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PEER REVIEW PROCESS AND ACCREDITATION OF MODELS

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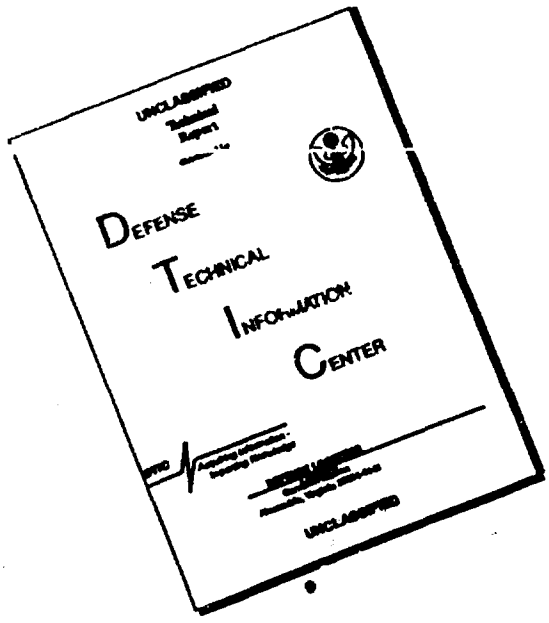

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Peer Review Process and Accreditation of Models

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Table of Contents

Executive Summary

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This research prescribes a general framework for accreditation of large scale military simulation models such as those used by CAA. Accrediting a model for a specific use is the direction toward which the Army is moving. A recent memorandum by the DUSA(OR) outlines a general plan for overseeing the accreditation of models as a necessary, time-saving procedure. The memorandum suggests that verification and validation (V&V) will be required for each model during model development and accreditation will be reviewed prior to each use of the model. This research includes an examination of peer reviews completed at CAA for the purpose of gaining insight into the existing accreditation process.

1. Introduction. The first chapter explains how the need for V&V has evolved over time and how real world constraints, e.g., time and money, have necessitated accreditation of models. Formal definitions for verification, validation, accreditation, and peer review are given.

2. Previous Peer Reviews. An overview of reports of previous CAA

peer reviews is presented. Reconstructing the techniques and the details of the analysis used in these peer reviews was difficult. Even though much effort and expertise went into these peer reviews, little information could be gained that would assist in the accreditation process because of the lack of formal documentation.

3. Literature Review. To ensure that this research was based on prior knowledge, an extensive search of relevant literature was conducted. Much published material was found on techniques for V&V. The more general published works are reviewed so that an individual conducting further research has a reference point. Additionally, Army policy and regulations on topics that may be encountered in the process of accrediting models are reviewed. Specifically, it is noted that accreditation is mentioned only in the DUSA(OR)'s memorandum on the subject.

4. A General Framework for Accreditation Procedures. This is the main body of the research. This chapter explains how the need for accreditation arises and then explains a general process, void of internal, administrative details, for a methodology for accreditation. First a single analyst, independent of the study team considering an application for the model, will review the accreditation status of the model. If the model needs accreditation, a full peer review team will be assigned to work with the analyst. This team will become familiar with the model, gain insight into the proposed study, examine previous studies where the model was used, and then make a recommendation as to

whether the model will be accredited for the proposed study. The accreditation proponent will then make the decision to accredit the model. The methodology as outlined in this chapter provides a basis for consistency and standardization.

5. Final Comments. A review of the major results of this research is presented. Additionally, suggestions for further research are given.

Chapter 1

Introduction

1.1. Purpose.

The purpose of this research is to (1) prepare an assessment of the effectiveness of peer reviews as they have evolved over the past few years for verification and validation (V&V) of large scale military models, and (2) develop a framework for the accreditation process. This research is being conducted for the United States Army Concepts Analysis Agency (CAA) in Bethesda, Maryland.

1.2. Background.

The military makes extensive use of highly complex simulation models for a variety of purposes. Major uses include:[1]

- Battle planning
- Wartime operations
- Weapons procurement
- Force sizing
- Human resource planning
- Logistics planning
- National policy analysis

Simulation and analytical models save the government time and money. For example, to decide if a different mix of scout and attack helicopters might be more effective than the current mix in a cavalry squadron, one might use simulation or analytic models.

Without simulation or analytical modeling, a test squadron would have to be selected and taken out of combat ready status for a lengthy amount of time to achieve the same results. A benefit of simulation is that it generates information about future, untried strategies and tactics, and about the effects of weapon systems not yet tested. This document concentrates on simulation models.

Many simulation models currently in use have evolved over time. Some of these models are composites of simpler models. Others began as complex models, but they have been modified numerous times to keep pace with new doctrine and a growing technology. These models have thousands of lines of code that were produced by numerous programmers over a period of years. In many instances documentation is lacking and in some instances documentation is nonexistent. Some of the older models were written before the need for program design language was recognized. This makes a review of the code more difficult for verification of the model.

Verification is a process of determining that a model accurately represents the developer's conceptual description and specification. Validation is the process of determing that a model is an accurate representation of the intended real-world entity from the perspective of the intended use of the model. Both verification and validation are continual processes. There is no defined point signifying that a model is verified or validated. The most difficult aspect of V&V is the determination that there has been sufficient V&V of a model to make a conclusive statement

about the model's credibility.

Just a cursory look at a model's code and comparing it to the model's requirements is only the beginning of the verification process, but it is not as thorough as a complete walkthrough of the code. To accomplish a thorough V&V, more techniques and statistical tests can be completed that will give additional confidence in the model. Thus, the more V&V a model receives the better, but there is a point of diminishing returns.[2] Discovering this point is a difficult but important goal, because an extensive V&V is very time consuming and expensive. In the absence of V&V, analysts have no confidence that a model can produce output from which reliable decisions can be made. With insufficient V&V, analysts may still have a low level of confidence in a model.

Confidence in a model is why V&V has become such an important issue. The need for all existing models to be verified and validated is important but generally considered more expensive than if the models were verified and validated as they were developed.[3] At present CAA has contracted V&V during the development of a new model, Global Deployment Analysis System (GDAS) which evaluates the capabilities and requirements of the mobilization base and deployment status of the deploying forces and provides input to CAA combat models.[4] Performing V&V on a model while it is being developed increases the model's cost approximately fifteen per cent.[5] The model can be changed more easily during its developmental stage. To perform V&V on all existing models is a more expensive and extensive task.

As an alternative to a full V&V, the Army is promoting accreditation of a model for a specific use.[6] Accreditation is the process of certifying that a computer model has achieved an established standard such that it can be applied for a specific purpose. The accreditation procedure recognizes that V&V of a model are continual processes and that full validation of the model may not be technically or economically feasible.

The standard Army approach to accredit any analytical research is by peer review, which is a detailed examination by expert observers who are independent of the analysts conducting the work.[7] Likewise, model accreditation may be accomplished by peer review.[8] The peer review is also considered an appropriate mechanism for obtaining prescriptions for improvement. Part of the process of verification includes adjusting a model to correct coding mistakes instead of just listing a model's problems.

The effective use of peer reviews as an assessment tool is dependent upon the consistency of evaluation methodology among the individuals within a review group and between different review groups. A standard methodology for a peer review would stabilize the differences among peer review teams. For example, one team might be more thorough than another team. The confidence in all peer reviews can only be as high as the confidence in the peer review conducted with the least amount of effort. In the long run, there will be a degradation in the quality of work without a prescribed standard. A standard to judge peer reviews will keep the level of effort consistently high. CAA would benefit from knowing

that all peer reviews of its models were completed with the same efficacy and consistency.

1.3. Current Issues.

Model V&V and accreditation are processes that cannot be immediately accomplished by edict alone. There are many questions that are unanswered, and new research is uncovering more questions. V&V in many ways is very elusive. No one can predict or pinpoint the exact amount of effort needed to ensure that a model is verified and validated. Clayton J. Thomas linked V&V to the uncertainty principle. This is more commonly referred to as the Hawthorne Effect.[9] The very act of collecting data biases the validation process, id est, if a subject knows that he is being observed he will perform differently.[10] Currently, some of the problems plaguing analysts are verifying and validating several models used in conjunction with each other, not enough usable combat data, and a world changing faster than it takes to V&V a model.[11] [12] Another problem that modelers have encountered has been adjusting input data so that the output makes sense to such a degree that the input data becomes unrealistic.

In the absence of a real world comparison, no matter how thorough is the V&V, the model may be incorrect. Modeling is very difficult and the forces interacting on events are numerous. One recognized problem is that all models seem to simulate combat at a faster rate than live combat.[13] Sometimes the mathematical principles of a model do not exactly represent the real world.

Output may appear reasonable for a defined range of input values, but unrealistic outside this range.

Without V&V, a model's credibility may never be assured. For an exhaustive V&V, the model may become obsolete before the V&V is completed.[14] Accreditation is a worthwhile concept, but it does not lessen the need for continuing V&V.[15] There are no easy answers. Investigation should continue in the application of V&V, because there are many benefits from credible simulation.

Chapter 2

Previous Peer Reviews

2.1. General.

In the last several years CAA has completed several peer reviews on various models. A listing of all peer reviews examined in this study is found in Appendix A. The final reports of these peer reviews range from briefing slides, to office memoranda, to printed and bound documents. Some of these peer reviews were actually completed by peers, others were not. Most peer reviews are indistinguishable as to whether they were true peer reviews completed by outside analysts or they were completed by model users.

The purpose of this chapter is to learn from previous peer reviews and to use this knowledge for the development of a methodology for accreditation of models. This chapter is not a critique of the effort and expertise involved in any of the peer reviews completed at CAA. Yet, a lack of formal documentation of these peer reviews has resulted in less insight than desired for the development of a plan for accreditation of models. Another problem in the lack of consistent documentation is that the outside reader can not distinguish which peer reviews were thorough and completed with extensive effort and which peer reviews were completed with less extensive effort. The lack of documentation in

the reports leads the outside reader to a low level of confidence for all of the peer reviews, even though many of the peer reviews are probably completely correct and accurate. No other government agencies' peer review reports were reviewed and no comment is made, nor should inferences be made, as to the comparison of peer reviews at CAA and peer reviews at any other agency.

These reports vary in their thoroughness, because of the absence of consistent definitions for verification, validation, and accreditation. One peer review claimed to validate a model by "determining the model is not invalid."[16] "Not invalid" does not mean "valid" just as "not guilty" does not mean "innocent." This peer review can not be considered a validation. Some of the peer reviews are verifications, some validations, some recommendations for improvements, and some are just comments. None were accreditations. Adherence to strict definitions of verification, validation, and accreditation will help distinguish the reports as to their type, and raise the reader's confidence level in these documents.

2.2. Techniques Used at CAA.

The overview of all peer reviews on models at CAA in the past few years has revealed the use of common techniques. These techniques, for the most part, are not explicitly stated in the peer review reports. The next three sections review the most used techniques for verification and validation.

2.2.1. Verification.

Most recent model verifications have preferred the use of one or more of the following techniques:

algorithm critique
expert opinion
review of documentation
comparison to other models

Algorithm critique is a review of the methodology used in the model, and the inspection of the code to insure that it reflects the methodology correctly. Expert opinion is an inspection of the modules to determine how reality is represented. Review of documentation is a study of past V&V, and any explanation of the model including what it does and how it does it. Comparison to other models is checking an algorithm from a model against a similar algorithm in a verified model. Other techniques are available, but the above mentioned techniques were found to be common in their use.

The following paragraphs are representative examples of information about a model that was gained using the above listed techniques of verification. These examples demonstrate the usefulness of verification. These and many other examples are derived directly from the peer reviews at CAA.

In many cases mistakes were discovered in the logic of the model and the reports were useful in this regard. Additionally,

functional area experts on the peer review team have uncovered many inconsistencies in somemodels being verified at CAA, indicating the usefulness of expert opinions.[18],[19],[20]

Overwhelmingly, peer reviews conducted at CAA have reported a lack of documentation on any past reviews of the models, and also a lack of documentation for explanation of the code. In one instance the only knowledge of the program was in the heads of the users, and this was lost when they moved.[21] Those analysts assigned to verify this model had a difficult task. Reviewing documentation is an excellent place to start a model verification, but the analysts were handicapped without this documentation of the code.

2.2.2. Validation.

There have been only a few peer reviews for the purpose of validation completed in the past few years at CAA. The techniques employed included:

- -comparing the model results to combat
- -comparing the model results to the results from training exercises
- -comparing the model results to the results of other models
- -comparing the model results to expert opinion.

The following paragraphs are examples of validation techniques used at CAA.

A study completed in 1986 validated CFAW concluding that the results reasonably compared to combat results from the Falkland Islands.[22] In addition, one of the modules was changed to reflect lessons learned from this study. Using this technique is not always practical because of the necessity of collecting real battle data which are rarely available.

The Ardennes contract effort built a data base from the Battle of the Bulge in order that a future study might validate the Concepts Evaluation Model (CEM), then the Force Evaluation Model and Joint Theater-Level Simulation (JTLS).[23] Collecting data based on older weapons has its obvious drawbacks, but this procedure can be useful in model validation because it reflects the intangibles of combat that are not so easily written into an algorithm. The major disadvantage is the lack of accurate data on all the outputs a model may generate.

A major training exercise can provide much useful data for model validation and is generally recognized as the next best source of information compared to live combat. The ongoing exercises at the National Training Center (NTC) at Fort Irwin, California are a potential source of data for model validation, but the exercises are usually at a smaller scale than that at which CAA models. CAA models theater level campaigns which are too large to be conducted at NTC where battalions are the usual participants.

COMO, a stochastic, critical-event-stepped, Monte Carlo model, has been validated by comparing results to exercise Hammer 87-1.[24] This peer review was well documented. The inconsistencies of the

model and a non-live fire air defense training exercise were explained in detail in the peer review. The major lesson learned from this peer review is that the prescription for collecting necessary data must be well conceived in advance of the exercise.

Validating a model based on other models is another method used at CAA. Micro-FASTALS, an IBM personal computer compatible version of Force Analysis Simulation of Theater Administrative and Logistic Support (FASTALS), was compared to FASTALS for validation. The results demonstrated that Micro-FASTALS is not as detailed as FASTALS, but still achieves consistent output in a more transportable hardware system.[25]

Validating a model based on other models has its merits, but it has a limiting effect. The upper bound of how accurately a model represents a system is constrained by how accurately the comparison model represents reality. Validation by model comparison will always be limited in this manner. Currently a larger problem for using model comparison as a method of validation is that there are so few models that have been thoroughly and properly validated, and existing documentation is generally below an acceptable standard for any confidence in the peer review.

Another method of model validation is that of comparing model output to expert opinion. This is analogous to comparing results of a model to live combat data but using a data base that comes directly from the memory of one of the participants. As years pass since the last extensive conflict involving the United States, this reservoir of combat experience will dwindle. In validating WARRAMP

it was determined from expert opinion that the artillery loses were too low.[26] Otherwise, this method of validation has not been used that often at CAA.

2.2.3. Accreditation.

Accreditation is more economically feasible than full validation. Accreditation will not replace the need for validation, but its intent is to certify a model for a specific purpose or use. Even though techniques of accreditation are similar to validation techniques, comparison to combat results is not necessary for accreditation.

In the past two years, no report from CAA proclaims itself to be an accreditation of a model. In fact, no review actually attempted to achieve the results of accreditation as defined in this report. No peer reviews were written to certify a model for a particular use, so there is no assessment of any peer review accreditation of models.

2.3. Level of effort.

Some measure of level of effort per amount of output could be very useful. It would be convenient to be able to predict that a structured walkthrough costs a certain dollar amount, or that a comparison to real battle data will cost another amount. Most peer reviews at CAA did not include a cost of the report, and none included a price decomposition into how resources were expended.

In addition the models vary significantly in size, documentation of code, program design language, complexity, and purposes; so that a specific prediction of cost for a specific technique becomes unrealistic. Two studies that validated two respective models using live combat data varied greatly in cost. The Ardennes study had a cost of $375,000 and the Falkland study had a cost of $40,000.[27] It would be convenient for CAA to know how much V&V it could get for a specific dollar amount, but this is very model dependent and must be handled on a case by case basis.

2.4. Conclusions.

The results of this review of past CAA studies on verification, validation, and accreditation are as follows:

(1) There has been inconsistency in the definitions of verification and validation.
(2) There is no standardized methodology for V&V currently in use.
(3) There is incomplete documentation within the peer reviews that have been conducted.

2.5. Recommendations.

A general framework is needed for consistent verification and validation of models. All models should have a well documented account of their verification and validation. This document should include at least the following:

-The purpose of the model

-A classification of the model

-A listing of important implicit and explicit assumptions

-A range of values for significant input values

-A listing of verification and validation techniques used

-All changes made to the model

-Identification of any areas that might become a problem under certain conditions

-Data on level of effort.

CAA should ensure that all peer reviews are examined by a higher authority than those conducting the peer review. This may be in the form of a Product Review Board. This will insure a level of consistency in the peer reviews. In addition a plan for accreditation should also be developed for application in those instances when a model needs to be certified for a specific purpose, and it is not economically feasible for a full validation to be conducted. Chapter Four presents such a plan.

Chapter 3

Literature Review

3.1. Recent studies on V&V.

There have been several books and reports that have suggested methodologies and techniques for V&V. All of these reports explained the need for V&V, and these are all in agreement with respect to the reasons for conducting V&V. The prescriptions for V&V differ somewhat, but the outline of some of these recommendations for V&V follow.

In 1969, Robert E. Schellenberger from Temple University, wrote "Criteria for Assessing Model Validity for Managerial Purposes." Even though this paper is twenty years old, it is applicable today. This paper describes measures for judging whether a model has been properly validated. Three kinds of validity are explained: technical validity, operational validity, and dynamic validity. Each of these kinds of validity are further categorized. Additionally, an analysis of assumptions is presented. The paper is very thorough in its explanations of validation criteria. This paper was written, not for an analyst, but for a reviewer of a model validation which makes it good background reading for the study of accreditation.

The National Bureau of Standards published a guidebook, in 1982, Software, Validation, Verification, and Testing Technique

Tool Reference Guide, with thirty techniques for V&V. Each of these techniques is clearly defined, explained in detail, and an example of its use is given. In addition, comments about cost and effort are added. A bibliography is also included for each technique for the reader's further reference. No formal proposal is given in this guidebook as to which techniques are better. The guidebook is simply a reference source.

Another National Bureau of Standards publication, A Software Testing Methodology Using the Cyclomatic Complexity Metric, published in 1982, explains how to test a program during the development and maintenance stages of a model. This publication specifically is concerned with verifying that a model stays within reasonable computational time. The book is a practical application of complexity theory and maintaining a program polynomial time solvable. Changes made to the model during accreditation have to be checked to ensure that computational time does not grow exponentially. The techniques presented in this publication can be used to prevent exponential growth of computational time.

Wayne P. Hughes edited a collection of papers in 1984 for the Military Operations Research Society. The book, Military Modeling, has two chapters - one by Clayton J. Thomas and the other by Wilbur B. Payne, which expound in depth on the importance of V&V. The final chapter in this book, written by Stephen Leibholz, is a thought provoking coverage of twenty open-ended questions that a modeler should ask about a model. Many of the questions and subsequent discussions are pertinent to accreditation of models.

It is an excellent reference source for conducting V&V of military models.

In 1985, W. J. Quirk edited a book, Verification and Validation of Real-time Software. Several methods and techniques for V&V are discussed but not in any detail. This book does not provide much information that can not be learned elsewhere pertaining to V&V. This book is another proponent for V&V during the development stage of a model.

Banks, et al., of the Georgia Institute of Technology prepared a document entitled The Verification and Validation of Simulation Models. This document, prepared for CAA in 1986, outlines a process for V&V during a model's development. The seven steps of model development are:

System feasibility

Requirements definition

Preliminary design

Detail design

Coding

Testing

Operations and maintenance.

This document suggests that a model's progress should not proceed to the next stage until the current process is verified and validated. The research attempts to quantify how much V&V is needed using a series of Go/No Go processes at the different stages of model development. Included in this document is a description of how these procedures should be applied. The techniques for

verification explained in this report are documentation, operational graphics, program design language, structured programming, structured walkthrough, and traces. Explanations for validation techniques are presented for comparison to other models, consistency checks, documentation, event validity, extreme condition test, face validity, historical data, and historical methods. The document gives an appreciation of how difficult it is to quantify the necessary amount of V&V for a model.

The General Accounting Office published a report, DOD Simulations: Improved Assessment Procedures Would Increase the Credibility of Results, in 1987. The GAO study concerned an analysis of the credibility of three Army simulation models. This report concluded that,

> The Department of Defense should adopt or develop and implement guidance on producing, validating, documenting, managing, maintaining, using, and reporting simulations of weapon system effectiveness.[30]

This report also stated that, "Credibility would be helped by better documentation of the verification."[31] Since the publication of this report, more emphasis has been placed on insuring that simulation models are more credible.

In 1988 Banks, et al., prepared another document, entitled Testing, Understanding, and Validating Complex Simulation Models. New ideas for performing V&V at CAA are suggested from analogies made to other systems in which V&V is prevalent. Control charts, acceptance sampling, fractional factorial design, and cluster

analysis are introduced and explained as statistical methods that may be modified or used directly for verification. Unusual applications of sensitivity analysis and Turing tests to the validation of complex military simulations are described. These techniques were used to validate models that had already been implemented. Sensitivity analysis and Turing tests have promise for use in model accreditation.

The Office of the Deputy Under Secretary of the Army for Operations Research maintains a catalog of combat simulations entitled American British Canadian Australian Catalog of War Games, Training Games, and Combat Simulations. The latest version, released in 1988, lists over one hundred combat models. For each model listed, a brief description, usually two pages, and a point of contact is given. The eleventh edition of the Catalog of Wargaming and Simulation Models was published in August 1989 and is now available from the Defense Technology Information Center. It describes models used by all U. S. services. An analyst needing a simulation for a study can use either of these catalogs as a good initial source for an appropriate model.

A short article, "Verification and Validation: A TRAC Approach," by Major Steven Flanagan outlined a methodology for V&V that was used at TRAC in 1988. Flanagan's approach to verification is:

(1) Methodology proposal review

(2) Preliminary design review

(3) Detailed design review

(4) Structured walkthrough

(5) Data review

(6) Check run.

His approach to validation includes:

(1) Check run

(2) Interfunctional sensitivity

(3) Surface validity

(4) Sensitivity analysis

(5) V&V products and by-products.

For all the government agencies, in the Army and elsewhere, there is very little published material on exactly how an agency accomplishes V&V. Practical application of which techniques of verification and validation an agency uses should not be a trade secret, and this article simply explains how one organization conducted V&V.

3.2. Department of the Army policy.

Currently, there are few specific regulations pertaining to V&V or accreditation. Generally the practice has been for local commands to develop policy, with little Department of the Army directed regulation. The following overview of Army publications may not be exhaustive, but the overview covers the more important aspects that concern CAA. This overview is presented as an initial guide to Army publications concerning model accreditation.

The Deputy Under Secretary of the Army for Operations Research [DUSA(OR)] has issued a memorandum, "Verification and Validation

and Accreditation of Models," that has a specific plan for V&V of models and for model accreditation. This memorandum is applicable to CAA. A copy of this memorandum is included as Appendix B of this report.

The regulation for CAA, United States Army Concepts Analysis Agency, (AR 10-38) does not specifically mention V&V of combat models. This is a short regulation describing duties, functions, and responsibilities of CAA. Accreditation and V&V of models are internal requirements that allow CAA to effectively accomplish its mission as defined in this regulation.

The Army Model Improvement Program is an Army regulation (AR 5-11) that, by its purpose, seems to govern V&V. This regulation is in the process of being re-written. Many changes are expected, and it will be directive in nature in that it will require validation and accreditation of all models to be used in formal Army studies and acquisition decisions. It will allow directors of analytical agencies to use discretion in the choice of methods for V&V and accreditation.

Army Studies Analysis (AR 5-5) describes how studies are to be written. As to whether V&V or accreditation of models are defined to be studies that must follow this regulation is not clearly indicated. If the V&V is accomplished during the development of a model then this study would be covered by this regulation.[26] Even if not required for accreditation, this regulation and the accompanying pamphlet outline a method for effectively conducting a study. The pamphlet lists six phases of

a study: (1) initiation, (2) validation, (3) development and conduct, (4) evaluation, (5) application, and (6) documentation and reporting. The pamphlet also lists duties and responsibilities for the members of a study team. An analyst can not go wrong by following the procedures in this pamphlet.

Threat Support to U. S. Army Force Combat and Material Development (AR 381-11) is one of the few Army regulations that specifically concerns the topic of V&V. Any result from a model simulation, under the jurisdiction of the Army Model Improvement Program (AMIP), which affects the threat must be sent to the Office of Deputy Chief of Staff for Intelligence (ODCSINT) where the threat results are validated. This regulation specifically mentions that CAA will obtain threat data for input from ODCSINT.[29] Having a specific outside agency validate the threat results from a model reduces CAA's need for an intelligence expert on a peer review team.

A regulation that does not seem to directly pertain to V&V is Configuration Management (AR 70-37). This regulation covers management of any item that has been designated by the government as a configuration item. If a model is so designated, then this regulation would have to be followed to affect changes to the model as in V&V and accreditation.

There are other regulations that may become involved in the process of model accreditation, but they will be very specific with respect to the topic covered The reference list in the Army Model Improvement Program is thorough enough to begin a regulation review

that might be necessary for a peer review.

Chapter 4

A General Framework for Accreditation Procedures

4.1. General.

This chapter presents a general framework for an accreditation methodology. Accreditation of a model is a cost effective alternative to V&V. The process of V&V can be streamlined so that the model can only be accredited for a specific purpose, and not for all possible applications.

Ideally, every model should be verified and validated during model development. Understanding that not all models in the inventory were verified and validated during their development, it may become necessary to accept the fact that a model may never be verified and validated. A thorough process could take so much time that the study results may become obsolete or the decision making may be made before the model is verified and validated. Realistically, accreditation or a review of accreditation of a model prior to each use may be the only acceptable practice for models that were never verified and validated during their development.

A model may be in use for a long enough time that tactical and technical changes may have occurred in the real world. There may be a modification of input data, or there may have been an additional module added to the model. These are all reasons why a

model, accredited for a specific purpose, is not guaranteed to remain credible.[32] The model users should be aware of this possibility and be prepared to report discrepancies of a model when these discrepancies are noticed.

The general idea is to insure that all studies using simulation will be conducted using accredited models. A plan must be established such that a simulation model is accredited by a peer review team that is independent of the model developers and model users.

If time or resources preclude an independent team model accreditation, or if this procedure is not followed; the final report should reflect whatever deviations have occurred. Future users of the model should be informed of the limitations of a shortened or non-independent accreditation process.

4.2. The need for accreditation.

There are several events that will cause CAA to initiate the accreditation process. First, CAA must initially accredit all models for which it is the accreditation proponent. Thereafter, CAA may be tasked to accredit these models whenever the Army Models Committee deems necessary. CAA may also be tasked to accredit a model that a different agency has decided to use in a study. CAA's performing the accreditation in this instance insures the independence of the peer review. Internally, CAA may wish to accredit a model for an in-house study. The independence of the peer review team performing the accreditation is the responsibility

of CAA in this instance.

Another reason for initiating an accreditation process could be that the model may not be performing as it was designed. At the level above the user of the model, a tasking is made for an analyst to accredit the model in question. By whatever route a model is introduced to the accreditation process, the peer review process of accreditation should follow the steps explained below.

4.3. Review of Accreditation.

Before CAA assigns a peer review team to accredit a model, a single analyst should be assigned to review the current accreditation status of the model. It might be the case that a model has recently been accredited for a similar study, and a full accreditation procedure is not necessary. The individual analyst should make a recommendation for a full peer review accreditation of a model if he or she deems that it is necessary after accomplishing the following tasks:

1) Review all documentation of any past V&V's or accreditations
2) Review the audit trail of the model's evolution
3) Know the effectiveness of each study completed using this model

The analyst may make the decision that the model is already accredited for use. The decision should be made only if a model has been accredited for a similar study with the same range of values for input data. In addition, an inordinate amount of time should

not have elapsed since the model was last accredited for a similar study. If the model was being used in a study when a problem had been noticed with the model, the analyst should recommend a full peer review for accreditation at this point. Accreditation of a model by a full peer review is not necessary each time a model is used, but the assurance that the accreditation of a model is still current is important.

4.4. A full peer review.

After the analyst has made the determination that the model needs to be considered for accreditation for a specific purpose, a peer review will be requested. A peer review team will be assigned to work with the original analyst. A peer review team of three or four members will probably be sufficient. The senior analyst will become the team leader. The peer review team must be aware of all the factors that will influence it. The amount of time and money allocated for the accreditation process may be limiting factors with respect to the depth of the peer review. Additionally, Army regulations may dictate certain procedures. The output of the peer review team should be a completely documented report. Now the peer review team is prepared to initiate the following procedures.

4.4.1. Know the model.

The original analyst will give a detailed briefing to the other members of the peer review team on what was learned previously about the model being accredited. The peer review team

will then become more familiar with the model. Some tasks the peer review team should accomplish are as follows:

1) Know the conceptual model.
2) Know the underlying mathematical principles of the model.
3) Know all assumptions of the model.
4) Know the type of model, id est, deterministic or stochastic.
5) Know if the model was designed for combat development or for training.

4.4.2. Know the study.

The peer review team should become familiar with the demands and constraints of the proposed study. Specifically the peer review team should know the following:

-The purpose of the study
-The objectives of the study
-The importance of the study's results
-The urgency of the study
-The range of the study
-The type of study, whether a training study or a combat development study.

In addition, information about the input data will be useful in gaining a thorough understanding of the scope of the study. The source of the input data, and whether the study is using current

year data for input or projected data for input are two items that the peer review team will need to consider.

4.4.3. Know which functional areas of the model are significant.

A model might be more complex than what is needed for a study. The peer review team decides which functional areas of the model are significant to the study. Functional areas of the model that are not necessary for the proposed study do not have to be accredited. For example, if the study assumes no chemical agent attack, then a module that models the degradation of soldiers while wearing chemical protection suits does not need to be accredited.

4.4.4. Know how the model was used previously.

How well a model performed in the past may give an indication as to how well the model may perform in the future. Previous users of a model will have experience and additional insight into the model which may be beneficial. The model may have been used in the past for a similar study and performed poorly. Members of the peer review team should contact past users of the model. The team should not limit its contacts to the most recent users of the model, but should contact a variety of model users if this model was used for a breadth of applications and various studies. The peer review team will be looking for valid criticisms from former users of the model. This feedback is worth the extra effort required to locate model users even if they have had a change of assignment since they used the model.

4.4.5. Know current status of the system.

The peer review team should review changes in technology and tactics that have occurred since the model's most recent accreditation, if one has occurred. A thorough research of all significant functional areas is necessary to ensure that all changes are being considered. In addition, information on threat changes in these significant functional areas will be requested from ODCSINT. If a functional area is significant for the current study, but was not significant the last time the model was accredited, then significant functional areas should be researched for changes since the verification and validation of the model, and not just since the last accreditation.

4.4.6. Accredit the model.

After the peer review team has become familiar with the model, the study, and the latest updates in tactics and technology, the team must decide if the model can be used for the proposed study. Some additional items the peer review team may wish to consider are explained below.

4.4.6.1. Review the model's assumptions.

The peer review team should look at the assumptions of the model. It must be determined whether or not the study is going to violate any of these assumptions. A trivial example is that a model may assume a constant defense budget for all future years, but the

study might need to model the effects of a fluctuating annual budget.

4.4.6.2. Examine the range of values for model input.

The peer review team needs to examine the range of values for significant input data. This range must not violate any of the model's constraints on the significant variables. A movement plan to withdraw all troops from Germany must consider all means of available transportation. If the movement plan involves airlifting troops back to the United States, then the model's input -the number of aircraft needed- is constrained by current or projected inventory.

4.4.7. Write a formal report.

After all of the above items have been considered, a formal report must be written. This report should be thoroughly documented. Briefing slides may be included, but should not be the only written work produced. This report should include: a list of what was reviewed, a full explanation of the proposed study, a listing of all implicit and explicit assumptions of the model, a recommendation on accreditation, a list of which specific algorithms were considered, and a list of any recommendations for updating the model. The peer review team should not update or change the model. The report will be submitted to the Army Models Committee for accreditation approval.

4.5. CAA accreditation criteria.

CAA may wish to accredit internal models for certain studies even though accreditation is not required by the Army Models Committee. In this instance, CAA needs to establish accreditation criteria. CAA should task a senior analyst, not on the peer review team or on the study team, to review the accreditation report. This reviewer will approve or disapprove the accreditation of the model for the proposed study based on the peer review team's recommendation. If the peer review team made recommendations for a change of the model, the reviewer will recommend approval or disapproval of these changes. The Director of CAA will make the decision whether to implement these changes.

The reviewer of the proposed accreditation will base this decision on whether to approve the peer review team's recommendation for accreditation on the following criteria:

-The model has been verified and validated, or

-There is an acceptance by model users

-Study parameters do not violate model constraints

-Threat data has been validated by ODCSINT

-All implicit and explicit assumptions of the model have been identified

-All proposed changes to the model have been checked to ensure that these changes will not adversely affect other portions of the model

-All other approval standards of the Army Model Committee

have been met.

In addition, the formal written report of the accreditation should allow future analysts to gain the information that is explained in Section 4.3.[31]

Chapter 5

Final Comments

This document has examined documentation of results of unclassified V&V peer reviews at CAA. From this examination, a more formal framework for conducting peer reviews is recommended. Documentation of past V&V efforts has been inconsistent, and in many instances has lacked important information for a clear audit trail. Therefore, an assessment of the effectiveness of past peer reviews in terms of resources expended and time required is not possible at this time. Further research can be conducted comparing cost savings of accrediting models versus the loss of credibility from not conducting a full V&V each time the model is used.

A general outline of accreditation procedures is proposed in this document. Since certain types of applications of models are required to be accredited,[33] it is recommended that CAA adopt this procedure for model accreditation. Since the idea of accreditation of models is relatively new and not a standard practice, continued monitoring of this procedure is recommended. Through use, revisions may be made to enhance this accreditation methodology. More criteria for accreditation might be deemed useful from the continued use of the accreditation process. In addition, other steps of the accreditation process might become more streamlined through use and refinement. The documentation of future accreditations of models will become more detailed as time passes,

and the accreditation process will be less time consuming. Thus, ongoing review of this process is recommended. Only through continuous refinement will this process of accrediting models become viable.

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Appendix A

Peer Reviews at CAA

"Special Review of ARQ Model"	1986
"IDA Sustainability Study"	4 Jan 1986
"IDA Conventional Arms Control Work"	6 Feb 1986
"Comments on Phoenix"	3 Mar 1986
"Review of MICAF"	13 Nov 1986
"AFP Methodology"	11 Dec 1986
"Review of AFP Methodology, 3rd Memo."	17 Dec 1986
"AFP Validation Review, 4th Memo."	25 Feb 1987
"AFK vs. AFP"	2 Mar 1987
"Validation of CFAW"	20 May 1987
"WARRAMP Methodology"	10 Feb 1988
"Peer Review of WARF Methodology"	16 Feb 1988
"ARB Synopsis-FASTALS/Micro-FASTALS Comparison Final Results"	6 Apr 1988
"Ammo/WRE Analysis Plan"	18 Apr 1988
"COMMO Hammer Validation Study"	May 1988
"CAA History Activities: 1980-1988"	Sep 1988
"Review of MUPLAN"	23 Jan 1989
"MUPLAN and RECPOM"	2 Feb 1989
"Review of Aviation Modernization Acquisition Stategy Spearhead Model"	17 Mar 1989

Appendix B

Verification and Validation (V&V) and Accreditation of Models

DEPARTMENT OF THE ARMY
OFFICE OF THE UNDER SECRETARY
WASHINGTON, D.C. 20310-0102

30 OCT 1989

SAUS-OR

MEMORANDUM FOR: SEE DISTRIBUTION

SUBJECT: Verification and Validation (V&V) and Accreditation of Models

1. PURPOSE. This memorandum states policy and guidance providing quality assurance for, and establishing the credibility of, models. Included are all models used for studies and analyses, training, combat developments, education, operational planning, testing, and command decision aids. Immediate actions required by this memorandum are identified in paragraph 6c(1). The V&V and accreditation policies and responsibilities in this memorandum will be incorporated in the next revision of AR 5-11 (Army Model Improvement Program) (reference 1). A separate policy memorandum dealing with configuration management for models will be prepared and distributed in the near future.

2. REFERENCES. See Enclosure 1.

3. DEFINITIONS. See Enclosure 2.

4. BACKGROUND AND RELATED ACTIVITIES.

a. Expansion of the use of models by the Services, Unified and Specified Commands, Joint Staff, and other Department of Defense (DoD) agencies has led to the recognition of the need for clearer policy for the integrated development, acquisition, and application of models. The Defense Science Board, Army Science Board, Army Audit Agency, and General Accounting Office have noted such needs (see references 2-7).

b. The Organization of the Joint Chiefs of Staff (OJCS) has created the Joint Models and War Games Executive Council (JMWEC) (see reference 8). The purpose of JMWEC is to improve joint models and war games used by the Services, Joint Staff, Unified and Specified Commands, and other DoD agencies, by promoting efficiencies, economies, and interoperability in such models and war games. JMWEC is a forum in which the Army can recommend improved representations of ground warfare systems, operations, and concepts in models used throughout the DoD community.

c. The Army recognizes the need for credibility assessment for Army and joint models to provide for increased acceptability. Reference 9 suggested that the Army Model Improvement Program (AMIP) Management Office, now part of the U. S. Army Model Improvement and Study Management Agency (MISMA), develop a master plan and oversee an overall program of credibility assessment.

d. The increased use of models in support of operational test and evaluation (OT&E) has led the Director, Operational Test and Evaluation (DOT&E) to issue policy guidance (reference 10) on V&V for models used for OT&E.

e. Under AMIP (reference 1), the Army is developing and applying a family of analytical models. This family includes combined arms models and functional area models. The US Army Concepts Analysis Agency (CAA) is the proponent for the theater level, combined arms component; and the U. S. Army Training and Doctrine Command (TRADOC) is the proponent for the corps/division and battalion task force, combine arms components. Item system performance data used in the models are provided by the U. S. Army Materiel Command (AMC).

f. The Army is developing and fielding a family of training simulations (FAMSIM). These are administered under AR 350-38 (Training Device Policies and Management) (reference 11), which is under revision. The Army Staff proponent for FAMSIM and AR 350-38 is the Director of Training, Office of the Deputy Chief of Staff for Operations and Plans. For AMC, Program Manager, Training Devices is the materiel development proponent for FAMSIM. For TRADOC, Commander, Combined Arms Training Activity and National Simulation Center is the training development proponent for FAMSIM; Commander, TRADOC Analysis Command (TRAC) is the V&V proponent for FAMSIM; and Commander, Army Training Support Center is the proponent for AR 350-38.

g. Current DoD policy on V&V is stated in a number of publications, among which are references 12-14. Applicable Army policy and guidance are stated in references 15-20. Reference 18 contains useful guidance for V&V in general, V&V testing, independent V&V, and configuration control; reference 19 contains useful guidance on configuration control, V&V, and documentation; and reference 20 deals with validation of threat.

5. POLICY.

a. The Department of the Army recognizes the value of models to support training, combat developments, education, operational planning, and testing; to assist decision making through studies and analyses; and as potential command decision aids.

b. Department of the Army policy is to use models that are widely accepted as high quality within the Army and the larger DoD community. This goal will be attained through continuous attention to quality and V&V, and continuous commitment to improving the modeling process.

c. The Army has developed a body of knowledge of battlefield phenomena that will be applied in representing such activities. To the extent possible, models treating the same function will use consistent representations, with levels of detail dependent upon intended use.

d. The Department of the Army will perform and document V&V on any model over which it has control. V&V is an Army command responsibility. V&V of a particular model includes preparation of a written assessment plan and a written report. V&V are continual, in the sense that V&V activities are repeated as a model is modified; or new test, exercise, training, or operations data become available.

e. For a model developed and used by a Federally Funded Research and Development Center (FFRDC) or contracting firm in support of a major Army study, the Army sponsor will ensure that V&V has been performed on the model and ascertain its V&V status. This can be accomplished by including a requirement for V&V documentation, and stipulating acceptability criteria, in the Request for Proposal (RFP) and statement of work (SOW) (or other appropriate legal documents).

f. Accreditation is necessary if a model is not fully validated. The Army will establish and update the accreditation status of each standing model that supports key Army processes, especially a model that has repeated use, is widely distributed, and supports training or operations planning. This requirement applies whether the model is used in-house by the Army, or externally by a FFRDC, a contracting firm, the Joint Staff, or a major combatant commander. The need for accreditation is based on the recognition that V&V are continual processes and that full validation of a model may not be technically or economically feasible. A model will be accredited for a particular type(s) of application(s). Regarding frequency, a model will be subject to accreditation when the model is proposed for use for a new type of application, when a new reference version of the model is released, or when a sufficient period has passed to necessitate accreditation activities to be performed again.

g. V&V and accreditation will be included in an overall program of configuration management.

h. A standing model that satisfies one (or more) of the criteria listed below must be accredited for that type(s) of application(s). Examples are listed in Enclosure 3.

(1) Model that is used as a primary analysis tool in an Army cost and operational effectiveness analysis (COEA) for a Defense Acquisition Board (DAB)-level or Army Designated Acquisition System (ADAP)-level system.

(2) Model that is used as a primary analysis tool in a major Army Planning, Programming, Budgeting, and Execution System (PPBES) study; e.g., Mid-Range Force Study (MRFS), Support Force Requirements Analysis (SRA) (supporting Total Army Analysis), Program Force Capability Assessment (PFCA), OMNIBUS, or Total Logistics Readiness / Sustainability (TLR/S).

(3) FFRDC- or contractor-developed model that is a primary analysis tool in a major study sponsored by the Army.

(4) Training simulation in the Army FAMSIM.

(5) Joint model that represents Army activities and is used in a study sponsored by OJCS or the Office of the Secretary of Defense (OSD), or used by a combatant commander for planning or training. (Generally, Army V&V and accreditation for a joint model will be limited to examination of the representation of Army activities.)

(6) Model that is used as a primary analysis tool in the planning phase or evaluation phase of testing of a DAB-level or ADAP-level Army system.

(7) Decision support system that supports analysis performed by or presented directly to Headquarters, Department of the Army (HQDA).

(8) Model that is a primary education tool in the curriculum of the U. S. Army War College, U. S. Army Command and General Staff College, or U. S. Army Logistics Management College.

i. A model in one or more of the categories of paragraph 5h and used by or for the Army for the associated type(s) of application(s) must be appropriately accredited. Use of a model that has been judged non-accredited (i.e., unacceptable) for a particular type of application requires prior approval of the chairperson of the Army Models Committee (see paragraph 7c).

j. Validation criteria (i.e., standards of adequacy) will be identified as early in the development of a model as feasible. This is especially important for a model developed on contract.

k. V&V and accreditation activities will include assessments of the representations of concepts, tactics, and doctrine--from both Red and Blue perspectives.

l. V&V of threat portrayal will be performed by the appropriate intelligence authority, who will ensure that the representations of concepts, tactics, and doctrine are consistent with established intelligence positions and assessments.

m. As relevant test, exercise, training, or operations data become available, they will be used to support validation and accreditation of a model. Data from tests and exercises are most useful for "calibrating" the given model; i.e., making adjustments to input data or model logic to obtain closer agreement with an external index.

n. For a model used in testing (paragraph 5h(6)), the accreditation proponent will coordinate with the appropriate test and evaluation agency (e.g., Operational Test and Evaluation Agency (OTEA), or U. S. Army Materiel Systems Analysis Activity (AMSAA)) regarding acceptability criteria.

o. Results of validation activities for a high resolution model of a particular process will be used to support validation activities of a more aggregate model representing the same process.

p. A brief summary of the accreditation status of a model (in one or more of the categories of paragraph 5h) used or proposed for use will be included in an Army Independent Evaluation Plan (IEP), Test Design Plan (TDP), Test and Evaluation Plan, Test and Evaluation Master Plan (TEMP), final study briefing, or final written study report.

q. Resources required to perform V&V and accreditation of models will be identified in Command Operating Budget (COB) submissions.

r. Army goals, objectives, and plans for model V&V and accreditation will be disseminated throughout the DoD community. Inconsistent information provided to organizations external to the Army will undermine improvement efforts. Comments or problems concerning credibility of an Army model will be brought to the attention of the model's "accreditation proponent" (as defined in Enclosure 2) for resolution.

6. PROCEDURES.

a. V&V. Useful V&V procedures are shown in Enclosure 4. For a number of reasons--variety of model applications, diversity of levels of detail, and limitations on time and resources--selection of V&V procedures and associated acceptability criteria for a particular model will often require tailoring. Procedures are suggested for each of the life cycle stages of model development. For a model that has reached the application and post-deployment software support (PDSS) stage and for which V&V activities have been performed to only a limited extent (or not at all), many of the procedures listed under earlier life cycle stages may have to be applied.

b. Accreditation. Useful procedures for performing accreditation are listed below. Again, selection of the procedures and associated acceptability criteria will often require tailoring. In addition to a decision regarding acceptability, accreditation activities may also provide recommendations for enhancements to the model; this is especially appropriate if the model is judged non-accredited (i.e., unacceptable).

(1) Review of model documentation.

(2) Review of V&V documentation (plan and report).

(3) Review of how input data and scenario data are used or modified internal to the model.

(4) Review of configuration control and enhancement procedures.

(5) Recognition of the extent to which major components of the model have been validated.

(6) Recognition of previous successful applications of the model for similar purposes.

(7) Recognition of acceptance by users.

c. Initial accreditation.

(1) Current model. To permit initial accreditation of all models requiring accreditation (i.e., models in one or more of the categories of paragraph 5h), an initial time-phased program of accreditation will be conducted by appropriate accreditation proponents (Enclosure 2, paragraph 11). Within three months of

publication of this memorandum, each Army agency that is the accreditation proponent for one or more of the models requiring accreditation will prepare a list of such models (with associated types of applications; and associated model versions, if appropriate) and submit it to MISMA. Enclosure 3 offers an initial list for such purposes; however, that list requires careful review from the following perspectives: what organization is the proper V&V proponent for each model, which models require accreditation (additions or deletions may be appropriate), and what organization is the proper accreditation proponent for each model. Within the subsequent three months, each such agency will develop a one-time-only, time-phased plan (including acceptability criteria) for initial accreditation of those models, and submit the plan through MISMA for approval by the Army Models Committee. (It is recognized that use of a model may be necessary before initial accreditation activities are completed.)

(2) Future model. Subsequent to distribution of this memorandum, if a newly developed or existing model is proposed for first use in one of the types of applications listed in paragraph 5h, then an accreditation proponent will be identified (in accordance with Enclosure 2, paragraph 11), and that proponent will prepare and forward an accreditation plan (including acceptability criteria) through MISMA for approval by the Army Models Committee.

d. Subsequent accreditation. A model that has been judged accredited for a particular type of application is subject to re-accreditation when it is proposed for a new type of application, when a new reference version is released, or when the Army Models Committee determines that a sufficient period has passed to necessitate accreditation activities to be performed again. As always, accreditation will be preceded by preparation of a plan and forwarding it through MISMA for approval by the Army Models Committee. A model that has been judged non-accredited (i.e., unacceptable) for a particular type of application is subject to accreditation as soon as appropriate changes have been made to the model.

7. RESPONSIBILITIES.

a. V&V responsibility. The Army agency responsible for performing V&V for a particular Army model is the "V&V proponent" as defined in Enclosure 2. The V&V proponent may seek the assistance of another agency; e.g., the developer if a different agency, or agencies with functional area expertise. If the V&V proponent is the same as the model developer (or is the single

model user), then in order to foster objectivity, independent input to the V&V process should be sought from other elements of the agency or from other agencies. V&V proponents for selected models are suggested in Enclosure 3.

b. Accreditation responsibility. The Army agency responsible for accreditation of a model is the "accreditation proponent" as defined in Enclosure 2. The accreditation proponent prepares an accreditation plan (including acceptability criteria) and is the approval authority for accreditation. The accreditation proponent chooses the agency that is to provide the technical and administrative justification of the accreditation decision. Frequently, the agency providing that justification will be the same as the V&V proponent. The accreditation proponent will be different from the developers and users of the model, and generally at a management level higher than the V&V proponent. Accreditation proponents for selected models are suggested in Enclosure 3.

c. Guidance and approval. The Army Models Committee will provide guidance on V&V and accreditation. The Committee will approve accreditation plans (paragraph 6c and 6d). Annually, the Committee will review the list of models requiring accreditation and their accreditation status, and make recommendations for additional accreditation activities. If a model requiring accreditation has been judged non-accredited (i.e., unacceptable) for a particular type of application and is proposed for use for such an application, then a written request must be forwarded to, and written approval obtained from, the chairperson of the Committee.

d. Monitoring. The MISMA will coordinate accreditation plans (see paragraph 6c and 6d). Annually, the MISMA will publish a list of models requiring accreditation and their accreditation statuses (with associated types of applications).

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Encls

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REFERENCES

The following documents are referenced in the main body of the memorandum:

1. Regulation, AR 5-11 (Army Model Improvement Program), 15 August 1983.

2. Report, Defense Science Board, "Report of the Defense Science Board Task Force on Computer Applications to Training and Wargaming", May 1988.

3. Report, Army Science Board, "Ad Hoc Subgroup on the Use of Army Combat Models for the Analysis and Training of Joint/Combined Operations", January 1988.

4. Report, Army Science Board, "Final Report of the Ad Hoc Subgroup on the Use of Army Combat Models for the Analysis and Training of Joint/Combined Operations", August 1987.

5. Report, U. S. Army Audit Agency, "U. S. Army Training and Doctrine Command Analysis Command - White Sands Missile Range, New Mexico", Report SW 88-10, 12 May 1988.

6. Report, U. S. General Accounting Office, "Guidelines for Model Evaluation", GAO/PAO-79-12, 1979.

7. Report, U. S. General Accounting Office, "DoD Simulations: Improved Assessment Procedures Would Increase the Credibility of Results", GAO/PEMD-88-3, 29 December 1987.

8. Memorandum, Joint Chiefs of Staff Basic Policy Guidance on Modeling and Wargaming, SM-82-89, 31 January 1989.

9. Memorandum, Commander, TRADOC Analysis Command, ATRC, 4 April 1988, subject: Peer Group Review of Army and Joint Models.

10. Document, Director, Defense Operational Test and Evaluation, "Policy for the Application of Modeling and Simulation in Support of OT&E", 24 January 1989.

11. Regulation, AR 350-38 (Training Device Policies and Management), 15 October 1984.

12. Directive, DoDD 7920.1 (Life-Cycle Management of Automated Information Systems (AISs).

13. Standard, DoD-STD-2167A (Defense System Software Development), 29 February 1988.

14. Draft handbook, DoD-HDBK-287 (A Tailoring Guide for DoD-STD-2167A Defense System Software Development), 14 November 1988.

15. Regulation, AR 70-37 (Configuration Management), 1 July 1974.

16. Regulation, AR 25-1 (The Army Information Management Program), 18 November 1988.

17. Regulation, AR 25-3 (Army Life Cycle Management of Information Systems), 9 June 1989.

18. Pamphlet, U. S. Army Materiel Command, AMC-P 702-xx (Software Quality Requirements for Software Systems Development and Production), January 1985.

19. Letter, Commander, TRADOC Analysis Command, ATRC-RPP, 10 March 1987, subject: Policy Letter for Models Configuration Control and Documentation.

20. Regulation, AR 381-11 (Threat Support to U. S. Army Force, Combat, and Materiel Development), 14 April 1986.

DEFINITIONS

The following definitions apply to the main body of the memorandum:

1. Model. An abstract representation of a real-world entity (object, system, activity, or situation), including, as appropriate, subsystems and their interrelationships. For this discussion, a model is further restricted to one that is implemented as a computer program.

2. Simulation. A model that represents activities and interactions over time. A simulation may be fully-automated (i.e., it executes without human intervention), or it may be interactive or interruptible (i.e., the user may intervene during execution).

3. Type of model characterized by frequency of use.

a. *Ad hoc model*. A model that is developed to address a single, specific issue.

b. Standing model. A model that is developed to address a generic class of problems and is maintained on a continual basis to support multiple or recurring applications.

4. Verification. The process of determining that a model accurately represents the developer's conceptual description and specifications. In a large-scale model development, verification is applied at each stage to ensure that the products of that stage accurately implement the specifications from the previous stage.

5. Validation. The process of determining that a model is an accurate representation of the intended real-world entity from the perspective of the intended use of the model.

6. Configuration management. A discipline applying technical and administrative oversight and control to identify and document the functional requirements and capabilities of a model, control changes to those capabilities, and document and report the changes. Configuration management includes ensuring that the detailed design and the computer source code of the model are properly documented. (This definition and the next one have been adapted from AR 70-37, reference 15).

7. Configuration control. That element of configuration management that involves the systematic evaluation, coordination, approval or disapproval, and implementation of changes to the model source code. Included activities are--

a. Maintaining the reference version of the source code.

b. Controlling changes to the reference version and dissemination of those changes.

c. Ensuring that documentation of the model is up-to-date.

8. Accreditation. Certification that a model is acceptable for use for a specific type(s) of application(s). Accreditation is approval by management--based on experience and expert judgement--that a model is adequate for its intended use. The accreditation mechanism recognizes that V&V of a model are continual processes and that full validation of the model may not be technically or economically feasible. Hence, accreditation is possible even if the model is not fully validated. However, accreditation does not lessen the need for continuing to work toward full V&V.

9. V&V documentation. Documentation of V&V activities includes a written assessment plan and a written report.

a. Plan. The assessment plan has two components.

(1) Management plan. This component describes the tasks, schedule, and (personnel and computer) resource requirements.

(2) Analysis plan. This component describes scope, limitations, constraints, techniques to be employed, types and sources of data to be collected, and acceptability criteria.

b. Report. The report documents V&V activities and includes the following: brief descriptions of the real-world entity to be represented, intended purpose of the model, and design requirements; description of V&V activities performed; extent to which model meets acceptability criteria; and recommendations.

10. V&V proponent. The Army agency responsible for performing V&V on a given model (and version of the model, if there are multiple versions). The V&V proponent may seek the assistance of another agency; e.g., the developer if a different agency, or agencies with functional area expertise. Which agency is the V&V proponent depends on whether the model is in development or has been previously developed, who is developing (or developed) the model, who is using it, and who is maintaining it. The following cases apply:

a. Model that is under Army control and for which the Army V&V proponent has been established previously. That agency is responsible for V&V. Examples are the members of FAMSIM.

b. Model for which the Army V&V proponent has not been established, and that is being developed in-house by, or that is being developed under a contract sponsored by, an Army agency. The developing (or sponsoring) Army agency is responsible for V&V.

c. Previously developed model that is under Army control, for which the Army V&V proponent has not been established, that is in use by the Army, and that has a single Army agency as the user and maintainer. That agency is responsible for V&V.

d. Previously developed model that is under Army control, for which the Army V&V proponent has not been established, that is in use by the Army, and for which the Army user agency is different from the maintaining agency or for which there are multiple Army user agencies. The configuration control (users') group, if it exists and is under Army control, is responsible for V&V. Otherwise, the primary Army user is responsible.

11. Accreditation proponent. The Army agency responsible for accreditation; in particular, for setting acceptability criteria and being the approval authority. The cases below determine which agency has this responsibility.

a. Model that is or will be used by the Army. The Army agency that is or will be the primary customer of the analysis products of the model has accreditation responsibility. For a model developed and used by an FFRDC or contracting firm in a major study sponsored by the Army, the Army sponsor is the accreditation proponent.

b. Model that affects the Army, that is not under Army control, and that is not used by the Army. The Army agency that is the proponent for the appropriate mission area, function, or activity has accreditation responsibility.

MODELS SUITABLE FOR V&V AND ACCREDITATION

Below is a list of models suitable for V&V and accreditation. Several notes and caveats apply--

a. The models are only examples; i.e., the list is not all-inclusive. Furthermore, the designation of V&V proponent, identification as accreditation candidate, and designation of accreditation proponent, are subject to review and update. In particular, where a model is not identified as an accreditation candidate, the implication is that the model does not fall under a category of paragraph 5h of the memorandum and hence is not subject to accreditation (at least for the memorandum). If the model is in fact in one of the categories of paragraph 5h, then an accreditation proponent must be identified in accordance with Enclosure 2, paragraph 11.

b. Examples are not repeated. For instance, JANUS(T) is used for major Army COEAs, and thus is shown under first category. JANUS(T) is also used for training, testing, and education, but is not shown under those categories.

c. Where a V&V proponent is not designated, the Army does not control the model and hence cannot designate what organization is to perform V&V. In such a case, however, an Army accreditation proponent is identified. Where the model is developed and used by an FFRDC or contracting firm in support of a major Army study, the Army sponsor is the accreditation proponent.

CATEGORY OF MODEL	VERIFICATION AND VALIDATION CANDIDATE	VERIFICATION AND VALIDATION PROPONENT	ACCREDITATION CANDIDATE	ACCREDITATION PROPONENT
Model used for major Army COEA	ADAM		Yes	CAC
	BASEWAM		Yes	CAC
	CARMO	TRAC	Yes	CAC
	CASTFOREM	TRAC	Yes	CAC
	CISCIAD	USAADASCH	Yes	CAC
	COMO	USAADASCH	Yes	CAC
	CORBAN	TRAC	Yes	CAC
	DC2M		Yes	CAC
	EAGLE	TRAC	Yes	CAC
	ELAN	TRAC	Yes	CAC
	JANUS(T)	TRAC	Yes	CAC
	LDM	USALOGC	Yes	ODCSLOG
	TAFSIM	USAFAS	Yes	CAC
	TANK WARS	USAARMC	Yes	CAC
	VIC	TRAC	Yes	CAC

CATEGORY OF MODEL	VERIFICATION AND VALIDATION CANDIDATE	PROPONENT	ACCREDITATION CANDIDATE	PROPONENT
Model used for major Army PPBES study	AFP	CAA	Yes	ODCSOPS
	CEM	CAA	Yes	ODCSOPS
	FASTALS	CAA	Yes	ODCSOPS
	FORCEM	CAA	Yes	ODCSOPS
	WRAP	AMSAA	Yes	HQ AMC
Model developed and used by FFRDC or contractor	TACSAGE		Yes	CAA
	TACWAR		Yes	USAWC
	RSAS		Yes	USAWC
Training simulation	ARTBASS	TRAC	Yes	CATA
	ASSAULT	USALOGC	Yes	CATA
	BBS	TRAC	Yes	CATA
	CCTT	TRAC	Yes	CATA
	CSSTSS	TRAC	Yes	CATA
	DBIT	TRAC	Yes	CATA
	FB:B-C	TRAC	Yes	CATA
	TACSIM	TRAC	Yes	CATA
Joint model	JESS	TRAC	Yes	CATA
	JTLS		Yes	USAWC
	Joint Warfare System		Yes	
	SOTACA		Yes	USAWC
	TAM		Yes	
Model used for testing	ADATS (6-DOF)	MICOM	Yes	HQ AMC
	ALWSIM III	LABCOM		
	AMM	TACOM	Yes	HQ AMC
	ARTQUIK	JTCG/SS		
	AURA	BRL	Yes	LABCOM
	DBNUSSE	BRL	Yes	LABCOM
	EIEM	TECOM		
	EVADE II	AMSAA		
	GAMES I	AMSAA	Yes	HQ AMC
	GIFT	BRL	Yes	LABCOM
	HEAT	ARI		
	HELMATES II	AMSAA	Yes	HQ AMC
	HWIL	MICOM	Yes	HQ AMC
	IEW/FAM	TRAC	Yes	CAC
	MOSES II	AMSAA		
	MSE PAM	EPG	Yes	TECOM
	PARACOMPT	BRL	Yes	LABCOM
	REGSIM	AMSAA	Yes	HQ AMC
	RMP (6-DOF)	MICOM	Yes	HQ AMC
	SAMSMAE	AMSAA	Yes	HQ AMC
	SAMSITE	AMSAA	Yes	HQ AMC
	SESAME	AMSAA	Yes	ODCSLOG
	TARMS II	CAA	Yes	ODCSLOG
	VAST	BRL	Yes	LABCOM

CATEGORY OF MODEL	VERIFICATION AND VALIDATION CANDIDATE	PROPONENT	ACCREDITATION CANDIDATE	PROPONENT
Decision support system	ALBM	CACDA		
	BDEPLANNER	TRAC		
	Force Builder	USAFISA	Yes	ODCSOPS
	Organize the War	CAA	Yes	ODCSOPS
	SABRE	PAED		
	TAEDP	LEA	Yes	ODCSLOG
	TOPSIS	PERSCOM	Yes	PAED
Education model	*TBD*	*TBD*		

V&V PROCEDURES

Useful V&V procedures are shown here, categorized by the life cycle stage of the model. For the purposes of V&V, the life cycle of a model is described here in terms of the stages identified in AMC-P 702-xx (reference 18). An alternate decomposition of the life cycle, applicable to the procurement of information systems and found in AR 25-3 (reference 17), is not used here.

1. Life cycle stage. Model concept.

Basic description. The entity to be represented, the purpose of the model, and the general approach to representing the entity are described.

V&V procedures. Develop an understanding of the real-world entity to be represented. Assess the adequacy of the planned representation.

2. Life cycle stage. Requirements definition.

Basic description. Functional, operational, interface, and performance requirements are defined.

V&V procedures. Assess the extent to which requirements match the intended real-world entity. Initiate the written V&V plan. Establish acceptability criteria.

3. Life cycle stage. Preliminary design.

Basic description. The overall architecture of the model is defined. Technical approaches are described.

V&V procedures. Review the architecture and theoretical foundations to assess the adequacy of the preliminary design against requirements. Review the types and formats of required input data for appropriateness and availability. Update the V&V plan. Initiate the written V&V report.

4. Life cycle stage. Detailed design.

Basic description. The architectural design is refined. Embedded algorithms are described.

V&V procedures. Review the architecture, theoretical approaches, embedded algorithms, and underlying assumptions to assess the adequacy of the detailed design against the preliminary design. Review the representation of threat doctrine and tactics. Update the V&V plan and report.

5. Life cycle stage. Coding.

Basic description. The model is converted to computer source code.

V&V procedures. Review the source code to assess the adequacy of the code against the detailed design. Included here are techniques such as a structured walk-through, line-by-line code review, and inclusion of computer-generated warning messages and review of the results of such messages. Perform test runs (of components and of the complete model) to compare the results of the model with those known of (or anticipated of) the real-world entity. Update the V&V plan and report.

6. Life cycle stage. Testing.

Basic description. The model is tested for acceptability.

V&V procedures. Review input data for accuracy and completeness. Perform test runs, and subsequently examine program logic flow, data values internal to the model, output data generated by the model, results of computer-generated warning messages, and graphical displays of computer output. Determine the sensitivity of output data to input data. Compare output data with real-world data (including historical data); output data from validated models; test, exercise, and training data; and operations data. (Other models and data from tests and exercises are most useful for "calibrating" the given model; i.e., making adjustments to input data or model logic to obtain closer agreement with an external index.) Update the V&V plan and report.

7. Life cycle stage. Application and post-deployment software support (PDSS).

Basic description. The model is applied, and is updated to account for changes in the real-world entity being represented or to incorporate representations of additional entities.

V&V procedures. Perform additional V&V activities. Appropriate procedures include those listed under testing plus peer review by an outside panel of experts. Update the V&V plan and report.