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TRANSFERABILITY OF COMBAT MODELS; LIMITATIONS IMPOSED BY DOCUME--ETC(U)

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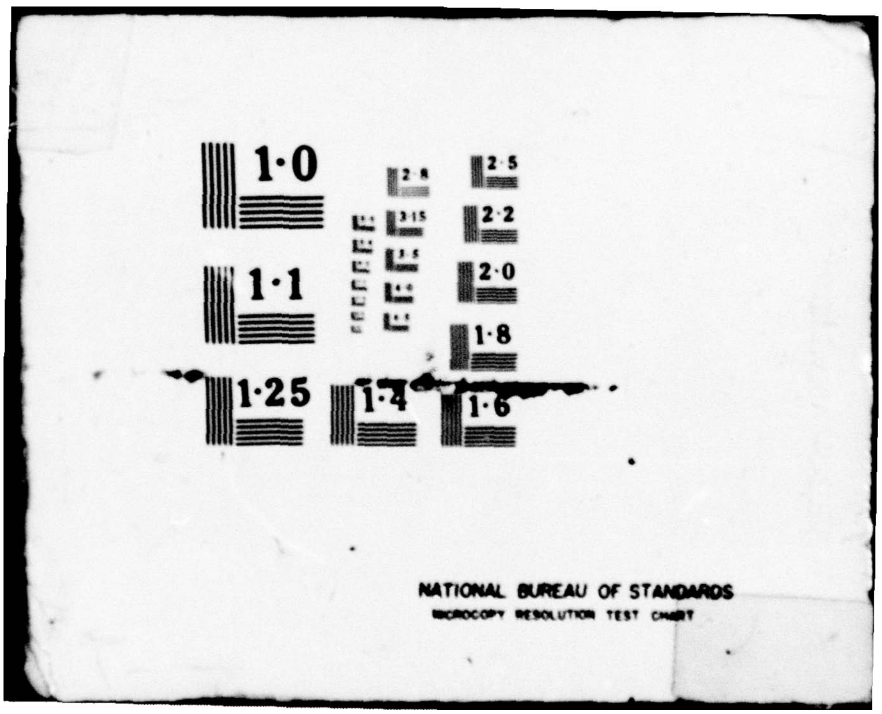
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DOCUMENTATION PRACTICES.

by

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This thesis proposes a hierarchy of documentation for combat models. It begins by examining criticisms and credibility of combat models to establish underlying causes and effects, and then it addresses model proliferation and ever increasing complexity as they affect one's ability to understand and transfer models. A methodology for determing whether or not a model is applicable to a specific problem

is presented, as are examples of potential problem areas. Current documentation practices are examined for conditions that limit the transferability of models and contribute to the credibility problem. The above examinations have lead to a proposed three-tier hierarchy of documentation, including for the analyst documentation that is presented from the context of discovery rather than from the traditional context of justification. Recommendations are made for supplemental studies to examine related issues.

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TRANSFERABILITY OF COMBAT MODELS: LIMITATIONS IMPOSED BY DOCUMENTATION PRACTICES

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ABSTRACT

This thesis proposes a hierarchy of documentation for combat models. It begins by examining criticisms and credibility of combat models to establish underlying causes and effects, and then it addresses model proliferation and ever increasing complexity as they affect one's ability to understand and transfer models. A methodology for determining whether or not a model is applicable to a specific problem is presented, as are examples of potential problem areas. Current documentation practices are examined for conditions that limit the transferability of models and contribute to the credibility problem. The above examinations have lead to a proposed three-tier hierarchy of documentation, including for the analyst documentation that is presented from the context of discovery rather than from the traditional context of justification. Recommendations are made for supplemental studies to examine related issues.

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I. BACKGROUND AND INTRODUCTION

A. BACKGROUND

Motivation for this thesis was initially provided by Professor James G. Taylor, who wanted to use an existing fully operating large-scale combat model as a teaching vehicle in a combat-modelling course in the Operations Analysis Curriculum at the Naval Postgraduate School (NPS). The original plan was to acquire the ATLAS (A Tactical, Logistical, and Air Simulation) model from the U. S. Army's Concepts Analysis Agency, convert it for use on the NPS IBM 360 computer and develop a manual for the setup and running of the model as part of the course. Then the attrition and movement routines of the model were to be analyzed as a formal thesis.

The project was especially appealing to the author because it conformed with a fundamental belief of his, that rather than developing new models if an existing model is appropriate for a given analysis it should be acquired and used. The concept is not original but was based on recommendations of the Army Models Review Committee. [1] Acquisition and use of ATLAS at the NPS would be an application of the recommended concept of transferring an existing model whenever its use is feasible.

In late Feb. 1979, the ATLAS model arrived via a magnetic tape, and the author proceeded to execute the above plan. After the expenditure of about four man-months of effort by the author and computer center programmers and 190 minutes of CPU time, ATLAS was successfully compiled and linked. This expenditure of effort was greatly in excess of the expected time to complete the task, given that the model has been in existence for ten or more years and is considered to be "simple" compared with other theatre-level models. Why had its transfer required such expenditure of effort?

In reflecting upon the above question, the author realized that even though a model may have been used for many years, its transfer can still be hampered by limited documentation. This thesis will relate the author's experience with ATLAS and his subsequent investigation of how documentation limits the transfer of existing models between agencies. It will also examine the related problems of model complexity, proliferation, credibility, transparency, and transferability. Based on this examination and the experiences of the author during seven years of operation research related assignments, a new concept of documentation to improve the transferability of combat models is proposed.

B. DEFINITIONS

In research conducted for this thesis the author discovered that in modeling the same word can have many connotations. For purposes of clarity the author adopted the definitions of modeling terms listed in the glossary of Ref. 1. This does not imply that they are the only or best definitions, they are only used as a point of departure.

Within the following text there will be references to combat models, theatre-level, large-scale, and small-scale models. For purposes of the remarks, discussions, and recommendations contained herein, the words can be considered synonymous. Since the initial impetus for the thesis concerned work with a theatre-level model this term readily crept into the author's dicussion. However, all these forms of models are just subsets of the concept of a combat model. What is addressed throughout the thesis is combat modeling. Particular comments referring to one of the subsets are just as applicable to combat models as a whole.

Although some remarks are addressed to the DOD, others to the Department of the Army, each is applicable to the other as well as the other services. The discussions, conclusions, and recommendations are equally applicable to other complex models as well as models in general.

C. MODELING AND MODELS

What is modeling? According to Morris [2] modeling is an intuitive process through which an analyst arrives at a model. On the other hand, a model is an inanimate object, an abstraction of reality [3], that is used by the analyst to answer questions about some future state of a process. This differentiation between modeling and a model is necessary to understand the implications of the facts presented and the conclusions drawn in this thesis.

To develop a model, the modeler goes through a process of discovery. This process is the trial and error procedure in which the designer tries to abstract the key elements of reality. Once he has done this and validated his model, the logical reconstruction of events leading to the model are documented in the context of justification. This logical reconstruction has little if anything to do with the actual process followed in building the model. No attempt is made to verbalize the actual psychological process, the problems encountered, or dead ends pursued.

Over time the initial simple model proceeds through a process of enrichment or elaboration. Through this process the model is modified and moved in evolutionary fashion toward a more elaborate representation of reality; in the process the model becomes more complex as it seeks to reflect the complexity of the reality it represents. Each time the model is enriched the reasons why and how it is enriched should be documented. For a discussion of the modeling process see Ref. 2.

D. INTRODUCTION

Since ancient times military planners have used wargames to investigate various aspects of possible future military operations. Historical development of war games can be found in Ref. 4 or other histories of war games in the open literature. The oldest known form of the wargame is a Hindu chess-like game called "Chaturanga". Modern war games had their beginning in 1664 thru the games developed by Christopher Werkmann called military chess. In the twentieth century the greatest proponent of war games till the end of WWII was the German Army. Through the development of the digital computer during the war a new facet of wargaming became possible. The use of the computer greatly reduced the time and effort required to conduct a war game. Computer assisted or computer run war games provide a means of gaining insights and experience in military problem solutions. [5] These computer war games help evaluate new weapons systems, study current and proposed military organizations and investigate the possible outcomes of future conflicts given particular weapons, organizations, tactics, and enemy forces. The basis of such computer wargames is the combat model. Although there are many military applications of combat models, this thesis is primarily concerned with those applicable to military strategy and force planning.

Military strategy and force planning has matured since WWII. Prior to WWII military technology evolved slowly; those responsible for strategy and planning could easily gain all the necessary knowledge about the relationship of military forces and weapon systems to national security from books or personal experience. Within one lifetime the amount of technological change was not sufficient to render experience invalid. The military did not plan on technological change; it merely adjusted to it.

During and subsequent to WWII, the rate of change of military technology began to increase in an almost exponential manner. A lifetime of experience could became obsolete in a few years; now mere adjustment to change was not sufficient, the military had to plan for change. This revolution in technology was incubated and nurtured by the advent of the digital computer: to keep pace with technology and its impact on strategy and force planning the digital computer was adopted as a planning tool. With it the means to assess and adapt technological change and incorporate it into military strategy and force planning was possible. [6]

Modern day force planning has become largely an analytical process that necessarily employs the digital computer. The digital computer has been incorporated into many of the myriad aspects of military planning and decision making in order to provide a scientific basis to these activities. In this thesis, the computer is considered only as a computational aid for combat models. The outputs of these models are used as aids to decision makers. Strategy and force planning depend primarily on large-scale combat models, which due to their complexity require the use of digital computers. Models can be of various types or classes; there is no agreed upon system of classification. Discussions of classification of combat models are contained in the literature. [3,7 8] This study is concerned with large scale computer simulations and analytical models as defined in Ref. 3.

E. SUMMARY

This chapter has discussed the background of this thesis, and it has provided some basic definitions and a general history of combat modeling to the present. Subsequent chapters will now address the following important aspects of models used for defense planning: criticism and credibility; proliferation, complexity and transparency, and requirements to transfer a model. Next a common element of each chapter, lack of adequate documentation, is identified as a contributing cause to each of the conditions discussed. This is followed by a proposed concept of documentation that will alleviate many of the problems discussed in this thesis.

II. CRITICISMS AND CREDIBILITY OF COMBAT MODELING

A. CAUSES OF CRITICISM

Critics and criticism of defense analysis and its tools, of which modeling is just one, are ever present. Criticism has not abated since the early sixties; it continues to the present and threatens funding, the life blood of analysis, in the Department of Defense. Informed private citizens and activitists groups have attacked the propriety of defense analysis and DOD decisions based on analysis. The poor public image was cited as a contributing factor to the poor reception of analysis in Congress. Because of seeming inconsistencies in analysis, Congress has become skeptical and disenchanted and has questioned the utility of analysis. [9]

According to surveys and studies conducted early in this decade [10] activity and expenditures on gaming and simulation peaked in the middle 1960's and were on a slight decline since then. These investigations indicated that machine simulation had generally been oversold and at that time Operations Research and modeling were undergoing a critical self-examination. [11] The criticisms were many and encompassed a wide variety of cause and effect relationships. Those of relevance to this study revolve about the inter-related areas of transferability, complexity, proliferation and documentation.

As the use of combat models increased, so did their initial acceptance and importance, and in turn the complexity of these models has also increased. Complexity has manifested itself in various forms: inputs, types of models, language, detail of actions and conditions simulated, simulated decision making and computing machines. Eventually the complexity of existing models, poor transparency, and difficulty of transferability caused numerous models to be developed that modeled the same or very similar combat phenonema. Unfortunately, at this juncture in the development of combat models (late 60's, early 70's) criticism and dwindling credibility occurred. This came about because for reasons not easily recognizable or understandable to decision makers, models supposedly modeling the same combat process under the "same" conditions produced different and at time conflicting results.

Analysis implies rigor and association with the scientific method, yet standards seemed to have waned; strict adherance to standards of scientific rigor and discipline were less than tenacious. Often analyses and models produced had methodological flaws. Often these flaws were not discovered until after an analysis had been accepted and decisions made. In studies involving models, one of the contributing factors to this situation was lack of detailed understanding of the model. Other contributing factors were the pressure of time and limited distribution. In the rush to meet deadline the quality of the work was often sacrificed. By not distributing a study or model to other agencies the extra set of eyes that can see a fatal flaw through an unbiased view were never used.

The use of more than one model has often resulted in decision makers being confronted by seemingly contradictory results of different analyses using different models addressing the same problem. No wonder that they have the impression that the models and methods used by analysts may not be very objective guides. Yet most analysts will argue that a detailed comparison of models, their assumptions, inputs and calculations, show that the results are not really contradictory. Differences in outputs are usually the direct result of differences in assumptions and methods of processing the input data. This in turn presents the analyst with two challenges: First, he must recognize and understand these seeming contradictions, and then he must resolve and convey to the decision maker these differences. Dr. Wilbur B. Payne, former Deputy Undersecretary of the Army for Operations Research speaking from the point of view of the decision maker who tries to draw valid conclusions from analyses that use such models, has argued that he has frequently seen such apparently contradictory results coming from various models addressing essentially the same problem. Furthermore, the decision making process in large organizations is such that the detailed comparison , if it is ever done , and resolution of seeming conflicts usually does not reach the decision maker. Hence, the decision maker is left with the conclusion that simulation results are not consistant and therefore of dubious reliability. [12]

Contradictory results of combat models is a factor cited by Huber [12] that has caused the very credibility of combat modeling to be questioned. Under ideal conditions a model should be directly connected with a continuing experimental program and should reasonably relate to other models that simulate the same or similar processes. The user must be especially watchful in this respect because the combat process does not easily lend itself to establishing a continuing experimental program. Many combat models are neither built nor used with any forethought given to their connection to other models. Each generally turns out to be a totally independent data generator. This precludes any meaningful experimental feedback in the on-going prediction process and results in a mass of unrelated and often contradictory data generated by many models.

The Army Models Review Committee report was the seminal publication on theatre-level combat models for the seventies. From it sprang a decade of proposals and counter proposals concerning theatre-level combat models. However, if one scrutenizes the literature of the previous decade a feeling of deja vu surfaces. Many of the ideas and arguments sounded in the seventies are in the literature of the sixties. For an example of the problems foreseen and warnings given, see Ref. 13.

B. IMPORTANCE OF ASSUMPTIONS

One of the key facets of any model is the assumptions that go into its development. The importance of assumptions whether in models or otherwise was recognized early in the development of systems analysis. When Mc Namara was Secretary of Defense, a continuing effort was made to insure assumptions incorporated into models were both explicit and consistent. Whether comparing force structure or strategy, Mc Namara considered it possible to select assumptions that will make any proposed weapon system or organization look optimal. [6] Likewise, experience has shown that there is no single "right" set of assumptions. There exists an almost infinite set of assumptions each more or less defensible. What is important is that the assumptions used in various submodels of a model are consistent. A model should not operate with one set of underlying assumptions in one submodel, while another submodel operates with a fundamentally different set.

Because there is no emperical data concerning modern large scale combat, analysis is relied upon to produce insights into the effects of existing or proposed weapons, force structures, and strategies. Using theatre-level combat models, the analyst can examine proposed weapons and force structures and possible outcomes can be forcast. Studies in the DOD [6] have shown that when alternative force structures and weapons are examined using different models, it is difficult to determine whether differences in outcomes are due to differences in weapons and organizations or assumptions and models used. Confusion can be reduced if each alternative is examined in a consistent manner by using the same model and assumptions. Differences that occur can then be attributed to the basic structure of the force options. The results can then be analyzed and understood in light of the method of calculation (i.e. the model) used and its inherent assumptions. Greater insights into the effects of weapon and force structure alternatives on combat outcomes can be gained by repeating the experiment using an alternative model.

When more than one model is used for the same force structure analysis often different results are obtained. These different results are caused by the different inherent assumptions of each model. If these assumptions are known informed discussion can take place because differences can be resolved through evaluation of the assumptions. If the assumptions are valid and acceptable, then the results must be accepted as the logical consequence of the assumptions. Assumptions considered to be unacceptable by decision makers can be eliminated by modifying the model. What quickly becomes evident is that a model produces a result based on its inherent assumptions; an equally defensible but different set of assumptions used in a model will produce another result, which may or may not be the same.

The DOD is quite aware of this aspect of modeling and has emphasized that there is more than one set of assumptions that can be used with a given model. It requires that all parties to the decision making process be aware of all assumptions leading to a result. To achieve this goal the DOD has required that all assumptions be explicit, reasonable, and consistent. This requires ferreting out hidden assumptions in models and insuring that the model indeed models what it claims to model. For interesting examples of the importance of assumptions see Ref. 6.

C. MODEL EVALUATION

Many solutions to the problem of model evaluation have been recommended; one concept suggests the use of full time dedicated independent reviewers as a way of improving the mechanics of quality control. [1] A reviewer provides a means through which the analyst's model is scrutinized; the assumptions and methodology are checked for internal consistency, unwarranted inferences, and clarity of presentation so that a determination can be made whether or not the model is a plausible representation of the real world. If it is a large complex model, the methodology should be clear, even to the point of sample calculations to guide the reviewer and analyst through the algorithms. Equally important is that input data and assumptions be explicit. If unnecessary proliferation is to be avoided, existing models must be made understandable to potential users and evaluated in some manner. It should not be necessary to create a new model just because an existing model could not be transferred or understood due to inedquate documentation.

In his study, Gass [14] proposes an elaborate approach to evaluation of complex models. Therein he highlights the need for model implementation and maintenance procedures as well as documentation of the model and the total modeling process. Suggested documentation of the process includes describing model objectives, assumptions, results, data sources, recommendations, etc. With such documentation the model can hopefully be evaluated and analysts can determine whether or not the model is valid for the problem at hand. However, Gass found that for most complex computer models, organizational exigencies and real-world pressures do not enable modelers to develop the necessary documentation.

Gass has stressed the need to validate models at three distinct levels, technical, operational, and dynamic. Technical validity is an assessment of model, data, logical, mathematical and predictive validity. Operational validity is an assessment of errors and divergences found under technical validity and the robustness of the model (i.e. whether or not the model can produce bad answers for proper ranges of parameter values). Dynamic validity is the method by which the model will be maintained during its life cycle so that it continues to be an acceptable representation of the real system. It includes the process through which the model structure is changed and validated. The ability to accomplish such validation will facilitate and enhance the use of models by anaylsts and decision makers other than those directly responsible for the development of the model. Fundamental to this process is detailed understanding of the model.

D. SUMMARY

If a model is to be of value it must be accepted by the decision maker. It is incumbent upon the analyst to provide the means of acceptance. Sufficient documentation must be provided by the model designer to enable the analyst to understand its methodology and structure. Key to credibility is objective evaluation. Documentation must provide insights into the assumptions and functioning of a model, so that it can be evaluated. Understanding and evaluation are complicated by complexity. Complexity and insufficient documentation can cause analysts to design new models rather than use an existing model. The existence of inadequately documented models describing the same reality is the basic cause of the criticism and lack of credibility of combat models. The next chapter will discuss complexity and how and why it contributes to unnecessary proliferation.

III. PROLIFERATION, COMPLEXITY, AND TRANSPARENCY

Unnecessay proliferation is the cause of some of the criticisms of combat modeling. Unnecessary proliferation means that a new model is created because inadequate documentation precludes the use of an existing model which otherwise would be adequate for the task at hand. Inadequate documentation either prevents understanding of the methodology and structure of the model or prevents the cost-effective transfer and conversion of the model from one agency and computing system to another. The latter condition is the one encountered by the author during the conversion of ATLAS. Better documentation would have significantly reduced the resources expended on the project. Futhermore, in a non-academic environment the demands of proceeding with an impending study would have encouraged analysts to develop a new model rather than struggle with poor or non-existing documentation.

Development of a new model can cause analysts to remodel a combat process using techniques and methodology that already exists; consequently funds are expended without advancing modeling. Irrespective of any advancements in techniques or improvements in methodology developed in remodeling an existing process, a major portion of the effort is devoted to redoing the basics. Time and money spent in redoing the basics are lost as far as improving models and modeling is concerned. In the DOD (especially the Department of the Army) there has been and continues to be a shortage of trained analysts. An obvious approach to alleviate this problem would be to eliminate any projects to develop models that would be redundant and share existing models. However, the ability to share a model is greatly influenced by its complexity.

When examining the practicality and feasibility of model sharing most emphasis has been placed on documentation. Huber [8] lists poor documentation and high personnel turnover as a prime reasons why models are not exchanged. The criterion used to determine whether or not a model is transferable is documentation sufficient to allow the recipient organization to be able to run the model without an inordinate amount of decoding and deciphering. Without adequate documentation the model is a puzzle to the recipient. Shubick and Brewer [10] found that few models exist in a sufficiently documented form that would satisfy commercial firm standards prior to distribution to their clientle.

A. PROLIFERATION AND HOW TO REDUCE IT

An area examined by the Comptroller General in 1974, [15] was sharing of computerized models. Models developed for specific purposes by one agency can often be used by other agencies for similar purposes. Applicability of models to new situations depends on their accuracy, purpose, validity, availability of sufficient documentation, and capability of the using analyst. The 1974 study surveyed 242 models that had a combined cost of over thirteen million dollars. An attempt was then made to obtain documentation for about one hundred randomly selected models deemed to have use at more than the originating agency. Information explaining the purpose, mathematical formulation, and operating instructions were not available for approximately one-third of the models. The survey identified the primary complaints of model users (programmers and analysts) as: operating instructions not available or not clear, hence, compounding the already difficult problem of preparing a model for use on a different computer; mathematics of the model not clearly explained, hence, restricting the understanding of the logic, capabilities and limitations of the model; sample inputs and outputs nonmatching or nonexistent or do not correspond with the sample data in documentation, hence, verification and validity of the model difficult to determine; flow chart explaining logic not provided or not current, hence, complex subroutines not easily understood. The investigation determined that benefits can be obtained by sharing computer models, however, before models can be shared adequate documentation must be prepared. Such documentation enabled the acquiring agency to determine whether a model met its needs and was the primary factor to successful conversion and operation of the model on a different computer. The potential for a cost-effective transfer is severely limited in the absence of adequate documentation. When such documentation is available to potential users of an existing model great savings are realized. An example was the transfer of a complex communications traffic analysis model from an Air Force agency on the West Coast to the Systems Development Command at Hanscom Air Field in Bedford, Massachusetts. [15]

Joint usage of existing models not only increases the availability of trained individuals to do further research and analysis, but it reduces the opportunity that different factions of the same organization are working at cross purposes. Conflicting concepts and proposals are necessary to vitalize an organization and make it viable, but developing a conflicting position that could be resolved prior to the expenditure of great sums of money and analytical talent is a waste. The sharing of a model or models between two conflicting agencies allows each to understand the underlying basis for their respective positions concerning an analysis of a decision making situation. While sharing may not resolve the conflict it certainly will preclude the expenditure of funds in the independent acquisition of information that is already available through the medium of an existing model. Sharing has eliminated retracing steps already taken and dead ends already discovered when applied in other fields , applied to combat modeling sharing will provide these minimal returns and has the prospective of providing even greater returns. If the basics are not reprocessed then more time and money is available for modifications to enhance the capability of an existing model, correct known deficiencies, or identify suspected deficiencies. Sharing has promise to improve the economies of modeling. [16]

Before sharing can be achieved certain basic conditiions must prevail. Five necessary conditions [17] to model sharing have been found. They are;

(1) a computer able to use the program with minimal modification;

(2) an adequate facility to run the model;

(3) adequate documentation of the original model;

(4) sufficient analysts with technical competence;

(5) formalized arrangements for sharing costs and responsibility for costs and coordination.

B. THE EFFECTS OF COMPLEXITY ON TRANSPARENCY

Complexity is a dichotomous issue in itself. Gass perceives an increasing use of more complex models [14], while Hardison, the Deputy Under Secretary of the Army for Operations Research at the 15th Annual US Army Operation Research Symposium called for less complexity. Disatisfaction of both senior military and civilian decision makers with complex models and studies was emphasized by Hardison. [18] These decision makers are convinced that Army models and the studies they support are too complex, elaborate the obvious, belabor needless details and overlook key issues. Timeliness is also affected by complexity. Failure to delimit results in failure to meet schedules which causes something to be sacrificed; often, in the case of models that something is adequate documentation.

A corollary of the complexity issue is that of transparency. If all the interactions of a model are to be understood by both the analyst and the decision maker it must be structured and programmed so that its methodology is easily understood. A model that fulfills this requirement is said to be transparent. At the 35th Session of MORS a leading cause of the general disenchantment with theatre-level models in recent years was attributed to a lack of transparency in most models. The proposed resolution to this problem was to include in the model only those interactions and factors that can be shown to influence the outcome. This in combination with mathematical formulation that is as simple as possible should produce the desired transparency. [19] Yet, at this same MORS session A.H. Cordesman OASD (Intelligence) in discussing theatre-level models remarked that models currently being developed go into unnecessary levels of detail in ways which seriously limit their value. This is partially caused by intermediate managers and decision makers requesting particular attributes be modeled. At times modeling efforts deviate from the maxim that only "essential" variables be modeled. As Morris [2] suggests, the purpose of a model is to include only those variables that characterize the process being modeled. At present diametrically opposed forces exist; while expounding the need to maintain models at a simple transparent level current modeling efforts go into details that detract from transparency.

A simple solution to the transparency-complexity problem may not be easily obtained. In spite of the professional rhetoric to the contrary, Gass [14] has found an increase in the use of complex models at all levels of government and industry. He attributes this to better trained analysts and the development and refinement of methodologies. Although simple models with readily understood assumptions, relationships and structure are preferred, Gass contends that decision making problem environments representative of the Federal Government sphere cannot be realistically or logically contained by simple models. Furthermore, senior decision makers generally do not possess a detailed understanding and appreciation of the methodologies employed in the various models employed to assist them in the decision making process. What is needed is a method through which the use and interpretation of the outputs of models by senior decision makers is facilitated. A model is usable only if it is understood and plausible to analysts and decision makers. They (particularly the decision maker) must be given the opportunity to explore the use of the model, become familiar with its predictions, and examine the relationships and assumptions implied by the model. In actuality the demands on their time generally preclude decision makers being involved at the detail levels implied above. Therefore, it is incumbent upon analysts to evaluate the models they use so that they are in a position to recommend to the decision maker to use or not use the outputs of a particular model. This implies intimate knowledge of the essence of a model.

C. SUMMARY

To reduce unnecessary proliferation and reduce costs the Comptroller General has recommended model sharing when feasible. Sharing a model requires:

- ability to use it with minimal conversion;
- adequate facilities to run the model;
- sufficient competent analysts and programmers;
- adequate documentaton;
- formalized arrangements for cost sharing and coordination.

Findings indicated that the great complexity of theatre-level models coupled with rapid turnover of personnel has resulted in models being used as "black boxes" with neither the computer technicians that run the model nor the analysts knowing explicitly what or how the model operated on the input data to provide the final results or output. Hence, the analyst was unable to adequately explain the results to the decision maker; with each occurence the credibility of modeling diminished. Concurrently models had proliferated to such a degree that the turnover of personnel exacerbated an already critical personnel shortage situation. Amelioration requires reduction of the number of models in use and detailed justification before developing a new model. [1] Reduction or the minimization of the growth of the model inventory implicitly requires that models be easily and quickly moveable from one using agency to another, i.e. posses transferability. Key to the resolution of the problems of complexity and transparency is documentation.

Complexity may be an unavoidable recourse of combat modeling because of the demands of managers and decision makers. Unless complex models are sufficiently documented to make them readily understandable and usable, analysts will create a new model. Rather than creating new models an atmosphere conducive to the sharing of models should be incouraged. Requirements to transfer a model are discussed in the next chapter.

IV. REQUIREMENTS TO TRANSFER A MODEL

The Review of Selected Army Models report [1] proposes that the number of models retained by the Dept. of the Army be reduced and that existing models be used where possible before a new model is commissioned. To properly evaluate an existing model a method for analyzing and verifying a candidate or candidates from existing model resources must be established. The more complex a model is the more difficult is this analysis and verification. [14]

Use of an existing model requires understanding of potential problems due to model design as well those problems expected to be encountered during transfer and execution. Design problems can include lack of adequate sub-models, failure to consider key variables, inaccuracies or lack of validation, computational difficulties, and inconsistent hidden assumptions. Problems during exection can be those of irrelevance, inadequacy of output, inappropriateness of assumptions, lack of connection to other models and results, statistical and extrapolation difficulties.

A. METHODOLOGY FOR ANALYSIS OF EXISTING MODELS

Before an existing model can be used it must be analyzed by the potential user. Examination of the literature for a methodology for conduct of an analysis generally produces a concensus. Such methodologies center on five general areas. [20] These are:

(1) inputs and outputs, i.e. the global structure of the model;

(2) the basic causal relationships assumed between variables; i.e. the local structure of the model;

(3) the detailed logic of the model;

(4) the numerical values of the data, and

(5) the time and resources required to exercise the model.

Additionally, an analysis should consider any experimental studies that allow comparison of the model predictions with the real world, other models or with the intuitive beliefs of the decision maker that will ultimately be presented the outputs and their interpretation. Such previous studies are useful in evaluation of a model for application to new problems or situations. Unfortunately, so far as combat models are concerned, comparisons with real world results are extremely limited. When such data is available (e.g. WWII and Korea) it is sparse, subject to conflicting interpretation, and of questionable accuracy. [21]

A detailed examination of the global structure of a model can forthrightly answer the basic question of such an analysis. Is this model capable of examining the problem at hand? The potential user is interested with whether the outputs measure the desired quantities and or qualities, and whether the desired inputs can be entered into the model in the form in which they are available. Using an existing model is not cost-effective if available input data must undergo a costly and time consuming conversion. There must be provisions in the model structure to allow changes in the input data to reflect changes in the combat process under examination.

The local structure is examined to expose important causal influences which may have been omitted for ease of computational effort or other reasons. This step is closely related to the abstraction process in the design of the model. It is most dependent on the detail and completeness of available documentation. It is critical because the importance of a causal connection can be quite subtle but very pervasive.

Examination of the detailed logic of a model identifies the hypothesis upon which the model is based. It reveals extent to which it is based on historical and experimental field data. It is another indicator of the appropriateness of the model to solve the problem at hand. This step also reveals the presence of inconsistent assumptions or inappropriate assumptions.

Finally, analysis of the time and resources required by the model provides the means through which the costs associated with the use of the model can be determined. To make rapid and accurate estimates the description of the model must provide explicit information of time requirements to gather and prepare required inputs as well as the time to execute the model given the inputs.

If models are to be truly transferable between agencies the above analysis must be comleted prior to any attempt to transfer a model. Accurate and complete documentation must be available if this is to be conducted. Such documentation will be available only if it is prepared concurrently with the development of a new model and in concert with any modifications made during the life of the model.

B. POTENTIAL PROBLEMS IN EXISTING MODELS

To adequately analyze an existing model the analyst must be familiar with potential problem areas. Farrell [20] has suggested that the analyst consider:

(1) the adequacy of submodels, i.e. do they model what they purport to model;

(2) whether key variables were overlooked during the process of abstraction;

(3) the possibility of inherent inaccuracies;

(4) possible computational difficulties;

(5) whether the model has inconsistent and inapproriate assumptions;

(6) possible inadequacy of output.

Among the problems of design can be found cases where the general model structure is adequate but reasonable submodels are not available. This is particularly true of sub-models involving simulated tactical or strategic decision making. Farrell [20] has indicated that most diagrams and flow charts of such sub-models do not reveal the sub-model inadequacy.

In designing a model the first and most difficult step is insightful abstraction by the modeler or modelers. To abstract the real world into a representative model, key variables, their basic causal relations and interpretation must be incorporated into the model. This step is very difficult to verbalize since any description of the process to be modeled will necessarily incorporate the results of abstraction in the elements of the description. This step is imaginative, creative, and complex; it is imperative that it be documented at the time of abstraction. Once a process has been modeled and time passes the explicit steps and reasoning thru which the abstraction was made cannot be adequately described by the modelers. Failure to consider key variables occurs at this almost invisible step of abstracting a process of the real-world into a model or sub-model.

In the review of an existing model it is these almost invisible steps of abstraction that must be thoroughly examined to insure all key variables are included in the model. Key variables can also be excluded because of lack of adequate sub-models or computational problems their inclusion or manipulation would precipetate. The reviewer or user of an existing model must carefully search for key variables that have not been modeled or are simply thruput in the model.

Another pitfall hidden in the design of existing models is inaccuracy or lack of validation. Often because of computational difficulties known experimental results have not been included in a particular model. This occurs most often as a result of exigencies on the modeler or modelers at the time the model is created. Exclusion of such experimental data results in inaccuracies. Lack of experimental support for portions of military models is another common cause of inacuracies which cannot always be avoided. Likewise, inadequate debugging of the model can be a reality. This is not serious as long as these inaccuracies are known. Unfortunately, these facts can escape a potential user if a careful review of the model design and its use is not made.

A thorough review of model documentation can reveal computational difficulties if the documentation is adequate. These difficulties usually involve either algorithmic imprecision or excessive date storage requirements. These limitations should be revealed by the documentation to the potential user so that proper use of the model can be made, unexpected or excessive costs are not incurred or another model can be selected.

The bane of analyst using an existing model is inconsistant hidden assumptions. Such assumptions included as part of the overall model can be at odds with those of sub-models, the data base, and data generating routines.

The most pervasive error awaiting the unwary user of an existing model is the *inappropriateness* of inherent assumptions. This potential error is the most difficult to detect when using a pre-designed combat model, since the user is generally not well versed in the process through which the abstraction of the real world was made. During the abstraction fundamental assumptions concerning the nature of the combat process as well as assumptions for computational reasons were made. Only through careful study of the line of reasoning followed at the creation can a would-be user become familiar with these assumptions. Care must be taken so that not only the explicit but also the implicit assumptions are understood and their effect on the combat process being modeled is comprehended. Unfortunately, the reasoning and logic followed in creation of a model are not included in current documentation.

If there are potential problems awaiting the unwary analyst in the design of an existing model, these are just the forebodings of greater problems associated with the actual exercise of the model. Foremost of these is irrelevance, that is caused by either attempting to use a model on a problem for which it was not designed or a failure to understand the problem thoroughly enough to select an appropriate model.

Concomitant with irrelevance is inadequacy of output. This results when useful information is inherent in the model itself but actual calculation and or display does not exist. Causes of such conditions are selection of an improper model or lack of full understanding of the intricacies of the model. Proper and adequate documentation and careful perusal will ameliorate the situation.

In complex simulations, both situations and key parameters will be varied and the results examined. The number of unique situations examined is limited by resource and time constraints, because of this the potential user must be sure that required outputs are readily available.

Adequate descriptions of the output of any random process are difficult to achieve under the best conditions. Under time constraints descriptions of the type of output provided by a model as well as how the outputs are collected is critical. Without it, the user cannot correctly interpret the results obtained. When available time and resources preclude simulating all situations the problem of extrapolating or interpolating between the particular situations modeled arises. There is no adequate general method for surmounting this problem; the problem is less severe the less complex is the model being used. Any statistical difficulties encountered only compound the problem. Surmounting this problem is a function of the ingenuity of the analyst and the detail of the documentation available to him. In the case of theatre-level combat models obviously, neither all situations can be simulated nor are there adequate historical or experimental data with which to compare the results obtained. A thorough accurate and consistent interpretation of the outputs of such a model is highly dependent on the analysts intimate familiarity with the mathematical structure within the model as well as interactions between the various input and output data. Such intimacy is obtainable only through available documentation if the analyst uses an existing model designed by someone else.

C. SUMMARY

Transfer of existing models between agencies is one way of reducing proliferation. Prior to such a transfer a potentionally usable model must be analyzed for applicability and approriateness. Such an analysis should consider:

- inputs and outputs;
- basic causal relationships;
- model logic and structure;
- available data and required data;
- time and resources required.

Many potential problems are contained in an existing model, among these are:

- submodel inadequacy;
- key variables excluded;
- inherent inaccuracies;
- computational difficulties;

- inconsistent assumptions;
- inappropriate assumptions;
- inadequate output.

The ability and to what degree model analysis and consideration of potential problems can be accomplished is determined to a great degree by available documentation. Adequacy of documentation is considered in the next chapter.

V. STATUS AND ADEQUACY OF CURRENT DOCUMENTATION

A. DEFINITIONS AND BACKGROUND

Program documentation is a collection of information to explain the design, development, and maintenance of the program as well as purposes, methods, logic, relationships, capabilities and limitations. [5] Except for the simplest programs it is difficult, if not impossible, for someone other than the originator to determine what is supposed to be accomplished by just reading the program code.

Documentation is necessary for: planning, programming, managing, operating and evaluating models. It is absolutely essential for: quick and effective changes; use of the model by programmers and analysts other than the originators; understanding of what is being done; interagency program sharing; verification of proper model operation. Through adequate documentation secondary users gain an understanding of a model and thus the model and its outputs are rewarded a level of credibility. It is vital if secondary users are to be able to run the model and make necessary modifications of the program. This restrains proliferation and duplication which can result in major savings; besides it tempers an already complex environment. Unfortunately, current documentation practices are such that the documentation to facilitate the use of existing models generally does not exist.

B. CURRENT DOCUMENTATION PRACTICES

Although documentation is an aspect of computer programming that was recognized from the inception of automatic data processing as being critical to successful programming, it has been and still is a major problem area. Unfortunately, for various reasons including time and fiscal constraints as well as lack of definitive guidance concerning requirements and standards, the bulk of the work effort concerning documentation has consisted of unfulfilled requirements. Notwithstanding the fact that programming has existed since the inception of ENIAC in 1944, the lack of adequate documentation received major attention in studies concerning models and simulations as well as investigations by the Comptroller General of the Army in the late sixties and early seventies. [10,15]

Irrespective of the aforementioned studies the problem of inadequate documentation persisted and was the subject of another investigation by the Comptroller General in 1974. [15] Over seventy federal installations in the continental United States, Europe, and Asia were surveyed. These included selected DOD Agencies as well as those of each of the armed forces.

The study cited several problem areas attributable to inadequate documentation. Increased cost of operations was high on the list. Because of inadequate documentation use of operating programs is hindered since current operators do not fully understand how and what is being done in a program. Therefore, when unexpected outputs are obtained it is difficult if not impossible to determine their validity. Equally perplexing is inadequate documentation of subsequent modifications incorporated into the model. In many cases without adequate documentation it was impossible for a new analyst and or programmer to use or modify an existing program. Ultimately such models have to be completely rewritten or the time required to make them usable was greatly in excess of the time required when adequate documentation was available. In a cited example inadequate documentation caused an agency to spend over a year to determine how a particular complex model operated. Another example indicated the difference of six man-months of work incurred because of the lack of sufficient documentation. Although the Comptroller General found it difficult to determine the aggregate cost of increased operating expenses due to inadequate documentation, he did indicate it was high because of the number of cases uncovered.

Lack of sufficient documentation was the major cause of the problems encountered by the author during the conversion of the ATLAS model. When machine differences required changing the program code there was minimal guidance as to which sections of the code corresponded to particular functions described in the user's manual. [22] Also, details of the mathematical structure of ATLAS are not contained in the manual. For details of the model structure references are made to a models manual [23] for the predecessor of ATLAS. The extent to which the structure of this model has been incorporated into ATLAS is not explicitly stated. The situation is further complicated by the fact that pertinent assumptions basic to the model formulae are not in the models manual; they are in the user's manual listed in a haphazard manner. Since the models discussed were originally designed for the predecessor of ATLAS there is no assurance that changes to the model formulae were not made during the evolution of ATLAS. This suspicion is enhanced by the fact that in 1973, five years after the design of ATLAS, a significant programming error was found. [24]

There are a myriad of reasons why model documentation is inadequate. One of the primary causes is that documentation guidelines and policies are developed by individual Federal departments and agencies. At the highest levels the guidance is necessarily general, as it moves down the organization further more explicit implementing directives are provided culminating in directives issued by the developing agency. Hence, some documentation is brief and simplistic; other documentation is detailed, voluminous and complex; neither may prove to be adequate. Adequacy is determined by the ability of other than the originators to use and understand the model. The Comptroller General found that even when guidelines and standards were prescribed managers of modeling projects failed to insure compliance. The type and content of documentation is often decided by computer technicians or ADP operators. [15] Shubik [17] has cited this practice as unprofessional since ambitious programmers have been known to change coding in the pursuit of computing efficiency without making note of the fact.

An examination of 264 model documentation packages at 10 California installations revealed none fully complied with the agency standards and most were incomplete, inconsistant, and inadequate. [15] In most cases programmers determined what documentation to prepare based on their own judgement. Managers responsive for developing models indicated that the reason standards were not adhered to was because of time contraints. Completion dates frequently were given precedence over preparation of adequate documentation. The desire to complete a model and get it operational by a given date overrode the need for documentation.

An aspect of managerial responsibilities concerning documentation is that it be kept current. Even if a model is initially adequately documented it will eventually be modified and its documentation must be likewise updated. This is a major problem because it requires diligence to update documentation. Given time and resource constraints and the exigencies of the decision making process it is a task that can easily be put off since the model will work without such documentation. The problem comes later when the personnel that modified the program become involved with other demanding problems, leave or are transferred. Later the documentation is difficult to prepare because the reasons why or how the modification was made become unclear or those that knew what was done are no longer available.

There are numerous comment cards in the ATLAS program that indicate changes were made. However, there is no formal documentation, with one exception, to indicate what or how these changes were made. Informal documentation provided was minimal and superficial and did not address all the indicated changes. The one exception was a formal document [25] prepared in 1974, which discussed improvements in the treatment of barriers and personnel replacements. A global variable and subroutine listing were provided but these were not up to date; had they been current the conversion would have been facilitated.

Poor or nonexisting documentation persists irrespective of the efforts of the Comptroller General and the Department of Defense. Inspite of the identification of this problem early in this decade [1,10,15] its presence continues to be a problem at the close of the decade. [3] The continuing lack of detailed documentation that enables an analyst to understand what goes on inside a model is cited by Shupack

[26] in 1979, as a limiting factor in the use of theatre-level combat models. Although there was a noticeable improvement, he found the level of documentation of IDAGAM not sufficient to insure the easy and proper use of the model without supplementing the available documentation. Without adequate documentation the analyst is apt to make erroneous conclusions regarding the processes occurring within a model.

Although documentation problems persist genuine attempts to resolve the problems have been made. Current combat modeling efforts at the Naval Postgraduate School are not only using languages especially designed for simulation but the documentation methods employed enhance the transparency of the model. For examples see Ref. 27, 28, 29. Other agencies have also made inroads toward improving the adequacy of documentation. See Ref. 30, 31, 32. Irrespective of these improvements the author believes a vital aspect of documentation is being overlooked. This aspect and appropriate recommendations are set forth in the next chapter.

C. SUMMARY

Studies as well as intuition reveal that to understand the workings of a complex model an analysts requires a detailed explanation of the calculations and data manipulation performed by a simulation. Implicit and explicit assumptions and inputs must be known if an analyst is not going to use a model as a black box. A detailed knowledge of the variables, subprograms and their relationships must be acquired if a model is to be transferred from one using agency to another. Rarely will both organizations posses the same brand of data processing equipment, more likely than not there will be great dissimilarities. Conversions from one machine to another requires that changes be made to the model. To change the model the programmer and or analyst must know the effect his change will have not on only the particular line of code he is changing but throughout the program. Analysts must not only know how a change will affect the physical minipulations and computations of the various parts of the model but how it will interact with the implict and explicit assumptions of the model. To gain this level of comprehension of a model designed by someone else the analyst and programmer of the gaining organization must consult the documentation provided with the model. Without such documentation analysts have chosen to construct a new model. Unfortunately, the general concensus of the investigations was that documentation was of dubious quality and generally inadequate. [1,10,15]

VI. PROPOSED HIERARCHY OF DOCUMENTATION

The discussion of who the user is, the role of the officer analyst, and the documentation concept that follows is based on seven years experience in operations research related assignments, discussions with analysts, programmers and students, and problems encountered during conversion of the ATLAS model. The author has drawn upon the above sources and selected literature [4, 15, 17, 33, 34, 35] to propose a new concept in model documentation. This new concept is intended to refine and supplement current documentation methods. Implementation of the proposed concept will hopefully fill a void that currently exists and will greatly improve the transparency and transferability of combat model.

A. THE USER AND THE ANALYST

Before proceeding further it is necessary to define the often referred "user". It is one of the more vague terms associated with combat modeling.

Now, who is the user? The user is the study director and/or decision maker. These individuals need documentation that provides an overview of the model, with indications of its capabilities and limitations and general applicability to the problem under study. The details of the conceptual basis of the model and how and what information can be provided along with an evaluation of its suitability should be provided by the analyst.

The analyst is the manipulator of the model. He is responsible for using the model to support the study objectives. This means he is responsible for the collection and insertion of input data and interpretation of the output data. If the model is small, he may do the coding; or if it is complex, a programmer may assist him in the coding process. Any interpretation of how the model represents reality is the analyst's responsibility. To fulfill this responsibility he must be familiar with the conceptual basis of the model, its underlying assumptions, how the model was transformed into the program code, and how the code operates to present the process modeled. The analyst must know if any changes to the conceptual foundation of the model occurred in the process of programming (coding).

There is a reluctance on the part of many military analysts to gain an intimate understanding of a complex combat model. Exingencies of the organization are some of the prime reasons. In the daily demands to manipulate a model and to produce results there is insufficient allocation of time to study the inner workings of the model. Reliance is placed almost exclusively on the user's manual to explain the results produced.

Some analysts (this is particularly true of the officer analyst) refuse to gain detailed understanding of the inner workings of a model because they do not perceive that to be their function. Their perception is that they are the user and do not require that level of detailed knowledge. Others hesitate to learn or become well versed in the functions of a particular model because they fear such expertise will label them and hence limit the scope of their future assignments. In discussions with officer analyst students and practicing officer analysts, the author found these attitudes to be quite pervasive. Many considered detailed knowledge of how a model operated to be in the realm of the programmer's responsibility. Little or no consideration was given to the fact that most programmers have little or no military background and cannot possibly relate the machinations of the program code to the combat process. The programmer views proper operation in terms of proper execution of programmed instructions. Whether or not instructions properly depict the realities of the combat process are beyond their scope of interest. They have neither knowledge, inclination or experience to evaluate the fidelity of the code.

Attitudinal attributes of military analysts can be understood in light of their rapid turnover in assignments. Rapidity of reassignment discourages the desire to gain detailed knowledge of any particular model. Most likely they will be reassigned shortly, to other type duties. If subsequent assignments deal with combat models, most likely, it will be a different model. Any time expended in the study of details of the model associated with the current assignment is considered of minimal value. When an effort is made to understand a model it is often frustrated by inadequate documentation.

Probably the most frequent attitude seen in officer analysts is the one associated with the military psyche, that of being a generalist. This attitude is the result of the total experience of the profession; it has been the way to reach success in the past, and many believe that it still is the way to success. Although there has been considerable effort to change this mind set, the example of the last few centuries is difficult to overcome. Compared to the existence of the military profession, the experience of the military analyst is of recent vintage. Only favorable experience will provide the impetus for change.

The transfer of models between agencies will contribute favorably toward convincing analysts to gain detailed knowledge of combat models. If they know that the effort expended now can be used at a later time in some future assignment, the effort will be considered worthwhile. But adequate documentation is a prerequisite of such transferability. Hence, there is an interdependency betweeen documentation and convincing military analysts to gain a detailed understanding of combat models. If they can see value in the expenditure of the time and effort, they will be willing to make the commitment.

Shubik [16] has found that the mathematical modeler and the person who understands the reality the model attempts to abstract are not necessarily the same person. The combat process is best understood by senior military decision makers who are generally unable to translate it into the appropriate abstraction and who generally desire greater detail than is necessary. A good model is one that is able to abstract and describe only that which is relevant to the problem under investigation. On the other hand the mathematical modeler is frequently an individual who generally lacks the experience and an appreciation of the nuances of combat which can lead to the development of an ill-structured model. The military officer analyst represents a step toward providing a modeler or model operator who not only understands the mathematical aspects but the military factors as well. If this capability is to be maximized when dealing with existing models, there must be documentation which allows the analyst to link the conceptual model formulation to the executable program. Then he can understand the conceptual basis of the model, insure the program fulfills the concept, and act as a source of information for the decision maker.

B. ORIGIN OF THE DOCUMENTATION SHORTFALL

The initial theatre-level combat models used in the United States were designed and operated by contract organizations (e.g. Research Analysis Corp.). These models had a manual referred to as a user's manual which provided an overview of the model, input requirements, and a description of the output. For an example see Ref. 22. Documentation within the manual was superficial, at most it provided the proverbial big picture. Sufficient information was provided to determine the general capabilities of the model, possible suitability for a particular study and a general indication of expected outputs. It provided little if any information on the insights that could be attained or subtleties of the model. The user for whom this "user's manual" was designed was a project manager or some level of decision maker. The details could be filled in by the persons who would operate the model, this most likely was the designer of the model. Because of budgetary reasons and doubts that these model operaters understood the nuances of military operations, the decision was made to bring these models directly under Dept. of the Army control.

When these models passed to Army control all documentation passed with them. Unfortunately, in most cases the documentation was minimal consisting primarily of program listings, operator instructions, global variable and subroutine listings, flowcharts, user's manual and possibly some limited discussion of the formulation of the model. These models were placed under control of the agency that would use them in support of force planning and strategy studies. The designated users that inherited these models were the military analysts (officers and federal employees) assigned to the organization that received the models. The analysts then took the model and the user's manual and proceeded to exercise the model in support of on-going projects.

Use of the user's manual by the analyst was mandated by the fact that input requirements and preparation were contained in it. However, when the models were initially transferred from the designing corporation to the Army no supplemental documentation was prepared or provided. Analysts were using a manual that provided only a superficial examination of the model. They performed analyses using a manual originally designed for a study director or decision maker. These "user's manuals" did not contain the detailed information of the model that is necessary if the analyst is to know and understand the machinations through which the input data is exposed to produce a given set of outputs.

Evenually conflicting results were obtained from models supposedly examining the same situation. When called upon to resolve or explain these discrepancies the analysts were unable to do so. To explain the conflicts a detailed understanding of the conceptual basis of the model as well as detailed information of the translation of the conceptual model into program code was needed. Only with this information could the analyst explain why two models examining the same combat process under the same conditions produced different results.

Analysts then discovered that the documentation provided with the model did not provide this insightful information. To answer the question the model designer had to be contacted. At times this was impossible because the actual model the designer no longer was with the firm that developed the model, nor was there available any supplemental information on the inner workings of the model. Instances in which the designer could be located usually proved just as unrewarding. In most cases the designer had no supplemental formal documentation. When he acted as the operator of the model on behalf of the Army he could answer such questions based on his design knowledge and daily contract with the model. Since there had been no formal requirement for such supplemental information, it never was prepared. Once the model passed under operational control of the Army, the designer was precluded from daily contact. Over time the designer's intimate familiarity with the model waned, especially the intracacies of the translation from basic concept to operating program code. If the designer had not done the actually coding, similar results were usually experienced when trying to locate the original programmer or obtain supplemental information. What the program code was actually doing was not readily apparent and documentation or personal knowledge of its operation were unavailable. The situation is best expressed by a quote from Robert Frost. When once asked by a critic what he meant by a particular phrase in one of his works, he replied, "When I wrote it God and I knew what it meant, now only God knows". This same situation will also prevail with combat models unless adequate documentation is created concurrent with the design and development of the model.

C. COMMUNICATION AND LEVELS OF PARTICIPATION

The prime purpose of documentation is communication: communication of why and how realities are abstracted and condensed into a form suitable for exercise on a computer to predict a future state of some combat process. Generally the level of professional communication between decision makers, analysts, and modelers has been low as attested by the credibility problem previously discussed. This coupled with the turnover of military decision makers and analysts has not enhanced comprehension of and control over large-scale combat models. Very often the information about context and limitations of these models has not been fully understood by the military analyst and therefore not clearly presented to the decision maker. Documentation that can provide such enlightenment to the analyst will be a significant step toward providing the required insights into combat models needed by decision makers. Through adequate documentation the user and analyst gain understanding, and with understanding can come acceptance and the decision to use the particular model.

In combat modeling there are three levels of participation with necessary intercommunication. At the highest level is the decision maker who uses the model as an aid to gain insights and in conjunction with judgement arrive at a decision concerning force structure or strategy. The intermediate level is occupied by the analyst, who either designs a model or uses an existing model; prepares inputs; exercises the model and interprets the outputs. If the model is new to the decision maker he also aids in the model selection process by recommending and explaining the inherent attributes of particular models in pursuit of a projected study. At the lowest level is the programmer, who writes the necessary code during model construction, explains the limitations of execution of a model on a particular computer, insures the model is processed as the program intended it and to code necessary modifications to a model. Each level has unique requirements and responsibilities and therefore the documentation required by each is unique.

The decision maker uses his documentation to gain an overall appreciation of a model and sufficient understanding to question the analyst on model details necessary to make a decision to employ the model and use its outputs. It provides a means of conducting discussions that can reveal what insights can be gained from a particular model. The decision maker uses his documentation as a link between the analyst and himself.

The analyst occupies the pivotal position between the decision maker and the programmer. His documentation is necessarily the most broad in scope as well as variation of detail. It must provide intimate knowledge of the model to allow selection, sufficient detail to answer questions from the decision maker and ask questions of the programmer. It must provide the key to the inner workings of the model.

Programmer documentation allows the programmer to maintain and modify the model and answer the questions of the analyst. It allows the programmer to maintain efficiency of operation and insure execution in accordance with the dictates of the design. It must clearly indicate how the computer interacts the inputs and programming code to produce the outputs.

D. A CONCEPTUAL THEORY OF MODEL DOCUMENTATION

Current texts that describe the documentation process usually are texts on the subject of computer systems. The guidance provided, though attempting to be general, is oriented toward documentation of programs that are bulk processors of systematic information, i.e. financial records, administrative records etc. Most emphasis is placed on how to use the available program to process the data available, minimal emphasis is directed toward how the processing is accomplished, because the processing is not complex but routine and easily understood. For an example see Ref. 33.

In the field of combat modeling little guidance is available in the form of textbooks describing documentation methodologies. In order to maximize detailed understanding as well as transferability of combat models a new concept of documentation is proposed and set forth in this section.

To fulfill the requirements discussed above the documentation must provide the complete understanding of how the model was created, underlying assumptions, explicit description of the formulations and numerical methods employed and detailed description of the mechanics of the program code and its execution. Most current documentation described as a user's manual (e.g. see Ref. 22), executive summary or by some similar title is sufficient to fulfill the proposed non-technical documentation that follows. Programmer's documentation is widely described in the literature of computer systems and needs just a few additions in respect to combat models. Assuming that the documentation is provided as described in the literature, minimal modification is required. Primarily this is a charting and cataloging procedure to allow ease of tracing variables through the program and understanding the linking of subprograms to the main program. Current documentation requirements stress flowcharting. Flowcharting is comparable to electronic schematics and allows one to see the logical flow of the process being programmed. In the coding step this logical flow is translated into a mechanical flow of variables through mathematical and logical formulations and subprograms. A charting procedure will be like a blueprint that shows the physical connection of the main and subprograms. The catalog will explicitly state how variables are interacted and passed between subprograms.

For the analyst's documentation a new concept is proposed. Rather than describing the model in the traditional manner, i.e. from the context of justification, the analyst's documentation should be presented from the context of discovery. [2] Using the traditional concept the model is documented by stating the assumptions of premises which determine the outputs of the model, showing the final mathematical formulae that represent the abstractions of the relavent characteristics of the modeled process, discussing the inputs required to support the given formulae, and listing the outputs that can be obtained from the model and inputs.

This is not the manner in which the model was formulated and such documentation in the context of justification does not enlighten the analyst in terms of how the designer arrived at this particular abstraction of the combat process. One must conclude that this type of documentation is not of great help to the inexperienced analyst if he is attempting to understand the essence of a combat model. If the analyst is to gain a intimate knowledge of the functioning of a model, he must be able to ascertain how the model came to be. This provides him two invaluable insights. First, he gains an insight into the abstraction process of the designer. It is a glimpse of the reasoning procsess by which the designer cut through the myriad of details to deduce the fundamental variables that allow a model to approximate the complexity of a given combat process without having to model each of the multitudinous factors that compose the actual process. Second, he gains knowledge of the factors that were considered as representative of the combat process but were discarded because they seemed not to be necessary predictors. This step in itself is worth the cost of providing this type of documentation. What it provides is a historic record of factors and related assumptions considered and reasons why they were ultimately rejected or accepted. The information provided must be succinct and allow understanding of the abstraction process without introducing voluminous detail and unnecessary costs. This will be an aid not only for the follow-on analyst but all those that come later. It will preclude subsequent analysts from expending time and money to determine why particular factors are or are not modeled. Hence, if they wish to modify or elaborate upon a combat model and information about previously considered and rejected alternatives is available, the expenditure of resources to reinvestigate a particular alternative and gain only duplicate information will be precluded.

E. REQUIRED LEVELS OF DOCUMENTATION

All the evidence gathered indicates three levels of documentation for models are required. These levels of documentation are:

(1) decision-maker level, (facilitates communication between the decision maker and analyst);

(2) analyst level (fosters communication between analyst and decision maker and enhances working relationship with the programmer);

(3) programmer level (provides detailed understanding of program code and facilitates communication with the analyst).

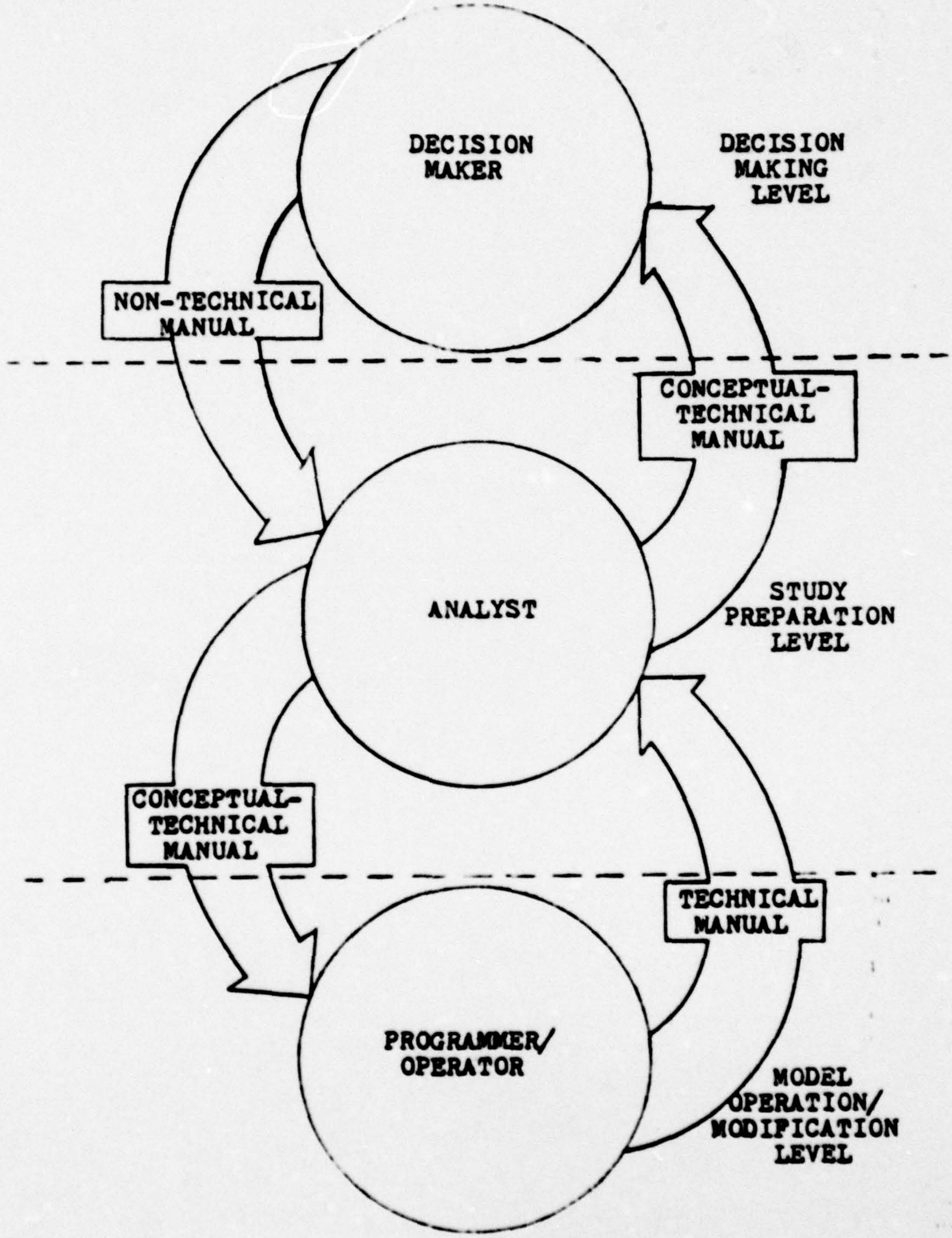

Figure 1 - PROPOSED HIERARCHY OF DOCUMENTATION

First, the decision maker who uses the model as an aid to his judgement requires a non-technical description of the model. Non-technical not because the decision maker cannot comprehend the technical details but because the exigencies of the organization preclude him from devoting the necessary time and effort. Second, the analyst that exercises the model, prepares the analysis, and assists the decision maker requires a technical description of the model. This enables the analyst to know how the model functions and explain and interpret the outputs of the model. Third, the programmer needs detailed documentation that explains the mechanics of the program. This documentation provides the means to troubleshoot problems encountered during routine running of the model and implement future modifications. The levels of activity and their required documentation are shown at Fig 2.

F. DECISION MAKER'S NON-TECHNICAL DOCUMENTATION

A non-technical reference manual for use by decision makers should provide sufficient information to determine general applicability of the model. It should include a general description of how the model operates and the major components, the specific purpose for which the model was originally designed and the known limitations should be stated. This will allow the decision maker to assertain the overall ability of this particular model to assist him in the problem at hand. The manual should describe the data requirements, available outputs, and any options provided by the model. This facilitates the initial planning process because it provides a basis for estimating the expected time to gather the input data and what to expect in the form of outputs. Physical limitations, such as computers for which usable versions of the model are available, the programming language used, and typical running times for the model, are necessary contents of the non-technical manual. The time of such senior managers is limited and valuable. Only that information necessary to provide a general description and basis for meaningful discussions between the decision maker and the analyst should be included. Any details required will be provided by the analyst, who will conduct the study, during planning, progress, and review sessions. Yet the documentation must make the model sufficiently transparent so that the decision maker understands what is happening and finds the model credible for the problem at hand.

G. ANALYST'S CONCEPTUAL-TECHNICAL DOCUMENTATION

The analyst's conceptual-technical reference manual must necessarily contain detailed information on all aspects of the model. This is the document that determines the overall worth of the model as an analytical tool. If sufficient detail is contained then the analyst can become intimately familiar with the model, so that any aberation encountered during operation of the model can be understood by him and explained to the decision maker. To maximize its value to an analyst, it should be written by the analyst or analysts that design the model. Their professional experience will guide them in providing the kind of information about the model that they would want if they were using a model designed by someone else.

The size of the analyst's reference manual will be a function of the complexity of the model. To be useful and credible a model must be transparent and transferable. To be transparent and transferable all necessary details of the model must be provided. Information on the data base used in the model, input requirements and format as well as output format and options must be detailed. All that can be assumed is that the analyst is knowledgeable in the use of the tools of his profession. In preparing the analyst's manual no prior knowledge of the model can be assumed. As Morris [2] recommended, the obvious should be written down. All constraints and limitations must be described in detail as well as assumptions used, logic flow and interactions. Sufficient technical detail to allow the analyst to manually trace inputs through the algorithms is necessary. Mathematical, statistical, and numerical methods incorporated in the model should be described including any new or unique applications. Any constraints which will affect the accuracy of the model must be identified. Obvious pitfalls must be stated; they are only obvious to the developer and in complex models without documentation they can even be forgotten by the developer. The physical processes simulated must be described including an explanation and rationalization of the techniques used. Each variable and the entity it represents must be clearly stated. Lastly, sufficient instructions describing how to set up and use the model and flow charts keyed to the program instructions should be provided. Equally important is a system that keys the description of each mathematical formulation in the manual to the appropriate section and lines of the program code. This will facilitate the location of the code, when the analyst wants to modify the model.

These are the basic requirements for the contents of documents to be prepared by the designer of a model. Each time a modification to the model is made, the changed program instruction, reasons why the change was necessary, how and what is affected in the model, and the rationalization for the particular modification should be documented and incorporated into the original documentation. This aspect of documentation is critical because analyst and programmers have been known to make small insignificant changes to programs without documenting them. Two results can come about because of this. Over time these minor undocumented changes accumulate, then one day those who implemented the changes transfer or depart. The newly arrived analyst now has a model which does not quite fit his documentation. If enough time has passed even those who made the change will not completely remember it when they are questioned or they are no longer available. Even more disheartening is that in failing to document, a critical inspection of the effect of the change on other parts of the model is not made. Unbeknownst to the individual the modification causes an effect elsewhere in the model that is not readily discernable at the time. Utimately, another modification is made and the model malfunctions or an anomalous output occurs. If undocumented modifications have been made and forgotten it may be impossible to trace the cause of the anomaly. If it can be traced, the cost of trouble shooting and correcting the model will be greater than the cost of documenting the modifications at the time of their addition. Current studies will be delayed with their attendant costs and the credibility of the modeling community will suffer. The decision maker justifiably becomes skeptical when the analyst cannot explain why the results of a model are not compatible with the decision maker's intuitive expectations. If a model is to aid in the decision making process its outputs must be explainable and understandable to the decision maker. If the analyst has not designed the model then his only source of the necessary information is the documentation supplied with the model.

H. PROGRAMMER'S TECHNICAL DOCUMENTATION

The final level of required documentation is the detailed information required by the programmer for the operation and maintenance of the model. This is the documentation that is discussed in great detail in all standard texts, while methods of documenting the conceptual basis of models is almost entirely foregone. The manual is necessarily prepared by the model programmer in conjunction with the analyst who has designed the model. It must contain descriptions of each global variable and in which subprograms the variable is found. Descriptions of the functions performed by the program, data flow charts, function flow charts, approximations and numerical procedures used are also contained in this documentation. Likewise, any implicit assumptions made by the programmer during the coding process to facilitate computation must be documented.

Often, though the analyst designer has structured the model to handle the general case, during implementation of the model on the computer some loss of generalization occurs. In the search for programming efficiency the computer programmer may code a combat process so that the model works for only those circumstance explicitly stated by the designer. Whereas the designer believes he has a general model the programmer has reduced the generality of the model. Unless this is documented by the programmer, in subsequent use of the model the fact that the model was programmed in such a manner may be forgotten. In this case the computer routines embody more assumptions than exist in the formal model designed by the analyst. It is incumbent upon the programmer to bring this fact to the attention of the analyst. He inturn must include this information in his documentation. Only he can conceptualize in terms of real world factors the impact of the programmer's assumptions on the inputs and outputs.

Further contents of the detailed programming manual must indicate primary and secondary storage requirements, error detection and recovery procedures, and instructions for initiation and termination of program operation. These pieces of information are required if other programmers are to be able to understand and operate the model. If a model is transferred this information is necessary to implement the model on a computer of different design. It provides the receiving programmer the necessary information to prepare system operating programs and procedures so that the model can be exercised by the receiving agency without inadvertently making changes to the logic of the model. This is especially critical for complex models. With such models attempts to restructure programs to overcome incompatibilities in storage or other machine requirements may introduce changes to the fundamental logic of the model unbeknownst to either the programmer or the analyst. Without adequate documentation such restructuring must be accomplished with only luck to guide the way and as complexity of the model increases luck is quickly depleted.

When the original programmer completes the programming (coding) of the model the model must be verified and validated in conjuntion with the analyst designer. When both are satisfied that the model is operating as designed a listing of the compiled assembled program should be made. This is then supplemented by a set of working notes on program operations, set up of the deck to exercise the model, special programming features and identification of potential problem areas and suggested solutions.

The compilation of the above documentation into a detailed programmer's manual will provide a sound basis for review and analysis of the model's capabilities and for maintenance of the model's logic; it will facilitate transfer and insure transparency. Furthermore, each time the programmer makes a modification to the program it must be documented and incorporated into the programmer's manual. Concurrently, it must be brought to the attention of the analyst to relate the programming change to the combat process modeled and update the analyst's and decision maker's manual. This coordination between the programmer and the analyst must always occur if both are to remain fully cognizant of what as well as how the model simulates the real world. Only through such documentation can a model be transferred to a new programmer and analyst team and be knowledgeably used.

I. INLINE DOCUMENTATION, A MAP THRU THE MAZE

A necessary adjunct to this proposed documentation package is documentation within the program. Such documentation should be in the form of comment cards that briefly describe the main program, the major sub-models, subroutine and each function subprogram. They should be inserted at appropriate locations so that logic of the program is readily apparent. Nothing is more frustrating to an analyst that is attempting to gain a quick basic understanding of a model than a series of calls to subroutines which inturn call other subroutines and or function subprograms. In a complex model this quickly hides the logic of the model from the analyst. To pierce this shroud the analyst must devote time that could better be used elsewhere. If the exigencies of the situation demand a rapid response and no other model is readily available this encourages the analyst to use the model as the proverbial "black box". This neither adds to transparency nor does it enhance the reputation of the analyst or operations research.

Most current programming texts recommend using comment cards to enhance understanding of programs. In complex models this is not a nicety but a necessity. Time devoted to this effort initially not only enhances the use of a complex model but reduces recurring costs. Professionalism demands that a model should not be used without understanding how it functions or at least believing one understands how it functions. The realities of military personnel policies dictate that military analysts will rotate rapidly through assignments. If a program is not documented internally this self-educating step occurs each time a new analyst uses a particular model. Given a complex model and normal personnel turnover a sizeable cost is incurred. With adequate internal documentation this cost will occur only once. Because of personnel rotation models not currently having such internal documentation should have it added. Though it will detract an analyst for an additional amount of time initially, over the longer term a savings will be realized. Each subsequent analyst will not have to start from scratch when trying to gain an understanding of how the model functions; understanding will be facilitated by internal documentation via comment cards.

J. UPDATING A MODEL'S DOCUMENTATION

Changes to models occur over extended periods of time. Obviously, at the time changes are instituted the process through which they were developed, why and how they were entered into the model and all assumptions used must be annotated in all appropriate documentation at the agency instituting the change. Some of these changes will be extremely large and will justify formal changes being printed and distributed for all affected documentation. Some changes will be small; formal printing of individual changes would not be justified. These would have to be accumulated and changes printed, when economically practical. The management of the process and the determination of when printing and distribution of changes is economically practical are beyond the scope of the thesis. They are important subjects and should be examined in some future thesis.

K. SUMMARY

Since the analysts and programmers that develop a particular model are not always present or available when the model is exercised, especially if it is transferred to another agency, it is their responsibility to detail their assumptions, simplifications and methodologies and provide evidence that the rationale behind their approach will produce results usable in the real-world environment as viewed by the ultimate decision maker. Analysts and programmers that create a model must provide documentation that establishes the issues examined by the model, underlying the objectives and assumptions, the usability and usefulness of the model. Only with such documentation can the analyst or analysts assisting a decision maker in the resolution of a particular problem conclude that the use of a specific model is appropriate. The real "user" of a model is the decision maker. The analyst must recognize in assisting the decision maker he is a model designer and model manipulator. The officer analyst must gain detailed knowledge of any model he uses in support of an analysis.

To acquire such knowledge a model must be adequately documented. In combat modeling there are three levels of participation each with unique documentation requirements. These levels are:

- Decision-maker level;
- Analyst level;
- Programmer level.

To enhance the ability of the analyst to fully understand the model his documentation should be presented from the context of discovery rather than the traditional context of justification. This will allow the analyst to know the alternatives considered and rejected in structuring a model as well as giving him greater insights into the underlying hypothesis of a model.

The types of documentation required are:

- Decision Maker's Non-technical Documentation;
- Analyst's Conceptual-technical Documentation;
- Programmer's Technical Documentation;
- Inline Documentation.

Since model modification and improvement is a continuing process the preparation of formal changes must be economically practical and carefully managed. This area of model documentation is suitable for a subsequent thesis.

VII. CONCLUSIONS, RECOMMENDATIONS, AND FINAL REMARKS

A. SUMMARY OF PROBLEMS DISCUSSED

Since 1973 the impetus in the Army modeling community has been to develop scenarios and models that can be used throughout the Army community for decisions on material requirements and force development. The ultimate purpose is to bring consistancy into the decision making process. Inherent in this goal is not only the need for standard agreed upon scenarios but for a repertory of models to be used by all interested agencies examining a particular facet of the Army. This does not necessarily mean that only one model should be used for a particular investigation. Because of the assumptions necessary to develop any model, given the necessary time and money it is best to exercise more than one model in order to get an indication of how the assumptions affect the outputs of each of the models. What is fundamental is the need for all agencies examining a given situation to be able to understand each other's models; this will provide the basis for intelligent discussion of the pros and cons of equipment and force requirements.

As operations research and system analysis have gained acceptance by DOD and Department of the Army, more combat models of various levels of military operations have been created and used. Increased use of models resulted in increased levels of complexity. Complexity in turn caused new models to be created when potential users could not sufficiently understand and use existing models given available documentation. This unnecessary proliferation resulted in unexplainable conflicting results which caused the credibility of combat modeling to be questioned. If this situation is to be resolved unnecessary proliferation must be checked and mutual understanding enhanced. To achieve this goal models must be easily transferable between investigating agencies. Fundamental to this ability is complete and up to date documentation of the model to be reviewed or exercised. This documentation will allow the potential user to analyze the model and determine its suitability for a given project.

Concomitant with the need to easily transfer models is the need to fully understand the machination by which a given set of input data is acted upon to produce outputs. If outputs of a computer model are to be useful they must be credible. Conflicting outputs of military models are consistently challenged by some government agency of the DOD, the Congress, the Executive Office or some other branch of the government. Unless these challenges are answered and conflicts explained, the credibility of combat modeling will continue to suffer. Some criticism is needed to purify combat modeling and identify errors that inevitably will appear, some eminates from those advocating a competitive model or concept and some of it is from those that criticize the validity and usefulness of combat modeling itself. At times inadequate documentation has precluded the explanation of conflicting results by the analyst and added to the criticism.

The Comptroller General [15] found that existing models have been used by other than the designer without thoroughly understanding their implications and limitations. At times this has resulted in erroneous conclusions being drawn and decisions made based on these conclusions. Subsequently, the errors are surfaced with a loss not only in dollars expended in pursuit of undesirable projects but in further loss of credibility for theatre-level combat modeling.

Adequate documentation will help alleviate some of the adverse publicity and loss of credibility that theatre-level combat modeling has experienced in the past. To a great extent this has stemmed from unexplainable contradictory results using models purporting to represent the same process. To allay the criticism of models and their outputs and to enable both the analyst that exercises the model and the decision maker that uses the outputs to aid in the decision making process the model must be understood. Understanding can be enhanced through proper documentation. Adequate documentation of the form proposed will facilitate communication between the decision maker and analyst as well as between the analyst and the programmer. Unless these communication links are established misunderstanding of combat models will persist and the credibility of combat models and modeling will suffer accordingly.

B. CONCLUSIONS AND RECOMMENDATIONS

The conclusions drawn from this research are:

- The decision maker is the "user" of a model.
- To be of value a model must be accepted by the decision maker.
- The analyst must relate the abstractions of the model to the actual combat process.
- The analyst is a model manipulator.
- The analyst must understand and explain the methodology and structure of a model.
- Understanding is deterred by complexity.

- Models are becoming more complex.
- Increased levels of complexity result in diminished transparency.
- Inability to understand and use existing model causes development of redundant models.
- Unnecessary proliferation causes conflicting results to be produced by similar models.
- Inability to explain conflicting results is the basic cause of a lack of credibility.

Proliferation can be reduced through model sharing. Sharing a model requires:

- ability to use it with minimal conversion;
- adequate facilities to run the model;
- sufficient competent analysts and programmers;
- adequate documentaton;
- formalized arrangements for cost sharing and coordination.

Prior to transferring a model it must be analyzed for applicability and appropriateness. Such an analysis should consider:

- inputs and outputs;
- basic causal relationships;
- model logic and structure;
- available data and required data;
- time and resources required.

Many existing combat models are characterized by:

- submodel inadequacy;
- key variables excluded;
- inherent inaccuracies;
- computational difficulties;
- inconsistent assumptions;
- inappropriate assumptions;
- inadequate output.

The degree to which meaningful model evaluation can be accomplished is significantly influenced by available documentation. Documentation is key to the understanding of complex models. The research conducted indicated:

- Adequate documentation is a necessary if a model is to be used by other than the originator.
- Organization exigencies deter adequate documentation.
- Documentation of combat models is generally inadequate.
- If a model is poorly documented it may be more economical to build a new one than share an existing model.
- Efforts are being made to improve documentation.

The author's experience with and research of combat model documentation indicates that there are three levels of interaction with combat models. These levels have unique and common requirements for documentation. To satisfy these requirements the author envisions three levels of documentation:

- DECISION MAKER'S NON-TECHNICAL
- ANALYST'S CONCEPTUAL-TECHNICAL
- PROGRAMMER'S TECHNICAL

The decision maker's and the programmer's documentation must provide the information listed in chapter six. It can be presented in the traditional manner using techniques contained in most computer system management texts. However, to function as the link between the decision maker and the programmer and to understand the nuances of the model, the analyst needs documentation that provides greater insights than possible with the current available documentation. These insights will be provided if the analyst's documentation is presented from the context of discovery rather than the traditional context of justification.

Many changes to a model occur over extended periods of time. The method of determining when it is economically practical to print formal changes, their disribution, control, and management is critical to the proposed hierarchy of documentation. These topics are appropriate for future research.

C. FINAL REMARKS

Acceptance or rejection of an expository thesis in matters such as documentation often depends on the skill of the pleader and the mood of the audience. Staring at the same set of evidence the parties to the debate can come to sharply different conclusions, since their preconceived notions may lead them to select and interpret the evidence in different ways. Even though one may initially find it difficult to believe that there are ways to acquire adequate documentation not yet tried by analysts or advocated by agencies researching the problem, the very complexity and pervasiveness of the problem suggests the possibility of combining the various proposals in different ways so that some combination will produce the desired goal. The proposal presented is but one possible means to achieve the desired end. Of even more importance is the fact that some methodology must be adopted to correct this lack of adequate documentation. With regard to theatre-level combat models, the problem has persisted for almost twenty years. Not only has it made it near impossible to easily transfer models between interested agencies but it has prevented military analysts from gaining full knowledge of the models they use.

The conflicting opinions and evaluations unmasked during this research confirm what is intuitively obvious: many of the historical judgements and decisions concerning operations research in general and theatre-level combat modeling in particular are based on subjective values as well as objective facts. Unlike the natural scientist or the analyst using a simulation, the researcher examining the process through which combat modeling has evolved, cannot reproduce the events and by experimentally altering the ingredients, change the result. The development of combat modeling is well documented; yet controversies have developed despite the voluminous sources. Analysts disagree not because one may be more knowledgeable about the subject than another, but because each weighs and evaluates differently those facts of which both have knowledge. There is little dispute about the details of what has happened in the development of theatre-level combat models but there is intense disagreement on the significance of past events and how to proceed in the future. The analyst has no fixed point from which to observe the stream of events concerning the development of theatre-level combat models. Analysts are borne along by the current and their interpretation of what has occurred is influenced by their view of where the stream seems to be headed and whether the apparent destination appears to be good or bad for the enhancement and development of the OR profession.

Although theatre-level combat modeling attempts to be scientific in its methods, it is rarely so in its outputs. Outputs are interwoven with subjective judgements, either through their interpretation or by way of the inputs that were instrumental to producing the outputs or in the very construction of the model itself. The relativity of subjective judgement, while discouraging, need not be debilitating to theatre-level combat modeling. Because these models are the only means of examining force structure questions vital to national security, analysts are confronted with the continuing task of rethinking the basic structures of these models. Past models can furnish us a vast reservoir of experience in theatre-level combat modeling which can be exploited to further this aspect of operations research. However, this reservoir can be effectively used for the enhancement of the profession only if what has been accomplished is adequately documented so that others may correctly use models previously developed. In this manner, even though no model can fully treat all the intricacies of the combat process, the analyst can enrich the profession through the continuing effort to better model the process fully using all the knowledge that has come before.

The concept of documentation that this paper proposes will not cure all the ills. It is but a proposal to correct a defect, inadequate documentation, that has long plagued theatre-level combat modeling. But if it is faithfully executed with the same energy and level of effort that has been expended in decrying the problem of inadequate documentation, then there is hope that the omission can be corrected. It is imperative that analysts adequately document newly designed models or modifications to existing models so that other analysts may use them properly. Before a project is considered complete it is the analyst's responsibility to insure that the vital step of documentation is accomplished. Only in this manner can there be assurance that the model designed or modified can be fully understood by those who subsequently want to use the model. Analysts using existing models must expand and supplement the current available documentation of existing models in the active inventory. The next time an existing model is used professionalism demands it be fully understood; any new undocumented factors uncovered in its examination should be formally noted and made a permanent part of the official documentation. In this manner past omissions will be corrected, the scientific method will be invigorated and the standing of the Operations Research profession enhanced. Subsequent results will then be more fully explainable and posses greater credibility and even if the conclusions cannot be final, because of the impalpable nature of the subject, the techniques of theatre-level combat modeling will be enriched by the process.

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