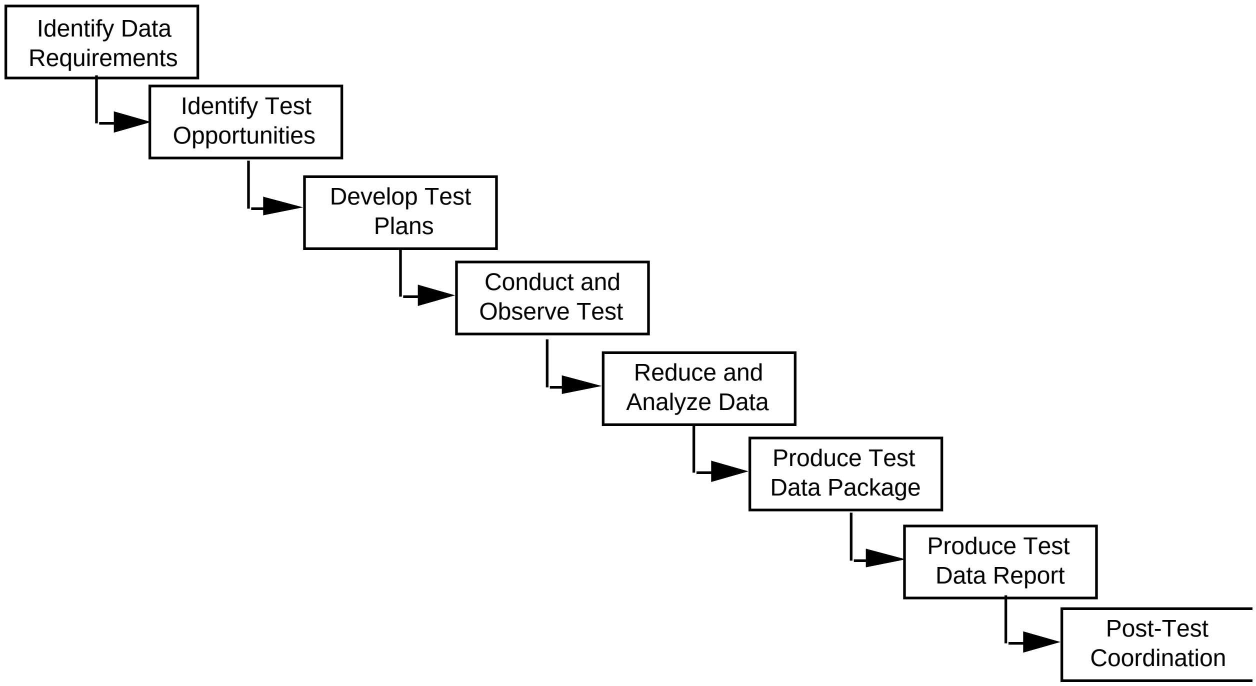

Figure 3-14: Validation Data Collection Process

Regardless of whether the test data is to come from piggybacking on another test or from a dedicated test, the T&E engineer should examine several test data factors to determine if the data are of the type, quality, and quantity required for comparing model outputs with real-world outcomes as represented by the test results. The following are the key factors that should be considered:

Types of Data. The data elements required for validation should be compared with the data elements that are going to be (or have been) collected during the test. For tests that have not yet occurred, the T&E engineer should determine which desired data elements are not in the data collection plans of the Test Director (TD), and should negotiate with the test host to determine whether the additional data elements could be collected during the test.

Quality of Data. Depending on the test host's test objectives, there may not be a requirement to collect data with a high degree of accuracy or a high sampling rate. Because the data collected for M&S validation needs to meet the accuracy and data rates specified in the NTP by sensitivity analysis and expert opinion, the T&E engineer should determine whether the test can meet these data quality requirements. If possible, this will be accomplished using existing instrumentation and modifications to the host's data collection plan. If the host cannot or does not want to pay for the instrumentation changes or additions, the T&E engineer should present the situation to the validation agent for resolution.

Sample Size. Sometimes the TD may require only a few samples of data or a few variations of trials to satisfy test requirements. The T&E engineer should determine if additional samples are required to satisfy the validation requirements, and if so, should negotiate with the TD to obtain these additional samples. To maximize the utility of a given test, the validation agent might wish to include additional systems in the test matrix. The T&E engineer should discuss the possibilities and negotiate the best possible test matrix for these validation effort.

Test Participantion. After test planning has been completed and the test actually starts, the T&E engineer should observe the test as closely as possible (within th TD’s constraints) to ensure that validation-specific data collection objectives are being met, and that the data are being collected as specified in the TP or TPS. If, during the test, data collection procedures or test conditions deviate from the test plan, the T&E engineer should be prepared to represent the validation agent, and make real-time decisions based on prior discussions and contingency plans. Key information gained during the test, including deviations from the TP or TPS, should be documented in a Test Report Supplement (TRS) for piggybacked tests or a Test Report (TR) for dedicated tests.

Test documentation in the form of a TR and/or a TRS are critical in capturing exactly what occurred during testing (vice what was planned), as well as specifics about the data that were collected and reduced. TRs are used for dedicated tests while TRSs are needed when the TD’s TR describes basic test results but does not include specific validation data requirements. The TRS describes all the additional flights, equipment, or instrumentation that are included in the test to make the data useful for validation. The TRS is especially beneficial to the analyst who is unable to observe the test or who is attempting to use the data for validation of another model long after the test is finished. TRSs should also include identification of variables, discussion of post-processing required, and data descriptions and formats for the data being passed to modelers for validation purposes.

As soon as possible after the conduct of the test, the T&E engineer should: collect the test data, usually after it undergoes some processing by the test facility; post-process the data to ensure that the data are complete, usable and presented in a format agreed upon in advance; and prepare test data packages for delivery to the validation agent for analysis and archiving. Test data packages consist of various forms of media, such as disks, tapes, hard copy graphs or listings, and reports prepared by the test range or TD’s agency. These data packages are provided to model developers and to the independent validator for their use in assessing the validity of model(s).

During testing and data collection it has been recognized that open air test ranges generally are not designed to collect data in the detail and with the accuracy desired for FE and model validations. The attention given to system calibrations and alignments has an effect on the usefulness of the data for M&S validation. Even after the range has smoothed and processed the data, it must be post-processed to identify the portions that are suitable for modelers and model validators. Modelers need to recognize that they are constrained by the quality of the data as it is generated by the range: test data cannot be rejected just because it does not meet the modeler's desired accuracy requirements; it may be the only real data available. Test data should not be released until complete TRs or TRSs are available for delivery at the same time. Without the TRs or TRSs to explain test conditions, identify variables, and denote usable data, users will expend unnecessary effort on trying to figure out what the data mean, and if they are any good. Data can be prematurely labeled as "bad" because of misinterpretation by those trying to use them in the absence of adequate documentation.

3.4.3.5 Calibrate M&S to Test Conditions

Before a model developer or independent validator can compare model outputs with test results, model outputs must be generated for the same conditions that were present during the test that is documented in the test data package. To generate these outputs under these conditions, the model must be calibrated to the article under test as well as to the test conditions. That is, the model constants and programmable elements must be adjusted to match the values of similar parameters recorded in the data package. In addition, input data for the model must be extracted from the data package and used when running the model. The idea is not to “tweak” the model so that its output matches the test data, but to calibrate all relevant input data to the model to match the test conditions. For example, often a model of a system may represent the average, or “spec” system, while the article being tested is a specific system which differs from the average due to unit-to-unit variations. Consequently, for a true test of the model’s ability to replicate the test data, the actual values representing the test article must be input to the model.

If validation is being done at the functional level, the adjustable parameters in the FE drivers (see section 3.4.2) that are used to exercise the function independently must be adjusted to appropriate values as defined in the test data package. These steps, at either the function or model level, constitute model calibration and are done prior to running the model or a function within the model to generate the outputs used for validation.

3.4.3.6 Generate M&S Predictions

The next steps are to run the model and generate outputs which can be compared to the same parameters measured during the test. The results of this comparison are then evaluated to determine if the model accurately represents this particular real world phenomenon well enough to be of use in the application at hand. If not, the reason for the difference, either model or source data, must be determined. If the problem lies in the model, the impact must be assessed. If suitable work-arounds are not possible, and if sufficient resources are available, the model may be modified. If work-arounds are possible, they will most likely be employed and the model used with specified caveats. In all cases, the results of the comparison and the analysis of any deficiencies are documented to support an accreditation decision.

3.4.3.7 Compare M&S Predictions with Test Data

The validation process consists of comparisons of model predictions with test data at the model level, the FE level, or both. The model level assessment determines if the model as a whole works correctly and produces results realistic enough for the application at hand. The FE level assessment determines if the simulation of the system's components represents real-system component operation well enough to be of use in the application at hand. The FE examination increases a model's credibility by eliminating situations where the overall model results are good but individual FEs have compensating errors. Data collection obtains test data for both FE evaluations as well as model-level assessments. In all cases, assessments of validity are made within the context of application-specific requirements for model fidelity and ultimate accreditation.

3.4.3.8 Evaluate Results and Diagnose Problems

The overall model is evaluated in terms of the requirements of the intended application and the acceptance criteria established for accreditation. For significant differences between model and test results, determination of "good enough" must be made by the relation between model fidelity requirements and problem MOMs (see section 3.1). Having both model level and FE level validation data, it can be determined where in the model many problems lie. Both model and FE agreements and differences with test results should be documented.

It is important to note that the evaluation of the model and its FEs must be based on those MOMs that are important to the application. A simple statistical comparison between test data and model output does not really tell a user whether the model is sufficiently accurate or complete relative to application-specific requirements for fidelity. That can only be determined by assessing whether the model supports adequate answers to the questions being addressed. Validation really only has meaning in the context of an application: the user wants to know if the model is demonstrated to be good enough for a given purpose. This means that the user has to analyze the application, determine what "good enough" means for that application, and only do enough validation to determine if the model meets those needs. The model user must search for "analytical significance" in validation results, not just statistical significance. That can only be done by relating validation results to appropriate problem MOMs.

3.4.3.9 Identify Problem Fixes, Workarounds and Risks

Any problem areas identified by the validation effort should be accompanied by an indication of where the problem lies in the model or the data, and some idea of its cause. This is facilitated by conducting FE level validation in addition to model level validation. By discovering which FEs are causing the problem, the user can have a fairly comprehensive idea of what needs to be fixed in the model to better match the validation data. If the data are suspect or shown to be deficient, additional sources should be sought while also addressing potential improvements in the process or instrumentation used to collect the data.

This leads to several options for the potential user of the model:

(1) Fix the problem: This may or may not be feasible within the budget and schedule of the user, depending on the magnitude of the problem and its importance to the user's application. If the model is of high interest to a number of users, it may be possible to pool resources to develop the required enhancements through the cooperation of the model manager and other

users. If the problem is resolved, any improvements or fixes to the model need to be implemented via the model's configuration management process.

(2) Devise a Workaround: For many applications, and many problem areas, it may be feasible to devise an alternative way to deal with a problem discovered by the validation effort. For instance, in certain applications where electronic countermeasures (ECM) are being employed and simulated, the models being used may not provide accurate enough representation of the effects of those countermeasures against a number of threat systems. In that case, it may be possible to derive community accepted measures of ECM effectiveness that could be used in the place of simulations of those systems. For other applications, that may not be an acceptable approach.

(3) Use the Model Anyway: In many situations, the user may simply have no alternative to using the model under review for his application. In that case, an assessment of the risks to the application program must be made. This is necessary because in this case the program is making use of a model which is known on the basis of validation work to be deficient; an assessment of the risks associated with that use will provide for at least informed use of the model. This risk assessment can be made on a generic basis, so that the risks are identified for various classes of application.

3.4.4 Document Validation Results

Any differences identified during the comparison of FE and model results with test results are written up as MDRs and are submitted to the configuration manager for resolution. All results of FE and model validation efforts are based on comparisons with test data and are documented in model validation reports, which are included as sections of ASP-III. Section 5 provides more detailed format and content guidelines for validation documentation that are tailored to support accreditation decisions directly.

3.5 Accreditation

Accreditation is defined in JCS Pub 1 as "an official determination that a model is acceptable for a specific purpose." As outlined in chapter 5 of the DMSO RPG this determination depends on a comparison between the modeling requirements determined by how the model is going to be used in an application, and what is known about the model's capabilities and characteristics. This comparison should result in a logical rationale that justifies accreditation. If any deficiencies are identified as a result of the comparison, some means of correcting or mitigating them must be developed to justify accreditation of the model. The model might be modified to correct the deficiency, some type of work-around might be used, or some restrictions might be placed on model use or data interpretation. In some cases, the impact of the model deficiency might be considered acceptable, and the model accredited despite the deficiency. In that case, the person accrediting the model has explicitly decided to accept the risks inherent in using the model for the application.

The accreditation process begins with execution of any non-V&V tasks identified in the requirements definition phase (see section 3.1). The accreditation assessment follows, and requires knowledge of the candidate model's capabilities and characteristics, and the modeling requirements specific to the application at hand. The results of this assessment (and its recommendations) are presented to the accreditation authority for a final decision, and are documented in an accreditation report. Figure 3–15: WBS for "Accreditation"15 shows the WBS for the accreditation tasks.

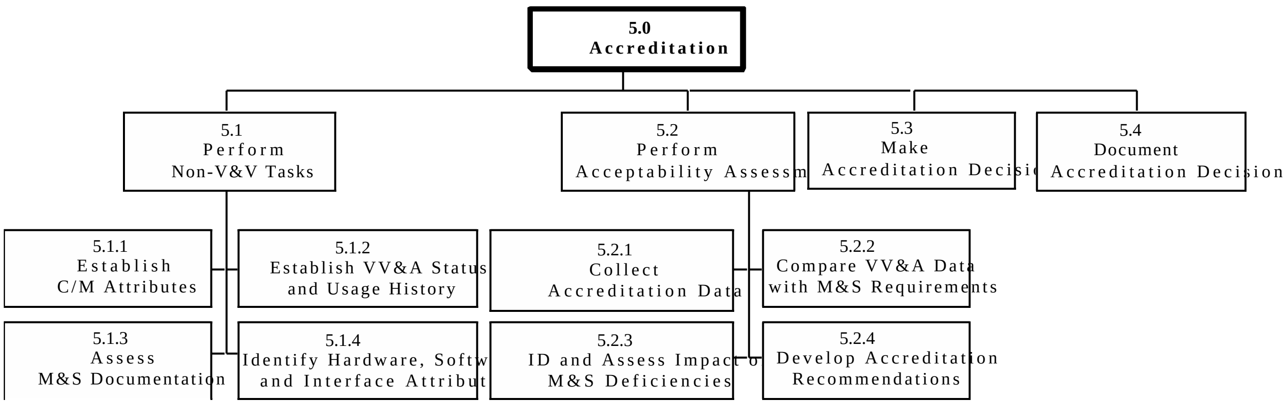

Figure 3–15: WBS for "Accreditation"

3.5.1 Perform Non-V&V Tasks

Non-V&V tasks typically involve the collection of data about model characteristics and development background that is usually available in model documentation or through the model manager. These tasks are usually done concurrently with the V&V efforts, and may provide information that is useful in some of the V&V tasks. These non-V&V tasks are grouped with the accreditation tasks only because the nature of the tasks is more closely aligned with accreditation than with V&V.

3.5.1.1 Establish Configuration Management Attributes

The configuration management (CM) baseline description for a model provides prospective users with an indication of how well the model (and changes to it) are controlled and supported. Models with poorly defined configurations and unspecified (or vague) change control procedures are likely to produce inconsistent results across the spectrum of users and applications, with the consequence that model predictions will not be highly regarded. Models whose configurations are well specified, and whose change procedures are well disciplined are more likely to have timely supporting documentation and to produce consistent, well accepted results. Moreover, well managed models have a lower risk of failing (i.e., having major faults discovered during) detailed V&V.

The CM baseline for a model consists of a description of the model, its development history, current version status (including documentation), applicable change procedures, model development policy (including beta site version testing and integration procedures), and any configuration management policies, procedures, guidelines and support functions in place for the model. Taken as a whole, these information elements provide the prospective user with a vantage point from which to assess the discipline with which a model has been developed, the important operational differences between extant versions, and the potential impact of model management discipline on the acceptability of model results. As such, CM baseline information is essential to the basic choice of a model for further V&V or accreditation for a specific application.

Once a documented CM baseline for the model is available, an evaluation of the existing CM procedures is conducted, including a review of CM plans for completeness, discipline, and implementation. The basic decision to be made in this analysis is whether or not the model is managed well enough to reduce the risk of its direct application to the problem at hand. Model management not only has an impact on credibility (as discussed above); it also has a profound and direct impact on the cost of accreditation. This is because V&V (and hence, accreditation) results have a short shelf life if the configuration of the model changes unpredictably.

At a minimum, a good CM plan should include provisions for identifying, maintaining and tracking the following items:

- Configurable items (as well as a brief description of these items)
- CM cycle description
- Change procedures and implementation policies
- Supporting V&V plans
- Documentation requirements

It is important to note that the documentation supporting a model should be considered a part of the model. Model documentation, therefore, should not only be listed as a configurable item, but should also be included in the CM process as a task to be performed concurrent with any model development effort.

In evaluating CM plan implementation, one should look for evidence that the extant versions are controlled, that the latest version is fully documented, that beta testing is completed prior to version release, and that changes are implemented in an orderly process. These are critical indicators that CM implementation follows the CM plan.

The nature of model development in DoD is that a new version is always being produced. Consequently, all models become “legacy” models upon first use. It is important, therefore, to be aware of the CM status of a model, and to decide when to jump onto the model’s train (or roller coaster) of development. This decision can have a profound effect on the nature and scope of V&V activities that may have to be performed. Furthermore, once a baseline version of the model is selected for use in the application, all subsequent V&V activities should be directed at that version. If a new version of the model is released before the application analyses are complete, the amount of functional change that has been introduced since release of the chosen baseline version will determine how many V&V tasks need to be repeated in order to maintain a viable picture of model credibility. CM is, therefore, the key to cost effective V&V and hence, to cost effective accreditation.[37]

3.5.1.2 Establish VV&A Status and Model Usage History

The purpose of this task is to convey to the prospective model user a sense of community acceptance of model results. Such acceptance is an indication of the confidence that has been (and therefore, which can be) placed in model results. Evidence of this type is not as conclusive as that supplied by detailed V&V results, and it would normally be inappropriate to base an accreditation decision primarily on the results of a VV&A Status and Usage History. As supporting evidence for model credibility, however, such information can shed important (albeit indirect) light on the acceptability of the model for a particular use.

Evidence of V&V activity for a model may be sparse for legacy models, given that heavy emphasis on VV&A is of recent vintage. However, if such documentation can be found, it is an important indication that the model's user community has enough interest and confidence in the model as a whole to conduct (and fund) such efforts.

Generally speaking, very little information about prior V&V efforts is available, because V&V results have, historically, been perishable, lasting only as long as the particular study or project was active[38]. A survey of model users can provide useful data on V&V performed for specific projects, but if older versions of the model were used, careful scrutiny of model usage and V&V results must be conducted via comparisons with the current baseline model version. If the history of model use is consistent with the intended use, documentation of this fact will serve to strengthen the case for the model's suitability for the application at hand.

It is also important to search for any prior evidence of an accreditation of the model. In cases where the model has been accredited for an application similar to the one at hand, many of the V&V results that were used to support the accreditation may still be relevant, requiring only updating for the current application or version of the model. Moreover, accreditation for a similar application imparts credibility to its use in the current application. It is essential to correlate accreditation with model version, however. If accreditation was granted for a substantially different version of the model, it will be necessary to compare versions to substantiate the assertion that the prior accreditation is applicable to the current case.

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37. For an analysis of current CM policies and procedures, and a recommended set of integrated CM requirements, see [reference 35].

38. Section 4.2 of the SMART Lessons Learned document outlines a CM approach that is linked to the V&V process to give V&V data a longer "shelf life" [reference 33].

The model's usage history is important also. Knowledge of how a model has been used by others provides one with a good indication of its range of applications and capabilities. This information may also provide important clues as to possible limitations to the credible use of model results. For example, if a model purports to simulate two types of systems or phenomena, but the user community consistently ignores or discounts the results of one of them, one might conclude that the model of the other system or phenomenon is not trusted or requires modification, or that there are better alternatives available.

Usage histories can usually be determined by a survey of current model users. Many models have active user groups, which are excellent sources of information about current model usage. In the case of models resident in repositories (e.g., SURVIAC[39]), distribution lists may be of value in identifying current users for the survey. It is especially important to identify prior uses of the model that are similar to the one for which the model is being considered.

3.5.1.3 Assess Model Documentation

The purpose of this activity is to evaluate a model's documentation set to determine if it is adequate to support credible use of the model. Unlike most V&V tasks, the criteria for adequacy of a model's documentation is independent of the application to which the model itself will be applied. This is not to infer that documentation assessment criteria are arbitrary, however. It is possible to specify objective criteria for documentation adequacy on the basis of existing standards and professional practice.[40]

Documentation assessment entails a review of the current status of a model's documentation with respect to standards developed for the V&V of models. A well documented model is supported by a documentation set consisting of a Software User's Manual (SUM), a Software Programmer's Manual (SPM), a Software Analyst's Manual (SAM), and a Software Design Document (SDD, or its equivalent). Each of these documents should contain certain information specific to its function[41]. The documentation assessment task reviews each available component of model documentation for completeness and compliance with the recommended standards. Discrepancies are noted, implications for model use and V&V are summarized, and recommendations for improvement of the documentation are provided.

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39. The Survivability and Vulnerability Information Analysis Center

40. The SMART Project developed such standards by reviewing MIL-STD, DoD-STD, JTCG/AS and service specific policies, procedures and guidelines [reference 1], relating to model development, and tailoring these standards to the problem of "V&V in reverse" for legacy models [reference 2]. The results set forth in references 1 and 2 specify the number, format and content of a minimum documentation set acceptable for informeduse of model results and efficient conduct of verification and validation.

41. See references 1 and 2.

Assessments of documentation quality may be against any standard or set of requirements, as long as the end result tells the user how well the documentation supports effective use of the model. The approach taken by SMART addressed first, what the minimum content requirements should be on the basis of objective standards and current practices, and second, how well existing documentation satisfied those requirements. One may argue with the standards that were developed and used, but they were objectively derived from widely accepted existing standards, and they provide a basis for objective evaluation of software documentation. Regardless of the standards used, however, the objective of documentation assessment is not so much criticism as it is identification of deficiencies that will impair the ability to reach a decision about whether the model is appropriate for the desired application. If it is determined that additional documentation is required, action by the appropriate authority to accomplish this task might be necessary before accreditation or further V&V can be accomplished.

3.5.1.4 Identify Hardware, Software and Interface Attributes

In order to know whether a particular model can be effectively used, one must determine if it can be run with the hardware and operating software that are available to the prospective model user. Furthermore, if there are any plans to automatically process either input data or model output data, the user must know if the model's structure and data formats are compatible with the available data processing software. To make these judgments, the user must collect information about what hardware and software the model is compatible with.

For some applications, there may be a need to run the model on a network of computers, or to integrate the model inputs and outputs with other models via a network. In either of these cases, the prospective user must understand the features and attributes of the model that might affect networking plans. This information about the model's hardware, software, and interface attributes is typically available in the model documentation. Supplemental or updated information is normally available through the model manager or the developer. In some cases, other users may have insights into the compatibility aspects of the model based on recent usage.

3.5.2 Perform Acceptability Assessment

As explained in previous sections, accreditation is an official determination that a model's capability and credibility satisfy the requirements imposed by the nature of the application. The acceptance criteria developed for the application explicitly document the characteristics that a model must have in order to be declared suitable for use. VV&A data obtained from existing sources or generated as a result of supplemental VV&A activities describe the model's capability and credibility characteristics. A comparison of VV&A data with M&S acceptance criteria forms the basis for an accreditation decision. The process entails three activities: an accreditation review, an impact assessment, and documentation of the results.

An accreditation review is, in its simplest terms, a comparison of the modeling requirements for a given application with the features, capabilities, and characteristics of the selected model(s). Such a review may be conducted by one person or a group of persons, depending on the complexity of the application. A single person review is appropriate when the modeling requirements for an application are simple and specific, and the M&S structure and outputs are straightforward and not complex. For complex applications, possibly involving multiple models, a review by an expert panel is more appropriate. A group of experts will also be necessary when the visibility of the application outcome or its political sensitivity requires a group consensus to demonstrate objectivity. In most DoD applications, the complexity of the application and the requirements for a hierarchy of models dictates the use of an expert panel for an accreditation review.

When an accreditation review is to be done by an expert panel, careful and comprehensive planning is essential to achieve a comprehensive and objective assessment of model suitability. Expert review panel composition is the primary factor in conducting a successful review. The review panel should consist of experts completely familiar with the intended application as well as analysts from the accrediting organization. Wherever possible, the review panel should also be familiar with the model(s) being considered for use. Representatives from the model developer should only participate in the review to explain and answer questions concerning the capabilities of the model(s) being considered. They should not provide any sort of assessment unless they are also the ones that will be doing the analysis using the model(s). A critical aspect of panel member selection is to make sure that the prospective members will have sufficient time available to prepare for and participate in the entire review process.[42]

To optimize the accreditation review and assessment process, and to establish a common knowledge base, the group should be supplied with a data package. This data package must contain a description of the application, previously developed M&S acceptance criteria for the application, and all documented information relative to the model's capabilities and credibility.

Depending on the size of the data package, sufficient time before the first review meeting should be allowed for the team members to review and familiarize themselves with the package. A review coordinator should be designated to resolve administrative problems, such as contractual and funding issues, conflicts of interest, scheduling conflicts, and concerns with company proprietary issues. A minimum two weeks before the first meeting should be allowed for the members of the group to review the provided materials. More time should be allocated for significantly complex applications or where administrative problems might be anticipated.

The agenda for each meeting should be prepared by the review coordinator, and passed to members of the team to obtain comments and additions. The following is an example of a general list of topics that should be addressed in one or more meetings prior to the actual accreditation review:

- Refresh team on application objectives, M&S requirements, and acceptance criteria;

42. See section 3.5.2 of the SMART Lessons Learned document for more guidance on planning and conducting an expert review [reference 33].

- Define, outline, and discuss anticipated review products;

- Discuss and resolve any differing interpretations of M&S acceptance criteria;

- Identify specific application or M&S issues to be addressed;
- Specify ground rules for recommendations and decisions (e.g., majority opinion or group consensus).

- Specify documentation responsibilities.

The purpose of the above agenda is to streamline the review process and to ensure that team members are fully briefed on review requirements and evaluation procedures. The agenda should be modified as circumstances dictate.

3.5.2.1 Collect Accreditation Data

Whether the accreditation review will be done by a single individual or by an expert panel, the first step is assembling all the pertinent information, which is normally documented in an accreditation plan and the various V&V reports. This information should include a detailed description of the application, the acceptance criteria that were developed to determine the suitability of candidate models, and any VV&A data obtained from archives or from supplemental V&V work for this application. The VV&A data should be a complete set of documentation that describes the model(s) capabilities and credibility. The accreditation data should also include a complete set of model documentation. If a single person conducts the review, that person will normally collect this data. For an expert panel review, the review coordinator will normally assemble this information into a review package and distribute copies to panel members.

3.5.2.2 Compare VV&A Data with M&S Requirements

The key step in the accreditation process is the comparison of M&S requirements and acceptance criteria with information on model capability and credibility as documented in various VV&A reports and model documentation. M&S requirements consist of functional, fidelity and operating requirements (see sections 3.1.2.1, 3.1.2.2 and 3.1.2.3, respectively). VV&A data includes data from archives, as well as data obtained through supplemental efforts performed for the intended application. Depending on the model(s) being used, archived data may reside in data repositories (such as DMSO's MSRR), in Service-related databases, or in the custody of the model manager, model developer, or previous model users.

The actual comparison of model capabilities with functional requirements requires a review of the model's purpose, intended applications, functional area template, assumptions, and limitations to determine if each functional requirement is satisfied by the model. The results of this comparison can be presented in a three column table. The first column would contain a list of all functional requirements; the second would contain a summary of the VV&A data showing whether or not the function was addressed in the model; and the third column would be an evaluative statement as to whether the function was adequately addressed in the model, as well as brief caveats or constraints could be stated about the model's representation of that function. The comparison of model operating and support features with operating requirements could be performed and presented in a similar manner.

The assessment of model suitability in terms of meeting fidelity requirements is somewhat more complex. Typically, fidelity requirements for applications involving engineering or engagement models are stated in terms of a tolerable error in the prediction of a particular parameter (typically an MOM or directly related to an MOM). Ideally, validation results for those models would also be stated in terms of the allowable difference between model predictions and real world data for that same parameter. These statements would be made for functional parameters within the model, as well as for top-level model outputs. The assessment of model suitability from a fidelity perspective, then, would be a comparison between the fidelity requirements specified for the application and the degree of correlation of model (or function) outputs with test (or other) data. The rigorous definition of decision criteria, MOMs, and model outputs done during the planning phase provides the structure which facilitates this comparison.

For more complex applications involving mission, campaign, or theater level models, fidelity requirements may not be directly measurable. In many cases the fidelity requirements may be much more subjective, and stated in terms of having predictions (for one or more parameters) that are "good enough" for the decision specified in the application, and a simple and purely objective comparison may not be feasible. In this case, the recommended approach to evaluating a model's suitability from a fidelity standpoint is similar to Face Validation: convene a panel of application experts to review the VV&A data, and make a subjective (albeit informed) judgment about the model(s) suitability for the application. This evaluation should also include a determination of what deficiencies exist regarding the accuracy with which the model represents real world, based on a review of the model's assumptions, limitations and known errors.

The final comparison is between the operating requirements and the operating attributes of the model. Available hardware and software configurations are compared with the hardware and software requirements as listed in the model documentation. The analyst's familiarity with the selected model(s) is evaluated to determine if any training, tutoring, or supplementary information is needed to allow proper and effective operation of the model. The configuration management practices and user support structure is evaluated to determine its adequacy to support possible model changes and effective model employment by the application analysts.

3.5.2.3 Identify Model Deficiencies

The comparison of M&S requirements with model capability and credibility will lead to a list of model deficiencies or unmet requirements. These unmet requirements may be:

- Functional requirements: the model does not address all the functions required to support the intended application;

- Fidelity requirements: the model (or its functions) does not have sufficient accuracy to support the intended application;

- Operating requirements: the computer hardware or software required to operate the model is not available to the user, or there is inadequate training or user support available to enable credible use of the model by the analysts assigned to this application.

Model deficiencies should be clearly stated in terms of unmet application requirements. For example, if the application requires that RF clutter be represented in the model, and the review shows that the clutter implementation is not sufficiently accurate, then a deficiency is cited. The deficiency statement should include a set of conditions, or a range of values, over which the deficiency exists or is applicable to the problem. A clear statement of the deficiency and the impact of the deficiency on the application, provides a basis for defining potential work-arounds that would address the deficiency.

Unmet requirements do not necessarily preclude accreditation of a model. A variety of techniques can be employed to work around functional or fidelity deficiencies. Operating deficiencies are seldom the cause of non-accreditation. In most cases, operating and support requirements can be met through equipment or software procurement, or through specialized training. The important factor is that all deficiencies related to the model's use in the intended application are fully identified so that work-arounds can be found, and so that risks resulting from these deficiencies and work-arounds can be evaluated and mitigated.

3.5.2.4 Perform Impact Analysis

When the M&S deficiencies or limitations have been identified, the effect of these deficiencies on the application outcomes or ultimate problem decisions must be assessed. Impact assessment is focused on the risk posed by model deficiencies on application objectives. It is assumed that all required supplemental V&V which the program can afford has been completed, and that the model still has some deficiencies or limitations that have a major impact on the application's objectives or outcomes. The accreditation authority, as well as those who review and approve decisions made on the basis of the model results, are interested in knowing what areas of the model are weak, how those weak areas affect model outputs, and how the affected outputs might impact problem decisions.

The analysis of model deficiencies requires the same type and level of knowledge about the application as was required for development of the acceptance criteria and the conduct of the accreditation review, including an in-depth understanding of application requirements and model capabilities and limitations. It is important to determine to what extent critical decisions are affected by model deficiencies or limitations. If critical problem decisions are affected by model deficiencies or limitations, then a determination of the risk must be made. The analysis of risk involves consideration of program status, performance and technical issues, budget issues and schedule. These factors must be weighed by their relative importance.

The risk analysis is the logical converse of the analysis used to determine M&S functional requirements (see section 3.1.2.1):

- First, define the anticipated effect of the missing or deficient function on the model's output.
- Then determine the effects of that output error on the application's MOMs.
- Finally, identify the impact of MOM errors on application or problem results or outcomes.

Any conditions or circumstances that might change any of the intermediate MOMs are also identified. These steps constitute the bulk of the risk assessment process.

A risk assessment is performed on each unmet requirement individually. The top level questions that are asked in determining risk include:

- If the requirement were not met, how would the expected decision be affected?
- Under what conditions, or within what parametric boundaries, would the expected decision change if the requirement under consideration was not met?
- If the unmet requirement is a function which involves random variables, what is the probability that conditions would occur which would result in a changed decision?

Other follow-on questions may become apparent based on the answers to the above questions.

These questions and the risk analysis process overall are focused on application decision(s) that may be affected by model deficiencies. Possible impacts on these decisions should then be evaluated in terms of the consequential impacts on operational impact, budgets and schedules. The magnitude of these impacts must be considered as part of the risk assessment. Certainly, if an erroneous decision is made due to false model outputs, and that decision severely reduces a Service's operational capability, the impact is much greater than one where only procurement costs are increased slightly. Also, if an erroneous decision caused a program to be canceled or significantly extended at increased cost, the potential impact is much more severe than if a program would merely be modified technically. All three factors (cost, schedule, and operational impact) are important in determining risk severity.[43]

43. A more detailed explanation of risk elements is contained in section 3.2.1 of the SMART Lessons Learned document [reference 33].

Once risks have been identified, techniques for reducing or eliminating the risk should be developed and implemented. Risk reduction and mitigation techniques vary widely depending on the type of application and the type of risk. The key to developing appropriate risk reduction or mitigation approaches is understanding the total analytical process being used, including the various interactions and interdependencies between model outputs, functions, MOMs, and decision criteria, and the way different model deficiencies will impact application outcomes. With such an understanding, various work-arounds, decision caveats, or risk reduction techniques can be synthesized and integrated into the program.

Some risk reduction techniques that may be used include:

- Use of supplemental models: For example, in applications that require mission level (or higher) models, where certain features of a particular system might be inadequately represented, other models that more accurately represent system-specific, engagement-specific, or phenomenological conditions might be used to determine particular parameters. These parameters could then be inserted into the higher level model to provide an output that addresses all the functions. This technique would only be useful if the number of model runs necessary to perform the analysis did not become prohibitive.

- Manual adjustments: Where selected models have functional deficiencies, and the relative effect of these deficiencies on particular output parameters can be determined, the analyst can manually adjust selected input or output parameters to account for the impacts of model functional deficiencies. This technique is useful when interrelationships between application parameters (such as MOMs) and model outputs are well understood and relatively simple.

- Boundary value analysis: In those cases where a model might have insufficient fidelity, where it provides inputs to another model or calculation, and where only a few variations are being studied as part of the basic application, the higher level model might be run using extreme values for selected inputs that would be affected. These extreme values would represent the outputs of a particular function if a maximum error were present. The effects of these extreme values on the top level decision(s) would be determined and the probability of their occurrence quantified.

- Sanity check: Where the application is complex and a number of deficiencies exist, the only risk mitigation technique might be to subjectively assess the validity of the model's predictions. This, in essence, becomes a face validation of the model based on the study results. The panel conducting such a review should consist of personnel who understand the application requirements and decision criteria, and who have a thorough understanding of data analysis and the model suite. This technique is of relatively low value and credibility, especially if a comprehensive VV&A plan was not developed and implemented, and if this technique constitutes the heart of the total VV&A effort.

In some instances the risk of accepting (or working around) the limitations or deficiencies in a model may be too high. Therefore the only alternative may be to identify the changes to the model that are required to reduce the risk to an acceptable level. Sometimes the changes will be unique to the application, but more often the changes will be useful to other users and would be incorporated into a later version of the model. The justification to support funding these changes will be easier if the impact of model deficiencies on technical decisions (and on budgets and schedules) is clearly defined and quantified. If any model changes are required to correct critical deficiencies, the additional V&V requirements on the changed portions of the model should be identified and implemented to ensure the fidelity and logical correctness of these changes.

3.5.2.5 Develop Accreditation Recommendations

The final accreditation assessment step is to develop accreditation recommendations. This involves developing consensus among the review panel, if a panel is employed. These recommendations must be supported by sufficient documented rationale. In most cases the accreditation authority will require at least an executive summary of the accreditation justification, backed up by a report listing the accreditation requirements and indicating the V&V results that demonstrate that the model satisfies these requirements. The accreditation recommendation can be any one of the following alternatives[44]:

- Full accreditation;
- Interim accreditation pending completion of additional tasks;
- Provisional accreditation within certain specified boundaries or under specified conditions;
- Non-accreditation. (If this alternative is recommended, it should be accompanied by additional recommendations as to how the underlying problem might be addressed.)

3.5.3 Make Accreditation Decision

Accreditation of the model(s) by the designated authority is the final step in the accreditation process. Authority for accreditation decisions is defined by individual Service directives. The administrative procedures and supporting documentation requirements will normally be specified by the accreditation authority, if not by Service directives. The procedures for reviewing and approving accreditation decisions vary between and within individual services. In addition, DMSO is exploring an accreditation process that requires a review of accreditation recommendations prior to final accreditation. These reviews are meant to ensure that the justification for accreditation is logical and complete. Where subjective judgment has been used as a basis for a recommendation, the review takes into account the qualifications of the personnel making the rec-

44. These choices are consistent with Principle 7 in Chapter 2 of the DMSO RPG which states that “Accreditation is not a binary choice.” [reference 45]

ommendations.

The review panels generally evaluate the documentation supporting accreditation, including the VV&A plan, VV&A report, and supporting V&V reports. They may also receive a briefing from the accreditation proponent to help put all of the information in perspective, and to identify critical aspects of the accreditation justification package. Where no formal reviews are required by service or DoD directives, the accreditation authority may require such a review to assist in evaluating the supporting justification. The factors to be considered by the accreditation authority when considering the formal review are: the complexity of the application and supporting model(s); the sensitivity and importance of the application; and the experience and capability of the personnel involved in preparing the justification. In all cases the benefits of such a review must be weighed against the costs in terms of time and money.

Where an expert panel is used to perform the accreditation assessment, timely coordination and planning might allow these two reviews to be consolidated into one. The accreditation review (a second team review in addition to the accreditation assessment itself) is called out as an option in the Air Force and Navy directives[45]. These two reviews might be combined into a single review to save time and resources. This would require joint selection/approval of the review panel.

Approval of the accreditation package constitutes the accreditation decision. Approval is indicated by a signature on the approval line of the executive summary. If the accrediting authority so desires, accreditation can be qualified in a number of ways as described in the previous paragraphs. In accordance with some service directives (e.g., Army or Navy accreditations) the completed package is forwarded to another activity for review and archiving.

3.5.4 Document Accreditation Results

The accreditation documentation should consist of the following material:

- An executive summary outlining the modeling requirements for the application, and stating which requirements the model meets. Model deficiencies should be identified, as well as impact statements and descriptions of work-arounds for identified deficiencies. Finally a statement of the accreditation decision should be included.

- An accreditation report that describes in detail:

  - M&S acceptance criteria
  - How the model fulfills these requirements
  - Model deficiencies
  - How the impact of these deficiencies will be dealt with.

45. See references 39, 43 and 44.

- Detailed V&V report(s) that contain the details of the findings from V&V efforts.

If the VV&A process included reviews by any technical or managerial body, the results of such reviews should be included in the documentation package. Information in any of these documents should not duplicate or repeat that contained in VV&A plans or other V&V reports. Where such information is germane, it should only be summarized briefly in the report, with reference to the original document for more detailed treatment of the material.

4. PUTTING IT ALL TOGETHER

The previous section described each of the WBS elements and explained how each of the respective tasks are accomplished. Recall that the WBS elements are not structured according to any sequential process; the WBS is organized by discipline. In any practical application of this process, some of the tasks may be omitted and the remaining tasks will be performed in a sequence that does not necessarily follow the WBS order. This section describes the sequence normally used to accomplish the tasks.

The VV&A process is part of and embedded in a larger problem solving process. Figure 4–1: VV&A Process extracts the VV&A process from the overall problem solving process, and relates the major steps to their appropriate WBS elements (down to level 2). Note that the first three steps shown are, strictly speaking, part of the larger problem solving process in Figure 1–1: The Problem Solving Process (which was adapted from the DMSO RPG) but are shown here as necessary preliminary steps for VV&A. Not shown in this diagram are the many data elements that flow between individual tasks and which establish the proper sequencing of the various process elements.

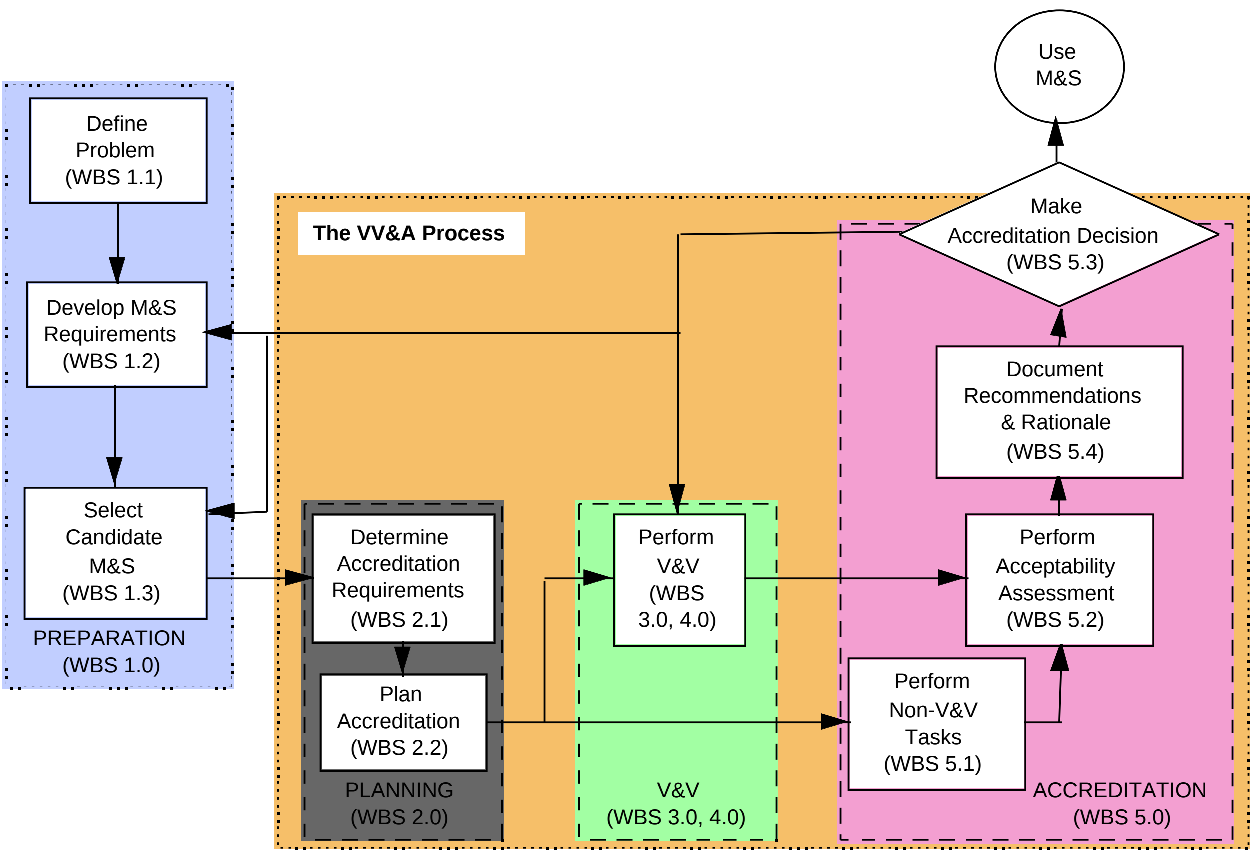

Figure 4–1: VV&A Process

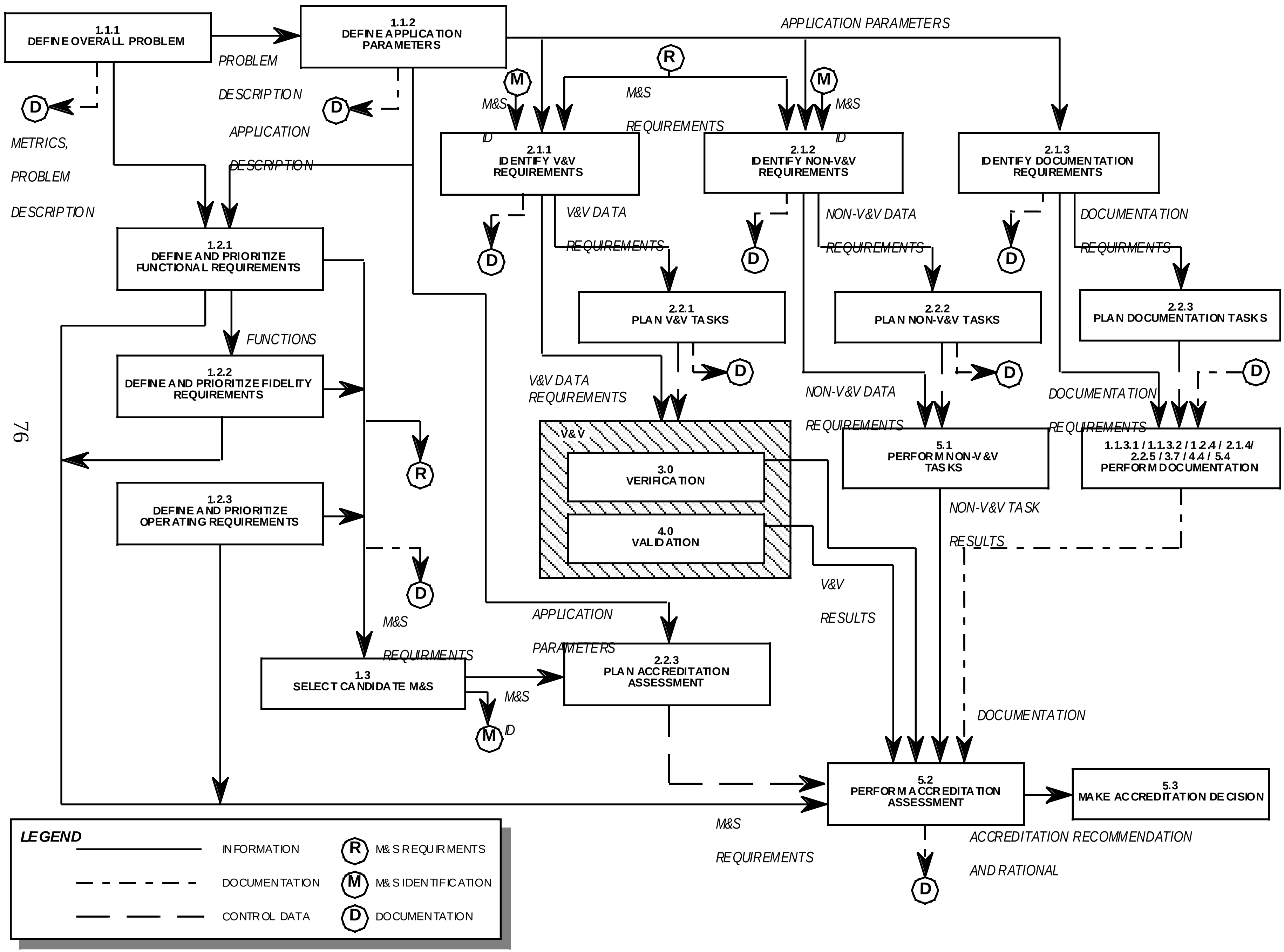

Figure 4-2: VV&A Data Flow

4.1 Data Flow Overview

Figure 4-2 shows the flow of important data between process elements. There are three data types: Information, Control and Documentation. The Information Flow constitutes the *raison d'etre* for the VV&A process. This is the data that enables an accreditation authority to state that the M&S is or is not acceptable for his or her purpose. Examples of information are the problem statement, the conditions under which the M&S will be used, the metrics needed to arrive at the ultimate decision and the data derived from verification and validation activities. Each of the WBS elements is intended to use some set of data, including information derived previously, and to process or transform it into other information. In the early stages of the process, each WBS element provides data to numerous follow-on elements, while in the latter stages, each element correlates and consolidates data derived previously into processed information that ultimately is sufficient to support an accreditation decision. Problem definition is always the first step in the process and M&S accreditation is always the last step in the process. In between numerous parallel activities take place.

The next type of data that governs process implementation is Control Data. After the preparatory steps are accomplished, the basic problem identified, and the solution approach determined, various planning steps take place that provide managers with the framework needed to control and track the execution of the VV&A process. These planning steps generate the control data. Examples of control data include schedules, cost estimates, test plans, etc. – all of the tools familiar to a program manager.

Documentation forms the historical record of the VV&A process and is the third type of data that flows between process elements. It refers to the written material used to record the results of each activity and transfer data (Information or Control data) from one WBS element to the next. Most importantly, accurate and concise documentation is essential for an informed decision by an accrediting authority. It should be noted that good documentation, in and of itself, often provides the accreditation authority with an added measure of confidence that the M&S is credible. Documentation Flow is more of a physical process than the other data flows. Information and Control Flows represent an exchange of ideas; Documentation Flow constitutes the medium for this exchange.

This section explains how the different data flows establish the sequence in which the VV&A process is executed and describes the task sequencing.

4.2 Information Flow

The purpose of the VV&A process is to generate the information needed to make a decision about a model's credibility. This requirement gives rise to the Information Flow described above, which in turn, establishes the sequence of individual VV&A activities described by the WBS. Each task, with the lone exception of WBS element 1.1.1.1, requires the data generated by at least one earlier element.[46] The most important data passed between tasks is shown in Appendix D provides a detailed list of the data needed to begin each element as well as the data that each task generates.

4.3 Preparation

Because the Information Flow sets the dependencies between VV&A activities, the activities associated with WBS element 1.0 (Preparation) are the most important steps in determining the credibility of a model. These steps provide the basic information required to perform all subsequent tasks. Unfortunately, these tasks are often neglected because managers believe them to be trivial. When this happens, V&V planning, which is typically done at a lower organizational level, proceeds without an understanding of what credibility, and thus what V&V, is really needed. The result is either M&S that are not credible, or excessive expenditures made to perform unnecessary tasks.

Without a clear understanding of the problem, its constituent M&S applications, the necessary M&S outputs, and how these outputs relate to the overall problem resolution, there can be no rational judgment on how much confidence is needed in model outputs. Absent this understanding, there is no clear justification for any particular level of V&V activity. A clear understanding of the credibility requirements is essential for properly tailoring the V&V activities and minimizing the resources expended on this part of the problem solving process.

As an explanation of the possible differences in credibility requirements, consider Figure 4–3: M&S Output Usage. Model outputs provide information that is used to make a decision of some type. Associated with that decision there are some potential benefits and possible risks. The information used to make the decision may come solely from model outputs, or it might include both model predictions and results from other sources, such as tests or historical data. Certainly, if the model outputs are only one factor, and possibly a minor factor, the degree of model credibility that is needed is much less than if the model outputs are the sole basis for a decision. Also, the level of risks and benefits that may result from the decision affect the model credibility requirements. Additional details on how credibility requirements are quantified are contained in subsequent sections. The important idea here is that credibility requirements will vary from one application to the next. Therefore it is important to articulate the problem (and the role of M&S in solving it) clearly, in order to develop the most appropriate and cost-effective VV&A plan.

The principal information elements determined during the preparation stage are the Problem Description, the Application Parameters, the metrics that will be used to make the problem decision, and the M&S Requirements. The preparatory steps include explicitly defining the problem, developing modeling requirements, and selecting the most appropriate model based on these requirements. The details of these activities are explained in section 3. In carrying out the preparatory steps, particularly the determination of modeling requirements, the development of functional requirements and fidelity requirements is an iterative process.

46. WBS Element 1.1.1.1 uses inputs from external sources - the tasking statement for example.

The functional requirements are determined first using knowledge of the required model outputs and metrics. Next, the required fidelity for each critical function is determined using knowledge of the study metrics and problem sensitivity to model outputs. Once the fidelity requirements are specified, a knowledge of parameter sensitivities may lead to identification of some second order functions that are critical to achieving the necessary fidelity in certain primary functions. In this case, these second order functions are added to the list of important functional requirements, and the fidelity requirements for these additional functions are determined. Figure 4–4: M&S Requirements Determination is a diagrammatic representation of this iterative process.

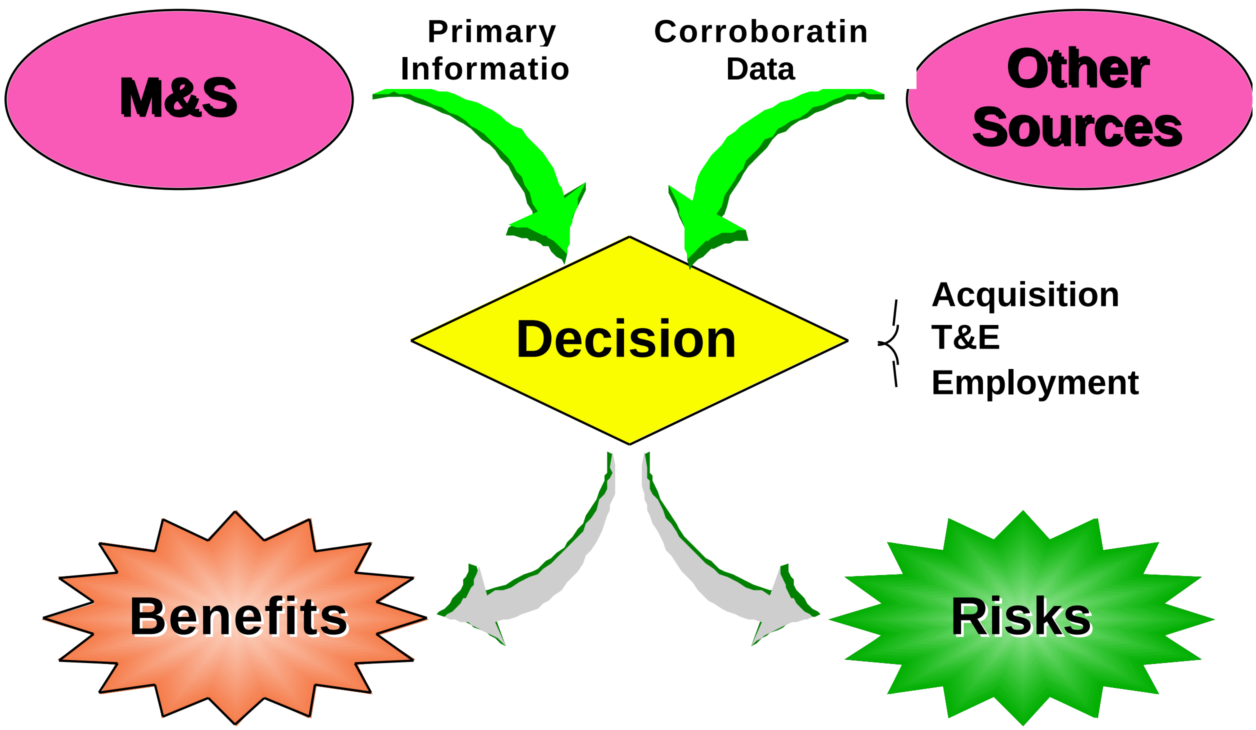

Figure 4–3: M&S Output Usage

Operating requirements are determined based on practical considerations concerning the facilities and manpower available to run the M&S. If a program only has access to a VAX computer, selecting a model which requires a CRAY is unacceptable. Likewise, the training of the people who will actually run the models must be considered. Defining the Operating Requirements requires a knowledge of available resources and an understanding of the problem constraints.

Once all of the M&S requirements are identified, selection of candidate M&S can take place. It turns out that definition of requirements and selection of candidate M&S often becomes an iterative process where identification of a particular requirement narrows the choice of models, and specific model characteristics suggest possible new requirements. Consider a hypothetical example of a missile intercept analysis. If the initial requirement is to identify miss distances for particular missile against range of aircraft then only those models capable of determining miss distance are acceptable. If we then find that there are a group of models that produce miss distance, but some are only accurate at medium altitudes, others good at low and medium altitudes and yet others good at any altitude up to 60,000 feet, our selection would require tighter definition of the requirements before the final selection could be made[47]. If the range of aircraft only included helicopters, any of the models would be acceptable. If the aircraft under investigation included the SR-71, none of the models would be adequate.

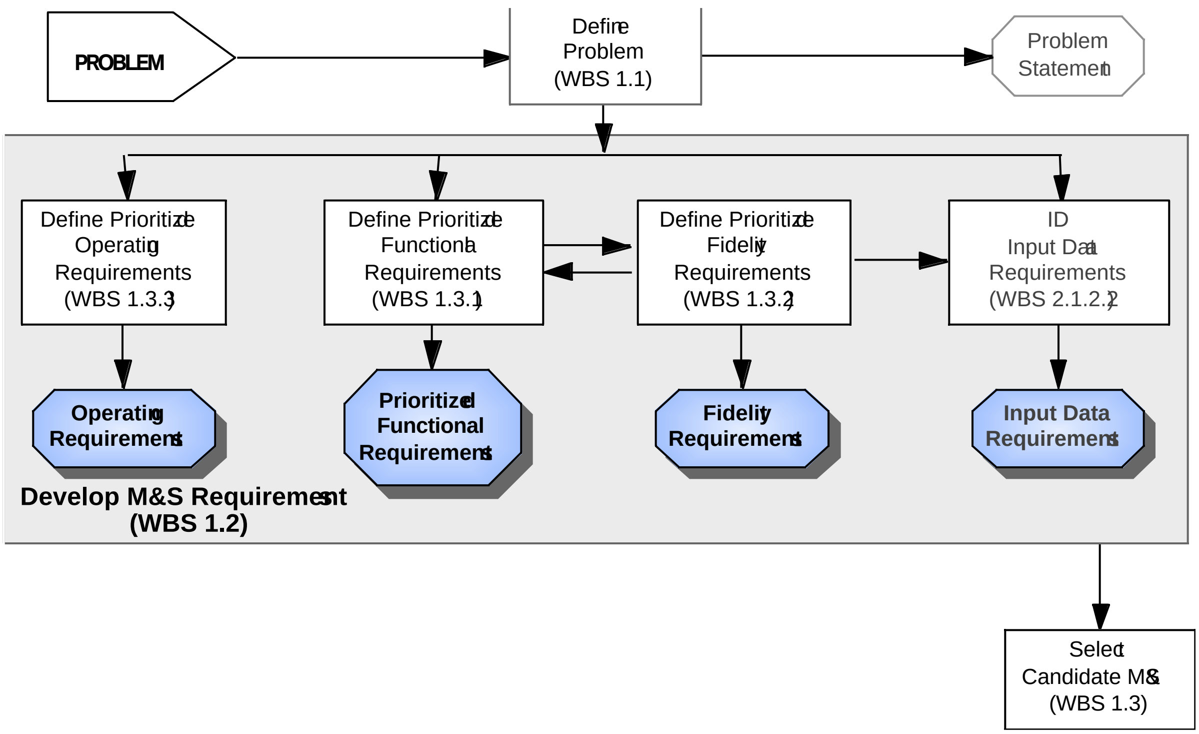

Figure 4–4: M&S Requirements Determination

The end result of the preparation phase is a set of M&S requirements, a comprehensive description of the problem and application, and a candidate model set. These pieces of information are used in the planning steps that follow.

4.4 Planning

Accreditation planning is essential to minimizing VV&A resources while still providing sufficient VV&A data to fully justify an accreditation decision. Accreditation planning involves two principal steps: determining accreditation requirements (which differ from modeling requirements) and preparing plans for V&V execution and accreditation assessment.

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47. Note that these statements imply that some data for the models exists, possibly from previous V&V. This demonstrates the importance of documenting the results of V&V for future applications.

4.4.1 Determining Accreditation Requirements

Accreditation requirements are divided into three categories: V&V information, non-V&V information, and documentation requirements. Documentation requirements are generally dictated by Service policies and/or the accreditation agent. Information requirements, both V&V information and non-V&V information, depend on the credibility needs of the problem itself. Applications with greater credibility requirements will require information of greater scope and depth. The process for determining VV&A information requirements is shown in Figure 4–5: VV&A Information Requirements Determination Process.

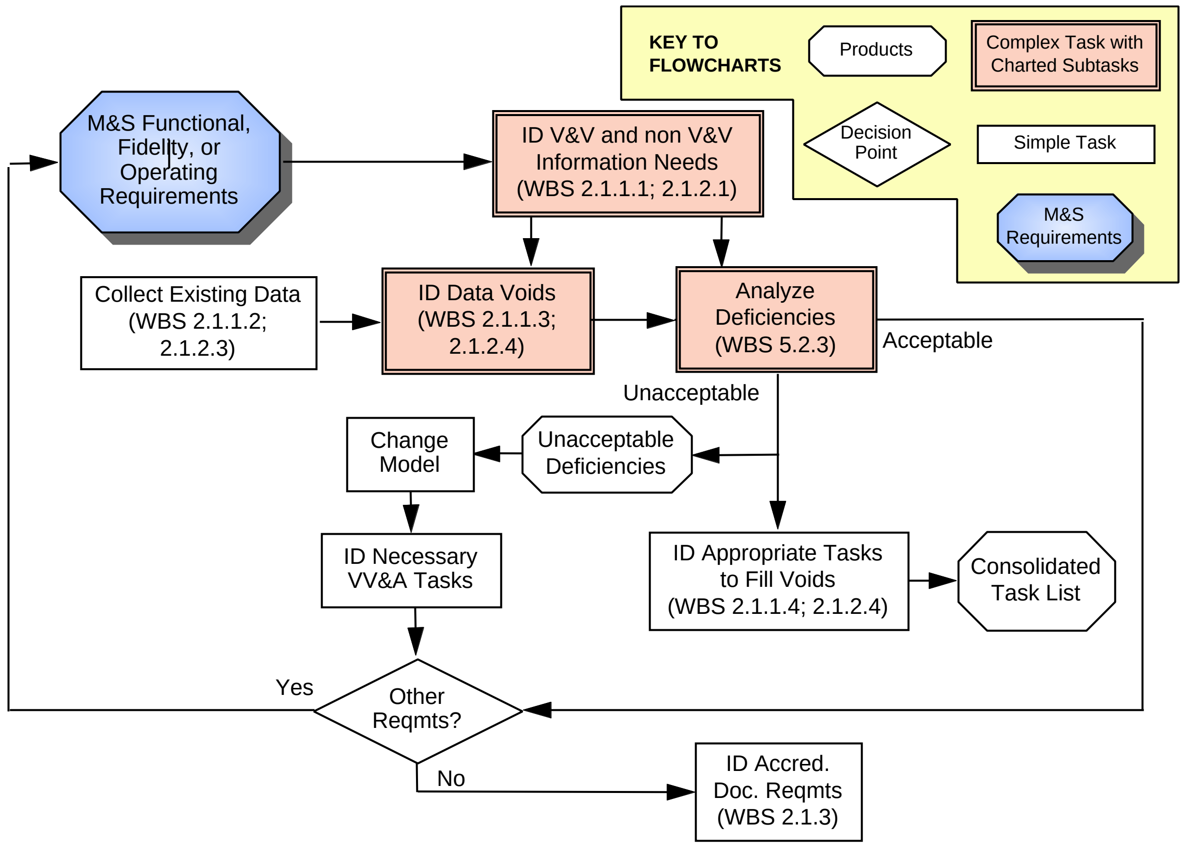


Figure 4–5: VV&A Information Requirements Determination Process

It should be apparent after studying section 3.0 of this process guide that determination of accreditation requirements cannot proceed without very detailed knowledge of the problem being solved and the role M&S will take in the solution. Planning for VV&A requires that the problem definition, application parameters and M&S requirements are available and that candidate M&S be identified. The planning process is then a matter of correlating M&S requirements with available model data (from prior VV&A efforts, for example) to identify any data voids. Once the data voids are determined, specific tasks (both V&V and non-V&V) are identified and resources allocated to accomplish them. Part of the reason the M&S requirements (functional and fidelity) are prioritized as part of the preparation stage is to allow V&V planners to focus resources on the most important requirements in case of a resource shortage.

To determine information requirements, one needs the list of functional, fidelity, or operating requirements along with all available and documented information about the model . The first question to ask is what types of information will provide insight into whether the model can satisfy this particular requirement. Table 4–1: Correlation of M&S Requirements with Data Sources is a listing of the types of data that are most frequently required to determine if a model can satisfy a type of requirement. If V&V information is needed, the next logical question is how much V&V information and of what type. The answer to this question is often stated in terms of the different V&V activities that might be performed. For example, model documentation (such as the conceptual model, a design specification, and the users manual) can provide basic information. Other V&V efforts, such as model decomposition, face validation, and results validation provide additional insight into a model's functional capabilities and limitations that would indicate the model's utility in specific applications.

The next logical question to ask is what V&V information is appropriate. The answer to this question depends on the credibility requirements of the particular application. The SMART Lessons Learned document[48] provides a detailed explanation of a method for determining the application credibility requirements.

Table 4–1: Correlation of M&S Requirements with Data Sources

For Assessment of Operating Requirements	For Assessment of Functional Requirements	For Assessment of Fidelity Requirements
Non-V&V Information Model Documentation Model H/W & S/W Compatibility Features User Support Services CM Process and Effects	**Non-V&V Information** Model Documentation VV&A Status and Usage History Output Data Parameters CM Process and Effects	**Appropriate V&V Information**
	Appropriate V&V Information	

Referring back to Figure 4–5: VV&A Information Requirements Determination Process, once the information requirements are known, archived V&V data are compared with these information requirements to identify information voids. This comparison should be done using a standard process to help ensure that all factors are considered. Figure 4–6: Process for Identifying Information Voids shows a standard process for identifying information voids. The "Intended Use Similar" check refers to the fact that V&V data are developed in the context of the intended use of the model, and it is possible that these data may not directly apply to another application of the model.

Before adding any information void to the list of tasks, the final step is to determine if the infor-

48. See reference 33.

mation void has a critical impact on the problem outcome or decision. This is done by tracing the effects of this void from its impact on model outputs to any resulting effect on the problem decision or outcome. Figure 4–7: Impact Assessment Process shows the process for performing this type of impact analysis.

An information void means that the credibility of certain outputs of the model or of a particular function cannot be ascertained. In making this analysis, the model hierarchy along with the relationships of model outputs to problem MOMs is used to trace the effects of the deficiency through to the ultimate decision or outcome. If there are any viable work-arounds that would negate these effects or reduce the potential risks, these would be identified and the effect of the work-around analyzed.

If the assumed model deficiency does not have a work-around, and is considered unacceptable in light of potential impacts on the ultimate problem outcome or decision, then this information void is added to the list of supplemental VV&A tasks. This process is completed for each information void discovered through an analysis of each functional, fidelity, and operating requirement, resulting in a consolidated list of VV&A tasks.

4.4.2 Planning Accreditation Activities

The consolidated list of VV&A tasks is the starting point for a classical planning effort. A diagram of the planning effort is provided in Figure 4–8: VV&A Planning Steps. The first step is to identify necessary resources and reconcile them with those available. Funding is typically the most constrained resource. If the available budget is not sufficient to accomplish all the required VV&A tasks, the budget must be increased or the risks resulting from insufficient credibility must be identified, acknowledged and worked-around or accepted. The logical process used to develop these VV&A requirements provides important justification for increasing the budget. It should be noted that if the budget is not increased, requirements are not adjusted; they are simply left unfulfilled.

Once the fiscal requirements have been reconciled with the budget, the VV&A schedule is reconciled with the program master schedule. Typically, if the master schedule does not allow completion of all the VV&A tasks prior to the time when an accredited model is needed, some work-around is found. Seldom is it possible to adjust a master schedule to accommodate VV&A requirements. A typical work-around is to perform the most important VV&A tasks first, and grant a preliminary or partial accreditation whenever necessary to meet master schedule requirements. Remaining VV&A efforts are then completed in parallel with other program efforts, and a final accreditation granted upon completion. In this way, the program is not interrupted and, yet, a full and final accreditation is made for record purposes. After schedule reconciliation the various task responsibilities are determined and tasks assigned as described in section 3.

An important part of the planning process is to plan the documentation. This planning step is important to ensure that the documentation will meet both accrediting and archiving requirements. Proper planning also helps ensure that the most cost-effective format is consciously chosen to minimize resource expenditures. It also helps to ensure that documentation actually is completed; too often a lack of planning in this area results in documentation being neglected in favor of finishing required technical tasks.

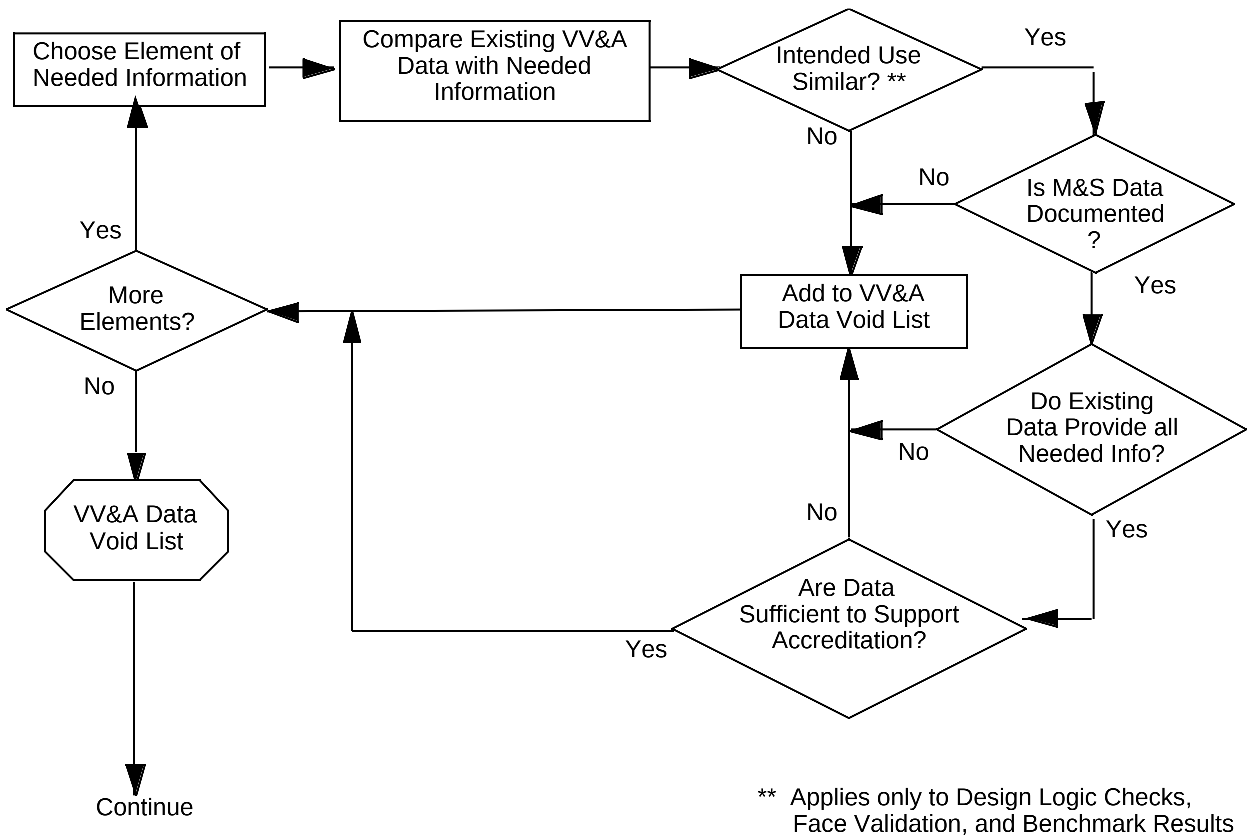


Figure 4–6: Process for Identifying Information Voids

The results of the planning stage (WBS element 2.0) are the V&V accreditation requirements, the non-V&V accreditation requirements and the documentation requirements. All of these are included in V&V plans that form the documentation data for this stage. The plans essentially provide the control data necessary to ensure efficient execution of subsequent VV&A tasks. It should be noted that the WBS element 2.1.3 (Identify Documentation Requirements) is the point in the WBS where documentation formats are identified. In as much as the results of the Preparation steps require documentation, this implies that WBS element 2.1.3 is one of the first tasks in the VV&A process and should be performed either concurrent with or immediately after the preparation tasks.

After all the requirements have been reconciled with master guidelines, and all the plans have been developed, the final step is to document the planning. It should be remembered that the VV&A plan is not the end product. The document is only a tool or a means of transmitting the planning decisions to others who must understand the plans in order to approve them or carry them out. The format of the VV&A plan should be consistent with the documentation requirements developed in the previous step.

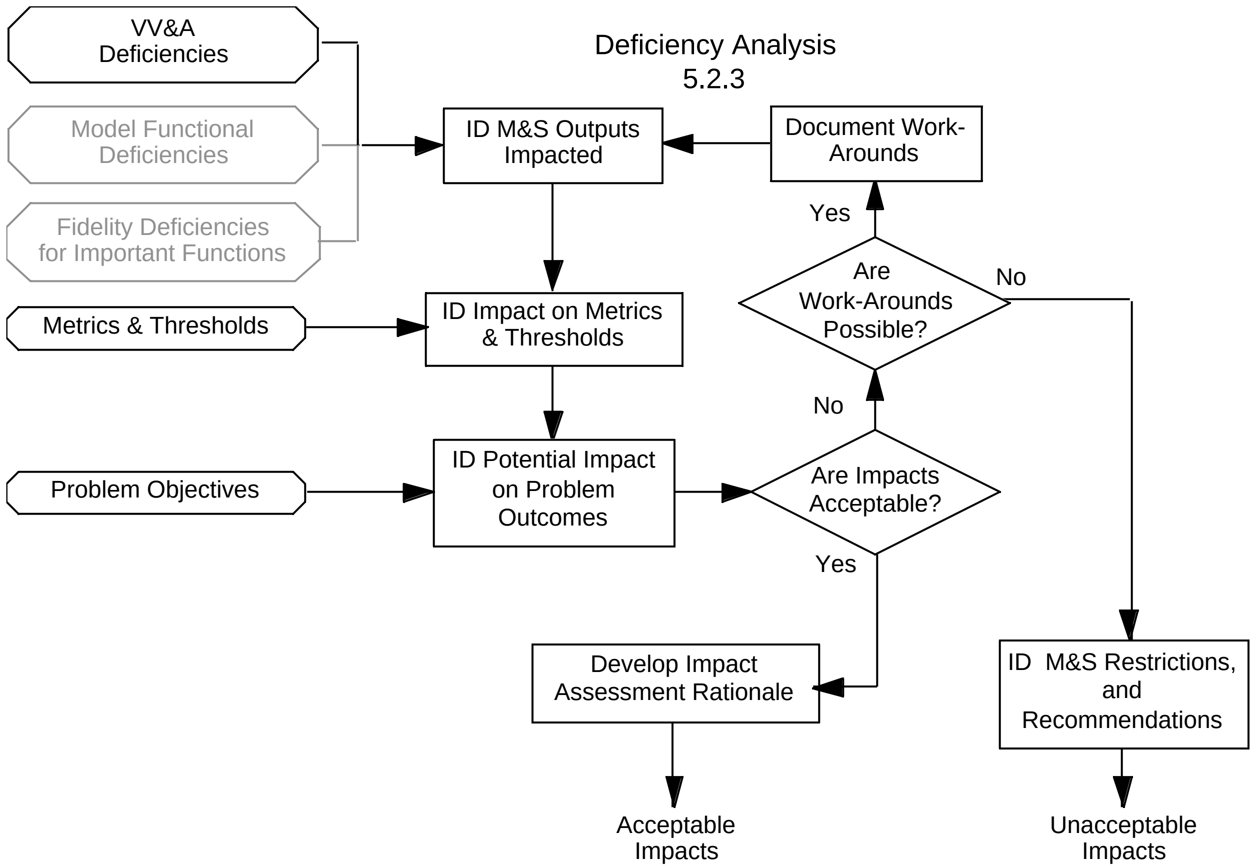


Figure 4–7: Impact Assessment Process

4.4.3 V&V

The individual V&V tasks and the techniques for accomplishing them were described in section 3. To minimize costs, these tasks should be sequenced in a logical manner so that the products or results of one task can be used in subsequent tasks. There are several decision points incorporated into the process to remind the verification or validation agent to gather existing data, or to check the task list to make sure that only necessary tasks are undertaken. The following paragraphs address the considerations that affect task sequencing and prior data usage.

4.4.3.1 Verification

The verification process, which is depicted in Figure 4–9: Integrated Verification Process, starts with a list of prioritized verification requirements which are a subset of the consolidated VV&A task list. Existing verification reports and data are checked to determine which requirements are satisfied by existing reports, or which can be satisfied by performing selected verification tasks using existing data. Those requirements that are satisfied are documented in an appropriate report as defined by the accreditation documentation requirements.

If there are any unmet requirements for which there are no suitable work-arounds, the verification steps are carried out in a logical sequence starting with software quality assessment and documentation assessment. If there are logical verification or code verification requirements, verification source reports are prepared (at the model and/or functional levels) and the detailed design specification developed. This is subjected to a logical verification to make sure that the design and inherent assumptions are reasonable from the perspective of the intended application. If code verification is required, it is only performed on those functions that are critical to the application. Other functions within the model can be assessed through face validation or logical verification.

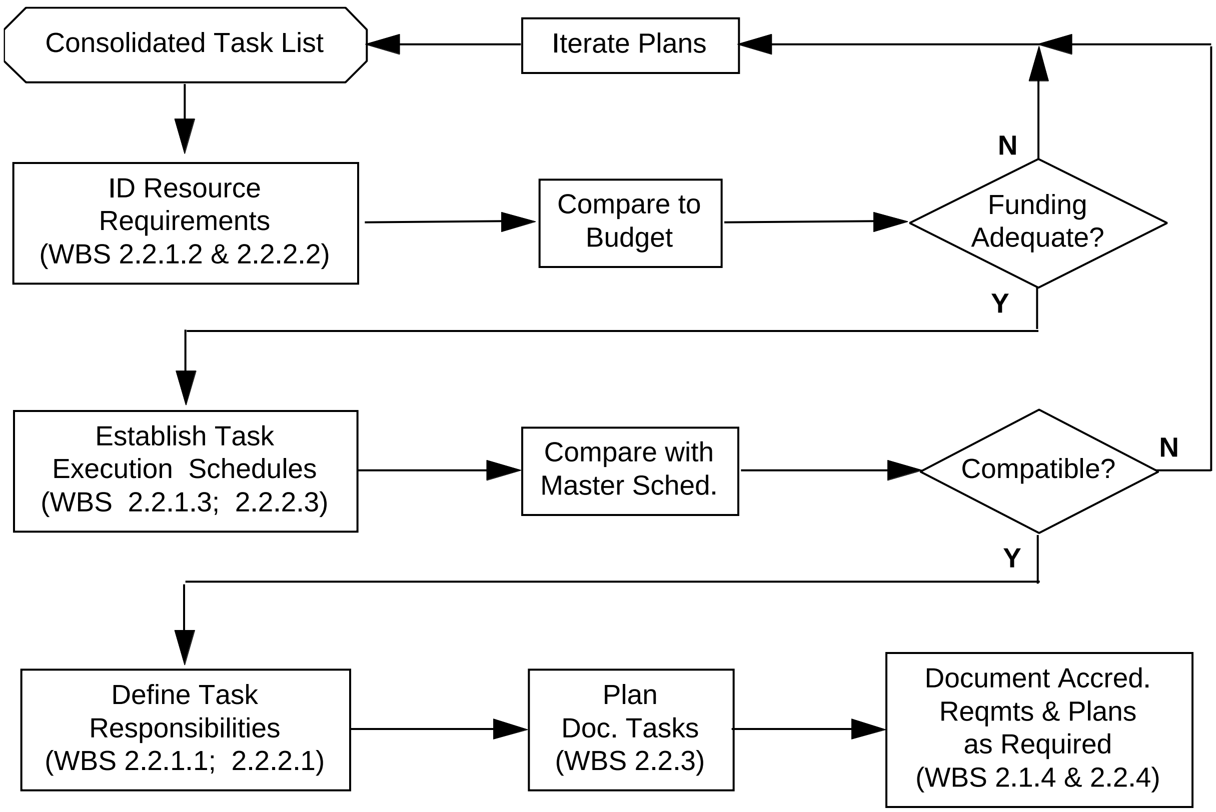


Figure 4–8: VV&A Planning Steps

Each step in the entire verification process is meant to build an ever more detailed justification that the code represents the developer's requirements, and is error free.

4.4.3.2 Validation

As with the verification process, the validation process begins with a set of prioritized validation requirements from prior steps in the process. These requirements are stated in terms of the functions within a model that need to be validated, and the types of information that are needed about each. As indicated in Figure 4–10: Integrated Validation Process, the first question is whether face validation is necessary. This is typically the easiest form of validation to accomplish, and is generally sufficient to impart at least a moderate level of credibility to a model.

The next question is whether existing validation reports provide sufficient information to satisfy any or all of the remaining requirements. If not, some detailed results validation will be required. The least costly means of doing results validation is to use existing data, either from tests or actual operations. Determining whether such data exist and are adequate is the third question. If so the actual results validation process is carried out, and the results documented.

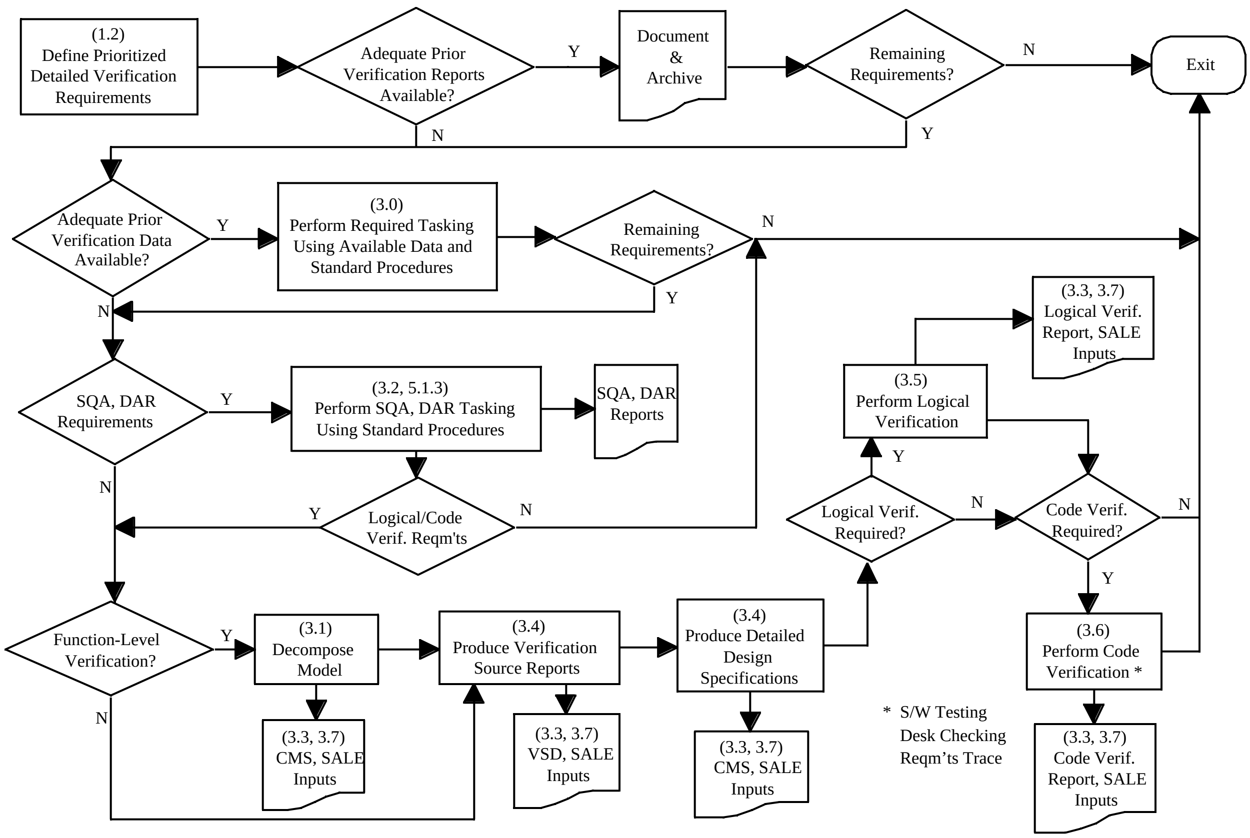


Figure 4–9: Integrated Verification Process

If there are not sufficient existing data for the necessary validation, data must be collected from test programs. The next question is whether there is any opportunity for piggyback data collection (collection of data from tests already programmed and funded for another purpose). If so, it is important to coordinate with the test planners and managers to ensure that any data collection requirements unique to the validation effort are factored into the test planning. These supplemental requirements may necessitate some supplemental funding from the validation agent. If funding is available, the data are collected and the validation carried out and documented. If funding is not available, the impacts of insufficient V&V must be assessed, and a report made back to the accreditation authority. Any test data that are collected should be fully documented and archived for possible future use in other validation efforts.

If there are no opportunities for piggyback data collection, the next step is to definitize the data requirements for a dedicated test, and estimate the resource requirements to perform the dedicated tests to collect validation data. The program manager or accreditation agent must either provide the necessary funding or curtail the results validation effort. Any curtailment of necessary results validation will have impacts on model credibility that must be evaluated in terms of the impact on the ultimate problem outcome or decision.

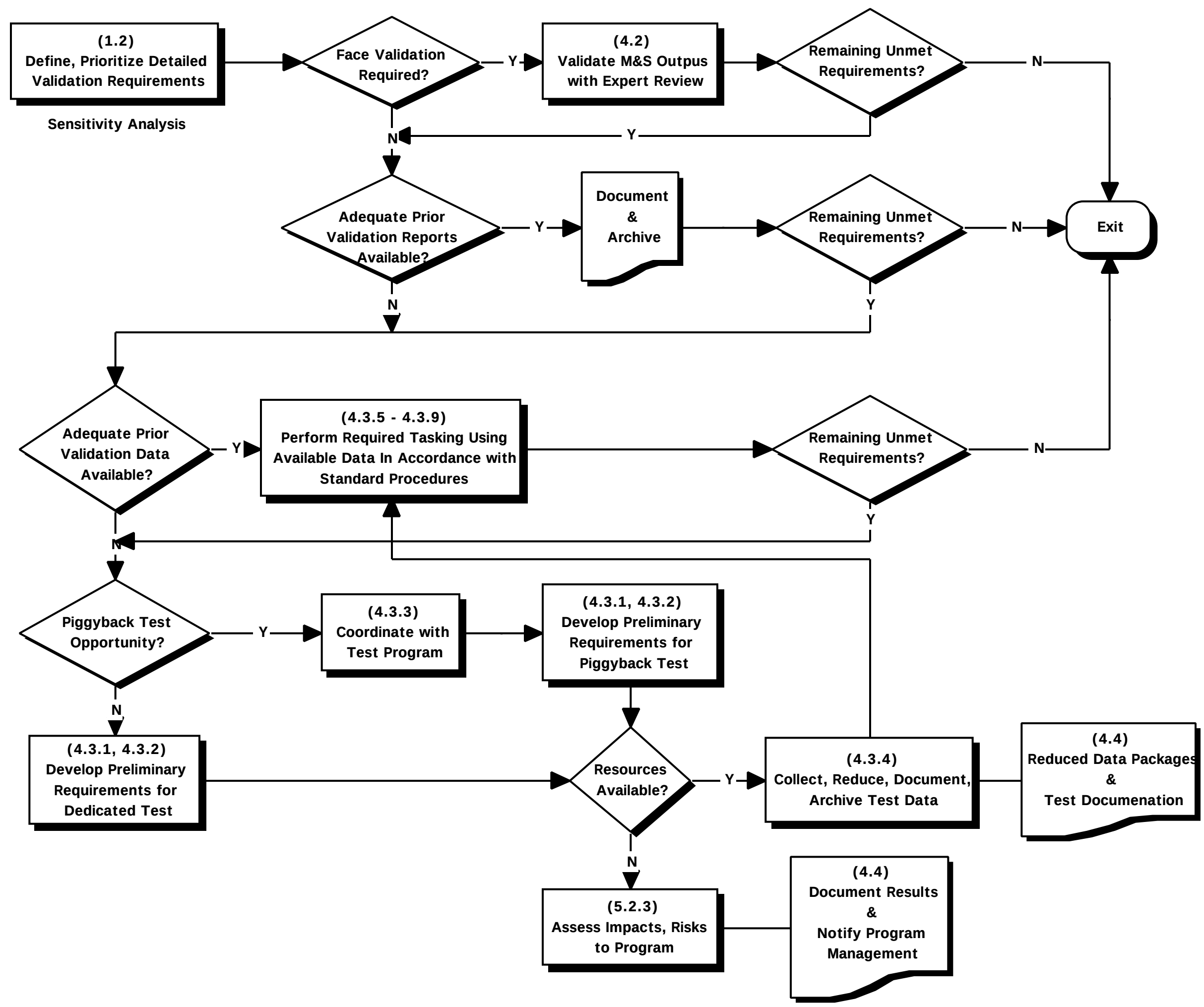


Figure 4–10: Integrated Validation Process

Once source data to perform results validation is available, the process for actually validating the model or function is shown in Figure 4–11: Validation Process Details. The process begins with preparation of the validation analysis plans. The formality with which these are documented is a matter left to each individual program, and should be addressed in the VV&A documentation requirements. The next step is to calibrate the model to the test article and test conditions. This means that the input data and any adjustable parameters within the model are made to correspond to the values that represent the system tested and the environment in which it was tested.

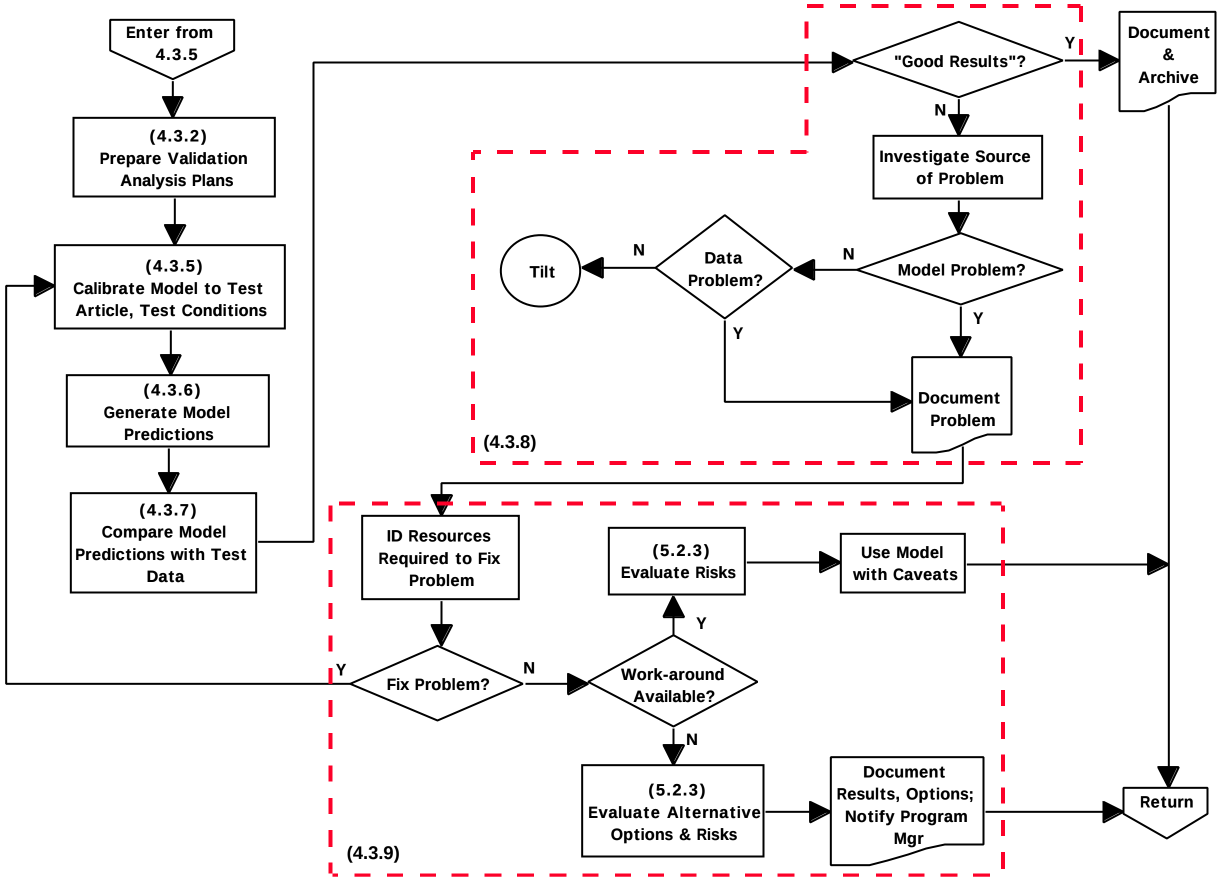


Figure 4–11: Validation Process Details

The next steps are to run the model and generate outputs, which are then compared to the same parameters measured during the test. The results of this comparison will be evaluated to determine if the model accurately represents this particular real world test or operation to within the tolerance defined by the requirements of the application. If not, a careful analysis of the results should indicate whether the cause of the difference is related to the model or erroneous validation data. If the problem lies in the model, the impact of the problem on the model outputs that are important to the application must be assessed. If suitable work-arounds are not possible, and if sufficient resources are available, the model might be modified. If work-arounds are possible, they will most likely be employed, and the model used with appropriate (and well-specified) cautions. In all cases, the results of the validation comparison and the analysis of any deficiencies discovered are documented as part of the rationale that supports the accreditation decision from the validation standpoint.

As with verification activities, results validation should only be attempted for those functions within the model which are determined to be critical to the application at hand. All other functions can be assessed through face validation, sensitivity analysis or a combination of the two. By focusing on critical functions within the model, the validation agent can minimize V&V costs while maximizing benefits.

4.4.4 Accreditation

Recall that the final part of the VV&A process is accreditation (WBS 5.0) which includes these steps:

Perform non-V&V tasks
Perform acceptability assessment
Document recommendations and rationale
Make accreditation decision

Each of these steps is fully described in section 3. Performing the non-V&V tasks is essentially an effort to collect information about the model. The information needed to start this task is the consolidated task list which identifies those non-V&V tasks that are necessary for accreditation. This effort can be performed in parallel with the V&V tasks since no V&V results are needed to start the effort.

The acceptability assessment brings together all the information collected to this point through the process. The information that is needed includes V&V results, non-V&V data collected to fulfill accreditation requirements, and M&S requirements. In addition information on the criticality of the application and the credibility requirements are needed to effectively perform any impact assessments that might be needed. The product of the acceptability assessment is a comparison report, a list of model deficiencies that impact the application, and an analysis of these deficiencies that shows whether any are critical or whether the model can be accredited despite the deficiencies.

If it is decided that the model is not suitable and cannot be accredited, theoretically the entire process is repeated, starting with a review of the modeling requirements to ensure that they are both essential and accurate. Other models might be evaluated to determine if a different one would be more suitable. If there are no other models available, the selected model will most likely undergo modification to make it suitable. In this case, all changes to the model must also undergo V&V in accordance with the original requirements. In the ideal case, the V&V effort will uncover the model's unsuitability well before the package gets to the accreditation authority, and appropriate steps will be taken to either make the model suitable or find a different model.

A more likely result is that the V&V efforts will either still be ongoing or not yet begun when an accreditation decision is needed. In this case, all the available information is typically assembled into a preliminary package. This preliminary information is often sufficient to support an interim or provisional accreditation. In these cases, any additional V&V requirements should still be performed to support a final accreditation.

4.5 Control Data Flow

Control data is that data required to ensure timely, cost effective execution of the VV&A program.

It is the only product of the planning process and consists of familiar program management planning tools like task plans, statements of work, budgets, work orders, and schedules. Various management reports might be called out in the individual statements of work and generated as secondary products of the V&V and non-V&V tasks. If so, these reports also fall into the control data category.

4.5.1 Planning Tasks

As discussed in section 3, planning tasks include planning the V&V efforts, planning to collect non-V&V data that is required for accreditation, and planning the documentation effort so that the rationale for accreditation is clearly and concisely presented to justify the final decision. The inputs needed to do the planning includes the accreditation requirements (both V&V and non-V&V information) and the documentation requirements. The program master schedules and information on programmed funds are also needed. In addition, the planners should have information on the capabilities of the various organizations that will or could be involved in performing any of the VV&A tasks. The product of this effort is the planning data that provides managers the tools to effectively direct and control the remaining VV&A efforts so that all essential tasks are completed and extraneous tasks are precluded. Additional information on how to plan cost-effective VV&A efforts is contained in section 4.1 of the SMART Lessons Learned document[49].

Although the focus of most planning efforts is on gathering necessary information to support accreditation, other planning is also essential. Good planning that addresses the documentation tasks helps ensure that the documentation will be produced, it will be timely, and sufficient resources are available to complete it. Besides the documentation planning it is also necessary to fully plan the accreditation assessment activities. Section 3 identifies a number of possible alternative approaches for conducting this assessment. Adequate planning helps ensure that the selected approach is acceptable, necessary personnel are available, and suitable time is provided to perform and document the assessment.

It should be obvious that planning, to be effective, must be completed and approved before the tasks are performed. Although this statement appears trivial, often times real planning is bypassed in favor of having a plan prepared. Some program managers may initiate V&V efforts well before a VV&A plan is written. In these cases, real planning may or may not have been done and the eventual written plan only fulfills a bureaucratic requirement and documents activities after the fact.

4.5.2 Performing V&V and Non-V&V Tasks

Good accreditation planning produces a comprehensive and complete guide for conducting the V&V and other data collection tasks. The control data generated in the planning process establishes the guidelines that are used in directing these tasks so that necessary and sufficient informa-

49. See reference 33.

tion is generated to fully justify an accreditation decision. The information and data used to plan these efforts also provides a framework for assessing the sufficiency of the V&V results and, if necessary, adjusting the V&V plans based upon these results. In this way, the plans are living guidelines that are adjusted as additional information becomes available. The advantage of having a plan that truly does guide task execution is that any need for deviations from the plan can be easily recognized, justified, and documented. In this way the rationale and decisions made during the entire V&V execution phase can be retraced and explained to the accreditation authority and higher level reviewers if necessary.

4.5.3 Performing Documentation Tasks

Similarly, proper planning of the documentation tasks provides the guidelines for documentation structure and addresses the issues that often hinder completion of timely and suitable documentation. If documentation planning is adequate, the structure and content of each required document will be defined so as to minimize any dedicated effort by capitalizing on other products that are produced (e.g. annotated briefings). Through good planning a manager can focus resources on only those documents that are required by some higher authority or that serve an important purpose which justifies the expenditures are produced. Effective plans also help ensure that the resources needed to gather the results and prepare the documents are available when needed; that the personnel who will prepare the documents are available to do the work; and that the funding is available and provided when needed to get the work done in a timely manner. The primary advantage of planning the documentation effort is that necessary and appropriate documents are produced, when needed, and for the minimum cost.

4.5.4 Accreditation

Accreditation typically involves activities beyond just a decision by the accreditation authority. In most major applications, there is an assessment process where all the information that has been collected and documented is evaluated to determine if accreditation is justified. The next step is the presentation of the evaluation results to the accreditation authority along with a recommendation. In many of the services, the accreditation authority's decision is reviewed by higher authority or a review body constituted by higher authority. This review can take place before or after the actual accreditation decision.

Good accreditation planning addresses all of these steps. It provides the control data that enables the accreditation agent to prepare for and guide each of these steps. Where necessary, the planning data is the basis for establishing the liaison and transferring funds as necessary to carry out each of these steps on time and in the proper sequence.

4.6 Documentation Flow

Documentation, as discussed earlier, provides the medium through which data is passed from task to task within the WBS, and serves as the historical record for the VV&A effort. The latter is important for two reasons. First and most importantly, the accreditation decision performed as the final step of the VV&A process will depend on the accuracy and clarity of the documents provided. Good documentation will provide an indication to the decision maker that the claims of suitability for the selected M&S are supportable. Incomplete or unclear documents will cause the decision maker to question the M&S suitability. Secondly, the documentation produced will provide future accreditation efforts with information that can reduce the amount of V&V necessary for their purposes. Although this reason is somewhat altruistic, all that is required is compliance with a documentation standard recognized by the VV&A community so that pertinent data is easily accessible. The essential pieces of information that are needed to accredit a model and that must be documented are:

- a description of the problem and application
- a list of the M&S requirements (including functional, fidelity, and operating requirements)
- a description of the model, its capabilities and weaknesses
- V&V results that include impacts on model strengths & weaknesses
- results of the comparison between M&S requirements and M&S capabilities
- results of any analysis of model deficiencies found through the above comparison
- accreditation recommendations and decision

Because the documentation serves to record results of each step along the entire VV&A process, the essential pieces of information noted above should be documented as they are produced. The problem and application descriptions should be documented as soon as possible and updated as additional iterations occur during the entire problem solving process. Similarly, M&S capabilities and limitations should be recorded as the results of each data collection task is completed. The recommendations and rationale are documented prior to the accreditation decision, to provide the accreditation authority with a fully understandable rationale for the record. If the recommendations and rationale are generated by an expert review panel, the documentation plans must address who will prepare the documents and how they will get the review results from the panel. The package given to the accreditation authority includes a signature line which, when filled in, is the documentation of the decision itself.

5. DOCUMENTING VV&A ACTIVITIES

Documentation of VV&A activities is usually the last thing on anyone's mind during a typical fast-paced program, and it is the first thing that gets jettisoned when money gets tight and time gets short. Part of the reason for this is that documentation is not an exciting activity, and usually gets put off until last. Another reason is that very few have a good idea right at the start as to what should be documented in the first place, or how. Fortunately, both DMSO and JASA have been able to develop guidelines for the documentation of VV&A plans and reports that can help the struggling program manager or VV&A agent get a leg up on documentation activities right from the start. The sections below provide general guidance on how to document VV&A plans and reports. These guidelines are tailored forms of the guidance found in the DMSO VV&A RPG for use in acquisition applications M&S. Specific details of how V&V documentation should be arranged for application to the accreditation of model(s) used in acquisition are provided in Appendix B. These details were developed on the basis of experience with supporting model accreditation for models used in acquisition, as well as on surveys of the acquisition M&S community.[50] A more detailed explanation of the benefits of standard reporting is contained in section 5 of the SMART Lessons Learned document[51].

5.1 Accreditation Plans

The Accreditation Plan is a very important piece of documentation, serving numerous purposes. Properly constructed, the Accreditation Plan lays out the grand strategy of VV&A, including expert reviews and V&V activities that can be used to justify a recommendation to accredit a model for a specific purpose. A well-documented plan serves an important psychological purpose in accreditation as well: it demonstrates that the VV&A effort, despite whatever conclusions it may result in, was well-planned and executed. Poorly articulated Accreditation Plans suggest haste and inattention to detail, and may call into question the "good faith" with which the effort was conducted. The ability to demonstrate a rational approach to the definition and fulfillment of model credibility requirements goes a long way to set an accreditation authority at ease, not to mention those who must evaluate the credibility of the accreditation decision itself (e.g., a DAB review panel).

An Accreditation Plan serves numerous purposes: it provides a clear and concise statement of the application; it documents the specific functional, fidelity, and operating requirements for the application, including a description of the analysis that generated these requirements; it identifies the models that have been selected for use, and summarizes the existing V&V status of those models; it summarizes the results of a comparison of existing VV&A (and other) data with the modeling requirements; it identifies the V&V deficiencies that are identified as a result of this comparison; it defines and describes the additional V&V that should be done to support accredita-

50. See the Accreditation Requirements Study report [reference 7].

51. See reference 33.

tion of the model for use in the stated application, and provides an indication of the priorities assigned to the different V&V requirements; finally, it spells out specific plans for accomplishing these V&V tasks. In some cases, the V&V plan itself may become a separate document. Where any of the required information is provided in separate, already published documents, the accreditation plan should only summarize this information and provide references to the source document(s).

Based on section 6 of the DMSO VV&A RPG, JASA has developed a standard outline for VV&A plans that it has applied to numerous M&S applications in acquisition. Appendix B-1 provides this outline in the form of a Data Item Description (DID) suitable for inclusion in contracts or as references for statements of work (SOWs). One of the sections of the DID for a VV&A Plan provides detailed preparation instructions as to format and content.

It should be noted that the inherent value of an accreditation plan is to record essential information elements and to provide guidance to personnel who will perform the various VV&A tasks. Once the accreditation decision has been reached and reviewed, the plan only provides information on the application to aid future model users in evaluating model suitability for their application. The important element is the planning data that will be used to guide the entire accreditation effort. Preparation of the accreditation plan must be integrated with and follow the planning effort. It cannot be contracted out as an end in itself.

5.2 V&V Results

Based on the WBS elements for V&V (the 3.0 and 4.0 series) that have been described in section 3, one would think that simply developing a report format for the product that results from each activity would be the simplest thing to do. It turns out, however, that in addition to specifying the documentation products that should result from each V&V activity, there are logical groupings of V&V results that, when taken together, address larger issues related to the credibility and maturity of a model. We have organized the V&V products that result from the 3.0 and 4.0 series of activities into three “Accreditation Support Packages”. Each package contains the technical results of a collection of V&V activities that speak to one of three major issues of model credibility: development status and acceptance of results, functional characterization and design, detailed V&V results. The following sections discuss each of these aspects of model credibility in more detail. Appendix B-2 provides detailed documentation specifications for each WBS task individually, but placed within the context of the discussion below.

5.2.1 Accreditation Support Package I: Model Overview

This Phase I Accreditation Support Package (ASP-I) is designed to provide a characterization of the current state of a model with respect to criteria related to its general acceptability for use. The information collected in this phase characterizes a model well enough to provide an initial determination of its suitability for a particular application. It also provides confidence that the model is managed and supported well enough to yield consistent results across its spectrum of users and applications. The information required to assess the development status, maturity and acceptability of model's results consists of the following elements:

a. A description of the configuration management baseline for the model, including version history, current version status, model development policy (including beta site provisions), documentation availability, and a summary of configuration management policies, procedures, guidelines and support functions in place for the model;

b. A summary of implicit and explicit assumptions and limitations inherent in the model because of its design and/or coding assumptions or structure, as well as any implied constraints to the use of the model that are a consequence of these assumptions or structures. A listing of known errors or anomalies found as a result of prior V&V efforts should also be included;

c. A review of the model's development, verification and validation (V&V) and usage histories, as well as a summary of prior accreditations that includes what V&V work was done to support accreditation, whether accreditation was granted, and for what application(s);

d. A review of the status of model documentation with respect to its conformity to accepted software documentation standards, as well a review of documentation with respect to verification requirements, and;

e. A summary of overall software quality as characterized by conformance to accepted design and coding practices.

ASP-I provides the details of these information elements in a single document. The degree to which each information element is complete and current can provide a good indication of whether a model is suitable for further consideration for use in a particular application.

5.2.2 Accreditation Support Package II: Functional Characterization

The Phase II Accreditation Support Package (ASP-II) is designed to provide the prospective model user with information about the details of model design, as well as its function-level sensitivity to changes in typical input parameters (or combinations of input parameters). The information provided in this document is typical of that which is normally reviewed as part of a logical verification and/or face validation effort. The end product of such reviews is normally an assessment of the suitability of the model for the problem at hand from the standpoint of design adequacy and functional reasonableness. The information provided to characterize model functionality is:

a. A Functional Element Breakdown of the model in terms of its functional hierarchy, as well a detailed description of the purpose and implementation of the function;

b. A Conceptual Model Specification, which describes both the top level and function level design requirements and specifications, as well as algorithms used to model the physical phenomena within the simulation, and which identifies a set of assumptions and conditions for which the simulation correctly produces intended results, and;

c. A Sensitivity Analysis, which exercises the model and its functions over the full range (or the maximum, minimum and highest probability values) of major model variables (or combinations of variables) to assure correct, corresponding changes in model output.

ASP-II provides the technical details of each of these items in a single document. When coupled with ASP-I information, ASP-II provides the user with the best possible confidence in top level model results short of detailed V&V, which is addressed in ASP-III.

5.2.3 Accreditation Support Package III: Detailed V&V

The Phase III Accreditation Support Package (ASP-III) is intended to provide the model user with a high confidence statement of model credibility, backed by detailed verification and validation assessments. ASP-III includes an assessment of the accuracy of the code implementation, as well as data that bear out how well the outputs of the model reflect the “real world”. The information is presented in two main sections:

a. A Verification Report, which consists of examinations of algorithms, data values, and each executable statement in the code for a given function, as well as completion of software testing, to ensure that each design element or requirement is satisfied by that portion of the code, and;

b. A Validation Report, summarizing the results of comparisons between function-level and/or overall simulation predictions with real world data from a variety of sources (e.g., developmental, operational, laboratory, and/or bench testing, Intelligence or T&E reports, etc.).

ASP-III provides the technical details of each of these items in a single document, and represents the most detailed assessment of model credibility possible within the scope of the verification and validation conditions reported.

5.3 Accreditation Reports

Appendix B-3 provides a standard outline for an Accreditation Report. A primary part of the accreditation report is the summary page that also serves as the accreditation decision paper. It contains a very short summary of the evidence that the model is suitable and records the signature of the accreditation authority to indicate acceptance of the rationale.

The body of the accreditation report is similar to the accreditation plan in that it summarizes the model acceptance criteria and the model capabilities based on V&V results. In this case the V&V results include both prior V&V and the supplemental V&V performed in accordance with the accreditation plan. It also documents the comparison of the requirements with the capabilities and identifies any model deficiencies.

Where deficiencies exist, the accreditation report provides an explanation of what steps will be taken to negate the effects of the deficiency and/or identify risks associated with accepting the model results in spite of the identified deficiencies.

With this format, the accreditation authority will have a logical and clearly presented justification of the model's suitability for the desired application. This document will be the primary evidence to support model credibility during subsequent program reviews where challenges to the M&S outputs might be expected.

6. WHERE TO GET MORE HELP

In the above sections we have tried to define and describe a VV&A process applicable to typical acquisition applications of M&S, based on the best available guidance on both policy and procedure. In particular, we have discussed the necessary precursors to VV&A activities; we have described how to plan, execute and document the results of VV&A efforts; and we have tried to show how to relate the results of VV&A activities to actual accreditation decisions. This overview is not the sum total of all available expertise related to the VV&A of models used in acquisition, however. Table 6–1: VV&A Cross-References correlates a list of numbered references (found in Table 6–2: Numbered References) with the phase(s) of VV&A activity to which they most closely apply. If you need more information on VV&A planning, for example, references 3, 6 through 8, 29, 32 and 33 will be of particular help. The references also summarize the contents of each citation to facilitate the determination of applicability.

In addition to these resources, the following links to Internet Home Pages related to VV&A may be helpful:

Director, Test, System Engineering and Evaluation (DTSE&E)	http://www.acq.osd.mil/te/
Defense Modeling & Simulation Office (DMSO)	http://www.dmso.mil
Defense Modeling, Simulation & Tactical Technology Information Analysis Center (DMSTTIAC)	http://DMSTTIAC.HQ.IITRI.COM
Army Model Improvement and Study Management Agency (MISMA)	http://www.misma.army.mil:443/misma/
USAF Directorate for Modeling and Simulation (AF/XOM)	http://xom.hq.af.mil
Joint Electronic Combat Test using SIMulation (JECSIM)	http://on-site.nawcwpns.navy.mil/~jecsim/
Joint Accreditation Support Activity (JASA)	http://www.nawcwpns.navy.mil/~jasa/
Navy Modeling and Simulation Catalog	http://sneezy.nosc.mil/30_org/31Files/TSG/NMSC/Index.html

Table 6–1: VV&A Cross-References

REFERENCE	PREP	PLANNING	VER	VAL	ACC	GENERAL
1			X			
2			X	X		
3		X				X
4			X	X		
5			X	X		X
6		X				X
7		X			X	
8	X	X				
9	X					
10	X		X	X	X	
11						X
12			X	X		
13			X	X		
14			X	X		
15			X	X		
16			X	X		
17			X	X		
18			X	X		
19			X	X		
20			X	X		
21			X	X		
22			X	X		
23			X			
24				X		
25						X
26						X
27						X
28				X		
29	X	X			X	
30			X	X	X	
31						X
32	X	X	X	X	X	
33	X	X	X	X	X	
34						X
35					X	
36						X
37						X
38						X

REFERENCE	PREPARATION	PLANNING	VERIF’N	VALID’N	ACCRED'N	GEN'L BACKGRD
39						X
40						X
41						X
42						X
43						X
44						X
45	X	X	X	X	X	X
46						X
47						X
48						X

Table 6–2: Numbered References

1. Ellis, Dr. Sharon, and Timothy Krenz. *Software Verification Requirements Study for the SMART Project*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-92-SM-011) June 1992. Documents the requirements for performing software verification on mature models. It defines a minimum set of documentation that is necessary to support such verification efforts.
2. Ellis, Dr. Sharon, M. Tichenor, T. Krenz, and B. O'Neal. *Documentation Assessment Report for ESAMS, ALARM, and RADGUNS*, ENTEK Inc. Albuquerque NM (ENTEK/ABQ-93-0144-TR) December 23 1993. Identifies the format and content requirements for model documentation and provides specific recommendations for upgrading documentation for the three identified models.
3. Gravitz, P. D. and W. Jordan. "An IDEF0 Process Model of the DIS VV&A Process Model" *The Proceedings of the 1995 Summer Computer Simulation Conference* Ed. Oren, T. I. and L. G., Birta. July 1995, 627-632. Describes a series of block diagrams that are useful in planning and explaining a VV&A program for a DIS model.
4. Hall, D. H. and P. R. Muessig. "SMART Project Contributions to Survivability M&S" *Aircraft Survivability* (Summer 94): 9-11. Describes the three phase V&V methodology developed by the SMART Project and applied to selected aircraft survivability models.
5. Hall, David, and Dr. Paul Muessig. *Annotated Briefing for the SMART Project Proof of Concept*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-92-SM-019) July 1992. Summarizes the results of the Proof-of-Concept demonstration carried out by the SMART Project. This effort demonstrated the essential project functions and served as justification to continue the project.
6. Jordan, W., D. Charen, C. Cotten, and R. Lewis. "Planning, Optimizing, and Costing Verification, Validation, and Accreditation (VV&A) for Distributed Interactive Simulations (DIS)" *The Proceedings of the 1995 Summer Computer Simulation Conference* Ed. Oren, T. I. and L. G., Birta. July 1995, 597-602. Describes a methodology and accompanying tool that can aid in estimating VV&A costs for a distributed simulation that is undergoing development and concurrent V&V.
7. Laack, D. R. *Accreditation Requirements Study Report, Volumes I and II*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-93-SM-020) February 1994. Describes the policies governing VV&A within the DoD. Also summarizes common practices employed by those performing VV&A efforts throughout the three services.
8. Muessig, P. R. "Cost Vs. Credibility: How Much VV&A Is Enough?" *The Proceedings of the 1995 Summer Computer Simulation Conference* Ed. Oren, T. I. and L. G., Birta. July 1995, 166-175. Describes a logical structure for V&V activities and explains how V&V efforts can be tailored to a particular use or application.
9. Muessig, P. R. "SMART Comes of Age" *Aircraft Survivability* (Winter 94/95): 10-11. Describes how the SMART process for accreditation analysis was used to identify accreditation requirements for selected aircraft survivability models that are part of the modeling hierarchy in the Tomahawk Mission Planning System.

10. Muessig, P. R., and D. R. Laack. "Accreditation of Survivability M&S." *Aircraft Survivability* (Winter 94/95): 11-13. Describes a rational process for determining accreditation needs, performing V&V, and using the results to accredit aircraft survivability models for particular applications.

11. Muessig, P. R., and D. R. Laack. "Cost Effective VV&A: Five Prerequisites." *The Proceedings of the 1996 Summer Computer Simulation Conference* Ed. Ingalls, V. W., J. Cynamon, and A. V. Saylor. July 1996, 409-414. Explains how these five prerequisites were identified and provides rationale why they are important.

12. Muessig, P. R., B. Allred, S. Ellis, T. Goodman, and Ed Wixson, *Phase III Accreditation Support Package for the Advanced Low Altitude Radar Model (ALARM) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-008) July 1995. Details the results of detailed verification and validation efforts on ALARM.

13. Muessig, P. R., B. Allred, S. Ellis, T. Goodman, and Ed Wixson, *Phase II Accreditation Support Package for the Advanced Low Altitude Radar Model (ALARM) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-007) June 1995. Provides software design detail and sensitivity analysis results for ALARM. This information is designed to support logical verification and face validation of the model

14. Muessig, P. R., G. Born, J. Hancock, B. O'Neal, and T. Silco, *Phase III Accreditation Support Package for the Enhanced Surface to Air Missile Simulation (ESAMS) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-011) September 1995. Details the results of detailed verification and validation efforts on ESAMS.

15. Muessig, P. R., G. Born, J. Hancock, B. O'Neal, and T. Silco, *Phase II Accreditation Support Package for the Enhanced Surface to Air Missile Simulation (ESAMS) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-010) August 1995. Provides software design detail and sensitivity analysis results for ESAMS. This information is designed to support logical verification and face validation of the model

16. Muessig, P. R., Lt Col K. Cheek, L. Hamilton, J. Hancock, B. S. Ellis, and G. Lapman, *Phase I Accreditation Support Package for the Enhanced Surface to Air Missile Simulation (ESAMS) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-009) February 1995. Provides a standard set of data that characterizes the general acceptability of ESAMS. The information included in this report is: configuration management data, summary of assumptions, limitations, and known errors, summary of V&V and usage history, an assessment of documentation quality, and an assessment of software quality.

17. Muessig, P. R., S. Ellis, D. Landis, and G. Lapman, *Phase I Accreditation Support Package for the Advanced Low Altitude Radar Model (ALARM) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-006) May 1995. Provides a standard set of data that characterizes the general acceptability of ALARM. The information included in this report is: configuration management data, summary of assumptions, limitations, and known errors, summary of V&V and usage history, an assessment of documentation quality, and an assessment of software quality.

18. Muessig, P. R., S. Ellis, T. Krenz, G. Lapman, B. O'Neal, and V. Ross, *Phase I Accreditation Support Package for the Radar Directed Gun System Simulation (RADGUNS) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-012) May 1995. Provides a standard set of data that characterizes the general acceptability of RADGUNS. The information included in this report is: configuration management data, summary of assumptions, limitations, and known errors, summary of V&V and usage history, an assessment of documentation quality, and an assessment of software quality.

19. Muessig, P. R., T. Krenz, T. McCormick, B. O'Neal, and V. Ross, *Phase III Accreditation Support Package for the Radar Directed Gun System Simulation (RADGUNS) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-014) June 1995. Details the results of detailed verification and validation efforts on RADGUNS.

20. Muessig, P. R., T. Krenz, T. McCormick, B. O'Neal, and V. Ross, *Phase II Accreditation Support Package for the Radar Directed Gun System Simulation (RADGUNS) (U)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-013) January 1995. Provides software design detail and sensitivity analysis results for RADGUNS. This information is designed to support logical verification and face validation of the model.

21. Muessig, P. R., H. Cronkhite, M. McAnally, T. Overcash, T. Morris, and J. Hancock, *Phase I Accreditation Support Package for EADSIM Model Status Report*, draft. January 1997. Provides a standard set of data that characterizes the general acceptability of EADSIM. The information included in this report is: configuration management data, summary of assumptions, limitations, and known errors, summary of V&V and usage history, an assessment of documentation quality, and an assessment of software quality.

22. Muessig, P. R., H. Cronkhite, M. McAnally, G. Born and B. O'Neal, *Phase II Accreditation Support Package for EADSIM Functional Characterization Report*, draft. January 1997. Provides software design detail and sensitivity analysis results for EADSIM. This information is designed to support logical verification and face validation of the model.

23. O'Neal, B., and A. Cook. *A Software Quality Assessment Process for DoD Models and Simulations*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-016) October 1995. Describes a process for analyzing the structure and content of modelM&S software to assess whether good software engineering practices were used which, in turn, provides an indication of the likelihood that errors are present.

24. O'Neal, Barry W. *T&E Assets Database Assessment for the SMART Project*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-92-SM-010) December 1991. Describes the capabilities and features of database products that could support test planning and data collection efforts for model validation. Identified the Test and Evaluation Long Range Investment Plan (TELRIP) database and the DoD T&E Assets database as likely sources of information. Also noted that the Air Force Systems Command Program Manager's Guide and Directory to Test Centers of Expertise appeared to contain useful information for planning data collection efforts in support of modelM&S validation.

25. Pace, D. K. "Affordable and Effective Verification, Validation, and Accreditation of Computer Simulations" *The Proceedings of the 1995 Summer Computer Simulation Conference* Ed. Oren, T. I. and L. G., Birta. July 1995, 182-187. Explains the importance and rationale for performing VV&A on modelsM&S.

26. Ritchie, Adelia E. (Ed.) *Simulation Validation Workshop Proceedings (SIMVAL II)*. Military Operations Research Society, 2 April 1992. Includes articles that describe the individual disciplines within the overall VV&A umbrella.

27. Sanders, P., and R. Miller. "Model Verification, Validation, and Accreditation (VV&A) Common Ground Within the M&S Community." *PHALANX, The Bulletin of Military Operations Research,* September 1996: 1 & 30-32. Provides an overview of a Colloquium attended by non-DoD M&S experts; summarizes their views on VV&A.

28. Simecka, Karl. *The Adequacy of Field Test Data to Support Model Validation*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-92-SM-018) July 1992. Summarizes the results of a comparison between range capabilities and validation data requirements to answer a basic question as to whether field test data was sufficiently accurate for validation purposes.

29. SMART Project Office, *An Accreditation Support Framework for DoD Models and Simulations*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-004) January 1995. Describes an incremental model accreditation support process developed under the auspices of the Susceptibility Model Assessment with Range Test (SMART) Project. The process entails a determination of the minimum essential V&V tasks to support specific accreditation requirements, executing that V&V using a disciplined approach, and using the V&V results to logically support an accreditation decision.

30. SMART Project Office, *Document Description for SMART Accreditation Support Packages*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-003) January 1995. Describes the format and content requirements for recording V&V results in the Accreditation Support Package (ASP) format. ASPs are designed to facilitate the location and use of V&V data to support accreditation analyses.

31. SMART Project Office, *Susceptibility Model Assessment and Range Test (SMART)*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-92-M-009) June 1992. Describes the fundamental concepts and planned activities of the SMART Project.

32. SMART Project Office, *Minimizing the Cost of Simulation Credibility*, Unpublished workshop notes, November 1996. Describes the fundamental accreditation concepts developed under the SMART project and how these concepts are applicable to the models used by AEDC. Also outlines how a local VV&A infrastructure could be established to support command-wide use of these concepts.

33. SMART Project Office, *How to VV&A Without Really Trying; SMART VV&A Lessons Learned*. Describes supplementary information and suggestions regarding implementation of the SMART VV&A methodology. JTCG/AS-M-009 June 1997

34. SMART Project Office, *The Road to Credibility,* The Final Report of the Suceptability Model Assessment and Range Test Project. Reports on the accomplishments and results of the SMART Project over the period 1992 through 1996. JTCG/AS-M-010 June 1997

35. SURVIAC, *Configuration Management Requirements Study*, JTCG/AS (AIR 4.1.8), Naval Air Systems Command, Washington, D. C. (JTCG/AS-95-M-005) May 1995. Proposes a set of generic configuration management requirements that are necessary to maintain the verification and validation status of models.

36. Dept. of Defense Directive 5000.59. *DoD Modeling and Simulation (M&S) Management.* 4 January 1994. Establishes policies and assigns responsibilities for management of M&S throughout DoD.

37. Dept. of Defense Instruction 5000.61. *DoD Modeling and Simulation (M&S) Verification, Validation, and Accreditation (VV&A).* 29 April 1996. Implements policy, prescribes procedures, and assigns responsibilities for VV&A of DoD models.

38. Dept. of Defense, *Department of Defense Dictionary of Military and Associated Terms*, (Joint Publication 1-02), 23 March 1994. Provides definitions of terms that are commonly used throughout the DoD.

39. Dept. of Defense, Air Force Instruction 16-1001. *Verification, Validation, and Accreditation (VV&A).* 1 June 1996. Implements Air Force Policy Directive 16-10; provides Air Force VV&A procedural guidance.

40. Dept. of Defense, Air Force Policy Directive 16-10. *Modeling and Simulation (M&S) Management.* 30 January 1995. Establishes Air Force policy governing M&S; assigns responsibilities for various M&S management functions; establishes a requirement for an Air Force M&S Master Plan.

41. Dept. of Defense, Army Regulation 5-11. *Army Model and Simulation Management Program.* 10 June 1992. Establishes the Army M&S Management Program and the Army M&S Executive Council; Provides policies on model VV&A, configuration management, data management, and release of Army models.

42. 6Dept. of Defense, Joint Staff Instruction 8104.01. *Verification, Validation, and Accreditation of Joint Models and Simulations.* 12 January 1995. Provides guidelines for implementing DoD policies within the Joint Staff.

43. Dept. of Defense, SECNAV Instruction 5200.38. *Department of the Navy Modeling and Simulation Program.* (Draft). Establishes the Navy modeling and simulation program, assigns responsibilities, and establishes the Navy Modeling and Simulation Office.

44. Dept. of Defense, SECNAV Instruction 5200.XX. *Verification, Validation, and Accreditation (VV&A) of Models and Simulations (M&S).* Draft 25 October 1996. Establishes policies and procedures for model VV&A within the Dept. of the Navy.

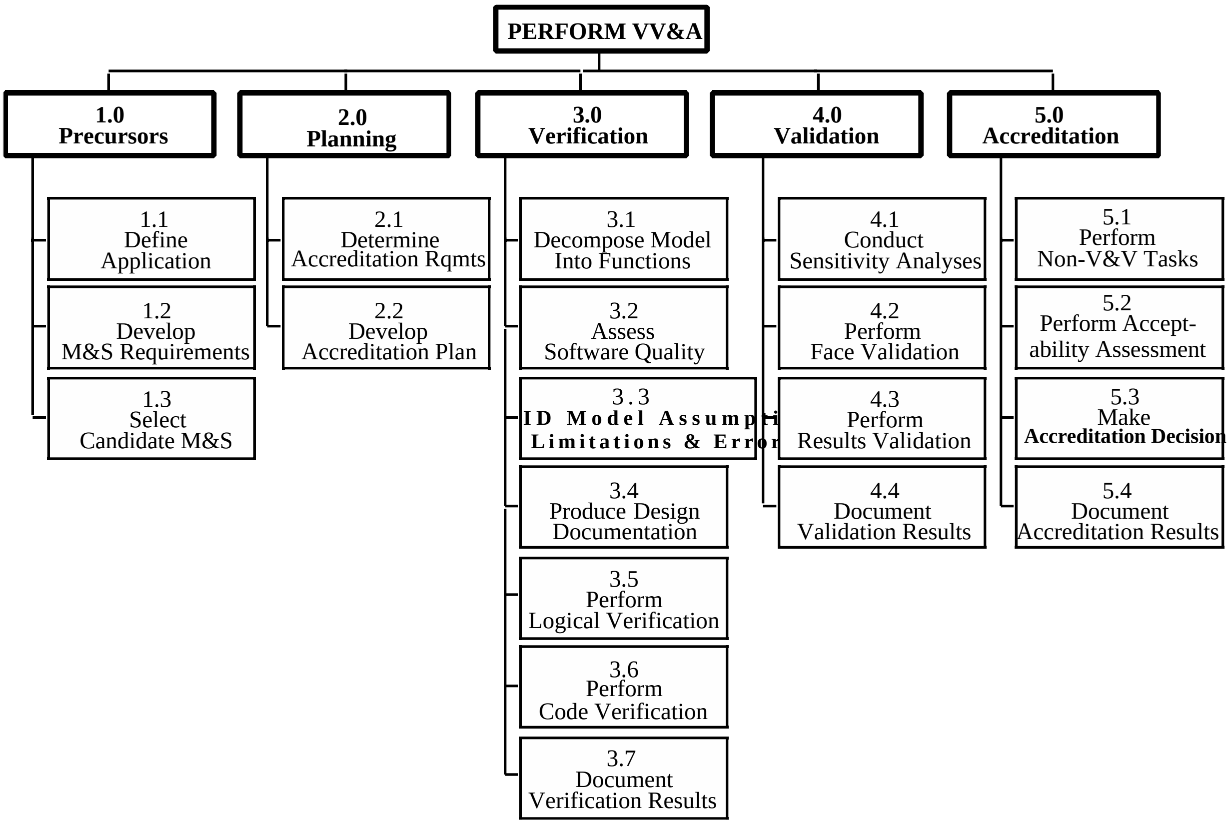
45. Dept. of Defense. *DMSO VV&A Recommended Practices Guide '96.* Draft November 1996. Contains descriptive and procedural information to assist and guide VV&A practitioners in carrying out their duties.

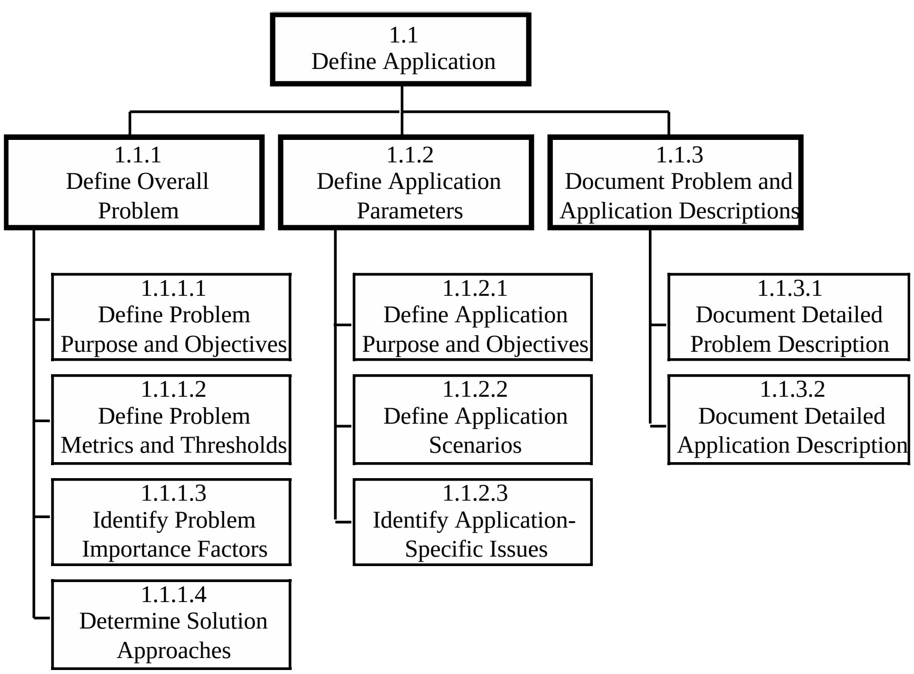
46. Dept. of Defense. *Modeling and Simulation (M&S) Master Plan.* October 1995. Identifies DoD wide goals regarding M&S management; defines an orderly approach to achieving each goal.

47. Dept. of the Army Pamphlet 5-11. *Verification, Validation, and Accreditation of Army Models and Simulations.* 15 October 1993. Provides procedural guidance for conducting and documenting VV&A programs on Army models.

48. Williams, M. L., and J. Sikora. “SIMVAL Minisymposium - A Report.” *PHALANX*, *The Bulletin of Military Operations Research*, June 1991: 1-6. This minisymposium report provides consensus definitions of many common VV&A terms and techniques.

APPENDIX A
WORK BREAKDOWN STRUCTURE CHARTS FOR VV&A


PERFORM VV&A
1.0 Precursors
2.0 Planning
3.0 Verification
4.0 Validation
5.0 Accreditation
1.1 Define Application
1.2 Develop M&S Requirements
1.3 Select Candidate M&S
2.1 Determine Accreditation Rqmts
2.2 Develop Accreditation Plan
3.1 Decompose Model Into Functions
3.2 Assess Software Quality
3.3 ID Model Assumpti Limitations & Error
3.4 Produce Design Documentation
3.5 Perform Logical Verification
3.6 Perform Code Verification
3.7 Document Verification Results
4.1 Conduct Sensitivity Analyses
4.2 Perform Face Validation
4.3 Perform Results Validation
4.4 Document Validation Results
5.1 Perform Non-V&V Tasks
5.2 Perform Accept-ability Assessment
5.3 Make Accreditation Decision
5.4 Document Accreditation Results


1.1 Define Application
1.1.1 Define Overall Problem
1.1.2 Define Application Parameters
1.1.3 Document Problem and Application Descriptions
1.1.1.1 Define Problem Purpose and Objectives
1.1.1.2 Define Problem Metrics and Thresholds
1.1.1.3 Identify Problem Importance Factors
1.1.1.4 Determine Solution Approaches
1.1.2.1 Define Application Purpose and Objectives
1.1.2.2 Define Application Scenarios
1.1.2.3 Identify Application-Specific Issues
1.1.3.1 Document Detailed Problem Description
1.1.3.2 Document Detailed Application Description

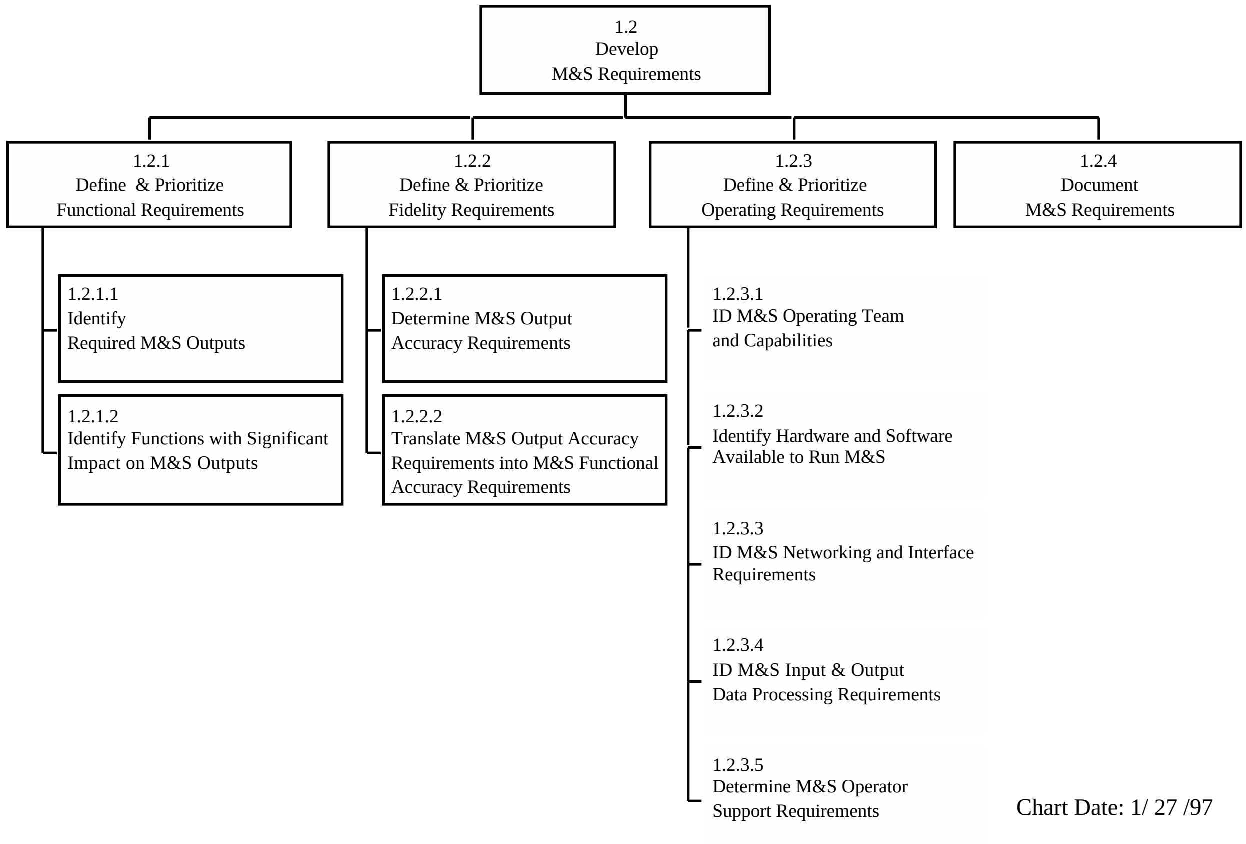
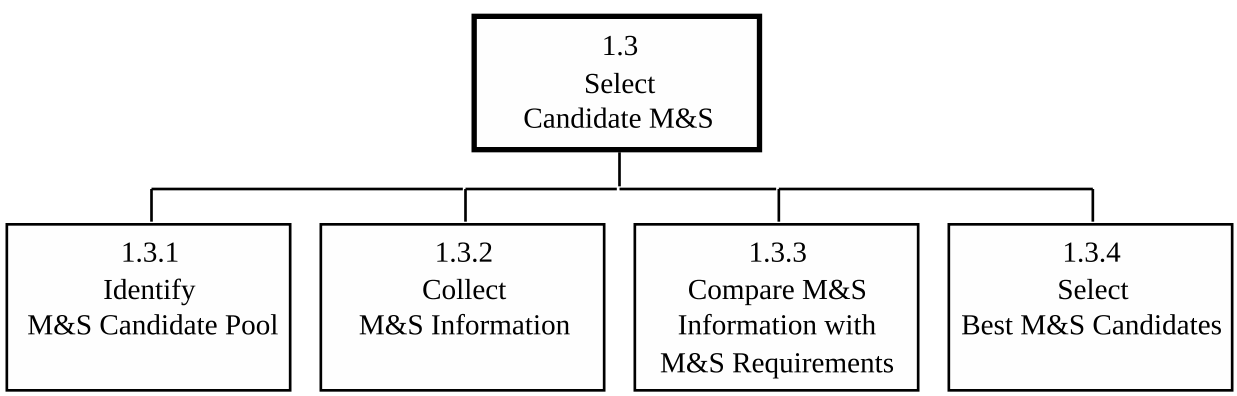


Chart Date: 1/ 27 /97



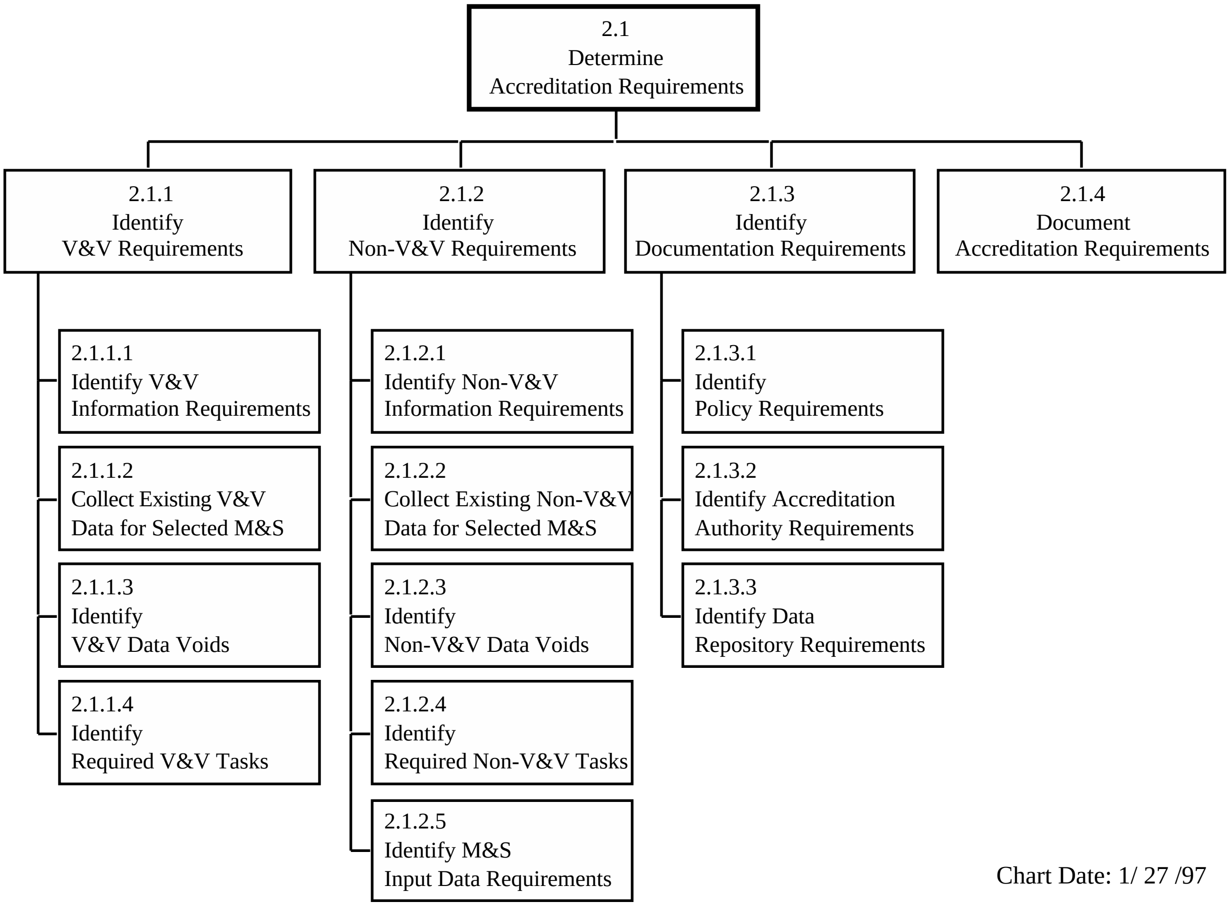
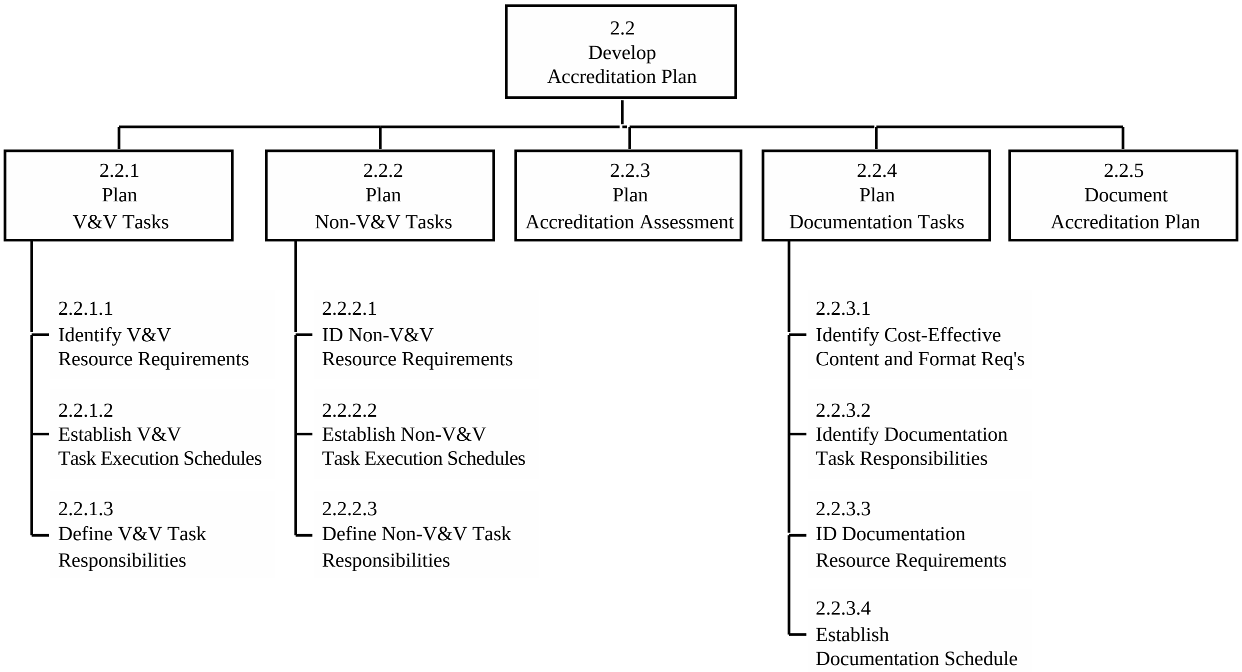
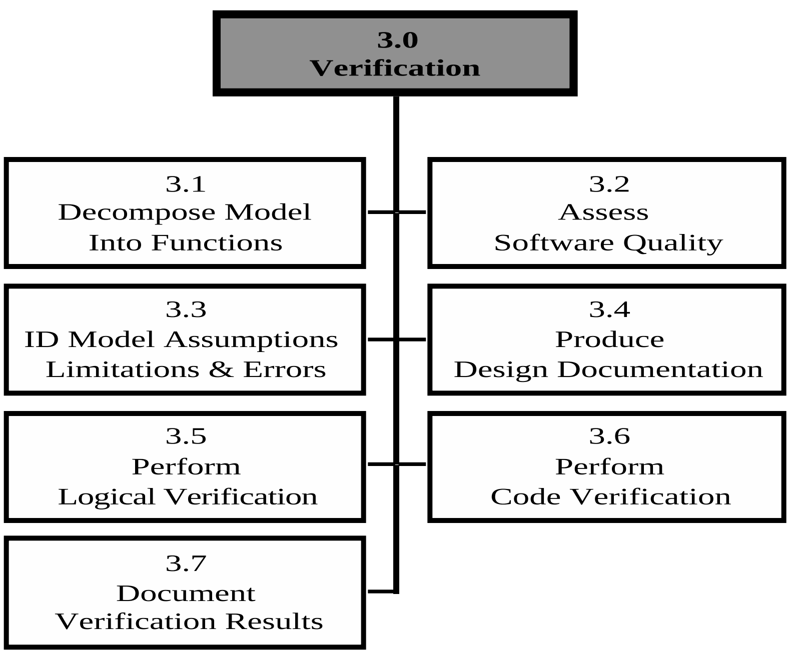
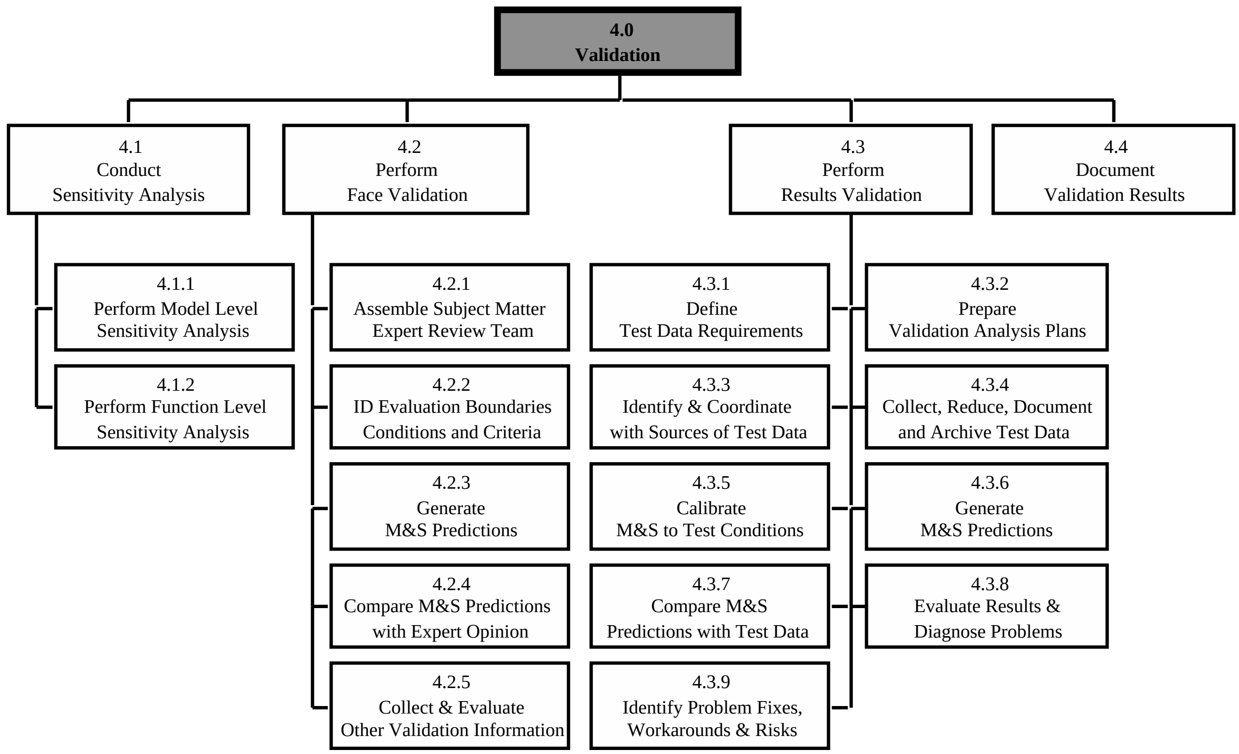


Chart Date: 1/ 27 /97


2.2
Develop
Accreditation Plan
2.2.1
Plan
V&V Tasks
2.2.2
Plan
Non-V&V Tasks
2.2.3
Plan
Accreditation Assessment
2.2.4
Plan
Documentation Tasks
2.2.5
Document
Accreditation Plan
2.2.1.1
Identify V&V
Resource Requirements
2.2.1.2
Establish V&V
Task Execution Schedules
2.2.1.3
Define V&V Task
Responsibilities
2.2.2.1
ID Non-V&V
Resource Requirements
2.2.2.2
Establish Non-V&V
Task Execution Schedules
2.2.2.3
Define Non-V&V Task
Responsibilities
2.2.3.1
Identify Cost-Effective
Content and Format Req's
2.2.3.2
Identify Documentation
Task Responsibilities
2.2.3.3
ID Documentation
Resource Requirements
2.2.3.4
Establish
Documentation Schedule


3.0
Verification
3.1
Decompose Model
Into Functions
3.2
Assess
Software Quality
3.3
ID Model Assumptions
Limitations & Errors
3.4
Produce
Design Documentation
3.5
Perform
Logical Verification
3.6
Perform
Code Verification
3.7
Document
Verification Results



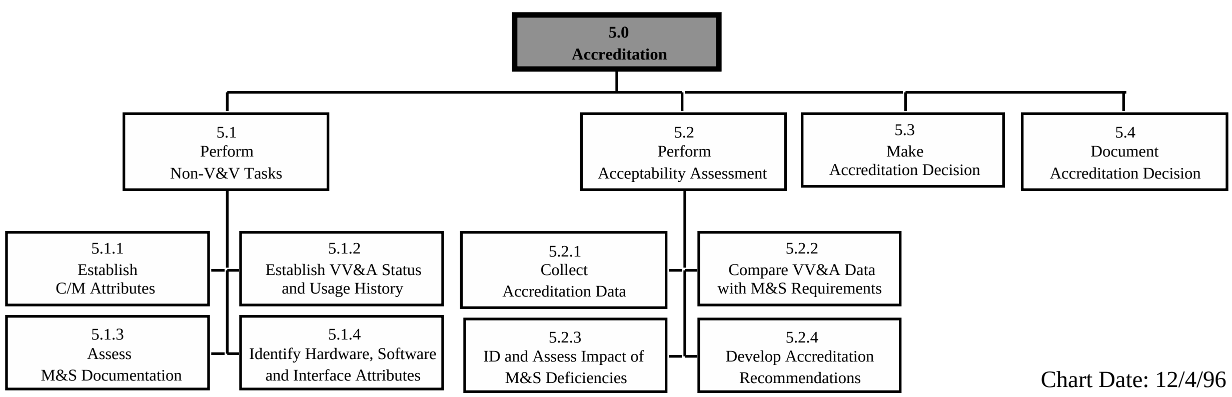


Chart Date: 12/4/96

APPENDIX B-1
ACCREDITATION PLAN DATA ITEM DESCRIPTION

TITLE

Accreditation Plan for Models or Simulations

IDENTIFICATION NUMBER

DESCRIPTION/PURPOSE

The Accreditation Plan documents the requirements or acceptance criteria for a model or simulation that will be used in a particular application (analytical study, training system, operations planning system, etc.). It identifies what verification or validation steps will be done to determine if a model meets these requirements, and sets out the plan of action, costs, and milestones for accomplishment of these steps.

APPROVAL DATE

OFFICE OF PRIMARY RESPONSIBILITY

DTIC APPLICABLE

GIDEP APPLICABLE

APPLICATION/INTERRELATIONSHIP

This Data Item Description provides content and format preparation instructions for an Accreditation Plan that specifies how a model user intends to ensure that a model or simulation is suitable for use under a well defined set of circumstances. This DID is applicable to users of models who meet the criteria specified in individual DoD component instructions governing M&S VV&A.

APPROVAL LIMITATION

APPLICABLE FORMS

AMSC NUMBER

PREPARATION INSTRUCTIONS

Format

Any Accreditation Plan developed in accordance with this DID shall be submitted in both hard copy and electronic media. Electronic copies shall be either PC or Macintosh compatible and be translatable into one of the following word processing applications: MicroSoft Word, Word Perfect, (others as applicable).

Content

The Accreditation Plan shall contain the following information organized in the manner shown.

Title Page

A sample title page showing both the information and format is provided in attachment 1 to this DID.

Table of Contents

The Table of Contents shall identify all sections and subsections (to the second level) along with page numbers. It shall also identify all tables and figures with their respective page numbers. Any attachments or appendices shall also be listed.

Executive Summary

The executive summary shall contain a one paragraph summary of the acceptance criteria that have been derived from the intended application. It shall also contain a paragraph summarizing the results of any previous V&V and how that information compares with the acceptance criteria. Any unsatisfied criteria will be identified. Another paragraph will identify any supplemental V&V which will be done to satisfy these criteria and will identify the cost, schedule, and performance responsibilities for carrying out that additional V&V.

Section 1: Introduction

The introduction to the Accreditation Plan shall describe, in general terms, the application in which the model or simulation is to be used. It should also explain why such use is necessary or desirable and what decisions or outcomes are intended from this application. Identify the types of models or simulations that are needed and the general functions or types of predictions that are expected from these models or simulations. Identify which model or models are to be addressed in this plan and which functions or types of predictions will be generated by them.

Section 2: Derivation of Acceptance Criteria

Analysis of the Application: A brief description of the analysis used to develop the acceptance criteria should be presented. The following specific steps should be described:

- Definition of the decisions to be made or the outcomes of the application

- Identification of all the factors and environmental phenomena that could have an impact on the outputs of the model and on the overall decisions to be reached.

- Definition of measures of effectiveness (MOE) or measures of performance (MOP) that are critical to the final decisions. These MOEs/MOPs are the parameters that are quantified and used to make the decision that is the purpose of the application.

- Identification of model outputs that affect the MOEs/MOPs. Also the degree of impact of each model output on the MOE/MOP should be described.

- Determination of the amount of error that is tolerable in the MOEs or MOPs.

Acceptance Criteria Development: A summary of the steps used to develop acceptance criteria from the application analysis described in the previous paragraph should be presented. The product of this development process should be a list of acceptance criteria. These criteria should be listed in three categories: fidelity criteria, model features and capabilities, and operating requirements.

Fidelity: These criteria are developed by allocating the tolerable error in the MOEs or MOPs to the model outputs. This error constraint can be further allocated to functional elements that have the greatest impact on model outputs used in the application. If allocated to this functional level, these fidelity criteria should also be listed.

Functional: Functional requirements are derived from the factors and environmental phenomena that impact the model outputs. A list of those factors and environmental phenomena that have a major impact on model outputs are to be listed in this section. Determination of which ones have a major impact is done considering the tolerable errors at both the model and functional level.

Operating: Operating requirements for the model or simulation are derived from an analysis of the user's computer equipment, software used to process model inputs or outputs, and the experience level of the analysts using the model. This section should contain a list of hardware that might be used to run the model or simulation, any software that will be used to preprocess input data or reduce output data, and any documentation, model training, or support that is considered necessary to correctly use the model and interpret its results.

Section 3 - Model Description

A brief (one to two paragraph) description of the model, its algorithms, and basic principles should be provided. The development history of the model should be provided in another paragraph.

Intended Applications: The purpose(s) for which the model was developed should be given in this section. Any explanatory material that is necessary to understand the nuances or limitations on intended usage should also be provided. Any additional uses that have been demonstrated through past usage should also be summarized.

Model V&V Status: A summary of previous V&V work should be presented. This summary should present the results of past work in the following categories:

Documentation Assessment	Software Quality Assessment
Configuration Management Program	Assumption/Limitation Derivation
Sensitivity Analysis	Face Validation
Input Data V&V	Output Data Validation
Logical Verification	Detailed Verification (Code Check)
Detailed Validation (Data Comparison)	Benchmark Results

If the model V&V results are summarized in the Accreditation Support Database, the database report should be used as this summary.

Assumptions and Limitations: Provide a list of known assumptions and limitations for the model or simulation. This list should include assumptions and limitations identified by the model developer as well as any that might have been identified through past V&V activities.

Section 4: Identification of Supplemental V&V Requirements

The purpose of this section is to present the rationale and basis for performing any additional V&V work. This rationale is based on the principle that known information about the model, its capabilities and fidelity, is compared to the acceptance criteria for the application. Any criteria that are not addressed or satisfied with existing information must be satisfied through additional V&V. An introductory paragraph explaining this rationale and how it applies to the particular application should be presented.

Comparison of Model to Acceptance Criteria: A specific listing of acceptance criteria and known model information should be presented in this section. For any criteria that are not satisfied, the following notation should be made “Requires additional V&V”.

Section 5: V&V Plans

V&V Tasks: Each of the V&V requirements, identified in the previous paragraph, should be explained in this section. The scope of effort to accomplish the required task should be described. A description of how the task will be accomplished should be presented. If any supplemental tasks (such as test data collection) are needed, they should be explained.

Responsibilities and Task Assignments: Identify the personnel and/or agencies that are intended to perform each V&V task shown in the previous paragraph. Provide an explanation of why each was selected.

Resource Requirements: The resources needed by each organization to perform the identified V&V task should be identified. A brief synopsis explaining why the resource is needed should be included. Resources that are to be addressed include: funds, personnel in addition to those presently available, equipment, information, and cooperation or coordination with other agencies.

Schedule: The schedule for accomplishing the above tasks should be presented in this section. Typical Gantt charts should be used whenever feasible.

V&V Risks: Any risks related to accomplishing the intended V&V should be presented. The probability of the risk occurring, any circumstances that affect it, the contingency plans, and mitigation plans should be discussed.

Section 6: Accreditation Process

This section of the Accreditation Plan presents the plans and techniques for comparing all V&V results to acceptance criteria. It should explain the process that is to be followed to fully justify the use of a model for a particular application. The form of the expected results should be identified. If certain results are anticipated the expectations should be discussed.

Risks and Contingency Plans: Any risks related to model accreditation based on the planned V&V activities and results should be identified. The factors that might increase or mitigate each risk should be identified. Any mitigation or contingency plans for dealing with each risk should be discussed. If a risk materializes, the overall effect on model credibility and on application results should be discussed.

Section 7: Accreditation Process Deliverable(s)

The documentation that will be produced as a result of the accreditation process should be identified. For each document the following topics should be addressed.

Report outline: The outline of the intended report should be presented. Wherever possible the outline should conform to the appropriate Data Item Description. For accreditation reports, the outline should contain a one page accreditation signature page showing the review and approval chain that will be used to accredit a model or simulation.

Report content description: The level of detail that is to be reported in any documentation should be clearly defined in this paragraph. The major topics of the report, as specified in the outline, should be explained separately. If an existing Data Item Description or other type of specification already exists for the intended report, a statement that the report will be prepared in accordance with that specification or DID is sufficient.

APPENDIX B-2
ACCREDITATION SUPPORT PACKAGE SPECIFICATIONS

INTRODUCTION

The purpose of this appendix is to summarize the purpose and content of model and simulation Accreditation Support Packages (ASPs). ASPs integrate the key elements of M&S credibility (verification, validation and configuration management, or VV&CM) into standard products that directly support accreditation decisions.

The information elements and VV&CM tasks summarized in the ASP format were derived from an Accreditation Requirements Study [B-2, B-3], the aim of which was to identify key accreditation information requirements across the services, correlate them into an integrated list and assess how verification and validation (V&V) products could be tailored to meet them. The structuring of accreditation support information into phases of activity derived from a natural grouping of these key information elements into three categories: model overview, functional characterization for expert review, and detailed V&V. The technical elements of the VV&CM process combine to generate products that support accreditation of M&S at various levels of detail. These levels are characterized by how much information about the M&S is available at the end of each phase. The three phases of accreditation support activity are both incremental and interdependent, viz., Phase II accreditation support products build on those produced in Phase I, and so forth.

Phase I accreditation support activity is geared toward determining the status of a simulation. Typical questions addressed are: How is the simulation managed and supported? What has it been used for, by whom, and was it accredited for that use? What is its V&V history? How well is it documented? What is the quality of the software? What are the simulation's known assumptions, limitations and errors? The end result of Phase I efforts should provide evidence as to how well the simulation is managed and whether it has produced adequate results across a spectrum of users with similar applications (from which accreditation efforts may be leveraged). Furthermore, assessments of documentation and software quality provide the potential user with information that can be used to assess risk of successful completion of further V&V tasking.

Phase II accreditation support activities are aimed at characterization of functionality and a determination of simulation "reasonableness" based on a review by subject matter experts (SMEs). Input data verification and validation, comparison of simulation outputs with intelligence data or best estimates, and a review of sensitivity analysis results are combined with a top level review of assumptions, limitations and errors to produce an assessment of adequacy in each functional area of the model. Although fraught with the pitfalls inherent in subjectivity, the Phase II expert review, in conjunction with Phase I model status reports, provides the best possible assessment of macro-level simulation results short of detailed V&V (Phase III).

Phase III accreditation support activity is "classical" V&V: a detailed verification of the code, including desk checking, software testing and comparison to design specifications, coupled with extensive comparisons of simulation predictions with all available sources of test data. Because of its cost, Phase III accreditation support activities are not usually performed on an entire simulation. Rather, they are tailored to specific applications, and only those functions required to ascertain credibility for those applications are subjected to detailed V&V.

Taken as whole, this accreditation support process provides an incremental approach to assessing M&S credibility that can be tailored to the needs of individual applications. Moreover, information developed in support of one application benefits future users of the same simulation, who can build upon prior V&V information to tailor an accreditation plan focused on their specific requirements. This is most clear in Phases I and II, where the information developed is model specific vice application-specific. But even Phase III accreditation support activity benefits from prior V&V by other users with different applications because, over time, the entire simulation becomes characterized. In this way, V&V becomes "market driven," and no one sponsor has to pay for the V&V or accreditation of an entire model. This is made possible by the development of standard V&V products, the ASP documents.

ASP-I (MODEL STATUS REPORT)

The following material summarizes the general format and content of ASP-I:

Executive Summary

Provides introductory material sufficient for the understanding of Phase I accreditation support on model selection and use. The Phase I Accreditation Support Package (ASP-I) is designed to provide a potential user with a characterization of the current state of the subject model with respect to criteria related to its general acceptability for use. The information collected in this phase should characterize the model well enough to provide an initial determination of its suitability for a particular application. It should also provide confidence that the model is well enough managed and supported to yield consistent results across its spectrum of users and applications. Results of assessment efforts are summarized, preserving the relevant detail of the constituent sections without sacrificing brevity.

1.0 Phase I Accreditation Support Package Description

Provides explanatory material describing how ASP-I is organized, and what the reader will find in each section. This section also describes the purpose and results of Phase I accreditation support activities in greater detail.

2.0 Configuration Management Baseline

Provides introductory material that describes the importance of CM for the model and summarizes the status of existing and/or planned procedures for its management. User interest in approaches to CM and workable procedures for effecting required changes in the model are addressed via a brief description of how the model is managed and maintained for its user community. The configuration management (CM) baseline description for the simulation provides prospective users with an indication of how well the it is controlled and supported. The CM baseline for a simulation consists of the following:

2.1 Simulation Description. Provides a brief description of the simulation and its intended purpose. Indicates the authors, owners, and other particulars related to a general description of simulation attributes. Also provides information on the hosting platforms, the operating systems, software and other operating requirements.

2.2 Development History. Summarizes the development history of the simulation, beginning with its origins and tracing its development and sponsorship throughout the years of its existence, including a full description of release changes. Describes what enhancements, features and capabilities were added to the simulation between such changes, as well as a technical description of major changes in modeling capability and approach.

2.3 Version Description and Current Status. Identifies all configurable items for the simulation, including code and documentation (including V&V documentation). This information consists of the configuration identification number, the item description (or a title if the item is a document), the document number, the date of its publication, its security classification, and any remarks or pertinent comments.

2.4 Change Procedures. Describes how changes to the baseline version of the software are implemented, with a flow chart identifying all organizational participants in the CM process. Describes their duties, including the relationships among the organizations involved, the responsibilities and authorities of all participating groups, and the makeup of the configuration control board (CCB), if one exists, and how CM policies are generated and enforced.

2.5 User Support Functions. Describes any user support functions in place or planned for the simulation. Items such as on-line bulletin boards, training classes, newsletters, phone-in technical assistance, software pre- and post-processors, etc. are examples.

2.6 Assessment and Implications for Use Identifies and prioritizes any deficiencies in the CM process that should be considered prior to use of the simulation.

3.0 Summary of Assumptions, Limitations, and Errors

This section of ASP-I helps the user determine, at an early stage, whether or not a simulation's assumptions, limitations and errors place it outside the realm of applicability to the problem at hand. Coupled with the it's usage history, the summary of assumptions, limitations and errors can be a valuable simulation selection tool.

3.1 Assumptions. Provides a description and discussion of the assumptions upon which the simulation was developed, as well as those pertaining to user inputs and simulation outputs.

3.2 Limitations. Describes and discusses limitations (software and/or documentation) identified during any V&V efforts that might restrict the simulation's usefulness for certain applications. Describes and discusses the limitations that pertain to user inputs and simulation outputs.

3.3 Errors and Anomalies. This section presents a description and discussion of errors and anomalies for the software and/or documentation, as well as information on their sources. Typical sources might include documented SME reviews, V&V reports, model documentation, user group meeting briefings, etc. Particular attention is paid to errors that might restrict model applicability or usage, especially if they are documented incorrectly (e.g., analyst manual says X but Y is in the code). If SME review findings result in major caveats to model application, these are documented here as well.

3.4 Implications for Use. Summarizes the impact of known assumptions, limitations and errors on simulation use. Specifies boundaries beyond which credible use of the simulation is not supported on the basis of these assumptions, limitations and errors; for example, what applications are specifically excluded as a result of its assumptions, limitations, errors.

4.0 V&V Status and Usage History

This portion of ASP-I summarizes applications the model has been used to support, and the extent to which those applications have been supported by V&V documentation.

4.1 V&V Status. This section summarizes any documentation that may be available to support a picture of the V&V status of the model, including studies or programs for which verification and/or validation efforts were conducted, their sponsors, and points of contact, the type of V&V performed, date of publication, etc.

4.2 Usage History. Summarizes the history of prior uses of the model based on inputs from user surveys, model managers, model developers, government agencies, and any other pertinent sources of such information. Includes a description of each application and any notes or comments on the suitability of the model for that application, and whether the model was formally accredited for that use and the accreditation report titles, if they exist.

4.3 Implications for Use. Summarizes the usage history and V&V status of the model in terms of possible valid applications. Provides information that should be useful to a prospective model user who knows nothing about the model: What factors would you look for in the model's usage history that would give you confidence that the model could reasonably be used in a similar application? What criteria for model credibility would be satisfied by documented V&V efforts? What about the maturity of the user group, the diversity of applications for which the model has been used, professional opinion, etc.? What factors in the usage history and V&V status lead to these conclusions?

5.0 Documentation Assessment

This section reviews the current status of a model's documentation with respect to standards developed for the verification of mature M&S. The standards were developed by reviewing MIL-STD, DoD-STD, JTCG/AS and service specific policies, procedures and guidelines relating to M&S development, and tailoring these standards for mature M&S. The results are set forth in [B-4, B-5], which specify the number, format and content of a minimum documentation set acceptable for rational use of model results, and efficient conduct of verification and validation.

5.1 Completeness. Summarizes and references the standards set forth in [B-4, B-5] for completeness of a documentation set. Describes the available documentation set for the model and highlights differences between recommended and available documentation sets.

5.2 Compliance. Summarizes and references the standards described in [B-4,B-5] for documentation format and content. Describes the correlation between the recommended format and content standards for each document and the actual format and content of each available piece of model documentation. In addition, discusses the information content of the complete documentation set relative to the total information content recommended by the standards.

5.3 Recommended Modifications. Describes in detail any modifications needed to bring model documentation in line with recommended standards, considering the needs of the model's user community and the scope of model use.

5.4 Implications for V&V. Summarizes the implications of the current state of model documentation on verification and validation efforts that may be planned for this model. Implications for configuration management should also be discussed, especially if major modifications to documentation are recommended.

5.5 Implications for Use. Summarizes the implications for model use of any differences between the recommended and the actual format and content of the model documentation set. This section requires some analysis and insight, and may reflect the subjective judgment of the analyst. This section should give the prospective model user a clear understanding of the potential impact that the current state of model documentation has on the credibility and understanding of the model's results.

6.0 Software Quality Assessment

This section gives the prospective model user an indication of the conformance of model code to accepted software development and documentation practice. The structure of the source code of a given model is analyzed from a software engineering perspective in three major areas: use of programming standards; computational efficiency; and memory utilization. Assessments of software quality are usually compiled by an independent evaluator, who may not seek inputs or consultation from developers or users of the models in order to maintain as much objectivity as possible. They may also be accomplished without actual execution of the program software, which will preclude assessments of run-time factors and I/O requirements. In any case, the choice and relative weights of quality factors, as well as the scores assigned to them, will result in a subjective assessment that is shaped by the experience and opinions of the evaluator.

6.1 Programming Conventions. Describes any conventions (especially ANSI or other programming standards) used during the development of the software and how well the software adhered to those standards and/or conventions. This includes an evaluation of the following elements: use of embedded comments, use of module preambles, source code formatting, logical file processing, variable declarations, and programming logic.

6.2 Computational Efficiency. Provides a description of the code elements that affect efficient implementation and/or execution of the software. This may be a point of minor interest depending upon the user and the intended target system for the model, but machine dependent aspects of the implementation can significantly affect its use. The following factors examine the efficiency aspect of the actual coding: modularity, algorithm development, and variable allocation.

6.3 Resource Utilization. Efficient use of memory by the software has become less important than other quality factors due to its declining cost and increasing availability, but this ahs been offset by the need for M&S to access and use new devices. Memory use, however, can be a critical factor for some real-time applications that may also be restricted to a particular type of processor and its associated operating system. Memory management procedures employed in coding should also be documented here, especially if portability or readability of the code has been affected. Equally important can be the degree to which the software makes use of external storage, display, and/or user input devices, which will be substantial requirements for hardware or man-in-the-loop (HWIL/MIL) applications.

6.4 Implications for Use. Summarizes the impact of any deficiencies in the software quality, as defined by the above criteria, on model use. Identifies those conditions that will impede proper functioning of the simulation, maintenance and use of the model, interpretation of results, debugging efforts, et cetera.

ASP-II (FUNCTIONAL CHARACTERIZATION)

The following material summarizes the general format and content ASP-II:

Executive Summary

The purpose of Phase II accreditation support documentation is to provide the prospective model user with confidence that the model inputs and outputs are reasonably valid representations of real world conditions and outcomes. This confidence is typically achieved via reviews by subject matter experts (SMEs) familiar with the real world phenomena simulated by the model. The end product of this review is the identification of that set of problems for which the model is expected to produce reasonable results (the application domain). The conclusion of this section describes the level of confidence in the model that could be derived from the software design information and sensitivity analysis conclusions contained in the ASP-II document.

1.0 Phase II Accreditation Support Package Description

The Phase II accreditation support document contributes to face validation activities by providing software design information and the results of sensitivity analyses that address model functionality. Assumptions and limitations inherent in the model design can be found in the Conceptual Model Specification in Section 2.0, and errors found as a result of exercising the functional elements of the model over ranges of input conditions are reported in the Sensitivity Analysis results of Section 3.0 Other V&V activities that contribute to an SME review in support of Phase II accreditation are input data verification and validation, comparison of model outputs with intelligence data or best estimates, and review of model assumptions, limitations and errors.

2.0 Conceptual Model Specification

This section of ASP-II provides top level and detailed software design information that can be used to develop a list of inherent assumptions and limitations in the model. This design information is usually contained in the SDD for models under development, or in the CMS for mature models.

Top Level Software Design. Describes the top level software design of the model, including a description of major model components and their inherent assumptions and limitations. Describes the logic flow through the major components, including a logic flow diagram. It continues with a description of data flow through the major components. A descriptive overview of the source code hierarchy, a wiring diagram, and descriptions of major component subroutines (modules) are provided. This section concludes with any high level implementation requirements, such as programming language, hardware, and operating system compatibility requirements.

Implications for Use. This section provides an interpretation and summary of the design assumptions and limitations that result in a definition of the domain of reasonable model use. The intended ranges of target types, altitudes, speeds, environments, radar types, frequencies, etc. should be included in this summary. A set of recommendations to remedy any shortcomings or complications due to a given assumption, approximation, or error also should be part of this description.

Detailed Software Design (By Functional Element). This part of the document, n separate sections, describes the detailed design of each functional element (FE) within the model. It includes a description of the Functional Area Template (FAT), which is the top-level decomposition diagram of the model and its functions. Included for each FE are: a functional area description (FED); the FE design requirements; a description of the FE design approach at a detailed level, including relevant calculations and algorithms; a description of the software design of the FE, including a subroutine call tree for FEs comprised of multiple subroutines; a table of module names and brief descriptions of each; and a functional flow diagram of the FE using standard flowchart symbology. The detailed design descriptions for each FE conclude with a summary of essential assumptions and limitations either implicit or explicit in the design.

3.0 Sensitivity Analysis

A tabular summary of sensitivity analysis results at the FE and model levels is provided and briefly discussed in the introductory section.

Implications for Use. Summarizes limitations and constraints on model use that accrue from a review of sensitivity analysis results at both the function and model levels. Included are heretofore unknown assumptions or errors discovered as a result of sensitivity analysis. The impact of specific sensitivities that will have an affect on how the model might be used are discussed. Special attention should be paid to errors or anomalies in the model that were discovered during the sensitivity analysis process. From the results described in this section, the user should be able to identify areas of model sensitivity that could affect intended use of the model for a specific application.

For each functional element in the model, the following are provided:

3.1 (Functional Element Name) Description. Provides a description of the functional element (FED) being investigated from both a theoretical standpoint (i.e., what is this function, in general?) and a practical standpoint (i.e., how is this FE implemented in the model?; what simplifying assumptions are made to implement this FE in the model?). This should provide sufficient background information to give the reader an appreciation of the importance of this function within the larger context of model output.

3.1.1 Objectives and Procedures. Lists the specific objectives of the sensitivity analysis for this FE at both the FE and model levels, which FE level parameters or parameter sets were varied, and over what ranges. Describes what MOEs were used to assess the sensitivities at the FE level and the model level, baseline test cases, output modes, assumptions and any limitations to the scope of this portion of the analysis.

3.1.2 Results. Shows the function-level and model level impact of variations in FE input over the range tested, and provides an assessment of how function-level sensitivities would impact data collection objectives for this functional element. How do the model level sensitivities impact functional element validation priorities? Were any anomalies or model errors discovered during the analysis? Do the results indicate any heretofore unknown (or little known) limitations and constraints on model use?

3.1.3 Conclusions. Discusses the results of the previous detailed sections, and provides: (1) implications of sensitivity to data collection requirements for validation of this FE; (2) implications of sensitivity to model level results and the necessity of data collection for this FE; and (3) implications of specific FE sensitivity analysis results to model use and credibility.

3.2...3.n (Functional Element Name) Description. Continues this cycle of subsections for as many FEs as have been evaluated.

4.0 Data Verification

Data verification is defined as the use of techniques and procedures to ensure that data meet constraints defined by data standards and business rules derived from process and data modeling. In effect, that means an assessment of where the data came from, who has used the data before and for what purpose, how well are the data documented and supported? It's really a review of the sources of data and how consistently the data are defined, between collection, storage (data basing) and being used by the model. Data verification mostly concerns the input databases which feed the model for a specific application. Information on user data verification efforts for the model inputs are summarized in this section of ASP-II.

5.0 Data Validation

Data validation is defined as a documented review by subject area experts and comparison to known or best estimate values as appropriate. This is a function performed by either the model user or by agencies who have responsibility to certify the data, such as intelligence agencies who "validate" (their term) the parameters which represent foreign systems. Results of data validation efforts are summarized in this section of ASP-II.

6.0 Face Validation

Face validation is aimed at establishing the “reasonableness” of model outputs, given well defined input conditions. It is typically accomplished by a team of subject matter experts (SMEs) who have detailed knowledge of real world results of the phenomena being modeled. SMEs review input data sources for acceptability, define input scenarios based on required applications, and analyze model outputs to assess whether they appear realistic or representative of results that might occur in the real world under the same set of conditions. Face validation is not validation in the classical sense, but it does provide a more credible and detailed stamp of approval than the mere fact that a model is widely used. While expert opinion has sometimes been the validation mode of choice, its value is contingent upon the independence and level of expertise of the reviewers, and the scope of the review itself.

Face validation includes a review of results from four preceding activities:

(1) Input data verification;

(2) Input data validation, including comparison of model outputs with intelligence data or analyses, and/or known or best estimates of real world values for corresponding phenomena, and;

(3) Logical verification, or comparison of the conceptual model specification with the requirements of the current application; and

(4) Functional and/or model level sensitivity analyses.

ASP-II contributes to face validation by providing the results of detailed sensitivity analyses performed on the model and each of its functional elements, and by documenting the conceptual model specification. To complete face validation, it remains for the user to perform input data V&V, to compare model outputs with acceptable results (e.g., from intelligence sources or other models), to compare model functionality with application requirements, and to review all of these with respect to model acceptability criteria that are dependent upon the intended application. The results of such previous face validation efforts by users are summarized in this section of ASP-II.

ASP-III (DETAILED V&V RESULTS)

The following material summarizes the general format and content of ASP-III.

Executive Summary

The Phase III Accreditation Support Package (ASP-III) is intended to provide the model user with a high confidence statement of model credibility backed by detailed verification and validation assessments. The format of information in this package is tailored to identify clearly those areas where the model can be used to support analysis, testing, and acquisition decisions. The Phase III package includes an assessment of the accuracy of the code implementation as well as data that bear out how well this model reflects reality. This information is presented in two main components, a verification report and a validation report. Of interest to managers and users who need to make accreditation decisions will be general statements of model validity and applicability to specific types and ranges of applications.

1.0 Phase III Accreditation Support Package Description

Phase III accreditation support is comprised of two distinct activities: detailed code verification and validation at the functional element (FE) and overall model levels. Validation is accomplished through assessments based upon comparisons between FE and/or model predictions with real world data from a variety of sources (e.g., developmental, operational, laboratory, and/or bench testing, S&TI or FME reports, etc.

2.0 Verification Results

The purpose of code verification is to provide a detailed examination of the computer code. This is usually accomplished by looking at individual modules until the model or simulation has been examined in its entirety. The main objective of this task is to ensure that design requirements have been satisfied and that the algorithms and equations being used are properly implemented in the code. A second objective is to ensure that appropriate coding practices are being used and that the software can actually be executed as implemented. Code verification consists of four major elements:

(1) Correlating design requirements with cited references;

(2) Correlating code implementation with the design specifications;

(3) Code auditing for correctness of implementation; and

(4) Testing of all executable statements.

This section provides the prospective model user with a determination of how accurately the model's code implementation represents the conceptual description specified by the developer, as well as an assessment of how closely the model code follows the design specifications. It contains a summary of verification activities on this model up to the present time, a description of the verification methodology employed, a summary of verification findings, listings of deficiencies discovered during verification efforts, and an assessment of the impact of these findings on model use.

Implications for Use. This section addresses discrepancies, anomalies, and errors found during the code verification process that have an actual or potential impact upon the operation or credibility of the model under investigation. Any recommendations concerning model development and/or improvements required to bring it up to a specified level of capability or credibility should also be discussed here. The following sections are included for each verified FE:

2.1 Detailed Results for (Functional Element Name). This section contains the actual verification work performed. The functional element being examined will be called out, citing the major subroutines and algorithms that were verified in this portion of the code. A description of the results of tracing design elements into the code will be included, as well as the results of desk checking of software and any test cases run. Any coding errors or anomalies identified during verification should be presented here, along with suggested corrective action. These errors should also have been documented in model deficiency reports (MDRs) and submitted to the model manager and the configuration control board for action and approval.

2.1.1 Overview. This section includes a functional element overview and a verification overview. It provides a description of the functional element and how it represents its real world counterpart, identifying any assumptions or conditions that affect the functional element's performance. The verification overview should identify the subroutines and algorithms that were verified as part of the assessment. Descriptions of the constituent subroutines should also be included.

2.1.2 Verification Design Elements. A list and description of the design elements that were addressed for verification of the FE. These come from the CMS sections in ASP-II.

2.1.3 Desk Check Activities and Results. This consists of three main elements and makes up the bulk of code verification: (1) correlating the software design with cited references; (2) correlating the code with the design specification; (3) a thorough code audit. Results are often summarized in tables that are correlated to design elements documented in respective ASP-II CMS sections.

2.1.4 Software Test Cases and Results Provides a description of each test case performed and the result. Discrepancies noted are also documented here so that subsequent testing can be directed to verify corrections of anomalies and/or errors.

2.1.5 Conclusions and Recommendations. Contains all discrepancies found in the code body applicable to the functional element. The condition, credibility and completeness of the code should also be noted in this section. Recommendations for resolution of discrepancies, improving, or otherwise enhancing the code should be described with respect to the routines and/or algorithms found during examination functional element.

2.2...2.n Detailed Results for (Functional Element Name). Repeats the above cycle of sections for each FE verified.

3.0 Validation Results - Function Level

Provided in this section are descriptions and results of assessments that have been applied to functional elements of the model. These consist of correlation and comparison statistics derived from test data measurements and FE predictions. Validation procedures will vary from simple to complex in accordance with the function or phenomena being simulated (validated) and the ease with which the phenomena tested can be represented by the model. At the FE level, bench test data in the form of characteristic response curves and single point measurements can often be used to assess the representation of a function (e.g., a servo) in the model. At the model level, several or all of the functions are usually exercised in an attempt to predict data that were collected from an operational test. Comparisons of these predictions with actual measurements usually leads to statistical goodness of fit or correlation values that are used to assess the validity of the model or the function for the type of situation or scenario during which the data were collected.

Implications for Use. Summarizes the impact of the FE validation results and conclusions on the ability of the model to provide accurate predictions for specific FEs. This section also describes any impact of these results on overall model credibility in the form of limitations and/or constraints on model use and possible corrective actions available to model users. The following sections are included for all validated FEs:

3.1 Results for (Functional Element Name). Familiarizes the reader with the purpose and function of this particular FE from both a theoretical and a modeling standpoint. Provides a description of how this element is modeled in the software, along with a justification of any assumptions and/or approximations made to implement this function in the code. The justifications should include reference to any expert investigation and any standard work in the appropriate technical field that would support the software implementation. Summarizes in tabular form the results of all validation activity for this FE, including test source, major test variables and degree of correlation (or other statistical MOE) for each test. The following sections are included for each test case used to assess this FE:

Assessment Description - Case I. Describes the test data that were used in the comparison with model predictions for this case. A summary of the range of values over which the FE was tested should be included, as well as some indication of whether the test data represent stressful, ambient, or non-stressful conditions for FE test comparison. The test should be described in brief, with frequent reference to the Test Plan Supplements (TPSs) and the Test Report Supplements (TRSs). Describes the statistical analysis procedures and MOEs used to evaluate the comparison between test data and model predictions. The choice of MOEs and procedures should be well explained and justified for application to this FE. Boundaries for acceptable variation between model predictions and test data observations should be clearly identified. This information should refer to the Notional Test Plans (NTPs) if they are applicable.

Results. Provides a detailed description of the results of comparing test data with model predictions. Interpretation of the statistical analysis described in the previous section should form a major part of this section.

Conclusions. Provides an explanation of the results that should assess the impact of the results not only on functional element credibility, but also on overall model performance. A statement as to the validity of the function given the results should be made, but may be tempered by qualifications related to the data available for the assessment. Recommendations for further work or assessment should be included in light of the current findings.

Assessment Description - Case 2…n. Adds test cases as they are obtained for this FE.

3.2 ... 3.n Results for (Functional Element Name). Repeats the above cycle of sections for however many functional elements have been assessed.

4.0 Validation Results - Model Level

Results of validation assessments at the model level are presented in this section and address the set of Critical Analytical Issues (CAIs) normally associated with the model. A set of Measures of Effectiveness (MOEs) are identified for each CAI to guide and support the assessment performed and the conclusions formulated from that assessment. These conclusions form the basis for recommendations for further investigation of any new issues discovered during the assessment, as well as a statement of the credibility of the model in its current configuration.

Implications for Use. Summarizes the impact of assessment results and conclusions on the ability of the model to provide accurate predictions of performance for the CAIs addressed. This section also describes any impact of these results on overall model credibility in the form of limitations and/or constraints on model use and possible corrective actions available to model users. For each Critical Analytical Issue addressed, the following sections are provided:

4.1 Summary of Results for (CAI name). Describes the CAI being resolved, and states why this CAI is critical to model performance and utility. Summarizes in tabular form the results of all validation activity for this CAI, including test source, major test variables and degree of correlation (or other statistical MOE) for each test. For each test case for this CAI, the following sections are provided:

Assessment Description - Case 1. Describes the test data that were used in the comparison with model predictions for this CAI, including a brief description of the range of values over which the CAI was tested, as well as some indication of whether the test data represent stressful, ambient, or non-stressful conditions for the test comparison. The test should be described in brief, with frequent reference to the Test Plan Supplements (TPSs) and the Test Report Supplements (TRSs). Describes the statistical analysis procedures and MOEs used to evaluate the comparison between test data and model predictions. The choice of MOEs and procedures should be well explained and justified for application to this CAI. Boundaries for acceptable variation between model predictions and test data observations should be clearly identified.

Results. Provides a detailed description of the results of comparing test data with model predictions. Interpretation of the statistical analysis described in the previous section should form a major part of this section.
Conclusions. Provides an explanation of the results that assesses their impact on overall model credibility. These statements may be tempered by qualifications related to the data available for the assessment. Recommendations for further work or assessment should be included in light of the current findings.

Assessment Description - Case 2…n. Repeats the above cycle of sections for however many assessments contribute to resolution of this CAI.

Results.

Conclusions.

4.2 ... 4.nSummary of Results for (CAI name). Repeats the above cycle of assessment cases for each CAI applicable to the model.

Assessment Description - Case 1.

Results.

Conclusions.

REFERENCES

B-1 Muessig, P., et al, *Accreditation Support Package (ASP) Document Description*, Susceptibility Model Assessment and Range Test (SMART) Project, NAWCWPNS, China Lake, CA, 93555-6001, November 1994. (publication UNCLASSIFIED.)

B-2 Laack, D., *A Comparative Analysis of Tri-Service Accreditation Policies and Practices, Volume I of the Accreditation Requirements Study Report*, JTCG/AS Central Office (AIR516J), Naval Air Systems Command, Washington, DC 20361-5160, 1994, (JTCG/AS-93-SM-020).

B-3 Laack, D., *Information Requirements in Support of Accreditation, Volume II of the Accreditation Requirements Study Report*, JTCG/AS Central Office (AIR516J), Naval Air Systems Command, Washington, DC 20361-5160, 1994, (JTCG/AS-93-SM-020).

B-4 Ellis, S. and Krenz, T., *Software Verification Requirements Study for the SMART Project*, JTCG/AS Central Office (AIR516J), Naval Air Systems Command, Washington, DC

20361-5160, 1992, (JTCG/AS-92-SM-011).

B-5 Ellis, S., et al, *Documentation Assessment Report for ESAMS, ALARM, and RADGUNS*, Entek, Inc. for the SMART Project, NAWCWPNS, China Lake, CA, December 23, 1993. 33 pp. (ENTEK/ABQ-93-0144, publication UNCLASSIFIED.)

APPENDIX B-3
ACCREDITATION REPORT OUTLINE

SIGNATURE PAGE

Summary of evaluation results, model deficiencies, and impact analysis
Statement of recommendation for ACCREDITATION

ACCREDITATION PLAN SUMMARY

Reference approved plan or include as appendix

DESCRIPTION OF DEVIATIONS FROM PLAN DURING EXECUTION

COMPARISON OF V&V (AND OTHER) MODEL DATA TO ACCEPTANCE CRITERIA

Include validation boundaries
Emphasize limitations to model suitability

IDENTIFICATION AND ANALYSIS OF MODEL DEFICIENCIES

Work-arounds for selected deficiencies
Impacts on problem outcomes due to deficiencies

APPENDIX C

GUIDELINES FOR DEVELOPMENT OF WORK PACKAGES
Sample SOW's for ASP's

STATEMENT OF WORK

Assessment Update of Air Combat Survivability Methodology

1. SCOPE

The purpose of this task is twofold: (1) to provide the Susceptibility Model Assessment and Range Test (SMART) Project with Accreditation Support Package (ASP) updates for a suite of six aircraft survivability models and simulations (M&S), and; (2) to use these ASP's to evaluate the credibility of the Air Combat Survivability methodology used by the Office of the Secretary of Defense (OSD). The technical require-ments of the Statement of Work (SOW) for Contract TBD that apply to this task are TBD.

1.1 Background.

The SMART M&S credibility assessment process converts the technical results of verification, validation and configuration management activities into a product known as the ASP. This package is used by acquisition and testing programs across DoD to substantiate the use of M&S in major acquisition and testing decisions. The verification sec-tions of the ASP document the correctness of M&S software with re-spect to design criteria and analysis requirements, al-lowing decision makers to evaluate the applicability of the subject M&S to their analyti-cal or testing requirements. The validation sections of the ASP document the results of comparisons between M&S predictions and empirical testing, allowing decision makers to assess the confidence that can be placed in M&S predictions for specific applications. The configuration management sections of the ASP doc-ument the degree to which M&S development is controlled and managed, allowing decision makers to assess the "shelf life" of analytical and testing results taken from M&S. Taken as whole, the SMART ASP provides a level of confidence in the analysis of phenomena affecting air vehicle survivability hitherto unob-tainable in a single package.

This SOW provides for the update of ASP material, and for assessment of OSD's Air Combat Survivability methodology from the standpoint of the credibility of its component M&S as defined by the ASP's.

1.2 Model Descriptions.

The following paragraphs describe the aircraft survivability M&S that constitute the focus of this delivery order:

ESAMS (Enhanced Surface-to-Air Missile Simulation) is a one-on-one digital com-puter model used to evaluate air vehicle survivability against surface-to-air missile (SAM) sys-tems. Key characteristics of a SAM engagement are modeled, including sensor acqui-sition and track, missile launch and flight dynamics, missile guid-ance and control, offen-sive/defensive countermeasures and warhead fuzing.

ALARM (Advanced Low Altitude Radar Model) was designed to analyze the detection performance of ground based radar systems against aircraft targets. It uses detailed forms of the radar range equation to determine the ability of a radar system to detect a target in the presence of clutter and multipath, and permits inclusion of either standoff or on-board jammers.

RADGUNS (Radar-Directed Gun System Simulation) consists of a set of programs that simulate target detection, tracking and shooting performances of several AAA weapon systems against passive aerial targets. Components of the weapon system are mod-eled at either the subsystem or circuit level, including search and track radar systems, a set of anti-aircraft guns, a fire-control computer/servo sys-tem to aim the guns, and a crew to operate the system.

TRAP (TRajectory Analysis Program) is used to analyze the kinematic trajectory char-acteristics of an air-to-air missile. TRAP simulates up to three vehicles: the launch ve-hicle, the missile, and the target. It is built around a detailed missile fly-out model, with simplified launch vehicle and target models.

BRAWLER is a stochastic, event-driven model designed to simulate air-to-air combat between multiple flights of aircraft in visual and beyond-visual-range (BVR) scenarios. Special emphasis is placed on simulating cooperative tactics and on capturing the importance of situation awareness in the combat environment. Human decision-making processes are modeled through the use of "value-driven decision-making" and an "information-oriented decision architecture." The model addresses interactions between airborne radars, weapons, warning devices, expendables, and communications in the processing of information that drives pilot decision logic and produces discrete event outcomes. Outputs consist of a run-time log of events, a machine-readable history file for generation of graphical displays, a database used by the report generation utility, and a printed diagnostic file of user-defined parameters and errors produced during execution.

EADSIM (Extended Air Defense SIMulation) is a many-on-many analytical model designed to simulate the interactions among command, control, and communications (C3I) nodes, weapon systems, and intelligence sensors in air defense and short range ballistic missile (SRBM) defense scenarios. The model provides a simulation environment that permits evaluation of operational performance and engagement processes for airborne and land-based platforms and predetermined measures of performance and effectiveness can be used to evaluate changes in system performance parameters, operational procedures, or C3I architectures. Both Red and Blue forces are modeled at the individual system or mission level for single and multiple engagements during the course of the battle. The model is graphics based, event and database driven, and can produce a variety of engagement statistics report files. It has evolved through a process of integration that began in 1986 when the Communications Simulation (COMSIM) and Network Analysis Model (NAM) provided by the U.S. Army Signal Center were combined with the Operational Performance Model (OPM) and Joint Tactical Information Distribution System (JTIDS) produced by the Assistant Secretary of Defense (ASD).

2. APPLICABLE DOCUMENTS

The following documents form a part of this SOW and reference to them will be neces-sary to perform the work specified herein:

2.1 Government Documents.

MIL-STD-483A	Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs (4 Jun 85)
MIL-STD-1521B	Technical Reviews and Audits for Systems, Equipment, and Computer Programs (4 Jun 85)
DOD-STD-2167A	Defense System Software Development (29 Feb 88)
DOD-STD-2168	Defense System Software Quality Program (29 Apr 88)
JTCG/AS-91-SM-002	Software Development Standards Manual for JTCG/AS Computer Simulations (January 1991)

2.2 Other Publications.

Michael S. Deutsch, Software Verification and Validation: Realistic Project Approaches, (Englewood Cliffs, NJ: Prentice-Hall Inc., 1982)

SMART Data Collection Process Document Description; (Draft).

SMART Accreditation Support Package (ASP) Document Description; (November 1994).

SMART Project Plan; (3rd Revision, January 1994).

SMART Project Management Plan; (July 1992).

Accreditation Support Framework for DoD M&S; (January, 1995).

3. TECHNICAL REQUIREMENTS

3.1 ASP Updates.

The following items describe the components of the ASP that require update for each subject model. All subtasks listed under this task heading shall be performed in accordance with the technical specifications provided in the SMART V&V process documentation referenced in section 2.2. The contractor shall provide update pages for each ASP for each of the subject models that summarizes the technical results of each of the subtasks listed below. Each ASP shall be written in accordance with format and content specifica-tions referenced in section 2.2. This format has been approved by DoD for use in making ac-creditation decisions for survivability M&S.

3.1.1 Documentation Assessment.

The contractor shall review and update the current assessment of available documen-ta-tion for each subject model, including: assessments of: the completeness of available model doc-umentation; the compliance of each component (or volume) of the set to accepted, tailored standards for mature M&S; recommendations as to how the documentation set should be modified to bring it into compliance with those standards, and; a listing of implications of the current state of documentation on model use and V&V efforts.

3.1.2 Software Quality Assessment.

The contractor shall review and update the existing software qual-ity assessment for each subject model. The assessment shall consider three major areas of software quality: programming conventions, compu-tational effi-ciency and memory utilization. The contractor shall also review current software quality as-sessment methodology and provide an updated set of assessment requirements to be used in fu-ture soft-ware quality assessments.

3.1.3 Configuration Management Baseline Description.

The contractor shall review and update current con-figuration management baseline information for each subject model, including: a model descrip-tion; a summary of its development history; a current version description and a summary of its development status; a description of change procedures in effect for the model; a summary of available user support functions, and; an analysis of implications of configuration management procedures on the credibility of the model and its results.

3.1.4 V&V Status and Usage History

The contractror shall review and update the V&V status of each subject model, including any documentation that may have been developed since the last ASP update. Studies or programs for which verification and/or validation efforts were conducted, their sponsors, and points of contact, the type of V&V performed, date of publication shall be included. Particular attention should be paid to results of such V&V efforts and their applicability to current model versions. The contractor shall also review and update the history of prior uses of each of the subject models based on inputs from SURVIAC, user surveys, model managers, model develop-ers, government agencies, and any other pertinent sources of such information. The contractor shall provide listings of specific studies that have used the subject models, their sponsors, and points of contact (if available). Included shall be a description of each application and any notes or comments on how (or whether) the suitability of each model for each application was determined. The contractor shall also indi-cate whether each model was formally accredited for each use and provide a listing of accredita-tion report titles, dates and points of contact, if available.

3.1.5 Summary of Assumptions, Limitations, and Errors.

The contractor shall review and update the list of assumptions, limitations and known errors that currently exist in the sub-ject mod-els and that may have come to light since the last ASP update. Under “Assumptions” the contractor shall provide an updated description and discussion of the assumptions upon which the model was developed, as well as those pertain-ing to user inputs and model generated outputs. Under “Limitations” the contractor shall describe and discuss updated limitations (model and/or documentation) identified during any V&V efforts that might restrict the model's usefulness for certain applications, including limitations that pertain to user inputs and model generated outputs. Under “Errors” the contractor shall describe and discuss updated error listings and anomalies for the model and/or documentation, as well as information on their sources derived from docu-mented subject matter expert (SME) reviews of the model, V&V

reports, model documentation, user group meeting briefings, and other pertinent sources of information. In all of the above, particular attention shall be paid to assumptions, limitations or errors that might restrict model applicability or usage.

3.1.6 Model Decomposition.

The contractor shall review and update the listing of each subject model's functional capabilities, and shall identify how model development activities since the last ASP update have affected the generic functional area templates developed for the subject models. (These templates are available from the SPO as GFI). The contractor shall submit proposed revisions to the templates to the SPO for review and approval, after which the contractor shall develop a written description of each new or modified model function that describes the purpose of the function, why it is included in the model, what the function does, and how it is implemented in the code.

3.1.7 Conceptual Model Specification.

The contractor shall review and update the top level software design specification for each subject model based on a review of functions developed or modified since the last ASP update. The updated specification shall include a listing and description of new or modified software design requirements, new or modified documentation, and new or modified model code. In addition, the contractor shall provide updated descriptions of design requirements and implementation approaches for each model function developed or modified since the last ASP update for each subject model. At both the top level and the function level, the contractor shall provide an updated summary of new or modified limitations and assumptions made in the implementation of each of the design requirements for each subject model. The contractor shall also identify the sources of data and algo-rithms used in any new or modified code.

3.1.8 Sensitivity Analysis.

The contractor shall review and update the re-sults of function level and model level sensitivity analyses for any model functions developed or modified since the last ASP update for each subject model. Sensitivity to as-sumed conditions or data used to implement function algorithms shall also be deter-mined. Variables not controllable by direct (user) inputs shall be identified. Function level sensitivity analysis shall be aimed at identifying which functional input parameters have the greatest impact on function level outputs. Model level sensitivity analysis shall be aimed at quantifying the impact of function level variability on model level outputs.

3.1.9 Functional Element Verification.

The contractor shall review and update the re-sults of detailed verifi-cation efforts for any functions developed or modified since the last ASP update for each subject model. Included for each new or modified function shall be a verification overview, summaries of design elements verified, desk check activities and results, and software test cases and results. The contrac-tor shall also provide verification conclusions and recommendations for each new or modified function verified.

3.1.10 Functional Element Validation.

The contractor shall review and update the re-sults of comparisons between model function predictions and test data (collected under task 3.2) for any model functions developed or modified since the last ASP update for each subject model. The functional element validation shall include a plan describing statistical measures of ef-fectiveness and analytical pro-cedures that were used to validate each new or modified function. The contractor shall validate the function level outputs of the subject models in accordance with these plans using prior test data (supplied as GFI by the SPO) or test data collected under task 3.2.

3.1.11 Model Level Validation.

The contractor shall review and update the results of comparisons between model predictions and test data (collected under task 3.2) for each subject model. The model validation shall include a plan describing statistical measures of effectiveness and analytical procedures that were used in the validation effort. The contractor shall validate the top-level outputs of the subject models in accordance with these plans using prior test data (supplied as GFI by the SPO), or test data collected under task 3.2.

3.1.12 Model Deficiency Reports.

Model deficiencies uncovered during execution of any of the technical tasks described above shall be documented in a Model Deficiency Report (MDR) and provided to the SPO as part of the monthly progress report (MPR) described in section 4. Problems encountered during the use of any of the technical information sup-plied by the government during conduct of any of these tasks will be documented in the MPR's also. Reso-lution of discrepancies will be coordinated with the SMART Project Office (SPO) and other technical resources suggested thereby.

3.2 Test Data Collection and Reduction.

The contractor shall collect test data and associ-ated documentation to support function level and model level validation as described in subtasks 3.1.10 and 3.1.11. The contractor shall provide Test Plan Supplements (TPS) that summarize each test from which data are to be collected, and which identify additional data, in-stru-mentation, sce-narios, and op-erations that would make the basic test more useful to SMART validation objec-tives. The TPS will also identify any resources required for this special data collec-tion, and es-timate the costs of those re-sources. The contractor shall participate in test data collection to the extent permitted by the test sponsor in accordance with the terms of pre-negotiated Memoranda of Understanding (MOU's) between the SPO and the test sponsor. The contractor shall en-sure that the resulting data are of the types and for-mats required for compari-son with model out-puts as specified by developers of each of the subject models listed in section 1.2. After collec-tion of the data, the contractor shall summarize test results in a Test Report Supplement (TRS) fo-cused on SMART validation objectives and concerns. The TRS shall summarize the test as actually conducted, with specific emphasis on deviations from the test plan summarized in the TPS and an analysis of their impact on the data collection effort. When required, the contractor shall provide any data reduction required to convert stan-dard range test data products into products usable for validation. The contractor shall then provide a Reduced Data Package (RDP) consisting of reduced data from the test on electronic media in a format specified by the SPO appropriate to each validation objective. The contrac-tor shall deliver the TPS, the TRS and the RDP to the SPO for distribution and archiving.

3.3 Analysis of Air Combat Survivability Methodology.

The contractor shall integrate the results of tasks 3.1 and 3.2 into an assessment of the DoD air combat survivability methodol-ogy from the standpoint of the credibility of its component M&S. The report shall focus on deficiencies in component M&S identified by completion of the above tasks, and shall summarize recommended improvements and corrections to the existing methodology.

4. SCHEDULE

4.1 Period of Performance.

From award through 30 June 1997.

4.2 Deliverables and Schedule.

A.Within 30 days of award of this delivery order, the contractor shall pro-vide a Task Management Plan (TMP) that includes the following information for each major task:

1. Budgeted cost of work scheduled projections;
2. A schedule for completion;
3. Technical progress assessment criteria;
4. Quality assurance considerations;
5. Risks that might impact cost or schedule, and;
6. Risk mitigation plans or considerations applicable to each identified risk.

The TMP for each task in this Delivery Order will be structured in accordance with the Work Breakdown Structure (WBS) identified in the SMART Project Plan (section 2.2), and will be reviewed by the SPO within 15 days of receipt. The ap-proved TMP will provide the basis for reporting status, progress and prob-lems each month.

At the end of the period of performance, the contractor shall produce an omnibus TMP that summarizes the history of actual task execution relative to the plan, and that clearly delineates where plan deviations have impacted technical perfor-mance objectives.

B.Monthly Progress Reports (MPRs) for any subcontractors associated with the delivery order will be provided to the SPO no later than 5 working days after the end of each month. The contractor will provide an aggregated MPR for all subcontractors in the form of CDRL Item 0003 no later than 15 working days after the end of each month. This latter item will include documentation of meetings, trips, test plans, data transmittals and all technical progress applicable to each task or subtask assigned. Particular attention will be paid to status with respect to the cost, schedule and performance projections defined in the TMP. Included in the MPR will be any MDRs discovered during the reporting period. Other items (e.g., draft MOUs, test reports, data, and items required for specific tasks) will be provided as they become available.

C.A Quarterly Progress Report (QPR) will be due 90 days after award of this delivery order. QPRs will be due every 90 days until the end of the period of performance and shall summarize technical accomplishments, fiscal status, risk issues and recom-mendations developed during the reporting period.

D.The following items will be delivered during the period of per-formance as specified below, depending upon the applicable task:

Accreditation Support Package (ASP) draft update pages for each subject model will be provided nine months after the start of the period of performance. The update pages will contain all information called out in the relevant subsections of task 3.1, and shall be written in accordance with the format specifi-ca-tion for ASP's developed by the SPO and referenced in section 2.2. The final version of the update pages, with all M&S inputs and SPO comments integrated, will be delivered at the end of the pe-riod of perfor-mance.

Test Plan Supplements and Test Report Supplements will be provided for review as soon as possible after all rele-vant information is collected for each test opportunity.

Reduced Data Packages will be provided immediately after the test sponsor authorizes release of the data and the data have been reduced.

The Air Combat Survivability Methodology Assessment Report draft shall be due eleven months after the start of the period of performance. The final version incorporating SPO com-ments and community review will be due at the end of the period of performance.

E.A final status report, accompanied by a package of briefing materials, will be provided to the SPO that will summarize the overall technical accomplishments, levels of effort, and shortfalls with re-spect to planned objectives for all subtasks under this delivery order.

5. SPECIAL CONSIDERATIONS

5.1 Security Classification.

5.2 Place of Performance.

5.3 Travel.

5.4 Government Furnished Material.

5.5 Technical Coordination.

Technical Assistant:Alternate Technical Assistant:
Contracting Officer's Representative (COR):

Notes to Contracting Officer:

Section 5.3: Travel explanation

Froms	To	Trips	Persons	Days/Trip

APPENDIX D
DATA REQUIRED FOR AND PRODUCED BY EACH WBS TASK

WBS #	WBS Title	Data Inputs	Data Outputs
1.1	Define Application	–	–
1.1.1	Define Overall Problem	–	–
1.1.1.1	Define Problem and Objective	•Tasking statement	•Problem Definition •Study objectives
1.1.1.2	Define Problem Metrics and Thresholds	•Problem definition •Study objectives •Technical Information	•Study Metrics •Study Thresholds
1.1.1.3	Identify Problem Importance	•Problem definition •Study objectives	•Impact Assessment •Affected organizations •Visibility of problem outcome or decision •Decision Risk •Sponsors Identification of Importance
1.1.1.4	Determine Solution Approaches	•List of M&Ss •Test Data •Historical Data •Analytical Tools •Function Capability of Each Tool •V&V History Of M&S	•Candidate List of Solution Approaches
1.1.2	Define Application Parameter	–	–
1.1.2.1	Define Application Purpose and Objective	•Application Description •Problem Description	•Application Purpose and Objective
1.1.2.2	Define Application Scenario	•Application Description	•Application Parameters •Assumptions •Scenario Definition, e.g.: • Participating organizations • Forces • Systems • Environments • Boundary Conditions
1.1.2.3	Identify Application Specific Issues	•Application Description	•Issues •Concerns
1.2	Develop M&S Requirements	–	–
1.2.1	Define & Prioritize Functional Requirements	–	–
1.2.1.1	Identify Required M&S Outputs	•Study Metrics •Study Thresholds	•M&S Outputs •Data Flow Logic Tree
1.2.1.2	Identify Functions With Significant Impact of M&S Outputs	•Study Metrics •Study Thresholds	•Contributing Functions for Each M&S Output •Critical Functions Check List
1.2.2	Define & Prioritize Fidelity Requirements	–	–
1.2.2.1	Determine M&S Output Accuracy Requirements	•Study Metrics	•Study Metrics •Parameter Sensitivities
1.2.2.2	Translate M&S Output Accuracy Requirements Into M&S Functional Accuracy Requirements	• Study Metrics • Parameter Sensitivities	• M&S Functional Parameter Sensitivities
1.2.3	Define & Prioritize Operating Requirements	–	–

WBS #	WBS Title	Data Inputs	Data Outputs
1.2.3.1	Identify M&S Operating Team and Capabilities	• Candidate List of Operation Team	• List of Operating Team • Capabilities of Individuals
1.2.3.2	Identify Hardware and Software Available to Run M&S	• List of Available Hardware and Software	• Selected Hardware • Selected Software
1.2.3.3	Identify M&S Networking and Interface Requirements	• List of Available Hardware and Software	• Network and Interface Environment
1.2.3.4	Identify M&S Input and Data Processing Requirements	• Application Description	• Pre and Post Processing Data Requirements
1.2.3.5	Determine M&S Operator Support Requirements	• Application Description	• Training Requirements • Support Personnel Requirements • Repair and Maintenance Support Requirements
1.3	Select Candidate M&S	–	–
1.3.1	Identify M&S Candidate Pool	• M&S Requirements	• List of M&S That Satisfy Requirements
1.3.2	Collect M&S Information	• M&S Requirements	• M&S Documentation • Previous V&V Reports • Model Mgrs Input • Previous Users Input • Development and Usage History • Model Strengths and Weakness
1.3.3	Compare M&S Information With M&S Requirements	• M&S Documentation • Previous V&V Reports • Model Manager Input • Previous Users Input • Development and Usage History • Model Strengths and Weakness • M&S Requirements	• Comparison Data
1.3.4	Select Best M&S Candidates	• Comparison Data	• List of Suitable M&S
2.1	Determine Accreditation Requirements	–	–
2.1.1	Identify V&V Rqmts.	–	–
2.1.1.1	Identify V&V Information Requirements	• M&S Requirements • Application Rqmts.	• V&V Information Requirements
2.1.1.2	Collect Existing V&V Data for Selected M&S	• M&S ID	• Existing V&V Data
2.1.1.3	Identify V&V Data Voids	• M&S Requirements • V&V Information Requirements • Existing V&V Data	• V&V Data Voids
2.1.1.4	Identify Required V&V Tasks	• Existing V&V Data • V&V Data Voids	• V&V Tasks
2.1.2	Identify Non-V&V Requirements	• –	• –
2.1.2.1	Identify Non-V&V Information Requirements	• M&S Requirements • Application Requirements	• Non-V&V Information Requirements
2.1.2.2	Collect Existing Non-V&V Data for Selected M&S	• M&S ID	• Existing Non-V&V Data
2.1.2.3	Identify Non-V&V Data Voids	• M&S Requirments • Non-V&V Information Requirements • Existing Non-V&V Data	• Non-V&V Data Voids
2.1.2.4	Identify Required Non-V&V Tasks	• Existing Non-V&V Data • Non-V&V Data Voids	• Non-V&V Tasks
		•	•

WBS #	WBS Title	Data Inputs	Data Outputs
2.1.2.5	Identify M&S Input Data Requirements	• M&S Requirements • Application Rqmts	• M&S Input Data Requirements
2.1.3	Identify Documentation Requirements	• M&S Requirements • Application Rqmts	• Documentation Requirements
2.1.3.1	Identify Policy Requirements	• Application Parameters	• Policy Requirements
2.1.3.2	Identify Accreditation Requirements	• Application Parameters	• Accreditation Requirements
2.1.3.3	Identify Data Repository Requirements	• Application Parameters	• Data Repository Requirements
2.2	Develop Accred. Plan	–	–
2.2.1	Plan V&V Tasks	–	–
2.2.1.1	Identify V&V Resource Requirements	• Application Requirements • M&S Requirements • V&V Data Rqmts.	• V&V Resource Requirements & Plans
2.2.1.2	Establish V&V Task Execution Schedules	• Application Rqmts. • M&S Requirements • V&V Data Rqmts.	• V&V Task Execution Schedules
2.2.1.3	Define V&V Task Responsibilities	• Application Rqmts. • M&S Rqmts. • V&V Data Rqmts.	• V&V Task Responsibilities & Execution Plans
2.2.2	Plan Non-V&V Tasks	–	–
2.2.2.1	Identify Non-V&V Resource Requirements	• Application Requirements • M&S Requirements • Non-V&V Data Requirements	• Non-V&V Resource Requirements & Plans
2.2.2.2	Establish Non-V&V Task Execution Schedules	• Application Requirements • M&S Requirements • Non-V&V Data Requirements	• Non-V&V Task Execution Schedules
2.2.2.3	Define Non-V&V Task Responsibilities	• Application Requirements • M&S Requirements • Non-V&V Data Requirements	• Non-V&V Task Responsibilities & Execution Plans
2.2.3	Plan Accreditation Assessment	• Applicat'n Parameters • Accred. Rqmts.	• Assessment Plans
2.2.4	Plan Documentation Tasks	–	–
2.2.4.1	Identify Cost-Effective Content and Format Requirements	• Candidate M&S • Application Parameters • M&S Requirements	• Content and Format Requirements
2.2.4.2	Identify Documentation Task Responsibilities	• Candidate M&S • Application Parameters • M&S Requirements	• Documentation Task Responsibilities & Preparation Plans
2.2.4.3	Identify Documentation Resource Requirements	• Candidate M&S • Application Parameters • M&S Requirements	• Documentation Resource Requirements & Plans
2.2.4.4	Establish Documentation Schedule	• Candidate M&S • Application Parameters • M&S Requirements	• Documentation Schedule
3.0	Verification	• Verification Requirments	• Verification Results
3.1	Decompose Model Into Functions	• M&S Documentation • V&V Data Requirements	• Model Functions
3.2	Assess Software Quality	• Software Code and Documentation • V&V Data Requirements	• SW Quality Assessment
3.3	Identify Model Assumptions, Limitations & Errors	• M&S Documentation • V&V Data Requirements	• Model Assumptions, Limitations & Errors
3.4	Produce Design Documentation	• M&S Documentation • V&V Data Requirements	• Design Documentation
3.5	Perform Logical Verification	• M&S Documentation • V&V Data Requirements	• Logical Verification Report

WBS #	WBS Title	Data Inputs	Data Outputs
3.6	Perform Code Verification	• M&S Documentation • V&V Data Requirements	• Code Verification Report
4.0	Validation	• Validation Requirements	• Validation Results
4.1	Conduct Sensitivity Analysis	• M&S Documentation • V&V Data Requirements	• Sensitivity Analysis Report
4.1.1	Perform Model Level Sensitivity Analysis	• M&S Documentation • V&V Data Requirements	• Model Level Sensitivity Analysis Report
4.1.2	Perform Function Level Sensitivity Analysis	• M&S Documentation • V&V Data Requirements	• Function Level Sensitivity Analysis Report
4.2	Perform Face Validation	–	–
4.2.1	Assemble Subject Matter Expert Review Team	–	–
4.2.2	Identify Evaluation Boundaries Conditions and Criteria	• M&S Documentation • V&V Data Requirements	• Evaluation Boundaries Conditions and Criteria
4.2.3	Generate M&S Predictions	• M&S Documentation • V&V Data Requirements	• M&S Predictions
4.2.4	Compare M&S Predictions with Expert Opinion	• M&S Predictions	• Analysis Report
4.2.5	Collect & Evaluate Other Validation Information	• Other Validation Information	• Analysis Report
4.3	Perform Results Validation	–	–
4.3.1	Define Test Data Requirements	• M&S Documentation • V&V Data Requirements	• Test Data Requirements
4.3.2	Prepare Validation Analysis Plans	• Test Data Requirements	• Validation Analysis Plans
4.3.3	Identify & Coordinate With Sources of Test Data	• Test Data Requirements	• Test Data Sources
4.3.4	Collect, Reduce, Document and Archive Test Data	• Test Data	• Processed Test Data
4.3.5	Calibrate M&S To Test Conditions	• ProcessedTest Data	• Calibrated Model
4.3.6	Generate M&S Predictions	• Calibrated Model • Processed Test Data	• M&S Predictions
4.3.7	Compare M&S Predictions With Test Data	• M&S Predictions • Test Data	• Comparison Report
4.3.8	Evaluate Results & Diagnose Problems	• Comparison Report	• Results and Problem Report
4.3.9	Identify Problem Fixes, Work-arounds & Risks	• Results and Problem Report	• Problem Fixes, Work-arounds & Risks Report
5.0	Accreditation	–	–
5.1	Perform Non-V&V Tasks	–	–
5.1.1	Establish C/M Attributes	•M&S Documentation •C/M Plan •Source Code	•C/M Attributes Report
5.1.2	Establish VV&A Status and Usage History	•Previous V&V Reports •Model Managers Input •Previous Users Input •Development and Usage History	•VV&A Status •Usage History Report
5.1.3	Assess M&S Documentation	•M&S Documentation	•M&S Documentation Assessment Report
5.1.4	Identify Hardware, Software and Interface Attributes	•List of Hardware and Software	•Hardware, Software and Interface Attributes Report
5.2	Perform Acceptability Assessment	–	–
5.2.1	Collect Accreditation Data	• V&V Results • Non-V&V Results • Documentation	• Accreditation Data

WBS #	WBS Title	Data Inputs	Data Outputs
5.2.2	Compare VV&A Data with M&S Requirements	• Accreditation Data • M&S Requirements	• Comparison Report
5.2.3	Identify and Assess Impact of M&S Deficiencies	• Comparison Report	• M&S Deficiencies Report
5.2.4	Develop Accreditation Recommendations	• M&S Deficiencies • Comparison Report	• Accreditation Recommendations Report
5.3	Make Accreditation Decision	• Accreditation Recommendations Report	• Accreditation Decision