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REPORT OF THE
ARMY SCIENTIFIC ADVISORY PANEL
AD HOC GROUP ON GROUND COMBAT
VEHICLE MOBILITY

25 MAY 1973

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I. EXECUTIVE SUMMARY

1. The Ad Hoc Group on Ground Combat Mobility was charged with studying and evaluating the methodologies in use by the Army for defining future ground combat mobility requirements and promoting new advances in ground combat vehicles. Aside from military judgment and combat experience, the principal tools in use are simulations in a variety of forms, i.e., the modelling of battle scenarios, either analytically or experimentally, as a means of appraising the worth of new combat concepts and materiel designs. Analytical simulations are, perhaps to an excessively large extent, based on computer-programmed models. Experimental simulations range from laboratory tests with limited objectives to full-scale field exercises.
2. The Group finds that Army decision-making in the area of ground combat mobility can be significantly enhanced through the development of a coordinated hierarchy of simulation tools. A coordinated hierarchy requires that (a) analytical simulations should be so designed that, ideally, each simulation model is compatible with all others, e.g., each subsystem model should be capable of convenient integration into a model at the next higher systems level; and (b) the analytical models should be validated by experiment, based on the philosophy of achieving an optimum interplay and mutual support between analysis and experiment.
3. The Group finds that current Army practice does not adequately emphasize or recognize the need for coordinating and experimentally validating the large number of analytical models which are in the Army inventory. This may account in large measure for the pervasive attitude of skepticism toward the use of the results of these models in Army decision-making that was apparent to the Group.
4. The Group recommends that a single agency be established at the Vice Chief of Staff level with the responsibility for monitoring and coordinating Army-wide efforts in the simulation area. Such an agency already exists at the command level recommended, but its program and authority are in a tenuous and formative stage. It is not the intent that this agency be given all-embracing powers, but its authority should be sufficient to insure that a properly structured set of simulation tools be developed within the total Army program. The agency should have adequate independent funding to permit it to conduct exploratory research on improved methods for achieving model compatibility and on new approaches to the design of simulations.
5. Improved field facilities to enable the experimental validation of simulation models for ground combat mobility are urgently needed. Seemingly adequate programs are in process at CDEC and MASSTER to provide them with the instrumentation capabilities essential for the conduct of meaningful validations. However, the mission priorities that have evolved at both these agencies do not reflect the importance of their role in developing Army simulation capabilities, and they have not been given the professional staffing resources needed for effective participation in such an effort.

6. The Group is of the opinion that senior Army management should become more deeply involved in the planning for Army simulation capabilities, particularly that program area or facet which includes ground combat mobility. At the present time, significant resources are being allocated to such activities with only minimal return, for the reasons already outlined. Since meaningful planning will involve cooperation among many of the organizational elements of the Army, the critical issues can only be resolved through decisions emanating from the level of the Vice Chief of Staff.

II. CONCLUSIONS AND RECOMMENDATIONS

As a result of its studies, the Ad Hoc Group reached conclusions and recommendations as detailed below. In the Group's opinion, these recommendations should be the basis for Army management implementation.

Conclusion No. 1 - Combat simulations, both analytical and experimental, have considerable potential to aid Army decision-making. They should occupy important roles in the planning process for determining future Army combat mobility requirements and in promoting and evaluating new ideas. The quality of the input from such techniques has thus far been minimal, for reasons delineated in subsequent Conclusions, but this does not detract from the considerable potential benefits which can accrue from proper use of simulation techniques.

It should be emphasized that simulation techniques will, at best, merely serve to strengthen the policy decisions which must be made by senior Army management. Such decisions must be based on a suitable combination of analysis, experience and judgment. Simulation techniques can reduce the degree of factual uncertainty underlying the final decisions.

Recommendation No. 1 - Army management should stress the importance of simulation as a tool for combat mobility decision-making, and commit resources adequate for the development of a full range of coordinated techniques directed toward this objective.

Conclusion No. 2 - Although some steps have been taken recently to correct the situation, the development of combat mobility evaluation techniques by the Army has to date been a largely uncoordinated evolutionary process with resultant gaps, incompatibility, and lack of adequate validation or sensitivity examination. Most simulation models employed were generated on an ad hoc basis to fulfill a specific need of a specific weapon system. As such, they have been funded out of that weapon system development program. They are not designed to have wide application, are not adequately validated, and are often abandoned after their initial usefulness is served.

Moreover, in its "analytical" programs, the Army has overemphasized computer simulation at the expense of problem formulation in physical, analytical terms in the original WW II spirit of operations research which attempt to identify the few governing variables and to illuminate their functional (for example, algebraic) interrelationships through classical mathematical analysis without the use of computers.

When we say "simulation" in this report, we thus intend to encompass not only digital computer simulation, but also analog simulation, mathematical analytical modelling, physical modelling, laboratory modelling (e.g., wind tunnel tests), field experiments, and any other simulation techniques available to the researcher.

Recommendation No. 2 - The group within the office of the Chief of Staff of the Army whose function is to monitor and coordinate the variety of major simulations being developed and used throughout the Army should be strengthened and expanded. Its primary objective should be to guide the Army toward the development of a comprehensive set of validated simulations which can be used in studies of new tactics for the evaluation of proposed new weapons systems, and for major component design.

In order to carry out its function effectively, the group should receive adequate, independent funding to accomplish its monitoring and cataloging activities, as well as to enable it to conduct exploratory studies of how simulations designed by various Army agencies can best be cross-linked and integrated, and also to explore new developments in simulation methodologies.

When major new simulation efforts are planned by an Army agency, this central group should have a strong advisory input in regard to the desirability of the new undertaking from the perspective of then-current Army efforts and planning.

Conclusion No. 3 - Analytical simulations represent theoretical constructions of the battlefield environment. Empirical relationships among certain of the variables may be used for simplification, and large-scale computers are generally employed to carry out the detailed calculations. Man-computer interfaces may be incorporated in the model to improve the realism of decision-making processes.

Since such simulations are theoretical in nature, it is essential that every effort be made to check them experimentally. The greatest failing of the current Army simulation effort is that no consistent philosophy exists for the experimental verification of analytical procedures, and only minimal planning is under way to correct this shortcoming.

Recommendation No. 3 - The Army should establish and implement a plan for the experimental verification of currently used analytical simulations. Efforts at MASSTER and CDEC in this direction should be substantially expanded and accelerated.

Conclusion No. 4 - Among the more important of the currently available simulation models with combat mobility implications are the following: at the Division level--DIVWAG; at the Battalion level--DYNTACS, IUA and CARMONETTE; at the engineering level--AMC Mobility Model. Each of these has obvious deficiencies, and only the AMC Mobility Model, to the best of our knowledge, is accompanied by a logical plan for its future improvement and development.

Among the deficiencies attributed to the various models are an overly limited representation of the battlefield scenario; excessive computer requirements in terms of size and times for running; and a lack of reprogramming flexibility. None of the models has been subjected to

adequate sensitivity analyses which may enable their simplification. Experience and insight from one model to the next have not been transferred, largely because each model is developed under time and program pressure. All of these models are based on digital computation, and essentially neglect the possible use of analog sub-models as a means for improving their realism and reducing the required size of the digital computer needed.

Recommendation No. 4 - A plan should be developed for the continuing improvement of existing Army combat simulations. Deficiencies such as unrealistic scenarios, excessive running time and large computer requirements should be addressed in a planned and coordinated program. Specifically, simplifications should be sought through the use of analog techniques and sensitivity analyses.

Conclusion No. 5 - Field combat simulations conducted by MASSTER at Fort Hood and CDEC at Hunter-Liggett Military Reservation have suffered from a lack of capabilities for the expeditious collection, recording and analysis of detailed data from field experiments and from combat histories. At both of these installations, the necessary equipment is being procured and installed to remedy some aspect of this lack of capability. It is evident that these facilities are urgently needed to enable the experimental verification of simulation models.

The missions assigned these installations do not, however, include a defined responsibility for incorporating model verification into the experiments they conduct. Should such a responsibility be given to them, they would need added resources in terms of professional personnel and funds to meet the need for interfacing with those designing the simulation models.

Recommendation No. 5 - Experimental verification of analytical simulations should be a continuing responsibility of those Army agencies which conduct controlled field trials. Each field experiment should be viewed as source material for this continuing effort; therefore, even if the experiment has other goals, an effort should be made to apply analytical techniques to such field experimentation in order to improve confidence in simulation techniques. Appropriate resources and Army-wide cooperation should be supplied to these agencies for this purpose.

Conclusion No. 6 - Improved combat tactics and new technology are synergistically linked, i.e., new technology enables the use of more effective tactics, and advanced tactical concepts spur the demand for new technology. Simulation techniques are powerful tools for conceptualizing new weapons systems and their tactical employment.

Thus far, unfortunately, analytical simulations have contributed little of important potential benefit in this area. The reasons have already been mentioned, i.e., current simulations cannot be reprogrammed flexibly to cope with new scenarios, the degree of realism inherent in the simulation is often less than adequate, and computer requirements are often excessive.

In addition, simulation efforts are usually directed to answer specific questions, and scope and funds are limited accordingly. As a result, little flexibility is allowed those conducting the simulations to explore promising and interesting additional aspects of the overall problem which are suggested by the result of the analysis.

Looking to the future, however, it is anticipated that these drawbacks can be considerably reduced. As one possibility, complete programs can be flexibly assembled from realistic subprograms, each designed to deal with a particular aspect of the battlefield scenario, and each formalized to the extent that it can be integrated into the main program without difficulty.

It should be noted, incidentally, that improved analytical simulations could afford considerable advantage in the training of combat commanders. This has been recognized by the appropriate Army agencies, and various models are currently being employed for this purpose. None of the models presently in use, however, possess sufficient programmatic strength and flexibility to serve this need adequately.

Recommendation No. 6 - A planned program should be implemented with the objective of advancing the art and science of designing flexible, realistic simulation techniques. A prominent part of this effort should be directed toward the assemblage of complete simulation models from submodels which are designed for convenient integration into the model as a whole. The use of such models for weapons systems conceptualization should be stressed; specifically, some flexibility should be allowed the designers of each experiment to encourage innovation.

III. PURPOSES AND DESCRIPTION OF THE STUDY

1. The Ad Hoc Group on Ground Combat Vehicle Mobility was activated in July 1972 in response to the ASAP Study Proposal (Appendix I). That document contains the following problem statement:

"Army methodology for defining requirements and promoting new advances in combat vehicles is not integrated and requires examination. The resultant effect is that advances, both in concepts and components, are not available on which to base new combat vehicle design."

Again quoting from the Study Proposal, the work of the Ad Hoc Group was to encompass three phases:

PHASE I

a. Assess the current simulation efforts in the Army and industry applicable to combat vehicles and their components, and suggest methods for integrating these programs into a total battlefield simulation.

b. Outline the general methodology which could rapidly evaluate, on a total scenario basis, the effect of various combat vehicle mobility parameters (speed, weight, signature, acceleration, resupply, etc.) on the total outcome of an engagement. It is anticipated that the effective development of this capability, coupled with near-real battle simulations at such test areas as MASSTER, Fort Hood, would provide an easily justified rating of priorities for increasing the technology in surface mobility. Furthermore, it offers a better method of determining proper R&D support for combat vehicle mobility in relation to other materiel areas.

PHASE II

a. Assess the current major Army battlefield test areas and evaluate their capability for testing mockup of "cheap" combat vehicles/components. This effort would evaluate the adequacy of the tools to validate new ground combat vehicle concepts under simulated combat conditions.

b. Determine what resource requirements would be necessary if the Army were to increase its efforts in ground mobility simulations and field test validations.

PHASE III

a. Provide a listing of technical areas with the largest payoff in the combat vehicle area consistent with approved basic operational concepts for the future Army.

b. For future use, provide an expansion of the methodology defined in Phase I, paragraph b above, to allow rapid evaluation of the current equipment inventory's effectiveness against a variety of postulated threats for use in such studies as CONAF.

2. While the problem statement appears to be an unduly harsh assessment of the current practices in combat vehicle design, the members of the Ad Hoc Group were in agreement that a review is in order to ascertain the effectiveness of the methods by which new combat vehicles come into being. As will be apparent, although the Group attempted to be reasonably responsive to the study request, time available did not permit the comprehensive treatment that this subject matter unquestionably deserves. The following guidelines for the study were emphasized and made clear at the first meeting of the Group:

a. It is not the purpose of the study to define the mobility requirements for Army vehicles. Rather, we are to appraise the mechanisms and procedures through which requirements are established; the manner in which the technical feasibility of these requirements is evaluated in the conceptual design stage; and the effectiveness of the design tools available for converting concepts into vehicle hardware.

b. Because of the broad charge given to the Group, it will be necessary that the highest levels of Army management be consulted during the course of the investigation. Particularly where complex and costly systems are involved, the role of top Army management in deciding future mobility requirements cannot be ignored. In fact, the primary purpose of the study might well be rephrased to answer the question: "Are senior Army officials being provided accurate and comprehensive data and information as a basis for arriving at sound decisions regarding major resource allocations to satisfy future Army combat vehicle mobility needs?"

During its studies, the Group did not overly concern itself with methodological details. The aim was to assess currently available methods and practices, to appraise the philosophies for their use, and to make recommendations regarding future directions for improvement.

3. During its investigations, the Ad Hoc Group scheduled seven meetings at various Army installations. The locations of these meetings, along with brief summaries of the proceedings, are given in Appendix III. It is to be noted that meetings were held with representatives of senior Army management, with representatives from various CONARC, CDC, and AMC agencies, and with specialists in simulation techniques. Since meetings could not be held at all agencies with significant inputs to mobility

decisions, organizations not visited were requested to present briefings at some of the Group sessions. The quality of the presentations, and the cooperation afforded the Group by all parties, were uniformly excellent. It is hoped that this report properly reflects the many excellent suggestions and ideas advanced by all those who worked with us.

This report was written on the basis of numerous working papers prepared by the members of the Ad Hoc Group. The file for the study contains the complete text of their contributions and is available for reference.

IV. WHAT IS COMBAT MOBILITY

1. It would be presumptuous to attempt to quantify so complex a quality as "combat mobility". In essence, a vehicle has suitable combat mobility when it is capable of being on-station in a combat area when needed, and when, as part of the total combat system, it can carry out its assigned mission in a timely and effective manner. As is inevitable in engineering designs, an increase in combat mobility can be achieved only through compromise with such other performance factors as cost, armor protection, payload and component complexity.

Technical Note 8-72 of the Human Engineering Laboratory draws a distinction between mobility and combat agility in the following fashion: "By mobility....we generally mean the ability of the combat-vehicle system (man/machine combination) to move (relatively) quickly from point to point on the terrain as required to accomplish its mission. Thus, relative tactical mobility in vehicles can be measured by comparing the times required for them to move from point to point over various terrain types as required by a variety of tactical missions." "By combat agility, we generally mean those movements of the vehicle, usually associated with ability to start, stop and turn quickly, which would allow it to avoid enemy fire and terrain obstacles." The limitations of using linear acceleration alone as a measure of combat agility are emphasized.

From the viewpoint of the Ad Hoc Group, and as is made clear in the ASAP Study Proposal, a realistic consideration of combat mobility must include a number of other important factors which bear on the total question. Mobility, only one aspect of combat performance, cannot be divorced from armor protection, range, fuel consumption, crew size, logistical supply, and so forth.

Hovering over all such considerations are the nature of the enemy threat, and the manner in which the combat vehicle will be used tactically. During the lifetime of the vehicle, it may be called on to perform a variety of missions over a variety of terrains, many of them no doubt unanticipated at the time the design is first crystallized. Life-cycle costs must be taken into account in deciding how much combat mobility the Army can afford. Inadequate reliability and maintainability are factors that may militate against the choice of otherwise desirable mobility hardware.

2. Perhaps the first conviction reached by the Group is that it is unrealistic to expect that the overall success of a new design can be judged quantitatively in terms of an established "index of merit", or even a small number of such indices. A common fallacy often advanced is that the capabilities of vehicles to perform various required functions can be evaluated (either on absolute or comparative scales); suitable weighting factors could then be assigned to reflect the relative importance of the various functions; and from this a composite index of merit could be derived to reflect the overall worth of a vehicle system.

As a practical matter, however, such a procedure will not lead to accurate and dependable results.

Many subelements of the total mobility problem can be studied effectively through simulation and experimentation, leading to valuable methods for appraising the extent to which new concepts and designs will fulfill certain functional requirements. Establishing a standard procedure for integrating these inputs into an overall index of merit, however, inevitably involves so many assumptions and approximations that the final result will be unconvincing at best, and possibly even misleading.

As in the past, the final decision whether to commit resources to a new vehicle concept will involve substantial elements of judgment and military intuition. This is particularly the case when significant departures from past practice are involved. The current pressures on Army management to seek quantitative justification for decisions, even when adequate tools are not yet available for that purpose, place extreme difficulties in the way of innovative and creative thinking. Unfortunately, these pressures come from all levels of government.

3. The interplay between new tactics and technological opportunities is a case in point. Computer simulations, which are extremely valuable management tools to support decision-making, are nevertheless characterized by distinct limitations. Practical programming restrictions require that simulations be designed to clarify certain aspects of the battlefield environment; they cannot be designed to duplicate the real world, and a simulation designed for one purpose can rarely be extrapolated to include the effects of a radically new set of tactical purposes. Where combat effectiveness is concerned, the synergism between tactics and mobility requirements is of paramount importance.

For example, the advent of the armored personnel carrier enables the exploitation of a rapid balanced-force advance of armor and infantry on the battlefield; attack helicopters and other close-support aircraft may reduce the role of the tank as an antitank weapon system; guided artillery, with its pinpoint accuracy, may reduce the role of the tank in attacking hard targets.

These factors make it very important that more concentrated attention be placed on the tactics-technology interplay in future decisions involving combat mobility. Later in the report it will be pointed out that methodologies to permit this can be developed, but that at the present time such efforts are fragmented and uncoordinated. What is needed is a management philosophy which encourages innovative ideas and then combines the process of innovation with computer simulations of the battlefield environment, field experimentation, and seasoned judgment of experienced officers into a unified methodology for planning and development.

4. Final decisions regarding resource allocations for new combat vehicles require a significant judgmental input. Very substantial help, however, can be given to the decision-makers through the mediums of analysis and experiment. It is pertinent at this point to examine the nature and variety of the tools that are presently available for this purpose, and to determine what methodological improvements should be pursued to reduce the level of uncertainty in the decision-making process.

V. METHODOLOGIES FOR STUDYING COMBAT MOBILITY EFFECTIVENESS

1. A variety of investigatory methods is available to those who synthesize and design systems. To be of optimum use, a spectrum of techniques must be organized according to an underlying philosophy into an integrated study plan. In the design of ground combat systems, including combat vehicles, there are three broadly defined steps in the process: conceptualization, optimization of subsystems and, finally, detailed design.

For the first step, the primary input is subjective judgment born of experience and strongly influenced by knowledge of advances in technological capabilities. This is particularly useful during the conceptual phases of a new design as an aid in establishing desired performance factors. Judgment must be bolstered, on the analytical side, by methodologies such as battlefield simulations and other war-gaming techniques. Where possible, conceptualization must also draw on the results of experimental techniques that should include maneuvers specifically designed to check the worth of new tactics/technology combinations.

Once the new system concept is reasonably well defined and desired performance parameters accepted, techniques must be available to optimize the design approach as the second phase of the design process. This system optimization phase must take into account the interrelationships among the various vehicle subsystems (armor, weapons, propulsion, etc.) and must point toward an integrated system that will not violate practical constraints and yet promises to approximate the overall system performance sought in the new design. System optimization is often accomplished through computer studies, but controlled experimentation is an equally important part of the optimization process. Thus, if a radically new propulsion system is under consideration to provide added mobility, a relatively low-cost "mobility test vehicle" might be constructed and tested; such a vehicle would incorporate the essential elements of the new propulsion system, but would attempt no hardware realism in other subsystems except insofar as they interrelate with propulsion performance. Approaches of this kind will be discussed later in more detail.

The third step in the process of converting a vehicle concept into final design of actual hardware consists of detailed engineering procedures, once again based on a judicious combination of analysis and experiment. These are the procedures which enable the detailing of the subsystems and components so as to insure their proper function, reliability and maintainability. Analytical methods include techniques for dynamic, static and fatigue design, reliability predictions, and so forth. Available experimental tools range from highly specific laboratory experiments to controlled experiments with essentially complete subsystems. Of the three broadly defined steps in design discussed here, this last category is philosophically the most traditional and best understood of the three, and also the most highly developed.

The preceding remarks indicate that both analytic and experimental techniques are necessary in order to advance the state of the art. In fact, the two must be mutually supportive and interrelated--the warp and woof, so to speak, of the design fabric.

It is worthwhile to recall at this point that the very essence and strength of the scientific method resides in the synergism between theory and experiment. Analytically framed hypotheses, subjected to experiment for verification and then refined, are used to predict the outcome of events in new circumstances. Continued experimental checks are necessary as the range of forward extrapolation is increased.

In a later part of this report, it will be pointed out that the inter-relationship between analytic techniques and experiment is not receiving adequate attention in the formulation of tools for combat mobility design. This applies particularly in the areas of concept formulation and systems optimization but carries through the whole development process. Many of the predictive methods now being used have not been subjected to experimental verification, and cohesive plans for doing so are not in evidence.

3. In order to set the stage for the further discussion, a few remarks are in order regarding the design of computer simulations for combat mobility applications. Specifically under consideration are computer models designed to simulate the battlefield environment for the purpose of exploring the combined potentials of new tactics and new technology.

As a first caveat, it must be kept in mind that computer simulations do not represent the real world; by the very nature of their design, they reflect an idealized view of an imagined situation, bounded by the comprehension of the model creator and by the practical limitations imposed by even the largest-scale computer.

It is also axiomatic that computer simulations have no internal capacity for innovation. The output from a model is completely determined by the analytic structure built into it by the programmer, and by the initial conditions prescribed for the run. Only with great rarity or by accident, therefore, will computer models lead to "imaginative" or "innovative" conclusions. The flash of inspiration, or the recasting of available knowledge into an unexpectedly creative new format, is beyond the capabilities of computer simulations. The shopworn cliché still prevails: People think, and computers keep records. On the other hand, it is quite clear that properly constructed computer models are invaluable aids in reinforcing and optimizing the potentials of new directions of thought.

If a computer model is designed to simulate in great detail a non-simple battlefield environment, the result will undoubtedly be a large-scale model involving many parameters and requiring lengthy computer runs.

To achieve maximum utility, it is necessary that a distinction be made between those parameters that are important and controlling and those which affect the model output in a relatively static, insensitive fashion. In order to make such assessments, special sensitivity studies are required, both through computer runs and through careful analysis of the data gathered during the field-experiment verifications of the total model. The objective sought is to reduce the model to its essential elements, so that use of the computer simulation to arrive at recommended actions will not be overburdened with unnecessarily time-consuming calculations.

4. The range of application of computer simulations for military problems is extensive. They can be employed as aids in studies of alternate tactics and strategies. They can be used to assess the effectiveness of present and future equipment. As training aids, they can make war-gaming exercises more realistic and improve the learning depth of combat officers. Finally, and of great importance, they can point the way toward conceptualizing novel and effective future weapons systems.

As yet, computer simulations have not had a significant impact on this last area of application. The uses thus far have been restricted to comparative studies between weapon system designs of relatively traditional character seeking to assess the improved performance of one system versus another. In appraising the results of such studies, incidentally, it should be kept in mind that quantitative performance estimates are of less value than achieving an understanding and appreciation of the relative roles of the various system mechanisms. Where the indicated performance levels among competing systems show small differences, it is clear that no reliance can be placed on the numerical results. At best, simulations provide only approximate answers, with margins of probable error wider than is customary for, say, engineering calculations.

The embryonic state of the art in designing and using computer simulations is no doubt the reason that simulation techniques have not found wider application in conceptualizing novel future weapons systems. As experience and confidence grow among the users of computer simulations, this kind of application will very probably emerge as one of the most fruitful uses of the technique.

VI. THE CURRENT STATUS OF COMBAT MOBILITY COMPUTER SIMULATIONS

1. Early in the discussions, it became quite clear that no one computer simulation model is available that treats both performance-related, engineering design details and overall combat effectiveness of ground combat vehicles. In fact, our analysis found three distinct categories of models to be of interest: engineering design models, battalion level combat models, and division level models. While there are overlapping capabilities among these models, the three categories are essentially complementary, and, unfortunately, in their present forms are not mutually interrelated in a way that will permit direct data transfer among categories.
2. The Group did not attempt a comprehensive review of every computer battle simulation model that might bear on ground combat mobility but rather limited our discussions to those simulations that appeared to us to be playing the most important, current roles in establishing ground combat mobility requirements, both qualitative and quantitative, which are related to acquisition for today's needs and to research and development for future needs. The simulations discussed, under those conditions are: Individual Unit Action (IUA), and IUA/Bonder, Dynamic Tactical Simulator (DYNTACS), CARMONETTE, Tank Sustained Operation Model (TANKSOM), Division War Gaming Model (DIVWAG), and the AMC Mobility Model. A summary description and evaluation of each of these models may be found in a separately published Annex to this report.
3. The three most important battlefield effectiveness models for ground combat vehicle considerations are IUA, DYNTACS and CARMONETTE. These provide transition between design models and division level combat simulations and, secondly, allow resolution to the individual weapon system level. All are concerned with the intense phase of combat involving ground armored vehicles; all are stochastic in nature, at least to some degree; all can handle either attack or defense; all are high resolution models; and all are played at the battalion level. None of them treats such peripheral interests as route march, resupply, post-attack action, vehicle reliability, maintainability or availability even though those activities are considered of the utmost importance to the design of combat vehicles for other reasons than the actual combat itself. IUA and DYNTACS resolve to the level of the individual vehicle. CARMONETTE permits resolution to the individual soldier and it also permits considerable flexibility in the size of forces that can be simulated.
4. DYNTACS has the advantage of some flexibility in choice of formations, in that the logic permits attack variations as intelligence is made available in the course of the battle. While DYNTACS is the best available combat model to assess the value of mobility in combat, it leaves much to be desired. IUA is particularly rigid in this regard, since the vehicle paths to the target are put in the computer at the beginning of the game with no changes provided for to respond to the course of the battle.

5. It is our conclusion that all of these models fall short of battle realism in several important aspects, the most important of which has to do with target acquisition. Adequate input data was said to be simply not available on the relative detectability of targets from within tanks. We were also informed that subroutines are not available to play the effects of suppressive fire or such obscuration techniques as smoke. Furthermore, it is not clear that any of the terrain subroutines adequately reflect concealment by vegetation. In fact, the group was informed that we do not really know how dependent results of simulations are on the terrain used.

6. Of these three battle models discussed, the IUA appears to be least useful for evaluating mobility design considerations. It does have the value of relative simplicity so that many runs can be made to get answers to specific questions like firepower effectiveness, but the computer exploration of more complex questions, such as changes in tank track design that could affect speed across country, requires an excessive amount of time.

7. The greater variability and flexibility of DYN TACS and CARMONETTE make them somewhat more useful in evaluating the significance of design changes that affect performance of vehicles, but the overall judgment of the Group is to support the CDC representative who remarked that he was "not highly impressed with current simulations as a way to get answers on new requirements." He cited the example of the military potential field tests of the TWISTER vehicle which reached the conclusion that the vehicle has good mobility; however, the decision-process could not be aided by a combat model that could balance the mobility gains against the increased cost and complexity of the TWISTER vehicle.

8. To help evaluate vehicle performance factors that are not specifically related to battle effectiveness, two models appear to be particularly useful: the Division War Gaming Model (DIVWAG) and the Tank Sustained Operation Model (TANKSOM). DIVWAG can give some insight on the value of speed of movement as related to larger-than-battalion-level operations, and also introduce logistics considerations. TANKSOM is an uncompleted reliability and maintainability model derived from an earlier model for helicopters called EPIC (Simulation Model for Evaluating Systems in Prolonged, Intensive Combat). If completed, TANKSOM could introduce considerations of forward support and rear echelon maintenance. It does quantify availability and repairability of the tanks involved in order to introduce this aspect of realism to the assumed engagement and give some evaluation of RAM design factors.

9. The AMSAA representatives reported on their use of a "hands-on" model, not yet named, at the division level that permits manual interaction almost anywhere in the game. The maneuver units are battalion size and among other advantages can account for air and artillery attrition. The group was also informed of other division level models such as the Research

Analysis Corporation Division Battle Model (DBM) and a Strategic Analysis Group model (LEGION). We saw no important relationship between those models and significant ground combat vehicle design considerations.

10. As far as we could determine, none of the models just discussed has been validated by anything approaching battalion level experiments or maneuvers designed for such validation. Some subsystems or subroutines have been validated, and the necessary input data obtained by experiments structured for that purpose.

11. The simulation model of interest that has had the most experimental validation is the AMC 71 Mobility Model, but, to date, that validation has been largely at the subsystem level. In fact, much of the model itself was built on the basis of experimentally obtained data from component and full vehicle performance tests. This model can be used effectively to assist in the design of a vehicle from the point of view of system performance; however, it cannot be used alone to evaluate a combat vehicle in the context of battlefield effectiveness. Rather, it should be used in conjunction with other combat simulations, such as DYN-TACS or CAR-MONETTE. In this respect, therefore, these and future simulations should be capable of being integrated with the AMC Mobility Model or accepting its output as a system input.

However, there are deficiencies of the Mobility Model that need correction. Among these are the need to improve the man-machine (ride dynamics) and man-terrain (visibility) submodels, and to extend the terrain data bank. We also need to develop improved component submodels to provide computer-assisted design and engineering. Additionally, the user must be required to present design and deployment guidelines in more specific, quantitative terms that can more easily be translated into engineering specifications.

VII. THE CURRENT STATUS OF EXPERIMENTAL FACILITIES FOR COMBAT MOBILITY INVESTIGATIONS

The experimental facilities of particular interest to this study are those directly related to the Army's capability to validate the simulation models just discussed. We appreciate that there are many other uses for those facilities, but for purposes of our study, we have limited our investigation to facilities that are uniquely suited to experimentation that can interact with, and in some measure validate, combat simulation models. It is easy to postulate plausible expressions in a combat simulation model for the interactions between equipment capabilities and combat effectiveness in an assumed battle; however, it is extremely difficult to validate these conjectures. Most of the combat models are built on plausible and largely unverified functional relationships among the many necessary data inputs. It is possible that their outputs are representative of a "real world" battle but it is also possible that they are seriously in error.

Facilities are available to use field experimentation progressively, as modelling goes forward, and to improve the data base that is involved in these functional relationships. In fact, some aspects could be verified well enough to remove them from the stochastic steps in the model. Experimental support to accomplish this is much more important than trying to improve simulation models by incorporating increased detail without experimental validation!

The Army has two facilities--MASSTER and CDEC--that are particularly suited for validation of battle simulation models with a complex of inputs, including enemy actions. Virtually all Army equipment test facilities where field test experiments are conducted can provide subsystem input data and model subroutine verification. Such facilities could be, and in some measure have been, used to validate the various subsystems within the AMC Mobility Model. The Group did not visit or discuss most of these many facilities, seeing them as beyond the scope of our study. Members of the Group did visit Project MASSTER at Fort Hood and CDEC at Fort Ord/Hunter Liggett Military Reservation (HLMR).

The Group was impressed with the scope of the facilities at HLMR, and the extensive instrumentation available. We were sobered to learn that thus far only battle experiments of no more than about 300 men, counting both friends and enemies were conducted. This attests dramatically to the difficulties involved in attempting to verify a ground combat simulation model that treats battalion size units.

The area, the manpower and the motivation exist at MASSTER to experiment with battalion and larger size engagements. Reasonably adequate position location equipment and battle scoring equipment are just now being installed. The capability to design an experiment to validate at least the subroutines of IUA, DYN TACS or CARMONETTE exists at MASSTER, but it is not apparent that there is any strong force in the Army pressing for such experimentation.

At both of these installations, it is clear that validation of simulation models is only an incidental activity to other missions and is not separately called out and funded. The staffs at both facilities recognize the potential opportunity concerning simulation validation and are anxious to see it exploited.

Conclusions reached by the Group and resulting recommendations for improvement of ground combat vehicle mobility can be found in Section II of this report immediately following the Executive Summary.

APPENDIX I

ASAP STUDY PROPOSAL

1. PROPOSED NAME. ASAP Ad Hoc Group on Ground Combat Vehicle Mobility.
2. STATEMENT OF THE PROBLEM. Army's methodology for defining requirements and promoting new advances in combat vehicles is not integrated and requires examination. The resultant effect is that advances, both in concepts and components, are not available, in an orderly manner, on which to base new combat vehicle design.
3. CONSIDERATIONS.

a. In planning for the Army of the future, considerable effort is expended in determining overall requirements. These requirements evolve from the national security missions assigned the Army as a function of the projected enemy threat and how the planner conceives the scenario--geographic locality, conflict duration, reinforcement concepts, etc. For example, Army ground mobility requirements are impacted mainly by expected geographical conditions.

b. The ongoing studies, Conceptual Design for the Army in the Field (1976-1982) (CONAF) and the Land Combat System Study I (1990), define the importance of such major program areas as air/surface mobility, command and control, strategic airlift, and air defense. These studies concentrate on using a specific inventory list of men and equipments to determine force development based on different tactics and doctrine. Most of the combat vehicles included in these studies are basically copies or derivations of current equipment on which new firepower equipment has been installed. The integration of advanced mobility concepts (electrical driven wheels, articulated vehicles, etc.) into such combat vehicles and their optimization to determine the degree of advancement is not established.

c. It is essential to develop the techniques so that alternative conceptual approaches can be quantified and programmed to provide rapid calculation of a complete scenario. This should include the capability of computing life cycle costs including RDTE, procurement, and operation and maintenance. These models can then be used rapidly to establish the influence of such parameters as vehicle weight, range, fuel consumption, speed, off-road capability, and others. Such effort, when established in an integrated manner, should determine the real combat vehicle requirements of the Army and point the way as to where to place research and development resources.

d. Current Army models are not able to exploit the sensitivity to battlefield success resulting from changing combat vehicle characteristics--mobility and weapon parameters. The already initiated component simulation programs such as the propulsion, ride, and suspension simulations at TACOM and weapon installation simulation at WECOM can be integrated to provide significant benefits. The outputs of one can become the inputs of the other.

e. A "Blue Ribbon Panel" has been convened to review the status of the Army wheeled vehicle fleet--its maintenance, procurement, use, and projected needs. Its goals are not in conflict with that of an ASAP Ad Hoc Group on Ground Combat Vehicle Mobility. It is anticipated that liaison will be maintained between the two groups.

4. PROPOSED TERMS OF REFERENCE. In view of the foregoing and its vital interest to the Modern Army even more so now than in the past because of restricted R&D funding, the study of ground combat vehicle mobility by the ASAP is appropriate. The objectives of the ad hoc group are outlined below:

PHASE I.

a. Assess the current simulation efforts in the Army and industry applicable to combat vehicles and their components, and suggest methods for integrating these programs into a total battlefield simulation.

b. Outline the general methodology which could rapidly evaluate, on a total scenario basis, the effect of various combat vehicle mobility parameters (speed, weight, signature, acceleration, resupply, etc.) on the total outcome of an engagement. It is anticipated that the effective development of this capability, coupled with near-real battle simulations at such test areas as MASSTER, Fort Hood, would provide an easily justified rating of priorities for increasing the technology in surface mobility. Furthermore, it offers a better method of determining proper R&D support for combat vehicle mobility in relation to other materiel areas.

PHASE II.

a. Assess the current major Army battlefield test areas and evaluate their capability for testing mockups of "cheap" combat vehicles/components. This effort would evaluate the adequacy of the tools to validate new ground combat vehicle concepts under simulated combat conditions.

b. Determine what resource requirements (education, personnel, hardware, software) would be necessary if the Army were to increase its efforts in ground mobility simulations and field test validations.

PHASE III.

a. For future use, provide an expansion of the methodology defined in Phase I, paragraph b above, to allow rapid evaluation of the current equipment inventory's effectiveness against a variety of postulated threats for use in such studies as CONAF.

b. Where possible, provide a listing of technical areas with the largest payoff in the combat vehicle area consistent with approved basic operational concepts for the future Army.

5. REFERENCES.

- a. Conceptual Design for the Army in the Field (CONAF).
- b. Land Combat System Study I (1985-1995).
- c. Military Technology of the 1980 Decade, ASAP 1970 Summer Study Report, Part 3, Mobility.
- d. WECOM Report on M60-A1, RE-TR-71-20.

APPENDIX II

DEPARTMENT OF THE ARMY
ARMY SCIENTIFIC ADVISORY PANEL
Washington, D. C. 20310

AD HOC GROUP
ON
GROUND COMBAT VEHICLE MOBILITY

LTG Austin W. Betts (USA-Ret)	Southwest Research Institute
MG Chester W. Clark (USA-Ret)	Private Consultant
Dr. I. Robert Ehrlich	Stevens Institute of Technology
Dr. Antonio Ferri	New York University
Mr. Errol J. Gay	Private Consultant
Mr. Martin Goland	Southwest Research Institute
Dr. Marvin R. Gustavson	Lawrence-Livermore Laboratory
Dr. William G. McMillan	McMillan Science Associates
LTC Melvyn D. Remus	Office, Chief of R&D, DA
Mr. Herbert K. Weiss	Litton Industries
Mr. Walter Eckhardt (Advisor)	Office of Asst. Vice Chief of Staff

APPENDIX III

Meetings Scheduled by the Mobility Group and a Brief Account of the Proceedings

1. 6 and 7 July 1972, Pentagon

a. Group personnel attending:

Mr. Goland
LTG Betts
Mr. Weiss
MG Clark

Mr. Gay
Dr. Ehrlich
LTC Remus
Mr. Hope (Added as special consultant)

b. Summary: The meeting was devoted to task analysis and background development.

c. Briefings and discussions:

<u>SUBJECT</u>	<u>BRIEFERS/AND ATTENDEES (designated by A)</u>
Main Battle Tank Task Force (MBTTF)	COL Charles K. Heiden COL Richard D. Lawrence (Both from the MBTTF)
Special Analysis of Wheeled Vehicles (WHEELS)	COL Kenneth R. Aboe BG Robert J. Baer (A) LTC Wayne E. Spilker (A) LTC George J. Mulcahy (A) Mr. Claron A. Robertson, Jr. (A) (All from WHEELS Group)
General Discussion of Mobility Problem	Mr. Jack I. Hope (Executive Office of the President)
Land Combat System I (LCS I)	LTC Phillips G. P. Eliot COL William T. Reeder (A) (Both from CONFOR Group)
Conceptual Design for the Army in the Field (CONAF)	LTC Harold A. Marvin COL William T. Reeder (A) (Both from CONFOR Group)
IUA, DYNTACS, CARMONETTE	Mr. James P. Smith (CDC Systems Analysis Group) Mr. Lawrence J. Dondero (A) (RAC) COL (USA Ret) Norman W. Parsons (A) (RAC) Mr. Dale E. Woomert (A) (AMSAA) Mr. Walter Eckhardt (A) (AVCSA)

General Philosophy

Dr. Robert B. Dillaway (AMC)
Dr. Marvin E. Lasser (OCD)

CDC Materiel Process

COL John E. Bell
Mr. John J. Rafferty
LTC James R. Henry
MAJ William E. Jones
(All from CDC Hqs)

2. 24 August, Fort Hood (Project MASSTER)

a. Group personnel attending:

Mr. Goland
LTG Betts
MG Clark

b. Summary: This subcommittee of the Group visited Project MASSTER to learn what, if any, role the project plays in the validation of simulation models and, more importantly, what capability they have for such validation activities. The subcommittee was briefed on the overall Project MASSTER program of tests and was given a description of instrumentation available, or on order, that could play a role in simulation validation. There was considerable discussion of ways in which Project MASSTER activities might be expanded to be more specifically directed to the validation of combat simulation models.

c. Briefings and Discussion:

SUBJECT

BRIEFERS/AND ATTENDEES

Organization and program,
Project MASSTER

MG R. M. Shoemaker
Dr. Phil Dickinson
LTC C. Stevens

STANO in mid-intensity
warfare

MAJ Burnell
COL Benjamin Harrison
COL Phillips
Mr. V. Henson
(All from Project MASSTER)

3. 28 and 29 August 1972, Pentagon

a. Group personnel attending:

Mr. Goland
LTG Betts
Dr. Ferri
Dr. Gustavson
Mr. Weiss
Dr. McMillan

MG Clark
Mr. Gay
Mr. Hope
Dr. Ehrlich
Mr. Eckhardt (Added as consultant)
LTC Remus

b. Summary: This meeting was again devoted to background development and task analysis. Dr. Joseph Sperrazza of AMSAA presented his philosophy on mobility. The Army's new materiel acquisition process was described. Comprehensive plans for future meetings were made.

c. Briefings and Discussions:

<u>SUBJECT</u>	<u>BRIEFERS/AND ATTENDEES</u>
IUA, CARMONETTE, Division Level Simulation and AMC Mobility Model plus general philosophy	Mr. Arend H. Reid Mr. Dale F. Woomert Dr. Joseph Sperrazza Mr. John W. Kramer (All from AMSAA)
DYNTACS	LTC Theodore D. Felber (From CDC Systems Analysis Group)
MICV Case History	LTC Peter B. Kenyon (PM MICV) Mr. Frederick C. Fischer (Office, PM MICV) MAJ William E. Jones (CDC Hqs) LTC Melvyn D. Remus (OCDR)
TANKSOM	Mr. Gary Nelson (CDC Maint Agency) Mr. James B. Campbell (A) (RAC)
New Materiel Acquisition Process	COL Lauris M. Eek, Jr. (OCDR)

4. 12 and 13 September 1972, Combat Developments Experimentation Command at Fort Ord and Hunter-Liggett Military Reservation, California.

a. Group personnel attending:

Mr. Goland	Mr. Weiss
LTG Betts	Dr. Ehrlich
Dr. Ferri	MG Clark
Dr. Gustavson	Mr. Gay
Dr. McMillan	LTC Remus

b. Summary: The ASAP Mobility Group met at CDEC to gain background information, to determine what resource requirements would be necessary for the Army to increase its efforts there in field test validations, and to see how CDEC might help validate the Army's currently used, mobility-related simulations. The first day was spent at Hunter-Liggett Military Reservation receiving briefings on facilities, recent and on-going experiments, instrumentation and overall capabilities. Typical instrumentation was observed at the instrumentation field maintenance facility and was followed by a comprehensive overflight of the entire reservation. The second day was spent in conference with the CDRCDEC and his staff.

c. Briefings and Discussions:

<u>SUBJECT</u>	<u>BRIEFERS/AND ATTENDEES</u>
HLMR Briefing	MAJ Richard B. Major (CDEC)
Command Briefing	LTC Frank S. Steward, Jr. (CDEC)
Instrumentation Briefing	COL Robert E. Hayes (CDEC)
Experimentation Synopsis	COL Worthington Mahone (CDEC)
WES Terrain Analysis Effort	Dr. R. P. Marchi (Braddock, Dunn, McDonald Scientific Support Laboratory)
Instrumentation Demonstration	LTC Richard C. Martin (CDEC)
General Discussion	BG Elmer R. Ochs (CDRCDEC) COL Robert Cunningham (CDEC) Dr. Marion Bryson (CDEC) CDEC Staff

5. 8 and 9 November 1972, Tank-Automotive Command, Warren, Michigan.

a. Group personnel attending:

Mr. Goland	Mr. Hope
LTG Betts	Dr. Ehrlich
Dr. Ferri	MG Clark
Dr. Gustavson	Mr. Gay
Dr. McMillan	Mr. Eckhardt
Mr. Weiss	LTC Remus

b. Summary: Background development on mobility-related R&D methodology continued with presentations on the AMC Mobility Model, HITPRO (by WECOM), and CAD-E. TACOM views of the recent MBT Task Force product were reviewed and, finally, a case history of the ARSV (SCOUT) Program was presented by the Project Manager.

c. Briefings and Discussions:

<u>SUBJECT</u>	<u>BRIEFERS/AND ATTENDEES</u>
Introduction and Overview	BG Chester M. McKeen, Jr. (DCDR, TACOM)
The AMC Mobility Model	Mr. Howard F. Dugoff (TACOM) COL Louis F. Felder* (A) (TACOM) Mr. Richard C. Navarin (A) (AMC)

*COL Felder attended all sessions.

Simulation at WECOM
(HITPRO & DYNITACS)

Mr. William G. Rankin (WECOM)

New MBT Program

Mr. Clifford D. Bradley (TACOM)

CAD-E at TACOM

Dr. Richard A. Lee (TACOM)
Mr. Howard F. Dugoff (A) (TACOM)

Simulation on ARSV Program
(Case History of ARSV)

COL Elmer L. Birk (PM ARSV)
Dr. Sidney M. Lenhoff (O, PM ARSV)
Mr. Norbert R. Slawski (O, PM ARSV)

Simulation for Military Use

Mr. Howard F. Dugoff (TACOM)

6. 6 and 7 December 1972, Fort Knox, Kentucky

a. Group personnel attending:

Mr. GoLand
LTG Betts
Dr. McMillan
Dr. Gustavson
MG Clark

Dr. Ehrlich
Mr. Gay
Mr. Eckhardt
LTC Remus

b. Summary: The Group reviewed combat vehicle philosophy and effort at the Armor Center and secured background information on testing and capabilities of the Armor and Engineer Board. A comprehensive briefing was received on Armor Center efforts, particularly the recent MBT Task Force work. Wide-ranging discussions were held with MG Desobry and his staff.

c. Briefings and Discussions:

SUBJECT

BRIEFERS/AND ATTENDEES

Battlefield Simulation

COL Carmelo P. Milia (Knox)

Armor Center

MAJ James M. Riley* (Knox)

Armor Philosophy and
Overview

MAJ James A. Logan* (Knox)

Simulation at Fort Knox

CPT Harry J. J. Bartosik* (Knox)

Operational Testing

COL Eugene J. Stokes, Jr. (Knox)
CPT Paul C. I. Hollowell (Knox)

Tank Testing

MAJ Harry Mullis (Knox)

*Attended by MG Desobry and his staff.

SIMFIRE

CPT Mathew McKnight (Knox)

**Human Engineering Laboratory
Armored Systems Tests**

Mr. Andrew J. Eckles, III (HEL)

General Discussion

**MG William R. Desobry (CDR Fort Knox)
BG Homer S. Long, Jr. (DCDR Fort Knox)
COL Carmelo P. Melia (Knox)
COL Christopher B. Sinclair (CDC Armor
Agency)
COL Eugene J. Stokes, Jr. (Armor and
Engineer Board)**

7. 16 and 17 January, Pentagon.

a. Group personnel attending:

**Mr. Goland
LTG Betts
Dr. Ferri
Dr. Gustavson
Dr. McMillan
Mr. Weiss**

**Mr. Hope
MG Clark
Mr. Gay
Dr. Ehrlich
Mr. Eckhardt
LTC Remus**

b. Summary: The Group met and interacted with Senior Army officials, obtained additional information on the interesting mobility experiment performed by the Human Engineering Laboratory, and finalized plans for the preparation of its report.

b. Briefings and Discussions:

SUBJECT

BRIEFERS/AND ATTENDEES

**Mobility TCP and Engines
to meet the energy crisis**

**Dr. William F. Banks (TACOM)
Mr. Howard F. Dugoff (A) (TACOM)**

**Meeting with Senior
Army Officials**

**Mr. Charles L. Poor (Acting ASA (R&D))
GEN Henry A. Miley, Jr. (CDR USAMC)
LTG William E. DePuy (AVCSA)
LTG John Norton (CDR USACDC)
LTG William C. Gribble, Jr. (CRD)
MG William A. Burke (DACSFOR)
MG George Sammet, Jr. (DCRD)
MG John H. Elder, Jr. (Dir Plans, ODCSOPS)
MG Curtis W. J. Chapman (DCDR USACDC)
Mr. Lawrence H. O'Neill (Chairman, ASAP)**

HELAST II

**Mr. Andrew J. Eckles III (HEL)
Dr. Leon Katchmier (A) (HEL)**

8. 14 and 15 March, Southwest Research Institute, San Antonio, Texas.

a. Group personnel attending:

Mr. Goland	MG Clark
LTG Betts	Mr. Gay
Dr. Ferri	Dr. Ehrlich
Dr. McMillan	Mr. Eckhardt
Mr. Weiss	LTC Remus

b. Summary: The Group completed drafting and editing its report.

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DEPARTMENT OF THE ARMY
OFFICE OF THE ASSISTANT CHIEF OF STAFF FOR FORCE DEVELOPMENT
WASHINGTON, D.C. 20310

16 JUL 1973

DAFD

MEMORANDUM FOR: CHIEF OF RESEARCH AND DEVELOPMENT

SUBJECT: Report of the ASAP Mobility Group

1. Reference: Letter DARD-ART, 12 Jun 73, subject as above.
2. As requested by referenced letter OACSFOR has reviewed the report of the ASAP Mobility Group and submits the comments below.
3. Comments on the recommendations of the report are as follows:

Recommendation No. 1: OACSFOR concurs.

Recommendation No. 2: The organizational location, procedures, regulations, and funding for any HQ DA group that monitors and coordinates model development is relatively unimportant so long as the group can provide the leadership and competence to perform these functions. Efforts undertaken to date by the group currently charged with these functions have been less than satisfactory even though the group is located at a high level and has been given a suitable charter. The major emphasis in this area should thus be given to ascertaining how to attain the required leadership and competence within existing resources rather than to matters that are more administrative in nature.

Recommendation No. 3: OACSFOR concurs. While such plans have been developed by the various Army analysis agencies there is a need for Army-wide coordination of plans of this nature.

Recommendation No. 4: OACSFOR concurs. Above comments on Recommendation No. 3 apply.

Recommendation No. 5: OACSFOR agrees that experimental verification of simulations is essential, but only the professional analysis agencies that develop and use simulations possess the knowledge, expertise, experience, and resources that continuing responsibility requires. The analysis agencies must identify verification and input data requirements and must participate in all phases of the test and experimentation process.

DAFD

SUBJECT: Report of the ASAP Mobility Group

Recommendation No. 6: OACSFOR concurs. Above comments on Recommendation No. 3 apply.

4. A number of general comments on the report are in order. While OACSFOR concurs with most of the recommendations, it is worth noting that these could easily have been made at the time the group began their review, and, in fact, have been made at various times by members of the Army analytical community. The deficiencies in Army simulations (for the study of ground mobility and all other applications) that the ASAP group identified are known to the Army analytical community, and many of the actions required to correct these deficiencies are equally obvious. There is little more depth in the body of the report. These observations clearly indicate that subject review is superficial and is not the kind of effort that the members of the ASAP should be asked to undertake.

5. The report shows little appreciation of the progress the Army has made in improving simulations. Over the years there has been a progression of significant improvements to such simulations as DYN TACS, IUA, and CARMONETTE. The report gives little recognition to such current developments as the various efforts to integrate models of varying resolution into coherent hierarchies. Furthermore, it does not acknowledge that various recent reorganization actions (e.g. creation of OTEA and CAA) should greatly facilitate further improvements, especially the validation of simulations by field experiments. It is disappointing that the ASAP group did not develop the historical perspective needed to evaluate the progress that has been made even though much remains to be done. This lack of historical perspective on the part of the ASAP group is considered to be a major cause of the shallowness of the report.

FOR THE ASSISTANT CHIEF OF STAFF FOR FORCE DEVELOPMENT:


ABRAHAM GOLUB
Scientific Advisor, OACSFOR

RECEIVED
OCT 11 1967

OCT 11 1967

ANNEX A

DETAILED STATUS OF COMBAT MOBILITY COMPUTER SIMULATIONS

TO REPORT OF THE

ARMY SCIENTIFIC ADVISORY PANEL

AD HOC GROUP ON GROUND COMBAT VEHICLE MOBILITY

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DETAILED STATUS OF COMBAT MOBILITY COMPUTER SIMULATIONS

INTRODUCTION: The Army has not consciously developed a simulation or collection of simulations that comprehensively treats the design and combat effectiveness of land mobility. In other words, it is impossible today to determine and/or predict the impact of land mobility on the battlefield using existing simulations.

This lack of ability to determine the impact of tactical land mobility on the battlefield causes the following:

a. Senior Army officials to make important decisions affecting mobility research without the assistance they might expect of appropriate simulations.

b. The spending of critical and scarce dollars for competing systems whose relative merit might more cheaply be determined by an integrated mobility simulation hierarchy as part of an overall methodology.

c. The missed opportunity for assistance in the requirements' determination process and subsequent concept validation.

The fact that the Army has no collection or hierarchy of simulations that comprehensively treats the design and combat effectiveness of land mobility is not meant to diminish previous accomplishments. However, as in any other art after initial implementation and partial success, a second generation opportunity presents itself which can provide significant improvement and allow related technologies to capitalize on the newly advanced state-of-the-art.

Such is the case now with land mobility. In Figure 1, one sees the eventual goal of a step-by-step hierarchy of simulations with overlap and interfaces such that the impact of land mobility on combat could truly be assessed. It is emphasized that what is not wanted is an over-all-model-to-end-all-models computer simulation. The step-by-step character of model relationships shown in Figure 1 is vital for it emphasizes that, at each step along the way, these simulations are expected to interact with decision-makers' subjective judgment, other analysis, experimentation, and testing.

A picture of the actual state of mobility modeling is contained in Figure 2. Simulation names inclosed by solid lines indicate an adequate first generation simulation--when considered with respect to mobility--such as the AMC '71 Mobility Model. A dashed line around the simulation name, for example, DYN-TACS, indicates the mobility related portions of the model are inadequate. The combination solid and dashed lines indicate

that the mobility related portions are adequate, at least marginally so. An analysis of Figure 2 then indicates that both the AMC '71 Mobility Model and its Mobility Subsystems (Modules) are adequate first general simulations. Also by virtue of the overlapping lines, there is a satisfactory interface between these simulations. The DYNATACS model does not have an adequate mobility routine and does not interface with the AMC 71 Model below or DIVWAG above. An adequate interface would mean that the output of the lower simulation in the hierarchy would be compatible with the input of the next.

Though it has not been completely proven, DIVWAG, because of the capability man has to interact with the model, is considered to have at least a marginally adequate mobility capability. The CONAF Evaluation Model (CEM), though basically a force structure model and not fully developed, is also shown to have a marginally satisfactory mobility capability. This conclusion is due to the difficulty in actually deciding, at so low a resolution, just how mobility would impact. Examination of this conclusion is itself in order, but far enough down the priority list to keep one from further considering it here.

Instead of overlapping, the lines between DIVWAG and CEM are tangent which suggests an interface is being developed.

The hierarchy depicted in Figure 2 is not meant to describe all mobility modeling. Of the hundreds of simulations recognized in the Army today, the ones commonly used in relation to today's mobility problems are listed in the hierarchy in Figure 3. Obviously other simple hierarchies similar to Figure 2 could be built from Figure 3. For instance, IUA or CARMONETTE could be substituted for DYNATACS. As will be shown individually later, like inadequacies also exist in these models. Similarly LEGION or DEM could be substituted for DIVWAG, or ATLAS for CEM; however, similar problems previously described are still evident. One step in the right direction, though, is the current attempts at interfacing CARMONETTE and DEM.

Again this review of combat mobility computer simulations includes only those simulations dealing with ground combat vehicle mobility and currently being used for a mobility-related mission. It is not a comprehensive review of all simulations simply because they contain some type of mobility subroutine.

Models selected for review are those listed in Figure 3. Following individual model review, overall shortfalls with respect to realism will be considered, simulation usages will be discussed, validation requirements will be mentioned, and, finally, conclusions will be drawn. In lieu of starting at either end of the mobility simulation hierarchy of Figures 1, 2, or 3, this review will start in the middle with the first level of operational simulations--the high resolution, company/battalion operational models--DYNATACS, IUA, CARMONETTE, GLOBAL and SABER. Such models are--at least should be--the heart of the hierarchy in that they provide the transition from design to operations. Basically these simulations model the intense form of combat involved in closing the last few thousand meters with the enemy.

COMBAT EFFECTIVENESS SIMULATIONS:

1. High Resolution Simulations: The comments on the simulations that follow are derived from the material attached as Tabs to this appendix. The material in the Tabs is derived from a variety of publications but basically from the 1971 Department of the Army Review of Selected Army Models and the 5th Edition of the Joint Catalog of War Gaming Models. References are listed in Tab R.

In general, high resolution simulations model the intense part of combat as the attacker closes the final few thousand meters with the enemy. Resolution within the model itself varies from an individual weapon system to a reinforced battalion. No route march, resupply or RAM are played in the simulations. An exception is that GLOBAL has a companion sustained operations model supplement available for use, that takes RAM into consideration. Generally the high resolution models provide an output in the form of a time sequenced event (activity) history.

a. DYNTACS (Dynamic Tactical Simulator): For greater detail on this model see Tab A. DYNTACS is a high resolution, stochastic simulation of battalion-sized engagements designed primarily to analyze individual weapons and performance. It was designed to depict the play of armored vehicles, wheeled or tracked, it cannot represent the individual rifleman. Due to its complexity and sophistication, DYNTACS requires large core space and a long running time. For these reasons, it is considered mainly as a research tool. Input preparation is time consuming. DYNTACS' capabilities include the delay, defense, meeting engagement and attack. Because of its dynamic route selection, based on reasonable mobility characteristic as inputs and the interaction of maneuver and fire, DYNTACS is considered to have the best mobility subroutine of the high resolution models. At first glance it would seem suitable for evaluating vehicles of varying mobility. However, the suitability for mobility evaluations is more apparent than real. The model, as are all high resolution models, is very highly dependent on hit and kill probabilities. For measuring mobility sensitivities, it is the best of the high resolution models all right, but it is the best of a poor lot.

b. IUA (Individual Unit Action): See Tab B. IUA is a stochastic model that was designed to evaluate the combat effectiveness of tank and anti-tank systems (no dismounted infantry other than antitank weapons can be played). Basically, mobility has almost no value in this model. Mobility and terrain are preprocessed during the months of preparation time. All movement is predetermined without reference to the course of the battle. The attacker always moves down a predetermined path regardless of what happened to those that preceded him. Changing this model to allow dynamic mobility submodeling would require a complete restructuring. Additionally, in favor of the defender, targets in hull defilade can not be visually acquired, and defenders are always in hull defilade. Other disadvantages of this model include lack of ability to play a delay, withdrawal or meeting engagement. Additionally, it is difficult to change terrain. There is also no tactical decision routine. On the advantageous side, however, what time is lost in IUA preprocessing is partially made up

by good running time (up to 30 replications in 2 1/2 hours of computer time allowing good response). Because of its mobility disadvantages, IUA must be rated near the bottom of operational models with respect to adequately modeling the impact of mobility on the battlefield.

c. BONDER/IUA (BONDER, not an acronym/Individual Unit Action): See Tab C. The BONDER/IUA deterministic model is an adaptation of the general BONDER methodology to the IUA simulation scenario. It replaces the stochastic nature of IUA with deterministic differential equations. This model uses the same terrain and mobility preprocessor outputs of the IUA model and, therefore, has the same basic disadvantages. Any change in mobility requires a new IUA preprocessor output. Thus, the value of mobility cannot be satisfactorily played through the BONDER/IUA. This model is fairly good for sensitivity analysis of weapon accuracy, rate of fire, lethality and acquisition data. Because of its deterministic nature, its speed of running is exceptionally good. In this regard and as a companion to the IUA, the BONDER/IUA represents a very desirable relationship that would certainly be in demand for mobility modeling. Consequently the Army should devise a fast running companion to whatever model is finally selected (developed or improved) to be the high resolution model capable of satisfactorily determining the impact of mobility on the battlefield.

d. CARMONETTE (not an acronym): See Tab D. CARMONETTE is a stochastic mathematical computer simulation of small unit combat to explore the significant factors affecting the outcome of small unit engagements. This model can play both vehicular weapons systems and dismounted infantry. All the infantrymen are played as perfect, doctrinal soldiers. As in the IUA model, mobility is all preplanned; mobility parameters are quite reasonable for a preplanned situation. One of the reasons for lack of a movement subroutine is that CARMONETTE is one model that has had some sensitivity analysis run on its parameters; and results did not appear sensitive to mobility--as it was played by this model. Nevertheless, CARMONETTE is considered by some to be the best high resolution model. For other than mobility uses, this may well be true, but the preplanned nature of its mobility situations surely eliminates it from contention, without modification, as a desirable simulation for mobility-related determinations. One advantage of the model is its speed of operation once set up (a few minutes for each run, which is comparable to the IUA). However, it has the same disadvantage of a long setup time (months). One outstanding advantage of CARMONETTE is its attempted interface with DBM. When--and if--successful, it will be the first good interface between high and medium resolution models.

e. GLOBAL (not an acronym, GLOBAL Computer Simulation): See Tab E. GLOBAL is a stochastic, computer simulation that was developed to support and extend field experiments at Hunter-Liggett Military Reservation. It has recently been used by the CDC Helicopter Task Force to investigate the helicopter in the antitank role. The most suitable applications, in order of usefulness, of the model appear to be ground to air, air to ground and, lastly, ground to ground. The ground mobility characteristics of this model seem unsuitable for ground mobility play because of the following: In the displacement process (from one predefined position to an alternate), the ground unit disappears from its original location

and reappears at the new, after a suitable time delay defined for displacement. Additionally, no evasive action is possible by maneuver units upon detection or receiving fire from an enemy position. Advantages of the model include the fact that it is quick to run (also meaning preprocessing, including mobility, is long and tedious) and there is an associated sustained operations model to impart some of the effects of RAM. Valuable information on the application of RAM to whatever high resolution model(s) is finally used for mobility play may be available from this sustained operations model association with GLOBAL.

f. SABER (Simulated Assault Battle Environment Research) Model: See Tab F. SABER is a stochastic model to simulate combat in assault environments in which some or all elements of one side move in a preplanned fashion and exchange direct fire with elements of the other side. Terrain in this model affects vehicle speed, line of sight and accuracy of fire from the moving vehicle. The model--as in most high resolution simulations--demands coordinated movement of attacking force elements. Vehicular movement is highly stylized and is always preplanned. In other words, this model has the same mobility liabilities as IUA, CARMONETTE and GLOBAL. The major use of SABER was in the MICV study.

g. Summary: No high resolution model measures up to the need for a satisfactory mobility-related high resolution simulation. Because of their preplanned, stylized, unrealistic mobility play, GLOBAL, IUA, and BONDER/IUA appear completely unsatisfactory. SABER has similar disadvantages. CARMONETTE also does not satisfactorily do the job. However, investigation into why sensitivity analysis of CARMONETTE eliminated dynamic mobility play may prove useful to learning more about the impact of mobility on combat. Finally, DYN-TACS, which does play mobility in a dynamic way, still falls far short of properly projecting the impact of mobility onto the battlefield.

2. Medium Resolution Models: Medium resolution models fit into the middle of the operational model hierarchy. In an integrated methodology these models would, at least they should, accept input from computerized high resolution models, such as DYN-TACS. Medium level models are able to include the full range of functional capabilities of forces necessary for sustained operations while still being able to simulate many detailed characteristics of units, intelligence, communication systems and aircraft. At the other boundary, medium level models should link with computerized low level simulations such as ATLAS and CEM.

Two characteristics of medium or intermediate level operational models are that they include human decision-makers as an essential part of the game and that the games use many estimated parameters, probabilities, and weights in a complex of plausible, but unverified, formulas. The effect of the compounding of estimates and these plausible but unverified formulas is almost impossible to appreciate, since a complete sensitivity analysis is out of the question. A derivative consequence of the complexity and man-interaction is that all games are relatively slow (real time at best).

The simulations that are going to be considered vary considerably in their stage of development. DIVWAG (the follow on game to DIVTAG II whose descriptive information was mainly drawn on for this status) is not yet a well proven game. It theoretically has great power and usefulness but needs more "shaking down." LEGION has not been extensively exercised by STAG (The Strategic Analysis Group) of ODCSOPS. DBM is a model that has capitalized on experience with CBM (Corps Battle Model) and is thus a follow on generation effort. The interfacing development between DBM and CARMONETTE is also noteworthy. Except for this pairing of adjacent hierarchy models, insufficient work has been done in interfacing. A more complete description of medium resolution models follows:

a. DIVWAG (Division War Game): See Tab G. DIVWAG is a computer-assisted war game designed to assist in evaluating Army doctrine and organization. DIVWAG is a follow on effort to the Division Through Army Group Tactical War Game (DIVTAG) effort that has been going on at Fort Leavenworth under sponsorship of CDC for many years. DIVWAG holds great promise. It can play almost any combat unit from platoon to division. It plays logistics and air interdiction. It, however, is unproven and needs "shaking down." Some of its disadvantages are the months of preparation time (unless preplay is already on file) and its slowness of play.

b. DBM (Division Battle Model): See Tab H. DBM is a two-sided, computer-assisted war game designed to assist in studying the effects of varied weapon mixes, organizations, tactics, and support levels on the combat performance of a division sized force in nonnuclear or nuclear warfare. The resolution of DBM is to the company level, and it has a game to real time ratio of 1 to 8. The model is a follow on to the Corps Battle Model and, thus, has second generation advantages. Another apparent advantage of DBM is its interface with CARMONETTE, a worthwhile first in interfacing simulations within the mobility-related simulation hierarchy. DBM outputs personnel and equipment losses, territory gained or lost, and effectiveness of units.

c. LEGION (not an acronym): See Tab I. LEGION is a computerized, two-sided, free play war game designed to portray the interaction between small units (down to company) when two division sized forces engage in ground combat to evaluate division level plans. LEGION, which plays most facets of combat, is one of the most complex games on the computer. The disadvantages of LEGION are not so much in the adequacy of modeling, which is excessive in its completeness and detail, but in the lack of well defined data to use in its submodels. Additionally, it is slow to run, taking 30 to 50 people a week to play 20 hours of combat.

d. Summary: The medium resolution models are computer-assisted war games. In recognition of the man-interaction, mobility play is considered to be adequate. Certainly the final results of the middle-model review now being conducted under the auspices of the Office, Assistant Vice Chief of Staff, should shed some light on the relative value of the middle models in determining valid combat and mobility evaluations.

3. Low Resolution Models (Theater and Corps): Low resolution or theater war gaming models, according to the simulation hierarchy, should be able to receive and use input from the middle level simulations to accomplish such traditional missions as testing of contingency plans, analyzing doctrine strategy and problems, and assisting in force planning.

These models are normally designed to predict the results of theater combat, in terms of territory controlled and resource (personnel and equipment) losses as function of various force levels, force mixes, and force employment.

Simple algorithmic methodology, using historic data, spawned models like ATLAS which largely depend on aggregated firepower scores and force ratios to determine engagement type and outcome.

The other mode, which resulted in such models as TCM, involves attempts to incorporate more detail into the representation of theater level warfare. Such games are less dependent on such firepower scores but still use them to determine the outcome of battle once started.

This annex will describe both ATLAS and TCM and then attempt to describe a follow on generation, compromise model, CEM.

a. ATLAS (A Tactical, Logistical and Air Simulation): See Tab J. ATLAS is a highly aggregated, expected value, fully automated simulation for studying the overall trends, effects, and interactions of ground, air, and logistic forces in conventional theater level of warfare to determine combat force requirements and capabilities. ATLAS models steady state warfare and is not suitable for modeling initial combat or prolonged combat without close evaluation. Prolonged combat is suspect because of poor supply representation in the model. There is also poor representation of close air support (CAS). Terrain is represented in the model by flow lines which specify the paths (and lateral boundaries) for combat units and mini sectors of which there are three types which specify the mobility potential of the ground--good tank country, average terrain, and road-bound only terrain. The fundamental basis of ATLAS is FEBA movement and casualty rates, both based on forces ratios (for which there is sparse backup). Another disadvantage is the continuous FEBA; therefore, there can be no porous battlefield with penetrations and exploitations. This constraint significantly limits the impact that mobility might have. Additionally, the judgments of model builders are buried in the model; it is hard for current users to apply their judgments to important parameters within the model. Another recognized shortcoming of ATLAS is the lack of any decision structure. This shortcoming led to development of TCM.

b. TCM (Theater Combat Force Requirements Model): See Tab K. TCM is a follow on to ATLAS and is also highly automated; however, a decision structure has been incorporated allowing simulated commanders--brigade

through Army Group--to perform estimates of the situation, make decisions and allocate resources. The result of this decision structure is decided in brigade level engagements whose results are aggregated to determine the progress of the theater battles. TCM was expanded to include three types of battalions rather than only one. Logistics, CAS and steady state limitations of ATLAS still apply. Terrain in TCM is played similarly to that in ATLAS. Another disadvantage discovered in TCM was that one could not distinguish between various degrees of winning--it was strictly win, lose or draw. There could be no big wins (or losses) with their resultant consequences. Output of TCM is similar to ATLAS: position of the FEBA and the states of the various units. As the CONAF (Conceptual Design for the Army in the Field) study was pursued, an improved follow on to TCM was devised and called CEM.

c. CEM (CONAF Evaluation Model): See Tab L. As a follow on to TCM, CEM has the capability to accommodate many battalion types. It has better intelligence play, and linear obstacles have been added allowing greater realism. Again, change of FEBA and degradation of states of forces is the basic output. Equipment losses are not directly available but can be determined. Once again, vehicular speed or mobility does not figure significantly into assessments. Penetrations or exploitation which might break the continuity of the FEBA--and capitalize on mobility--are not allowed. Also there is no direct means of injecting the effects of lack of maintenance. Since CEM is part of the CONAF effort which is continuing, there should be a continuing improvement to the simulation. An interface between CEM and DIVWAG is being pursued, at least investigated.

d. Summary: The low resolution models appear well developed, certainly the result of follow on generation efforts. Since they are steady state models, they take neither initial and far reaching movement on the battlefield nor the long term, lasting, and often decisive effects of supply and maintenance into account.

DESIGN AND ENGINEERING SIMULATIONS:

1. Very High Resolution Simulations: Within the mobility-related simulation hierarchy, the design simulations are the most validated. Such could be expected for the changes of doctrine, tactics, and scenario little impact on the elemental systems in the very high resolution simulation range. The two models to be examined are the AMC '71 Mobility Model and HITPRO, a hit probability model.

a. AMC '71 Mobility Model: See Tab M. The AMC '71 Mobility Model can predict cross-country speed of wheeled or tracked vehicles operating over any geographic area. It is a first generation model that is particularly useful for:

(1) Establishing mobility criteria which ensure a desired level of performance over a specified geographic area.

(2) Determining and comparing the expected performance of various vehicular concepts in a specified environment.

(3) Studying the effect of design changes on the cross-country performance of wheeled or tracked vehicles, which in itself is also a requirement for computer-aided design and engineering of military vehicles (CAD-E). The AMC '71 Mobility Model is well suited for (1) the assessment of the adequacy of existing vehicle performance prediction technology and hence for the unveiling of important knowledge gaps, and (2) sensitivity analysis to establish the relative importance of various vehicular characteristics which influence field mobility. The AMC '71 Mobility Model is the first comprehensive mobility simulation that systematically structures the overall knowledge of mobility of individual vehicle systems. The model is dynamic in that it is constantly being improved as new knowledge becomes available; it is still under development. It has proven its usefulness--even in its first generation state--to the WHEELS Study Group which recently completed the most significant mobility related study in the Army in recent years. The model is being further developed, under guidance from the Office, Chief of Staff of the Army, for use as a Department of the Army vehicular management tool. Current improvements underway include addition of an articulation capability and addition of a road speed capability. The terrain inventories and measurements undertaken in support of this model would allow evaluation of vehicles in most key world environments.

b. HITPRO (Hit Probability): See Tab N. HITPRO is a firing performance model of an armored weapons system, initiated to provide a design tool capable of evaluating tank fire-on-the-move performance. HITPRO deterministically simulates the dynamic gun pointing error of a ground mobile weapon system as it moves over known terrain. A firing tank is simulated moving along a test course defined as a series of circular arcs with specifically sized and spaced bumps; the tank fires at a constant velocity target which moves in a straight line. The output of the model is hit probability (suitable for input into high resolution models), vehicle speed, and gun aiming direction. HITPRO has been an important step in determining the important inputs of probability of hit. But, as can be seen from the description of the simulation a constant velocity target moving in a straight line does not account for what mobility and agility might do to increase survivability of the target vehicle. This relationship is crucial to the survivability of combat vehicles on today's and tomorrow's battlefields. The relationship, therefore, must be determined and appropriately incorporated into the appropriate areas of effectiveness within the mobility related simulation hierarchy.

2. Very, Very High Resolution Simulations: Within the hierarchy of simulations, modules of the AMC '71 Mobility Model and CAD-E are listed in Figure 3 as very, very high resolution simulations. Since the modules of the Mobility Model are discussed under the Model itself in Tab M, they will not be considered again here. For CAD-E (Computer-Aided Design and Engineering), see Tab O. CAD-E is the application of automated techniques to enable the engineer or scientist to accomplish his normal functions in

concept, design, and design evaluation, encompassing the use of computers in (1) conceptual design, (2) mathematical modeling and design prediction, (3) design preparation and automatic drafting, (4) prototype fabrication, and (5) automated simulation and testing. The potential of CAD-E is to allow an engineer/scientist to interact or converse directly with the computer to produce a combination of man and machine that can outproduce either. The most significant mobility application of CAD-E to date has been in the design of component parts. CAD-E is currently being interfaced with the dynamic ride module of the AMC Mobility Model in an attempt to improve understanding of the dynamic ride parameter.

SPECIAL SIMULATIONS: Special simulations are developed to extend methodology in key, but sometimes not often used, directions. Two models which point up worthwhile areas of special application are TANKSOM and the WHEELS Fleet Model.

1. TANKSOM (Tank Sustained Operations Model): See Tab P. TANKSOM models the maintenance of tanks during sustained operations. Tanks to be maintained are the product of breakdowns while going to battle; if successful, returning from battle; returning to the unit from maintenance; and battle damage. TANKSOM interfaces with IUA, and uses modified Lanchester equations for battle losses. Though its development was a giant step in the right direction, TANKSOM remains uncompleted and unvalidated. The priority to complete and use it died with the completion of mission of the MBT Task Force.

2. WHEELS Fleet Model: See Tab O and Figure opposite. It is a computerized procedure for projecting alternative Army vehicle fleet requirements and impacts (especially costs) based upon proposed changes to current vehicle authorization policies and criteria. This model and the AMC '71 Mobility Model were the key model efforts in the WHEELS study recently completed by Department of the Army.

SIMULATION SHORTFALLS: The following are observations of the Mobility Group on shortfalls that should be considered for improvement of current or for inclusion within new simulations.

1. Target Acquisition: The target acquisition capability in most simulations varies from marginal to poor. The current inability to properly model target detection, location and positioning leads one to conclude that not enough is known about this extremely important facet of combat. It would appear that this subject is worthy of research to improve overall understanding. Whatever research is done should include the interaction of smoke obscuration. As a sidelight, some interesting implications of how terrain affects detectability are being revealed in the recent HEL (Human Engineering Laboratory) series of tests such as HELAST I and II.

2. Night Combat: Night combat has often offered interesting dividends. Currently none of the high resolution simulations appears able to satisfactorily model night combat. This lack of capability suggests that advantages of night fighting equipment cannot be properly estimated. It similarly suggests that the understanding of night combat is poor. Action to improve this understanding appears to be in order.

3. Survivability: Survivability of an armored vehicle on the battlefield is a complex interaction of weapon system, human, and target characteristics. Additionally, survivability seems to be enhanced by mobility/agility, armor protection and low silhouette. Again insufficient information seems to be available to adequately predict the tradeoffs between survivability and mobility/agility. Research should be undertaken on a priority basis to determine this key relationship.

4. Air Interdiction: The ability to properly play air interdiction is lacking in all simulations. US experience since mid-World War II has allowed, even encouraged, neglect of this constraint. The capability of potential adversaries today demands that an ability be developed somewhere in the simulation hierarchy to simulate the impact of air interdiction. The recent efforts of the helicopter versus tank simulations are a step--small but properly oriented--in the right direction. In regard to the tank versus helicopter simulations however, the Mobility Group became concerned at the apparent bias in support of the helicopter. It is suggested that the subject of air interdiction be approached from a comprehensive viewpoint and include the effects of tactical aircraft as well as helicopters.

5. Logistics: Particularly in high resolution simulations the role of logistics is obscured by other factors. This neglect is probably necessary to devise a model that can be properly run in a reasonable time period. However, a warning sign emphasizing the logistics assumptions should be forceably highlighted as one inputs the scenario and reviews the results. Similar warning references can be made to the supporting but also neglected aspects of the route march, unit reorganization and RAM.

6. Terrain: Based upon the needs of creators and availability of good data at the time of simulation development terrain needs, description and usage vary widely over the full range of simulations. The lack of uniformity of terrain input and usage causes, among similar resolution models, a lack of cross-verification capability and, between adjacent resolution models, a general inability to interface. An immediate goal of all model improvement efforts or development should be the common usage of Defense Mapping Agency digitized terrain--or some other suitable standard.

7. Scenarios: For similar reasons the lack of scenario uniformity causes lack of reproducibility of simulation results, even by the same agency with the same model. Every group develops its own scenario to satisfy its own needs and seldom are any two the same. Scenarios should be prepared and available from one central agency for all users so that results can be reproduced and verified at other locations or at later times. If possible the scenarios should be automated.

USAGE: The usage of simulations in the ground combat vehicle mobility arena seems to center about the relative effectiveness or cost effectiveness of incremental changes in mobile weapons systems. Often statistical variation alone exposes such results to question. Since simulation or

experimentation has too many uncertain inputs and assumptions, some say that one cannot draw valid conclusions unless there is a valid statistical difference of at least 25%. It would seem, therefore, that more time should be spent in attempting to discern areas where big payoffs are possible, rather than attempting to measure barely discernible differences in mobile weapons systems.

It is felt that there are several areas of simulation usage within an overall combat vehicle development methodology which are ripe for exploitation but currently not being exploited. These areas are described in Section VI, Current Status of Simulations, of the main body of the report.

As they are now used, the current simulation hierarchy is used to model and suggest decisions on mobility, firepower and overall combat effectiveness. If nothing else, this report should suggest to the reader that most current simulations are not able to adequately model mobility and, specifically, not able to describe its true impact on the battlefield. The same comment is also true with respect to survivability and RAM, two other very important features of combat vehicles. The current ability to simulate firepower and armor rather well has led to simulations that place heavy--possibly undue--reliance on these parameters of effectiveness while neglecting, because they are difficult to understand and model, other important parameters such as mobility, survivability and RAM. It would appear that this lack of understanding should be attacked and overcome as soon as practicable. In addition to performance evaluation, the stated purpose of most models includes technological evaluation. However, little conceptualization and concept validation are done. Significant payoff opportunities appear to exist in this technological area.

Opportunities are also available through simulation to train personnel and determine new strategy and tactics. They are not being exploited. Consideration should be given to such exploitation.

Regardless to what purpose simulations are put, the questions invariably arise (1) how believable are these simulations, (2) how representative are they of true combat performance, and (3) are all key parameters considered? Consideration of these questions leads to the next subject of concern.

LACK OF VALIDATION: The current hierarchy of simulations usable within the ground combat vehicle development methodology are mainly unvalidated and unverified. Many have not been checked for sensitivity to their key parameters. In part, this is due to the fact that most models are (1) developed for a single customer to (2) answer a narrow set of questions in (3) a short period of time.

Model developers and users are not allowed the luxury of validating the ideas upon which the models are based or of checking the sensitivity of model parameters. With the exception of the validation work currently underway to validate the AMC '71 Mobility Model and the previous sensitivity analyses done on CARMONETTE, these statements apply to all Army mobility related and operational simulations.

Of course, the Group is not suggesting that one can verify medium resolution simulations such as DIVWAG, or low resolution simulations such as ATLAS. Due to size, complexity and aggregation, even high resolution model such as DYN-TACS cannot be completely verified. However, it is felt that performance models such as HITPRO and the AMC '71 Mobility Model can and should be validated. Also it is suggested that the modules and subroutines of high resolution models such as DYN-TACS can and should be validated. The Army has just not done enough validation in the past.

It is felt that CDEC and, after proper instrumentation is received, MASSTER have the capability for operational model validation. CDEC through its current two-sided free play maneuver with real-time casualty extraction is capable now of validation work.

A deliberate program should be immediately undertaken to validate the key simulations in the ground combat mobility development methodology. Additionally, the sensitivity of all models should be examined--in such a way that such sensitivity analyses are capable of being reproduced and checked by others.

CONCLUSIONS AND RECOMMENDATIONS:

METHODOLOGY: Conclusion: The ground combat vehicle R&D methodology needed to provide accurate and comprehensive data and information to senior Army officials as a basis for arriving at sound decisions regarding major resource allocations to satisfy future Army combat vehicle mobility needs is not a model-to-end-all-models, but a synergistic combination of simulations, analyses, and experimentation interacting with subjective judgment along each step of the way.

Conclusion: While numerous mobility-related simulation programs exist and some efforts to improve the situation are being made--though seemingly not properly supported at the higher levels--the mobility simulation efforts of the Army are for the most part fragmented, uncoordinated, and non-cumulative.

RECOMMENDATION: That the Army approve and establish an integrated ground mobility R&D methodology as recommended in this report and also based upon the recommendations of the soon-to-be-staffed Land Mobility Technology Coordinating Paper.

RECOMMENDATION: The Army establish as an R&D goal the development of a (ground combat vehicle) methodology composed of a synergistic combination of simulations, analyses, and experimentations interacting along each step of the way with subjective judgment.

MOBILITY MODELING: Conclusion: The Army does not have the capability of satisfactorily determining the impact of mobility on the battlefield in spite of the following:

a. The recent MBT Task Force feeling that current significant payoffs are possible in increased mobility.

b. Mobility as a key element of the principle of war, MANEUVER, allows the possessor to concentrate his combat power at the critical place and time.

c. The LCS I (Land Combat System I) study directed toward exploring the Army of the 1990's selected as a needed operation capability objective (OCO), the achievement of superior relative maneuver capability over any enemy.

MOBILITY MODELING: Conclusion: Though the recent MBT Task Force determined that experienced tankers (according to questionnaires) considered mobility just behind firepower in overall tank importance and well ahead of protection (mobility is emphasized as one of the three key parameters in almost every armor publication), the capability of simulating or modeling the impact of mobility on the battlefield is woefully inadequate.

RECOMMENDATION: The Army as a part of its mobility program give priority attention to programming funds to establish an integrated hierarchy of simulations that would be key structural members of any--especially ground vehicle mobility-related--R&D methodology.

MODEL HIERARCHY: Conclusion: The Army does not have an interfacing set of mobility-related simulations that span from engineering design through combat operations at the theater level, with the most serious gap at the high resolution simulation (battalion versus battalion such as DYN-TACS, IUA, CARMONETTE simulations) level.

RECOMMENDATION: A hierarchy of mobility-related simulations be selected spanning from engineering design through elemental (single vehicle) performance, system performance at the battalion and lower level, and system performance at the division and theater level.

RECOMMENDATION: A high resolution (battalion vs battalion equivalent to DYN-TACS or IUA) model be devised that incorporates the flexibility of the modular concept; has an improved mobility subroutine incorporating cross-country speed, road speed, and acceleration; interfaces with HITPRO and the AMC '71 Mobility Model and, if appropriate, an agility/mobility versus survivability model at the very high resolution side; interfaces with the DIVWAG or equivalent model on the medium resolution side; is not so constrained on tanks; and, via discrete modules, incorporates tactical air play, night combat, varying command and control, proper play of logistics, RAM, and better target acquisition.

RECOMMENDATION: A high resolution model review similar to the current middle model review be held to determine whether there is a need for development of a new high resolution model or whether a current model can be improved to successfully accomplish the mobility mission.

RECOMMENDATION: A fast running companion to the revised (or new) high resolution model should be developed (similar to the IUA and BONDER/IUA relationship) which deletes details which have a minor effect on the outcome and allows a much faster response and running time.

MODEL VALIDATION: Conclusion: Few resources are being spent in model, submodel, and system validation though there exists a shocking lack of validation in most simulations used in the vehicular R&D process.

RECOMMENDATION: A specific percentage of model-use funds be spent in validating assumptions, accomplishing sensitivity analyses, and generally validating results. Exploitation of previous CDEC experimental data now on tape should also be accomplished.

TERRAIN: Conclusion: One of the key parameters of mobility modeling is terrain; however, terrain inputs required for different models are not normally corresponding and terrain characteristics and usages, once in the models, are not similar.

RECOMMENDATION: The model selected for the mobility model hierarchy be built initially, or adopted to accept; Defense Mapping Agency digitized terrain and/or Waterways Experiment Station special (mobility model) digitized terrain.

SCENARIOS: Conclusion: Due to the lack of approved, available scenarios for common mobility system evaluations, field personnel are seriously handicapped and must develop such scenarios on an ad hoc basis; this causes an inability to later reproduce, confirm, or add to model results.

RECOMMENDATION: A set of approved scenarios based on expected missions, environment, intensity of conflict, airpower, etc., be published and used by all agencies in their evaluation of mobility systems. A definite system should be set up to modify and improve scenarios with time and usage.

OTHER PARAMETERS: Conclusion: Route marches, resupply, reorganization, and vehicular RAM (reliability, availability, and maintainability) are important facets of mobility modeling.

RECOMMENDATION: The above parameters be included as high up the mobility model resolution hierarchy as possible and, if in no other higher resolution location, certainly at the division model level.

OTHER PARAMETERS: Conclusion: Survivability relationships with mobility/agility are not satisfactorily known.

RECOMMENDATION: The relationship between survivability and mobility/agility be established and then properly included in an appropriate simulation within the mobility simulation hierarchy.

MODEL MAINTENANCE: Conclusion: Mobility and performance models are normally developed on an ad hoc basis to fill a particular need and then fall into disuse until resurrected to again fill another particular need.

RECOMMENDATION: To minimize the narrowness of purpose of performance models, recommend a plan of model improvement be initiated with a funding level of 20% of the funds spent on model usage, being fed back to improve the model itself (this effort could be called model maintenance).

TRAINING: Conclusion: Training of field grade officers and, additionally, teaching and idea experimentation by general officers does not seem to be a comprehensively planned Army activity.

RECOMMENDATION: War gaming be used by general officers for idea experimentation and teaching of field grade officers. Innovative ideas for doctrine and material for the R&D community could be expected as derivative outputs.

Also see Joint Catalog of War Gaming Models

NAME: DYNTACS

TITLE: Dynamic Tactical Simulator (DYNTACS)

PROPONENT: US Army Combat Development Command (USACDC)

DEVELOPER: Systems Research Group, the Ohio State University
(Begun in September 1965; initial operating date March 1967)

PURPOSE: Extracted from Joint Catalog of War Gaming Models
(hereafter referred to as the Catalog):

The DYNTACS model was developed to facilitate the prediction of the operational impact of design, organization, and doctrine decisions in various environments and tactical situations. It is a high-resolution simulation of battalion-sized engagements,

This model was designed primarily to analyze individual weapons and small unit performance. Because of its complexity and sophistication it is essentially a research tool, limited to examining a few situations to gain insight into the ground combat relationship,

GENERAL DESCRIPTION: DYNTACS is a closed computer simulation which can depict the play of armored vehicles, both tracked and wheeled. Terrain is described both deterministically and stochastically with a high degree of resolution. A unique feature is the dynamic route selection capability, enabling the vehicle to select routes within a broad axis of advance in response to enemy fire, presence of minefields, and other intelligence which is generated and transmitted during the simulation. Extensive use is made of algorithms to predict speed over terrain and hit and kill probabilities. DYNTACS is essentially a stochastic model and is highly dependent on valid input as to hit and kill probabilities. Because DYNTACS is a complex and sophisticated model it has great flexibility with respect to application. Capabilities include attack, defense, delay and meeting engagements. Besides its eight basic modules, the capability to handle helicopters, mines, air defense, missiles, and counterbattery fire have been or are being added,

Because of its movement module which uses an axis of advance with actual movement based on tactical difficulty--enemy action terrain, and vegetation all calculated internally--this model has the best mobility subroutine of all the commonly used high resolution models. This supposition is emphatically substantiated by the Department of Army Review of Selected Army Models in 1971 which indicated for DYNTACS that

a. It has the most realistic movement routine because maneuver and firepower are interactive.

b. It possesses good resolution of terrain factors affecting mobility and line of sight (LOS).

c. Movement, visibility, and fire are described in great engineering detail and [DYNTACS, therefore] is best suited to evaluate similar vehicles differing only in mobility characteristics.

INPUT PARAMETERS AND LIMITATION:

a. Limitations: Even considering the statements above and, in fact, agreeing that DYNTACS is the best of the currently used high resolution models to portray mobility, the ASAP Mobility Group concluded that the mobility capability of DYNTACS is more apparent than real. This conclusion was reached after extensive briefings by and talks with personnel associated with DYNTACS--from high, medium and low level managers to men who actually run the computer simulations. In other words DYNTACS is the best of the high resolution models for mobility modeling, but it is the best of a poor lot. This conclusion is substantiated by the last sentence of the extract from the Catalog above that states "DYNTACS is highly dependent on valid input as to hit and kill probabilities," emphasizing what is considered to be a characteristic of all the high resolution models: that firepower is considered the key parameter, not mobility.

b. General: There are over 600 common data entries, about half of which require initialization. Input preparation requires a significant amount of time and is a function of the numbers and types of elements played. Terrain and the numbers of elements are principal limiting factors as storage requirements increase significantly with increases in either factor. DYNTACS currently requires large amounts of core on third generation computers, and planned additions will increase both storage requirements and running time.

In summary, DYNTACS is considered to be space, time and mobility limited. Space limited because of the large core storage requirement described above, time limited per hour of combat per replication, and mobility limited because of reasons above. Other limitations relate to the model origin. Since it began as a model of armored engagement, the elements are vehicles with resolution to the individual vehicle. The model can represent tanks or crew served weapons but not individual riflemen. (Personnel casualties are not assessed.) In support of its mobility limitation, the model does not deal with route march, resupply, vehicle reliability, maintainability or availability.

c. Input: Some of the types of input data required with respect to mobility are (as extracted from the DA Review):

1. Direction of travel of each element at the start,

2. Maximum and minimum acceptable cover fraction for target weapons codes,
3. Maximum allowable velocity for simultaneous movement and firing.
4. Location error indication flag for each element,
5. Mobility code for each element,
6. Detailed mobility characteristics for each mobility type (weight of vehicle, output torque, sprocket torque versus speed, track area, vehicle cross section, suspension characteristics, etc.),
7. Maximum movement time (event time).
8. Firing formation to be assumed,
9. Recuperation time for each mobility type.
10. Maximum negative grade angle which is trafficable.
11. Maximum allowable lag distance.
12. Breakpoints for maneuver distance.
13. Desired movement directions for each unit,

NATURE OF OUTPUT AND PRECISION OF RESULTS: The output of successful runs is being examined to establish requirements for condensation and statistical treatment. A history or trace of the activities of each element is presently produced by the model along with summaries of the detection status of elements and a map showing location of elements at specified increments of time.

POSSIBLE IMPROVEMENTS: Consideration of all information gained on this model led to the following suggestions for improvement:

- a. Modify the AMC Mobility Model and DYNTACS to allow the Mobility Model to be the mobility module of DYNTACS.
- b. Determine the value of mobility/agility with respect to survivability and incorporate results into DYNTACS.
- c. Perform sensitivity analyses and validation of DYNTACS as a priority effort.

NAME: IUA

TITLE: Individual Unit Action (IUA)

PROPOSER: Armor Agency, US Army Combat Development Command.

DEVELOPER: Lockheed Missiles and Space Company,

PURPOSE:

a. To evaluate combat effectiveness of candidate tank and antitank systems,

b. To evaluate the relative combat effectiveness of alternative mixes of tank and antitank weapons,

GENERAL DESCRIPTION: In the intense phase of combat the IUA simulates an approximately battalion size force in the offense, defense or delay. It is basically a computer simulation of a small unit (company/battalion size) tank-antitank battle. The simulation of mobility and line-of-sight are done deterministically by mobility and terrain preprocessor computer programs. Terrain is introduced in terms of elevation, slope, soil types, terrain roughness, cover, concealment, and terrain obstacles. The elevation map is defined by a system of free triangles. The preprocessor programs take as input the terrain data discussed above, maneuver weapon mobility parameters, and information on the tactical plan, including descriptions of the maneuver weapon routes and data on various tactical control points. This preprocessing can take several months to accomplish. The IUA stochastic simulation submodel simulates target acquisition and weapon effects. The mobility and terrain preprocessor output becomes input to the main simulation. Also input are data on acquisition parameters, weapons systems accuracy, and weapon systems vulnerability. Simulation plays the interaction of various weapon systems including tank, antitank weapons, armored personnel carriers, artillery, mines, helicopter-borne weapons and tactical close support aircraft. The primary focus of IUA is on tank and antitank systems; other weapon systems effects are played with minimum detail compared to tank and anti-tank systems.

The structure of the simulation is "event-oriented", which means that time is not handled at uniform intervals. An executive routine determines the order in which events are processed and maintains a continually updated table which indicates the chronological order of events to be processed.

One "run" for a given set of input data usually consists of about 30 replications of the IUA simulation, and can normally be completed in from one-half to two and one-half hours of computer time.

INPUT PARAMETERS AND LIMITATIONS:

a. Environment:

(1) Terrain Area (Three terrain areas have been processed for input by breaking the areas down into variable-triangle sub-areas and preparing the various overlays discussed below,)

(2) Soil type overlay (1-5 types).

(3) Concealment overlay (1-6 types).

(4) Obstacles (1-13 types).

(5) Terrain Roughness overlay (1-6 types).

b. Order of Battle:

(1) Attack Axes (1 to 3 per simulation run).

(2) Attack Routes (1 to 12 per simulation run).

(3) Maneuver Weapons (1 to 6 per attack route).

c. Weapons Data:

(1) Armored Vehicles (1-10 types may be simulated).

(2) Maximum and Minimum Range (0-3000 meters).

d. System Parameters:

(1) Mobility Parameters (Vehicle Characteristics similar to DYN-TACS).

(2) Breakpoint and Analysis Point Criteria.

General:

a. Compared to other simulations, such as DYN-TACS, the IUA simulation has a short run time. (About one minute for replication, not including the terrain and mobility preprocessor inputs.) (The short run time for the simulation is due primarily to having all the terrain and mobility events preprocessed, and almost no tactical decision routines.)

b. In general, weapons effects for direct-fire ground systems are played well.

c. The target acquisition submodels are reasonable, given valid input data.

Limitations:

a. The most significant weakness is that all movement is predetermined without reference to the course of the battle. To change this feature would require a major restructuring of the model.

b. The current terrain model makes it difficult to play a different piece of terrain other than the two or three variations of the same terrain which have previously been processed. Good use is not made of microvegetation.

c. Line-of-sight is calculated from each route segment to the route objective point for routes on a given axis and to the axis objective point for other axes. All defenders associated with an axis have, or fail to have, line-of-sight depending upon the outcome of this check. All attacker overwatch weapons have line-of-sight to all defenders.

d. The only sensors that can be played in this model are those associated with the weapons systems.

e. Play of artillery, TAC air, and heliborne weapons is very stylized and unreal. There is no dismounted infantry play.

f. For any target, the time to fire the first round assumes that the weapon was already loaded. Thus, the reload time for a weapon which has just finished firing at one target and immediately shifts to another target is not played.

g. As with other high resolution models there is no play of the route march, resupply, reorganization or reliability, availability and maintainability.

h. Most of the data formats used by the IUA are not in the forms furnished by BRL, AMSAA, and TACOM. This means that hand conversion of the input data is required.

i. There is no delay for search and acquisition of next target following a kill.

j. Targets in hull defilade cannot be visually acquired.

k. Defenders are always in hull defilade and never move. Attackers are always in hull defilade when stopped. When motion resumes, target acquisition process resumes afresh.

l. Defense depends in large part on the target acquisition process about which there are many deficiencies in knowledge.

m. Acquisition information is not passed on. Weapon allocation information is passed instantly.

n. New acquisition sequence starts after each loss of LOS regardless of duration.

o. Target priority lists are independent of range.

p. No communications are played.

q. Fire terminates when target is killed and always terminates then.

r. The model can not examine delay, withdrawal or meeting engagement postures,

s. All tank rounds against antitank weapon targets have conditional probability of kill given a hit equal to 1.0.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: For each set of replications the output program compiles statistics which are averages for the set at each of three predetermined analysis points. These outputs include number of survivors by type, kills of opposing weapon type by type firer, kills by artillery and other systems, number of rounds fired by type and firing event statistics.

For each individual replication, the output program will provide all firing events and all impact events by weapon number, type, round and, in case of impact, type of kill.

FEASIBLE IMPROVEMENTS: It is feasible to improve the IUA models in most of the areas discussed above except for the deterministic-nature terrain and mobility submodels. A dynamic mobility submodel would require complete restructuring of the model.

SUMMARY: IUA provides an operational capability to evaluate alternative tank and antitank systems and various mixes of tank and antitank weapons. It takes into account acquisition, weapons effects, and mobility parameters. The model has a number of weaknesses, many of which are feasible to fix. However, a dynamic mobility submodel is not feasible without a complete restructuring of the model. It is possible that some of the good features of the IUA could be incorporated into some other operations model to which would be added a dynamic mobility submodel.

NAME: BONDER/IUA

TITLE: BONDER/IUA Computerized Ground Combat Model.

PROPOSER: Weapon Systems Analysis Directorate, Office of the Assistant Vice Chief of Staff, Army.

DEVELOPER: Seth Bonder and Associates.

PURPOSE: The purpose is to estimate the effectiveness of combat units as a function of weapon system mixes, weapon system operational characteristics and tactical assumptions, as well as variations in threat mixes and weapon system operational characteristics. The type of engagements analyzed include tank versus tank engagements (either Red or Blue attacks), mixed force (tank/antitank weapon systems with either Red or Blue attacks), and mechanized infantry defense against Red assaults.

GENERAL DESCRIPTION: The "Bonder Model" is essentially a generalized mathematical differential model of combat. This representation is a further development of analytic formulations of the type used in the Lanchester theories. One force is deployed in defensive position and the other in attack. The attacking force may advance over individual routes along the major axis. Both the attacking force and the defending force may consist of tanks, armored personnel carriers and antitank weapons. The analysis is computerized and is applied by aggregating individual weapon systems into groups and attriting weapons systems and personnel over successive short periods of time.

Stated in another way the "Bonder Model" is a generalized differential equation model of ground combat. It is an extension of the Lanchester analytic formulations. In contrast to the classical Lanchester approach, which based attrition rates on historical data, this model estimates attrition rates based on measurable weapon system parameters. It also allows playing of heterogeneous forces. Weapons of a given type in the same general location are aggregated into a single group. Different types of weapons and weapons of the same type in different locations are played as distinct groups.

Various submodels have been developed for target acquisition, round selection, and target allocation.

The BONDER/IUA model is an adaptation of the general Bonder methodology to the Individual Unit Action (IUA) simulation scenarios. It uses as input the terrain and mobility preprocessor outputs of the IUA model. It also uses the same input data as the IUA for weapons effects and acquisition parameters.

The BONDER/IUA model essentially replaces the stochastic play of weapons effects with a system of differential equations. The computer program uses an iterative time-step procedure to provide a numerical solution to these equations.

INPUT PARAMETERS AND LIMITATIONS THEREIN: Input data fall into four broad categories, each with numerous items. These categories are the basic scenario and weapon mix data, inputs based on weapon type, inputs based on round type, and vulnerability data,

a. Basic scenario and weapon mix data.

(1) Scenario type - attack or defense; short, medium or long range; PCR (MBT70 Producibility Cost/Reduction Study) pure tank, PCR mixed force or ATMIX (Antitank Weapon System Requirements Study).

(2) Route descriptions - for each route description point: axis, route, coordinates, terrain type, and cover,

(3) For each defender or attacker overwatch weapon: weapon type, coordinates, axis and route assignments,

(4) For each maneuver weapon: axis, route and section assignments.

(5) Mobility and line-of-sight (LOS) data (IUA preprocessor output).

b. Inputs Indexed on Weapon Type.

(1) Maximum Range (derived from hit probabilities),

(2) Range of Moving Fire. (derived as above),

(3) Moving fire dispersions indexed on weapon type, terrain roughness, and velocity,

(4) Response time correction factor for stationary firer and for moving firer (indexed on velocity).

(5) Pinpoint acquisition correction factor indexed on acquiring weapon type, range, for stationary firer and for moving firer (also indexed on firer velocity).

(6) Non-firing acquisition time correction factor for stationary targets and for moving targets, both indexed on acquiring weapon type and range.

(7) Response time correction factor indexed on range for two cases: moving firer, moving target.

c. Inputs indexed on round type (same round fired by two different weapon types treated as two different rounds),

d. Vulnerability data (indexed on both round and target weapon types),

(1) Single-burst kill probabilities for 1st burst and subsequent burst indexed on range.

(2) Probability of kill given miss for HE rounds and exposed personnel targets for 1st rounds and for subsequent rounds, indexed on range.

(3) PCR probability of kill/hit data indexed on: round, target, range exposure status, kill type, dispersion, and aspect angle.*

(4) TATAWS probability of kill/hit data: indexed as above except not indexed on dispersion or aspect angle.*

General: Run times are very short when compared to a comparable run with the IUA simulation. Normally turn-around-time for a run is overnight.

Sensitivity analysis can readily be made on weapon accuracy, rate of fire, lethality, and acquisition data.

Changes in the initial mix of weapons can be easily made, subject to the following restrictions.

(1) The data describing each weapon system must be available in the proper formats.

(2) The weapon type in an attacker maneuver section cannot be changed without obtaining a new IUA mobility preprocessor output.

A library of input data files resides on magnetic disc in USAMSAA. USAMSAA analysts have developed utility routines which allow these files to be easily modified to add, change, or delete data records.

Limitations: The most significant weakness is that the BONDER/IUA model is tied to the IUA mobility preprocessor for mobility data input.

The model can provide no information on the variability of the outputs.

The current operating computer program is inefficient in usage of computer core storage.

Some phenomena modeled in the IUA simulation are not included in the model. For example, the simulation keeps track of all ammunition lost each time a weapon is killed. The BONDER/IUA model does not provide this output.

The BONDER/IUA has the same serious mobility limitations of the closely associated IUA model. The value of mobility cannot be satisfactorily displayed through the use of the BONDER/IUA.

*Model uses PCR data for those cases where data are available in PCR form (tank versus tank only) and uses TATAWS data for other round target combinations.

NATURE OF OUTPUTS AND PRECISION OF RESULTS:

a. At the end of each time increment the following data are displayed:

- (1) Survivors by group.
- (2) Number of suppressed weapons by group (ATMIX version only).
- (3) Cumulative killer-victim scoreboards for each weapon type on each opposing weapon type.
- (4) Survivors by weapon type.
- (5) Cumulative ammunition expenditure by type (ATMIX version only).
- (6) Surviving fraction of "break-type" weapons for attacker and for defender. (See para c below.)

b. For each firing event:

- (1) Firing group number.
- (2) Target group number.
- (3) Round type code.
- (4) Moving fire or stationary fire.
- (5) Fraction of firing group allocated to target group.
- (6) The expected time to kill for this firing-target combination.
- (7) The amount of attrition.
- (8) The range.
- (9) The firer and target coordinated.
- (10) Velocity for firer and for target.
- (11) Game time.

c. A summary output is displayed at the point where a Blue or a Red "break" occurs. The break points are based on the surviving fraction of "break-type" weapons. The weapons to be considered "break-types" and the break points may be defined by the user. The summary includes initial numbers, losses, the loss ratio, and a Force Effectiveness Index (FEI). The FEI is the ratio of the fraction of Red kill potential destroyed to the fraction of Blue kill potential destroyed.

SUMMARY: Though the BONDER/IUA model is not suitable for mobility investigations, the relationship that it has with the IUA that (1) it is faster to run on a computer and (2) it is a simplified version of the parent are superior characteristics that might well be goals of the desired high resolution model. Whatever high resolution model is evolved or developed to allow satisfactory play of mobility should have a fast running, simple companion that will provide fast response answers where necessary and when possible.

NAME: CARMONETTE V

TITLE: Computer Simulation of Small Unit Combat (CARMONETTE V).

PROPONENT: US Army (ACSFOR and CDC).

DEVELOPER: Research Analysis Corporation (RAC).

PURPOSE: CARMONETTE V is a mathematical model of the significant factors affecting the outcome of small unit engagements. It extends the design of CARMONETTE III and CARMONETTE IV.

GENERAL DESCRIPTION: CARMONETTE is a full computer simulation of combat activities of units from platoon to reinforced battalion. These activities include target acquisition, weapon laying and firing, terminal effect (destruction and/or neutralization), movement of units, calling for and delivery of artillery and mortar fires, and the communication of target information among units. Terrain is explicitly represented in terms of cover, concealment and trafficability indices and the average elevation and vegetation height for each grid. Grid size is selectable within practical limits of 10 to 250 meters. Maximum map size is 63 x 63 grids. A maximum of 43 weapons and 15 command units can be played on each side. Unit resolution can be from individual soldier or vehicle to platoon. An input scenario depicts the type battle action desired. Battle time (60 to 90 minutes) is limited by changes in the combat situation which require changes in the scenario orders. The model permits analysis of the interaction of dissimilar weapon systems, infantry, mortars, artillery, tanks, guided missiles, helicopters and air defense weapons. The model is stochastic. Five to 20 replications per situation are required to get stable results.

CARMONETTE simulates the intense phase of ground combat from line of departure up to, but not including, hand-to-hand combat.

All combined arms are included: infantry (mounted or dismounted), armored vehicles, artillery and mortars, and helicopters.

Up to a reinforced battalion for each side can be simulated with resolution to individual vehicles, squads or sections or infantry, individual forward observers, and individual sensor fields.

The terrain is divided into 63 by 63 grid squares that are usually 20 to 100 meters on a side. Variations within a grid square are handled probabilistically, not deterministically.

All elements are doctrinal soldiers. Each element in a class has identical capabilities, identical reactions, and exactly follows orders, if not dead, not neutralized, or not preoccupied with other duties.

CARMONETTE simulates all functions of combat except resupply and evacuation. Fire, movement, and target acquisition are emphasized. All doctrine, SOP's, and commands must be programmed in advance. But their execution may be contingent on chance events.

Time is not handled at uniform intervals. Each unit has a clock. The time for the next event to occur is placed in that unit's clock. The program ensures that any other prior event is assessed before assessing the event in question. For example, a tank might be killed between its decision to fire and the trigger pull. This requires time-of-flight calculations only for those cases when the firing unit is itself fired upon, not for every firing. It ensures that a dead unit cannot fire.

There are four basic submodels: fire, movement, intelligence, and decision. These models are used as required by the unit's clock. There is no prescribed sequence.

CARMONETTE is the only small-unit combat simulation for which there are sensitivity analyses of its structure. During its evolution in the past 15 years, a number of refinements were dropped because of such sensitivity analysis or absence of reliable data. Others were added because they apparently affected the conclusions derived in analysis of the output.

The principal effect of this sensitivity analysis was to drop the early movement model in which the path of the unit was affected by enemy fire in a probabilistic way. There were four factors in this decision: (1) Data did not exist for determining the probability of decision to advance in the face of heavy fire as opposed to the probability of taking local cover or making small changes in the axis of advance. (2) The probabilities required to force units to at least try to take an objective were so high that they approached certainty. (3) Major changes in the route of advance could be handled by contingent commands with much greater simplicity and computer speed. (4) Minor changes in the route had little effect on weapon system comparisons for which CARMONETTE was developed.

On the other hand, it was found that neutralization and suppression had a major effect on weapon systems comparison, even though valid data on neutralization and suppression did not exist. Thus, these submodels were retained. Two other sensitive factors were recognition of a kill and erroneously pinpointing a target. Little combat data exist for either factor, but results were sensitive to both.

Other sensitive factors have not yet been incorporated into the structure of CARMONETTE because of constraints on time and money. A number of these were found during a Quadripartite comparison of CARMONETTE with UK and Canadian hand-played simulations of small unit combat. The major factors were: asymmetric target acquisition, tank fire from ridge lines, local effects of smoke, and communications errors.

INPUT PARAMETERS AND LIMITATIONS THEREIN: Unit inputs include number of personnel or vehicles, number of weapons by type (limit of 4 types), rounds of ammunition per type weapon (two types of ammunition per weapon), vulnerability class, mobility class, sensor type and element size class. Weapon inputs by type weapon include minimum and maximum range; means and standard deviations of aim, re-aim, load and reload time; average projectile velocity; conditional kill probabilities for each target vulnerability class; standard deviations for weapon accuracy at stated range; number of rounds per trigger pull; neutralization weight per round; size of muzzle flash (firing signature) and crew required. Sensor performance inputs include detection probabilities at four range brackets for four states of seeker and target activity. Mobility inputs include cross-country and road movement rates for five slope classes and three trafficability indices for each of five mobility classes. Input data can require up to 2,000 input cards. Data preparation for a new game requires two to six man-months.

Inputs

Numerical Limits:

1. 63 x 63 grid.
2. Each side has up to 36 units.
3. Each unit has up to 60 killable elements.
4. Each unit can have 4 classes of weapons.
5. Types of artillery - 8.
6. Fragmenting direct fire weapons - 10.
7. Non-fragmenting direct fire weapons - 18.
8. Target acquisition states - 4.
9. Terrain parameters - 7.
10. Commands - 18.

Terrain

Input Data:

1. Average elevation in square. (less than 4096 ft).
2. Height of vegetation (less than 64 ft).
3. Cover - 16 classes.
4. Net cover - 3 classes.
5. Concealment - 16 classes.
6. Cross-country trafficability - 3 classes.
7. Road trafficability - 1 class.

Mean slopes are calculated by difference in elevation between adjacent squares. Slopes affect mobility.

Cover is used to degrade the presented area of a target for calculation of hit probabilities for direct fire.

Net cover is used to determine the vulnerability of dismounted infantry to indirect fire,

Concealment is used to degrade the probability of detection. A target may be concealed but not covered (e.g., bushes) and hence be vulnerable to fire, if it is in sufficient volume.

A formula is used to define the grid-square size in terms of feasible compromises among computer running time, target acquisition scan time, and number of direct fire rounds fired at an average target.

Unit Characteristics:

1. Target class - 16.
2. Vulnerability class - 12.
3. Element-size class - 6.
4. Mobility class - 8.
5. Fire response class - 5.
6. Sensor class - 6.
7. Maximum men per vehicle.
8. Fraction of time available.
9. Hold fire range.

Except for #7 and 8, these indices allow detection and kill probabilities and movement rates to be calculated without detailed specification of performance measures. #7 refers to survivors after an APC has been killed, but its passengers have not. #8 allows artillery and aircraft to support non-simulated units some of the time.

Target Acquisition:

1. Four solid angle thresholds.
2. Define a basic scan time.
3. Enter a probability of loss of information between scans.
4. Enter transition probabilities by target activity and observer activity for each solid angle class.
5. Probability (Prob) of detecting a target that is dead.

There are four information states and 16 transition probabilities: not detected, nearest square, erroneously pinpointed, accurately pinpointed. Only 6 of the 16 transition probabilities need be entered. The computer will enter the rest by using a set of inequalities.

1. Prob of not detecting.
2. Prob of detecting but not pinpointing.
3. Prob of detecting and pinpointing.
4. Prob of keeping pinpoint.
5. Prob of losing a pinpointed target completely.
6. Prob of losing a detected target completely.

CARMONETTE IV has additional target acquisition capabilities of night vision devices, radars, and UGS operated through a simulated non-firing, non-moving unit that only detects and communicates nearest square information.

Mobility:

1. Rate of movement by mobility class, slope, trafficability.
2. Probability of move by cover and target acquisition state.
3. For aircraft only, define 5 rates of altitude change.
4. For aircraft only, define contour flying or level flight in three altitude classes.
5. Define 7 movement rates less than maximum for ground and air units.

Commands:

1. No more than 250 commands total.
2. Fire orders - 8.
3. Movement orders - 8.
4. Speed of movement orders - 8.
5. Target priority - 7.
6. Number of rounds in fire mission.
7. Times, areas, contingencies.

The 250 limit on the number of orders is not constricting to the tactical realism. The same order can be given to more than one unit.

The basic commands are: Move, stay, stop, fire, dismount, and skip. The latter refers to skipping a list of commands if a contingency occurs or does not occur.

Selection and assignment of targets to weapons is done by choosing among three target preference lists for each weapon and among three doctrines: danger first, effectiveness first, specified.

Weapons:

1. Max and min effective range.
2. Min size of crew.
3. Mean and std dev of time to aim first round.
4. Mean and std dev of time to adjust after first round.
5. Mean and std dev of reload time.
6. Average speed of round.
7. Size of impact area for artillery and mortar volleys.
8. Number of rounds per trigger pull for automatic weapons.
9. Neutralization effect of round.
10. Probability of recognizing a kill.
11. Tactical accuracy (CEP or standard P_K).

The minimum size of crew, neutralization, and accuracy need further explanation.

A crew operates at a fixed capability until casualties bring it below minimum crew size. When that point is reached, the weapon cannot fire.

Accuracy of all weapons is in standard deviations as a function of:

1. Weapon type,
2. First round or subsequent round against same target,
3. Previous round was hit or miss.
4. Target moving or stationary.
5. Firer receiving fire.
6. Degree of firer neutralization.

Neutralization is defined for each class of ammunition by giving it a number representing how much more neutralizing one round of that class is than one rifle round.

There are three neutralization thresholds for soft vehicles and dismounted infantry: pinned down, proceed with caution, and immediate evasive action. Armor can have the two latter states of neutralization. Helicopters can either abort mission, if on a firing run, or drop to treetop level if not on a firing run. These neutralization states are defined in terms of a certain number of rounds in a pre-established interval. The actual number of rounds are divided by the neutralizing effect of the ammunition before using the threshold table.

Limitations: The input simplicity of CARMONETTE is achieved only at the cost of greater sophistication required by the one who is inputting the data. The months needed to set up a run are not often available to the military user.

All elements in a unit must be in the same square and must move together. There is no formation modeled.

Stochastic variations in intervisibility are handled by separating cover and concealment characteristics for each square, allowing presented area for detection purposes to be treated as a fraction of time that the area is presented or the fraction of the area of a target that is in LOS full time. The two are equivalent according to the CARMONETTE logic.

Furthermore, when one element of a unit detects an enemy unit, all other elements of that unit are assumed to have detected the enemy. Additionally, if one element of a unit has been detected all other elements are assumed to have been detected.

Another weakness is that detection between like units engaged in the same activity is always mutually isotropic. There is no way for CARMONETTE to simulate the edge of a woods in which one side can see out but the other side cannot see in.

CARMONETTE has the liability of all stochastic models. Multiple computer runs are needed to give statistical reliability to results, However, each replication is comparatively fast, a few minutes each, and comparable to the IUA.

When a unit is fired on, all its elements are considered to be equally vulnerable,

The same accuracy is assumed for moving or stationary firers.

The probability of kill given a hit is treated as independent of the portion of target exposed. The distribution of impacts expected should vary with degree of exposure, target range and accuracy,

Columnar formations on roads cannot be simulated in terms of vulnerability to artillery fire. No units are masked by each other from any direct weapon of the enemy.

Mines cannot be played in existing versions.

The greatest weakness of CARMONETTE is in the communications. All elements in a square instantaneously know everything that any element has found. In CARMONETTE III no unit communicates any information to any other unit except to aircraft or artillery, and these are firing commands. In CARMONETTE IV communications are allowed but a standard delay is assessed for information transfer between units or between echelons. There is no queueing delay or loss of information or erroneous information communicated,

In CARMONETTE IV command and control units are not subject to attack. They travel with a "buddy unit," and are killed only when their last assigned supported unit is killed. When current "buddy unit" is killed they move on to next one listed,

Techniques for representing roads do not allow for a change of road type enroute,

General: CARMONETTE is considered by some to be the best of the high resolution models. Considering its overall capability and credibility due to performed sensitivity analyses, this allegation may well be true-- for other than mobility usages. With respect to simulations whose outcome might depend on mobility factors this model appears to have many of the shortcomings of the IUA.

With its link to the Division Battle Model, CARMONETTE is the only current attempt to link the two levels (high to medium resolution) of models.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: Outputs include a historical tape showing all actions of movement, firing, impact, neutralization state, information state changes, and personnel and vehicle casualties. Casualty events are also presented as a separate listing. Summaries of type weapon performance showing rounds fired and type targets killed are listed. If a multiple replication run is made, the means and standard deviations of weapon performance figures are listed.

NAME: GLOBAL

TITLE: Global Computer Simulation (GLOBAL).

PROPONENT: US Army Combat Developments Command.

DEVELOPER: Stanford Research Institute.

PURPOSE: The GLOBAL Computer Simulation Model was originally developed to support and extend the field experimentation by USACDEC at the Hunter Liggett Military Reservation. The first use of GLOBAL was to extend results obtained from the Company Tank Anti-Tank Experiment (1962). Since then the program has been enlarged and modified to simulate larger organizations (including the battalion) and more complex weapon systems, both ground-to-air and air-to-ground. The model has recently been used by the USACDC Helicopter Task Force in its analyses and in conjunction with field experiments, to determine the sensitivities of parameters.

GENERAL DESCRIPTION: GLOBAL is a stochastic model which is written in modular fashion to simulate different types of battles or levels of military organization. It contains 70 programs and subroutines. The program simulates on a discrete time-centered basis using an operational sequence approach. This approach consists of defining all operations to be performed by each submodel (subroutine), and then in each time increment cycling through each submodel to generate the events which occur as the simulation of the battle progresses. The program is divided into three distinct parts and executes on the computer in three overlays, only one of which resides in the computer main memory at any given time. An initial or main overlay which always remains in memory calls the three overlays in turn to execute the simulation.

The first overlay is sort of a management program with respect to data.

The second overlay reads and stores the scenario data and tactical deployment of the aircraft and ground units, all critical operational and system parameters, and the rules and options that are to be played in the game. This section of the program contains extensive error-checking routines when reading the input data and also prints the input data to provide a record for identifying the simulation runs.

The third overlay executes the battle simulation and provides a time-sequenced history of the major battle events together with summary tables and statistical means and standard deviations for assessing the outcome of the game. The simulation of the battle sequence of events is performed by sequentially processing five major submodels (subroutines):

1. Detection.
2. Selection.
3. Fire Mission: Composes overall fire mission subroutine.
4. Damage Assessment.
5. Game Update.

TAB E

The battle simulation can be terminated in three possible ways:

1. Attrition of a prespecified number of aircraft and ground units.
 2. Expiration of the battle simulation time.
 3. Completion of the flight scenario by any one of the aircraft.
- Running time for this model is near real time.

INPUT PARAMETERS AND LIMITATIONS:

Limitations: The ground mobility characteristics of this model are unsuitable for valid ground mobility play as suggested by the following extract. In the displacement process (from one predefined position to a predefined alternate position) the ground unit disappears from its original location and reappears at its new predefined location after a suitable time delay defined for displacement. In partial defense of the model, however, it must be said that alternate movement paths can be used with contingent stop routines. Similar to the IUA, GLOBAL requires preprocessing of movement and mobility data. This preprocessing is very tedious and certainly a limiting factor. The model is not properly documented,

Input:

Detection Probabilities:

1. Firer weapon type.
2. Target type.
3. Range interval.
4. Smallest target area.
5. Largest target area.

In addition to the normal type of weapon and target characteristic data for ground weapons this model requires significant input in the form of aircraft characteristics. This aircraft input highlights the emphasis of this model on the aircraft role.

General: A significant advantage is the associated Sustained Operations Model into which the results of GLOBAL can be fed to portray sustained operations' parameters. The model is quick to run. It can be used for air-to-ground, ground-to-air, and ground-to-ground type actions.

NATURE OF OUTPUT AND PRECISION OF RESULTS: A time-sequenced history of the major battle events is available as an option for each Monte Carlo replication of the game. If multiple games are sequentially played, overlays two and three are called repeatedly. After all replications of a game have been completed, a separate computer program (TABLES) processes the simulated battle data generated by GLOBAL. This ancillary program tabulates statistical means and standard deviations for fire missions and

damage events by weapon type, target type, and launch point, averaged over replications. The program also provides the following: the number of mission scrubs averaged over launch points and replications; kill exchange ratios between the aircraft and different ground units tabulated cumulatively by launch point; the number and type of damage events sustained by aircraft before, during, and after each launch point; and a final summary of all the different types of damage sustained by the aircraft during the game in addition to the final damage state of the aircraft at the end of the game.

A second ancillary program (DAMAGE) processes fire mission data of aircraft and ground units associated with each missile and burst firing. This program simulates the analytical gun model used to reduce the statistical variability in assessing the types of damage sustained from the fire missions. Probabilities for the different types of damage that can be sustained by the aircraft and ground units are computed by weapon type, target type, launch point, and replication number. These probabilities are also provided by launch point averaged over replications. In the case of ground-to-air fire missions, the probabilities for the different types of damage are also summarized according to whether the damage occurred before, during, or after each launch point.

SUMMARY: The obvious area of application of this model is in the ground versus air role. The ground mobility capability appears to be primitive and unsuitable for use in a comprehensive ground mobility hierarchy of simulations.

NAME: SABER

TITLE: Simulated Assault Battle Environment Research (SABER) Model

PROPONENT: US Army Weapons Command (WECOM)

DEVELOPER: Cornell Aeronautical Laboratory

PURPOSE: To provide a simulation of combat in assault environments with maximum flexibility, so as to facilitate research in areas concerned with direct fire weapons systems including their carrier vehicle.

GENERAL DESCRIPTION: The Simulated Assault Battle Environment Research (SABER) Model consists of a time step Monte Carlo battle simulation submodel supported by a data processor submodel for executive routine. The concept of the simulation submodel is that of simulating, by repeated operations in each of a series of discrete small time steps, a battle in which some (or all) elements of one side move in a pre-planned fashion and exchange direct fire with elements of the other side; the occurrence of fire events and some of the aspects of movement are determined during the simulation by input data and rules. Terrain is described in terms of its effects on: line of sight between weapon and target; vehicle movement speed; and accuracy of fire from moving vehicles. Weapons firing rules include a Monte Carlo determination of detection as a function of range and target selection based on a deterministic priority function; the remaining fire rules are based on weapon capabilities. Weapons effects levels are determined by Monte Carlo methods based upon weapon accuracy and target vulnerability as a function of range, and of attacker angular heading relative to the weapon. The model also provides for coordinated movement of the attacking force elements.

The capacity of the model is 50 moving elements, each of which can contain multiple weapons, and on the opposing side 30 stationary elements. The area of battle simulation is restricted by the degree of desired resolution of line of sight representation. For example, a battle area 4800 meters by 4800 meters has a line-of-sight resolution cell 100 meters square. The output of the simulation is a history of the significant aspects of the fire events, i.e., who acquires which targets, what firing is accomplished, and the result of each firing that occurs.

Any simulation model programmed for use on a large computer obviously possesses inherent growth potential, but it is felt that the SABER model's potential for expansion to permit it to handle even larger simulations is enhanced by its compatibility with any large-core computer using the FORTRAN IV programming language. The potential of the SABER model for modification to handle different problems than those for which it was designed is illustrated by its current use for an air-ground combat evaluation; this version of the model, which does not involve major changes to the program, is called SABER II.

As the simulation model is now programmed, provision is made for a game using 50 attackers, 30 defenders, 20 weapon types and 29 segments in each path for an attacker vehicle. Provision is also made for storing 40 weapon-target combinations each in defender kill probability tables and attacker kill probability tables. These provisions are made by reserving storage in core for the various tables which are required for the operation of the model.

If a situation arises where these capacities are not sufficient it may be possible to obtain more storage for one of these items (such as more attackers) by using a computer with more available core space than 256,000 bytes or by reducing the storage for other items (such as number of defenders, number of weapons, etc.). However, in order to do this it will be necessary to change the dimensions in the Simulation submodel, make corresponding dimension changes in the Processor submodel, and recompile both submodels.

The model was therefore designed to simulate in greatest detail those factors which most influenced the outcomes of direct fire engagements, such as the existence of line-of-sight and factors affecting chance of hit and expected level of damage resulting from hits. Other battle aspects simulated in detail usually contributed indirectly to the results of fire engagements (such as speeds of vehicles moving over changing terrain) but were actually designed to keep interrelated events and actions in consonance with the "real world"; an example is the maintenance of unit formations when some vehicles stop to fire.

The submodel structure for the conduct of play in each time interval consists of the following sequence of main subroutines:

<u>Subroutine</u>	<u>General Function</u>
Time Check	Update time.
Stored Event	Handle pre-planned event.
Move	Move Attackers--Determining (1) whether a vehicle's primary gun should be restricted from firing or released from such a restriction and (2) the new position of each vehicle by moving it along its path at the scheduled rate.
Fire Control	Check target status during fire missions.
Acquisition	Detect, select and acquire targets.
Fire Assessment	Determine results of firing.

INPUT PARAMETERS AND LIMITATIONS:

Input: The SABER Model Processor accepts data in the form of 26 tables, each of which is recorded manually on a coding form or forms and then punched into one or more IBM electronic punch cards. A list of table titles follows along with a more detailed expansion of the mobility-related tables.

Table Designation	Table Title
I. A	Weapon Parameters
B	Weapon-Target Parameters
C	Weapon Performance Data
D	Weapon Accuracy Data
E	Nominal Ranges
F	Terminal Kill Probability (Conditional) for Defenders Firing at Attackers
G	Kill Probability Parameters Sets
H	Terminal Kill Probability (Conditional) for Attackers Firing at Defenders
I	Detection Probability Data
J	Detection Range Intervals
K	Defender Element Position Data
L	Line-of-Sight Data
M	Attacker Vehicle Path Segment Data
N	Aspect Angle Sector Parameter Sets
O	Priority Function Parameter Sets
P	Play Area Boundary Data Sets
Q	Defender Target Dimension Data Sets
R	Attacker Target Dimension Data Sets
S	Weapon Activation Times
II. A	Attacker Vehicle Characteristics
B	Primary Weapon Fire Data
C	Supplementary Firing Position Configuration Data Sets
D	Defender Element Characteristics
III. A	Attacker Force Structures
B	Defender Force Structures
IV. A	Game Data

Table IM: Attacker Vehicle Path Segment Data. In this table inputs specify the exact path that each attacker vehicle will follow from the beginning of a game until the vehicle is killed or the game terminated. Each such path is divided into as many as 29 straightline segments, in each of which the vehicles heading and speed do not change. (However, speed changes related to path segment can be made during the play of a game.)

- a. Identification of attacker vehicle segment set.
- b. Identification of individual vehicle path within this set.
- c. Identification of individual path segment within this path.
- d. Type of segment (initial, intermediate or terminal).
- e. X coordinate of a location on this path.
- f. Y coordinate of a location on this path.
- g. Speed of attacker vehicle in this segment.
- h. etc. Data on other segments.

Table IIA: These inputs specify characteristics of attacker vehicles that influence their vulnerability, firepower, and movement capability.

- a. Identification of vehicle type.
- b. Target type identification of this vehicle.
- c. Identification of vehicle's primary weapon.
- d. Identification of vehicle's secondary weapon.
- e. Whether a firepower kill on this vehicle eliminates only the primary weapon or also eliminates the secondary weapon.
- f. Basic speed ratio of this vehicle type.
- g. Increased speed ratio for this vehicle type.
- h. Whether this vehicle type uses primary weapon fire restriction procedure.
- i. Identification number of this vehicle type's supplementary fire configuration, such as from firing ports.

Limitations:

- a. As listed in the section on inputs, SABER has the basic mobility problem of a non-dynamic mobility situation. Vehicular movement is highly stylized and is always preplanned. In other words, it has mobility liabilities similar to IUA, CARMONETTE, and GLOBAL.

b. SABER has many of the same non mobility limitations as its geneological brother, GLOBAL.

c. SABER has had limited use, with key usage only in the MICV development program.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: The output of the model consists of event histories which record each significant event as it occurs, though other events could be programmed. The following are typical program events:

Target acquisition.

Missile launch.

Target lost before impact.

Missile or round impact as miss, near hit, hit, kill of primary weapon, kill of vehicle's mobility, kill of increment crew, or complete kill.

Reload time.

The program provides for automatic printout, ahead of the event history, of the simulation submodel input tables to be used for that game. It also includes a subroutine that can be used to print (dump) the contents of most of the simulation tables used at various points during the progress of the simulation.

NAME: DIVWAG

TITLE: Division Through Army Group Tactical War Game Model (DIVWAG)

PROPONENT: US Army Combat Developments Command (USACDC)

DEVELOPER: USACDC Institute of Combined Arms and Support, and Booz-Allen Applied Research, Incorporated

PURPOSE: DIVWAG is a computerized combat simulation designed to support war games in low-, mid- and high-intensity environments to assist in evaluating Army doctrine and organization.

GENERAL DESCRIPTION: After a significant file loading phase, DIVWAG evaluates situations by simulating specific activities described by the user in a detailed scenario. The scenario is written in an easily used compiler language designed for this application. The source language scenario is automatically translated into a machine readable control sequence to guide the operation of the battle model. The battle model is a highly complex event sequenced simulation of ground and air unit activity with variable unit resolution from platoon to Army.

Simulation may be carried out on an area as large as a square 8,000 km on a side and up to 1,000 separate units may be played. The battle model produces a highly detailed event-by-event history of the simulated scenario. DIVWAG contains a number of programs to prepare summary reports from this history. These reports are produced completely at user option.

DIVWAG consists of five major subsystems with primary functions as follows:

- (a) DIVWAG Preparation (DIVPREP)--Establishes and updates the various tables and files and initializes the system.
- (b) DIVWAG Scenario Language Compiler (DSL)--Functions as a compiler to convert orders written in DSL into machine instructions.
- (c) DIVWAG Running (DIVRUN)--Schedules and executes unit activity assessments one at a time and in chronological order.
- (d) DIVWAG Output (DIVOUT)--Organizes and edits the DIVRUN output data and printout reports for each period.
- (e) DIVWAG Summary (DIVSUM)--Records its output for use by DIVOUT and DIVSUM. (The later subsystems create end of period and end of game reports respectively from accumulated battle histories.)

Although called a computer-assisted wargame, DIVWAG is more properly a combination of simulation and wargame, since the computer not only keeps records and assesses the outcome of engagements, but also plays a long

series of logically sequenced and interacting events. The simulation phase customarily covers about 4 to 6 hours of combat time.

The entire model is divided into 4 parts: an input read routine, a compiler that translates standard Army orders into machine instructions, the battle model itself, and an output routine.

The battle model is basically event-sequenced, although when units are engaged in close combat (in the so-called brigade level filter model, BLF) assessment is made in 1 minute time slices to allow interaction with external events.

There are 7 events that a unit may carry out: Stay in position, move, fire, engineer activity, a transfer of personnel or materiel, adjustment of unit status with regard to materiel or personnel losses or gains, and close combat. The close combat event includes special representation of firing, moving, target acquisition and assessment that differs from the representations of these functions outside of close combat. After the completion of each event, the unit's target acquisition and supply consumption is updated.

A unique feature of DIVWAG (like LEGION) is the representation of unit intelligence and firepower as a collection of type sensors and type weapons, each described by primary characteristics such as range, probability of acquisition, hit, or kill, rate of fire, vulnerability, etc. This is to be contrasted with those games that describe an entire unit by one or a few global indices of effectiveness. Another unique feature is the purported capability to vary the level of resolution being played by ordering units to subdivide into next echelon subordinate units or to aggregate to the next higher level. This capability has been little used and certain characteristics of the model limit its validity. A third unique feature is the DSL compiler that allows players to write orders in standard Army format and terminology.

The model includes representation of logistics units, air missions (but not air battle), and CBR effects.

INPUT PARAMETERS AND LIMITATIONS:

Input: Because of the larger number of routines, subroutines and operations included in the DIVWAG model, a complete listing of input data is not practical. However, these data are provided to the following files: tables of organization and equipment for all units, unit status, terrain, locations of rivers, facilities and obstacles, and weather conditions. In addition, data are input regarding such areas as characteristics and performance of weapons, hit probabilities, vulnerability, factors related to unit mobility, engineer tables concerning construction and demolition, target acquisition, and consumption rates for various classes of supply.

Detailed unit and weapon system characteristics such as move speeds, lethalties, rates of fire, acquisition probabilities, and numbers of

weapons and sensors constitute the bulk of the input data. Another kind of input consists of largely judgmental factors such as the degradation of move speeds at night or in bad weather, and the degradation in AA effectiveness due to target speed, altitude and tactics.

Finally, a set of detailed orders must be provided at the beginning of each period of simulated combat.

As with other large wargames, DIVTAG requires considerable time for designing the "experiment," writing scenarios, updating data files and scheduling the actual play. If most of the data describing the forces are already on file (e.g., from a previous study) this preplay time may be only of the order of a few weeks. Major changes in forces, locale, or type of issues being addressed could stretch out the preplay time to a few months.

Limitations: Slowness of play and a few poor submodels, especially intelligence and close combat, are the major limitations. The limitations of the close combat model are not just superficial (e.g., nothing in close combat depends on terrain); also at issue is the fundamental approach of trying to represent battalion size units as collections of independent sensing and firing systems controlled largely by rather arbitrary input factors. In that there is little logical structure to the BLF model, its validity depends on calibration with the output from high resolution models. (Of course, other middle scope models also have this problem to at least the same degree.) The disadvantage of BLF is that it is a rigid rather than flexible model of close combat.

More specific limitations include:

- (a) Communications between units is instantaneous and complete (a general lack of realistic communications).
- (b) However, unit intelligence is not communicated in any form to weapons engaged against other weapons.
- (c) Unit to unit target acquisition is not time dependent.
- (d) Intelligence degradation and target location error are independent of size of unit being observed.
- (e) Close combat is completely independent of terrain.
- (f) Rate of fire depends on range in basically same way for all weapon types.
- (g) Air-to-ground and ground-to-air detection is perfect out to maximum range, given that line of sight exists.
- (h) Weapons and sensors are uniformly distributed over unit circle (except in BLF where unit is assumed to be rectangular in shape).

In summary, the characteristics of DIVWAG that most limit its applicability are its slowness of play, the lack of communications, its poor representation of information acquisition, and the unrealistic simulation of close combat. Additional problems exist with regard to air attrition, assessment of artillery effects and representation of command structure.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: The DIVOUT and DIVSUM sub-systems provide complete reports. On user request, it is possible to obtain complete histories of units involved in a period of war game play. Status reports and intelligence summaries may be made at any point in the period and actual expenditures and casualties may be reported as a function of time. The overall output can be classified as complete unit histories, unit status reports, intelligence summaries and actual assessment rates.

Complete information on unit status can be had at the end of each simulation phase at the discretion of the user. Reports produced by the DIVOUT routine are of various types; fire, movement, engagement, transfer, engineer, assessment history, target acquisition, etc.

DIVWAG is able to provide extensive and detailed output data for analysis. The time spent on providing this data depends on the problem being addressed and the purpose of the analysis.

NAME: DMB

TITLE: Division Battle Model (DBM)

PROponent: US Army Combat Developments Command (USACDC)

DEVELOPER: Research Analysis Corporation (RAC)

PURPOSE: This model is designed to assist in studying the effects of varied weapons mixes, organizations, tactics, and support levels on the combat performance of a division-sized force in nonnuclear or nuclear warfare. DBM has replaced TACSPIEL as the primary division-level analytical war gaming model operated by RAC.

GENERAL DESCRIPTION: DMB is a two-sided, computer-assisted event sequenced model which may be played in closed, semi-open, or open mode. The computer program accommodates up to 350 units on each side. Units may be categorized into nine basic types; e.g., artillery, maneuver units, headquarters units, etc. Each basic type may be further subdivided into 81 subtypes. The level of unit resolution is normally the company, but may be varied to meet specific study objectives. The computer program maintains unit status files of personnel, supplies, and major items of materiel. A control group maintains a situation map showing unit locations at 15-minute game increments.

DBM is essentially a free game in that there are no constraints placed on the players other than those imposed by the characteristics of the weapons and equipment, tactical doctrine, and the scenarios. The game progresses on the basis of a continuing interchange of orders and reports between player teams and the control group. Periodically this cycle is interrupted to obtain a computer assessment and report of combat interactions, and an updating of the unit status files. The ratio of game time to real time is 1:8.

Although assessment procedures are primarily deterministic, stochastic procedures are used to convert fractional losses and single event probabilities to integers.

DBM permits the players to modify existing orders or issue new orders at any time as the game progresses. On the basis of current player orders, the control group reports the master map each 15 minutes noting critical events which will result. Message forms advising players of these events are prepared and filed for subsequent delivery following an assessed transmission delay time. Players are then free to respond with any orders consistent with their force capabilities. Spot reports of battle actions resulting from such orders are transmitted to both player teams by control. These reports will describe the general nature of the action, but will include no details.

The detailed assessment and reporting of battle actions are made by computer run. Inputs for the run, however, are prepared as the battle develops, rather than in 8-hour blocks. The period of game time covered by the computer assessment depends upon the intensity of combat; normally 2 to 4 hours during daylight, 4 to 6 hours at night. This determination is made by the chief controller for each run.

INPUT PARAMETERS AND LIMITATIONS THEREIN: DBM has three manual and seven computerized submodels. The manual submodels are (1) command and control, (2) movement and contact, and (3) intelligence. The computerized submodels are (1) high performance air, (2) helicopter lift, (3) attack helicopter, (4) artillery, (5) nuclear, (6) ground combat and (7) logistics. Each submodel requires a unique combination of fixed and variable inputs. Typical fixed inputs include weapon and equipment performance characteristics, environmental factors related to these characteristics, and unit characteristics. Variable inputs are obtained from two sources, (1) the unit status file, and (2) control group inputs for the assessment run. Control inputs describe each combat interaction to be assessed.

DBM accepts weapon characteristics data directly.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: Outputs include loss of personnel, major items of equipment and supplies, by unit, by cause; consumption of Class III and Class V supplies; territory gained or lost; and residual effectiveness of each unit. Periodic photographs of the situation map are included with the game narrative.

NAME: LEGION

TITLE: LEGION

PROPONENT: US Army Strategy and Tactics Analysis Group (STAG)

DEVELOPER: STAG

PURPOSE: LEGION is a computerized two-sided free play war game designed to portray the interaction between small units when two division sized forces engage in ground combat. The computer simulates the following actions of company or equivalent-sized units: surveillance, tactical decisions to include move and fire, formation and posture, and assessment of weapons effects from ground or air delivered conventional, nuclear and chemical munitions. Limited effects of communications and logistic support are also modeled. Simulated units are classified functionally as combat, fire support, combat support, service support, air support, or command and control. The player staff manually plays functions at battalion and higher levels. The model can be used to evaluate division level plans, to analyze the mechanics of combat at company level, or as a training vehicle for the player staff. In addition to evaluating operational plans, the model can evaluate tactical and organizational variations in the division.

GENERAL DESCRIPTION: The model operates as a stochastic man-computer war game. Up to 250 simulated units per side may be played on a 9,600 square kilometer game area, with action represented in cyclic intervals of 15 minutes duration (game time). The player has the opportunity to influence or control the action at one designated point in each cycle. Up to 150 game resources--personnel, vehicles, weapons, ammunition, etc.--may be defined, from which as many as 54 may be assigned to a simulated unit. The model is divided into 13 major submodels which simulate various aspects of the combat situation or provide for data handling and general control during each game interval.

Structure: Based on an initial scenario, players representing the division through battalion command levels play most aspects of combat by issuing fragmentary orders to the simulated units (companies, batteries) on the basis of messages and reports generated by the model. Computer submodels determine all interactions between units and actual fires and movements. Players on a side communicate with each other by telephone or face-to-face. Players communicate with simulated units by frag orders and messages.

Models:

1. Surveillance. Determines surveillance states existing between opposing units, a state consisting of a level of knowledge concerning size, type, and activity of potential targets.

2. Decision. Simulates decisions of simulated unit commands concerning formation, movement, and fire, based upon (1) orders and (2) surveillance knowledge. Calls for supporting fires.

3. Assessment

a. Conventional Area Fires. Lethal areas of fire concentrations are assessed on ground targets based on a geometrical analysis of the intersection of the FC's on the simulated unit.

b. Point Fires. Kill probabilities are used stochastically to determine losses to weapons in target units.

c. Chemical. Lethal persistent and nonpersistent agents both air and artillery delivered.

d. Nuclear. Includes blast, fallout, and thermal effects.

4. Air Action. Plays aircraft in direct attack of specified targets, in armed reconnaissance, pure reconnaissance, and transport roles. Plays ground-air defense. Air-to-air is not played.

5. Administrative Support. Plays reinforcement, resupply.

6. Communications. Assesses delays to messages based on distances between simulated unit and headquarters, and on activity of simulated units.

INPUT PARAMETERS AND LIMITATIONS THEREIN:

Input: The model is highly parametric. Fifty-four types of input forms are used to define resource capabilities, tactics, and the game environment. These parametric values remain constant for a given game. Twenty-seven types of fragmentary order forms can be used by the player to set or modify controlled variables for purposes of defining organizational structures and procedures, building simulated units and assigning unit missions. While the degree of detail and consequent amount of input varies with game objectives, considerable input preparation is usually required. The more than 1,500 parameters and variables are organized into over 200 data sets or files for processing by submodels in the computer.

Proving ground and analytical data of many types concerned with mobility of units, trafficability of terrain, terrain elevation, forestation culture; weather inputs for seasons, lethality and other data for weapons; fuel consumption rates, and transition matrices of action probabilities reflecting unit tactical doctrine, and of probabilities concerning changes in surveillance states.

Operations:

Preplay: No special player training. Inputs for a new situation might take 24 man-weeks of preparation.

Play: 3 - 30 players
2 - 12 controllers
1 programmer

At 15 min assessment cycle, one hour of combat in two clock hours.

Limitations: LEGION is probably one of the most complex games ever programmed on a computer. This complexity arises in large measure as a result of taking account of variables and processes which at this time are not really understood. The following key limitations will illustrate this point:

1. A decision of when critical game events are assumed to occur is based on a functional relationship between critical game events (CGE) and unit effectiveness indices (UEI). The unit effectiveness index (UEI), in turn, is functionally related to the performance indices (PI). The rationale between the relationship of PI to UEI and, in turn, UEI to CGE is not known and is not readily determined. The performance index (PI), in turn, is a function of cumulative casualty level, casualty rates, fire suppression, unit morale, leadership, training level and a factor called close combat effects. Although unit morale, leadership, and training undoubtedly affect the outcome of an engagement, neither the functional relationship between these factors nor quantitative estimates can be determined. By setting all these factors to equal unity a uniform weighting is implied; in addition this results in adding constants to an equation, altering a still uncertain relationship. In addition, undoubtedly there is an interaction between leadership, training, and morale, which may be as important as the individual parameters, but which remains ignored. The consequence of the above is that the generation of critical game events, which presumably affect the result of the analysis, is at best uncertain.

2. The decision model includes a routine to determine the change of state of a unit (move, fire, target selection, etc.). This decision is based on a vast set of transition matrices. The rationale for determining the values in these matrices is not available.

3. A similar factor concerns the intelligence estimates. Units can exist in any one of 16 intelligence states and each of these 16 states depends on 20 situational parameters. This results in these transition matrices involving some 4800 independent, transition probabilities for which no basis can be found.

Other Limitations:

1. The effects of air attacks and indirect fire are currently assessed in 15-minute time intervals. Direct fire events are assessed in 5-minute

time cycles. High resolution games indicate that fire fights last on the order of 5-15 minutes game time. Since all engagements are compressed into this short time period, a 5-minute assessment cycle is probably not realistic. Blue acquisitions are always assessed first and then Red acquisitions. If one side fires, the target it generates by virtue of firing cannot be identified until the next 5-minute cycle at the earliest.

2. In each assessment period Blue fire is assessed first and then Red returns fire, causing a bias. In addition, target acquisition is only assessed every 15 minutes. If one side detects the other but is not detected in turn, it could fire for three 5-minute cycles before fire is returned.

3. The air model, which is event cycled, has a 15-minute interval and the direct fire model, which has 5-minute intervals, present a phasing problem. In fact all targets expected to be attacked by air in the 15-minute cycle are removed before the direct fire and indirect fire weapons get a chance to attack.

4. The target acquisition model uses the frequently assumed exponential function for which the constants a, b still have to be determined. It is not evident that the Pza exponential (-br) equation, for which there is some rationale with respect to detection between individual targets, is also valid for the detection of groups of targets by groups of observers.

Cost: Full scale facility in use at approximately \$800,000 (if so used) provides 400 combat hours = \$2,000/div-hr.

The disadvantages of LEGION are not so much in the adequacy of modeling, which is excessive in its completeness and detail, but in the lack of well-founded data to use in many of its submodels, the tremendous effort required to apply it, the slowness of its running, and the difficulty of understanding what is significant in it and what is not.

Given a large and continued support for maintenance and sensitivity testing LEGION could be a useful research game. Even with such support, however, its credibility would probably not be significantly higher than other, simpler games and its cost and slowness would keep it considerably less useful.

The problem of input data goes beyond that of most models at this level because of the large number of parameters and performance measures involved in the LEGION submodels. For example, targets can exist in any one of 16 intelligence states and each of these depends on 20 situational parameters, resulting in some 4800 independent transition probabilities. An additional difficulty is that many of the formulas, weights, and relationships in the model are not adequately explained in the available documentation, nor, apparently, are any of the user's analysts able to explain them with any thoroughness.

The time and effort required to run LEGION is suggested not only by the large data bank that must be assembled, but, more directly by the fact that it takes 30 to 50 people to play about 20 hours of battle in one week. One can play with as few as 5 people but player decision making is naturally more aggregated and only about an hour or so of battle could be played in a week.

LEGION, like DIVWAG, resolves to weapon system types, and describes these by their accuracy, lethality, target acquisition capability and rate of fire. Unlike DIVWAG, however, LEGION aggregates these weapons systems only in companies rather than battalions or brigades, and therefore does not have nearly so great a problem with the uniform distribution approximation and the aggregation problem. Therefore, it appears that LEGION could be used for these mix problems if the decision model and the company level engagement routines were calibrated through comparison with high resolution simulations or by careful sensitivity analyses. Note in this description no mention is made of the impact of mobility. Such an impact would apparently have to be made through high resolution models such as DYN-TACS.

General: LEGION is similar to DIVWAG in that it is a player-assisted simulation in which units are represented as uniform distributions of independent sensors and weapons, described by individual characteristics. However, LEGION has important advantages over DIVWAG:

1. Division and battalion echelons are represented separately.
2. Players can issue frag orders to units every 15 minutes.
3. Unit resolution is at the company rather than at battalion.
4. Communication is simulated, including range limitations and delays.
5. Line-of-sight is determined by examining terrain elevation rather than by expected value formula and target acquisition representation is fairly complete with information existing in various states according to Markov process.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: The output consists of printed messages in military format from the simulated unit to the player informing him of unit actions and conditions, and six standard reports summarizing the status of all game units at each interval.

- (1) Messages to players concerning game events.
- (2) Status reports on units (periodic).
- (3) Statistics from computer assessment.

Ranking outcomes by judgment and analysis of status at end of play.

SUMMARY: This model is claimed to be suitable for evaluation of alternate division, organization, equipment, and tactical plans. However, its capability to evaluate the impact of mobility would probably depend on its interaction with a high resolution predecessor such as DYN-TACS.

NAME: ATLAS

TITLE: A Tactical, Logistical, and Air Simulation (ATLAS)

PROPONENT: Department of the Army (US Army STAG) - also used by SAGA

DEVELOPER: Research Analysis Corporation - Adapted by US Army STAG to support ODCSOPS requirement and Adapted by NMCSSC to support SAGA requirements.

PURPOSE: ATLAS is a highly aggregated, expected value simulation for studying the overall trends, effects, and interactions of ground, air and logistic forces in conventional theater level of warfare. It is used to determine combat force requirements and capabilities in conventional theater war.

GENERAL DESCRIPTION: ATLAS is a fully automated theater level simulation of ground and air combat. It is basically a planner's war game in that it encompasses most of the parameters of combat operations at about the same level of detail available in theater contingency planning. Ground interactions are based on selected types of Army divisions and employment planning factors. Air interactions are based on aggregated inputs simulating counter-air, close air support, interdiction, and air defense missions. Logistic interactions are based on a gross simulation of an intratheater logistic system to support the ground troops.

The theater of operations is divided into battle sectors which extend from the rear areas of one force through the theater to the combat area and into the rear areas of opposing forces. Sectors generally take on the frontage for a US corps. Within each battle sector the terrain is classified into one of three types according to its suitability for military operations. Notional lines of communication (LOC) are laid out running from end to end for each sector--one LOC per sector. Supply points or nodes are established along the LOC. Existing air bases are associated by sector with the nearest supply node.

The principal assessment is the daily determination of the change in location of the FEBA in each sector. The rate of advance of the attacker for each sector is selected from a lookup table according to the ratio of opposing units' firepower, aggregated for the sector, and posture of the defending units.

The aggregate firepower score for each sector includes all ground combat units, artillery support, and close air support. Each day the units' firepower scores are modified as a function of casualties sustained and the status of supply. A preselected fraction of firepower is withheld as sector reserve; however, reserves are only committed by defensive units in a disorganized retreat or orderly retirement.

ATLAS simulates a flow of units and tons of supplies in each sector from node to entry through the notional LOC and intermediate nodes to

TAB J

frontline units. LOC throughput capacity is degraded as a function of the number of enemy aircraft flying supply interdiction missions. When frontline units have less than two days supplies on hand, their firepower scores are reduced.

All tactical aircraft are aggregated into a notional aircraft with a notional ordnance load. All aircraft available are assigned one of five missions: SAM suppression, supply interdiction, airbase interdiction, close air support (CAS), and air defense. Missions are assigned according to the ratio of opposing aircraft. CAS sorties are added into the sector firepower total.

Arriving units and supplies are allocated to sectors according to a decision routine which gives priority to success for the attacker and to weakness for the defender.

INPUT PARAMETERS AND LIMITATIONS THEREIN: In general, the inputs for ATLAS fall into four major categories. These can be considered as environmental inputs which structure the theater, ground force inputs of committed and scheduled forces and their associated characteristics, logistic inputs which establish the supply requirements and constraints, and air inputs which provide performance, vulnerability, and characteristic data on aircraft, airbases and RAM sites. Depending on the availability of the data, an experienced analyst will generally require from two to three man-weeks to assemble and structure data for the first game play. The bulk of the inputs are rigidly tied to the initial design of the theater structure.

Inputs:

Theater data: Sectors, terrain classes, LOC's and throughput capacities, supply nodes.

Ground units: Division firepower scores, supply consumption tables, SAM effectiveness parameters, numbers of divisions by sector and reinforcements by day.

Tactical aircraft: Numbers of aircraft, CAS firepower scores, kill probabilities.

When running a simulation in a theater for which the sectors and terrain have already been laid out, and unit parameters are already available, the preparation time is of the order of a few hours. A few weeks would be required to develop new scenarios.

General: A status assessment is made every 24 hours. Six days of play take approximately one computer minute.

The principal advantages of ATLAS is its rapid rate of play. Once the theater forces and environments have been analyzed and the input data cards prepared, the relative impact of changes in deployments, arrival times of reinforcements, and any of the many other planning assumptions

can be ascertained within minutes of computer time. It is claimed that speed of play could be increased up to a factor of two with minor reprogramming.

Limitations: The core model in ATLAS is the firepower score/force ratio/FEBA advance model. This model has the inherent limitation of linearity so that ATLAS cannot be used for investigating the mix of combat forces.

Another limitation is the sparse empirical basis for the FEBA movement and personnel casualty rates, as functions of force ratio.

Although a relatively precise, mechanical methodology exists for calculating firepower scores from TOE's, ammunition lethal areas, kill probabilities, and ammunition expenditure rates, there is virtually no basis, except judgment, for relating these scores to FEBA advance and casualty rates.

To a large extent, the judgments of the model builders are submerged within the model structure, and it is difficult for current users to apply their judgments to the important parameters within the model.

Some limitations result from the view of combat taken by ATLAS:

- (1) No grand tactics are possible. Units do not interact with adjacent sector activity.
- (2) Cannot play a porous battlefield--no breakthroughs, no infiltration.
- (3) Only suitable for non-nuclear, linear FEBA combat.

Other limitations must be classified as those representations of theater combat which appear to be poor approximations. Many of these limitations are not immediately apparent from a description of the logic; they only surface through unrealistic theater outcomes.

(1) The logistics model in ATLAS is such that units in one sector can be denied supplies, and hence the units lose all their combat effectiveness, while units in adjacent sectors feel no effects of shortages. Furthermore, a unit will continue to fight at full intensity, despite a degradation of LOC throughput, right up to the time that supplies run out. For example, a unit could be attacking one day, run out of supplies the next day, and then be forced into a full-scale retreat. Because of these limitations, many ATLAS users choose to bypass the logistics model by using artificially inflated LOC capacities and incoming supply rates.

(2) Combat seems unrealistically intense: units continue with locked horns for the majority of the campaign. (The exception is that units degraded due to personnel casualties are selected for the constant portion of firepower withheld for sector reserve.) There is virtually no possibility for a quiet situation within a sector.

(3) The allocation of tactical air sorties can lead to unrealistic results where Red aircraft are assigned to one sector and Blue aircraft to another. Furthermore, assignment of air missions as a function of tactical air force ratio is said to be an inaccurate representation of actual TAC air employment strategies.

(4) The unit effectiveness is very sensitive to the casualties taken and to the replacement policy employed. A unit's effectiveness can be restored by a number of replacements equal to the number of casualties suffered.

(5) Intelligence functions are not played.

In summary, ATLAS largely depends on aggregated firepower scores and force ratios to determine engagement type and outcome. This reliance plus the limitation to fixed parallel sectors which excludes consideration of flanking movements, penetrations, etc., limits the impact mobility might have. These factors also limit the capability of ATLAS to look at other than periods of initial combat more than a week long without a thorough examination of results.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: All output is in computer printout form, somewhat similar to the input data format. As such, summary tables and graphic plots of the output data must be accomplished manually. Numerous print options are available to allow the user a choice in the level of detail wanted for a particular game. In addition to the medium level (normal production) printout, detailed summaries, by side and by sector, may be requested for each sub-model in ATLAS: ground, air, logistics, or the tactical decision model. There is also a variable print option which will allow changes in the time lapse of data printout; for example, the printout could be made daily for 20 days, every 5 days from D-20 until D-40, every 10 days from D-40 until D-90, and every 30 days thereafter. A retrieval program is available for use in conjunction with ATLAS. This program produces user-selected data tabulations from the ATLAS simulation output.

The main output is the daily trace of the FEBA by sectors. Additional statistics include casualties, supply consumption, and aircraft losses.

Postplay will vary according to the application of ATLAS. Typically, the model is used to develop force requirements in terms of theater based divisions and reinforcements. In this case, the primary output is FEBA location--and the postplay analysis will focus on how to change the forces in successive iterations. In that case, postplay normally involves a few hours.

NAME: TCM

TITLE: Theater Combat Force Requirements Model (TCM)

PROPOSER: US Army Combat Developments Command

DEVELOPER: Research Analysis Corporation

PURPOSE: To determine combat force requirements and capabilities in conventional theater war.

GENERAL DESCRIPTION: The battlefield is divided into "mini" sectors at the FEBA, from which expected "streamlines" of the movement of forces are extended across the entire theater. A decision model based on distinct division, corps, army and theater level estimates of the situation selects missions and allocates resources to respective subordinate commands. The outcome of each brigade level engagement is a function of the battalion composition of each force, the type terrain, and the type of the engagement. The outcomes are expressed only in terms of win, lose or draw, the change in a unit's resource state and movement of the FEBA in that brigade sector. Rules govern FEBA movement in such a way that a defending brigade can have at most one exposed flank. Close air support (CAS) is allocated to armies in proportion to the number of divisions in each army. Further availability of CAS is determined by initial allocations and rules for reallocation depending on attrition of aircraft and movement of the FEBA. Aircraft available for close air support are converted into equivalent artillery battalions which then help determine the outcome of the brigade level engagements. The number of interdiction sorties penetrating enemy airspace determines whether air environment is friendly or not. If it is not, a delay is imposed on the assumed flow of resources and reserve troops. Logistics, however, is not explicitly represented.

TCM has several valuable innovations:

- (1) Because the brigade level outcomes are functions of the mix of battalions, it is possible to represent interactions among different battalion types.
- (2) The brigade level outcomes are not the result of a particular model of close combat but can be purely judgmental, the outcomes of a high resolution simulation, or of some other calculation. In particular, the decision-maker can easily suggest and test hypotheses about the relative value of units.
- (3) Allocation decisions are made at various echelons from division to theater level on the basis of rough predictions of battle outcome, given the condition of units and available reserves and resources.

Period of assessment at each echelon is an integral multiple of period for the next lower echelon; for example: division, 12 hrs; corps, 1 day; army, 2 days; theater, 4 days.

INPUT PARAMETERS AND LIMITATIONS:

Input: Brigade level battle outcomes must be provided as input. These are functions of force composition and therefore must be changed if the characteristics of battalions change significantly (e.g., by modernization). Brigade FEBA movement, as function of type of engagement, type of terrain, and engagement outcome, must also be input. Change of battalion state is input as function of its previous state, type of engagement, the outcome of the engagement, receipt of new resources, and time available for rest and maintenance. Other principal inputs are assignment of terrain types to sectors, initial air allocation and strategy for reallocation, and firepower scores for commanders' estimate of outcomes which they use as basis for allocation of resources.

It is estimated that a few weeks would be required to develop new scenarios, terrain, and other scenario dependent input. If any basically new type battalions were being played, all of the outcome tables would need review and perhaps modification. This could involve months of work until such time as a complete algorithm is developed for generating outcomes as a function of weapon types and numbers. In general, the main inputs are objectives, resources, command decisions, and outcomes of brigade level engagements.

Limitations: Some of the main limitations of TCM are in the engagement outcome table:

(1) This table does not distinguish between various degrees of winning or losing so that the value of certain changes in the forces may not be readily discernible. On the other hand, the decision process tends to limit outcomes to the neighborhood of "draws" (i.e., units are not committed unless they have a fair chance of carrying out their mission). However, since the model does not distinguish between different degrees of winning or losing, the implications of a "big win" or loss are not reflected in changes of unit state (resource units lost) or changes in FEBA movement.

(2) The outcome table is for a particular set of 3 types of battalions. If one or more major weapons systems is changed in these battalions, large sections of the outcome table would have to be reviewed and possibly changed. This is a limitation on the full exploitation of the model rather than a disadvantage relative to other models of this scope; for example, if it were acceptable to use firepower scores to predict outcomes, changes in weapons would be easy to handle.

(3) At present, attack helicopters cannot be played without either treating them as close air support or identifying them as a special type of battalion, neither of which is completely satisfactory.

(4) TCM cannot play nuclear combat.

(5) Because close air support is converted by a constant equivalence into artillery battalions in order to determine its impact on the engagements, trade-offs between air and ground units cannot be adequately considered.

(6) There is no adequate representation of interactions among sectors; therefore, grand maneuvers such as flank attacks, deep penetration, and encirclements are not possible.

(7) TCM does not represent any logistics units and assesses only a single gross delay on reinforcement and resupply based on friendly or enemy air environment. This does not allow any study of trade-off between "combat" and "support," nor even any realistic and identifiable constraints that would affect outcome of a campaign lasting several weeks.

(8) TCM basically represents steady state warfare and therefore may not give reliable indications of the ability of a defense to hold a line during the first few days of an attack.

(9) Reconnaissance units are not played.

(10) TCM assumes that any unit whose state is above threshold for effectiveness will operate at full capability (without degradation).

(11) The development of outcome tables in which the outcome of the engagement is sensitive to unit organization, structure, and major equipment capabilities.

(12) Current ability to analyze only three nominal types of units (infantry, armor, artillery) and translating all units, including air support, to equivalents of these three types of units.

(13) The inability to represent attack helicopters or close air support adequately.

(14) Like ATLAS, TCM has fixed sectors and a well-defined FEBA that limits its ability to show the effect of grand maneuver and tactics. This, together with only meager data on FEBA movement rates and a very simplistic representation of the effects of interdiction render questionable TCM's prediction of the position of the FEBA after prolonged combat.

(15) While personnel and casualty losses are not played, per se, but only in terms of change of unit state, the relationships between these changes of unit state and FEBA movement as a result of engagement outcome are not well substantiated.

(16) Combat/support balance issues cannot be addressed directly because of the lack of any explicit representation of service support units.

(17) The very short planning horizon (one period) does not permit adequate play of intelligence or command, control and coordination (ground/air) factors. Furthermore, the decision alternatives considered are very limited (four types of mission, commitment of reserves).

(18) The absence of a logistics model will continue to restrict TCM to the analysis of only short combat periods.

General:

TCM simulates command decisions at the theater, army, corps, and division level. Missions and resources are assigned by both sides, at each level, according to computerized algorithms.

TCM provides a significant improvement over ATLAS by including this decision structure. However, it is harder to understand than ATLAS. It is similar to ATLAS in its efficient use of resources.

TCM is critically dependent on the determination of the outcome of brigade level engagements. This determination is currently performed by means of outcome tables which are based either on military judgment alone or on subjective evaluations of opposing FPS. Equally critical are the tables that relate engagement outcome (win, lose, draw) to resource losses and rates of movement. Although originally designed as a substitute for ATLAS in FOREWON, TCM development at RAC is currently being redirected as the principal model to analyze alternatives in the CONAF study.

TCM appears to be the best available model for addressing force level problems because of its representation of the multi-echelon command structure and allocation decisions. Its ability to generate engagement type distributions should still be checked against a war game.

TCM is sensitive to mixes of combat battalions on both sides.

NATURE OF OUTPUT AND PRECISION OF RESULTS:

The main output of the model is a position of the FEBA after a given number of days of battle. Also, however, the state of all units is displayed as well as resource units consumed.

TCM is not designed to produce extensive data for analysis, nor to provoke fundamental insights into theater war; rather it is a device to generate theater implications from brigade level outcomes and a series of allocation decisions. Therefore, extensive postplay analysis is not expected to be a part of TCM application.

NAME: CEM

TITLE: CONAF Evaluation Model (CEM)

PROPONENT: US Army Combat Developments Command

DEVELOPER: Research Analysis Corporation

PURPOSE: Simulate the employment of postulated forces in extended theater-wide combat and indicate the effectiveness of each force in terms of combat results.

GENERAL DESCRIPTION: CEM was designed to be responsive to the following key requirements:

- a. Should encompass all combat aspects of theater warfare.
- b. Should represent combat operations in a dynamic, not static indicator, way.
- c. Should provide a credible scope in terms of time, space, and combat operations--not just pieces of or quick looks at the battlefield.
- d. The operating time of the CEM should be acceptably short--allow evaluation of a force alternative in a week.
- e. Should be sensitive to important force characteristics.

Air warfare effects are simulated in the CEM. The cycle of operations at each level includes an estimate of the situation, decisions, engagement outcome, new estimate of the situation, etc.

INPUT PARAMETERS AND LIMITATIONS:

Inputs:

- a. Primary inputs are:
 - (1) Objectives.
 - (2) Resources allocated to the theater by the opposing nations.
 - (3) Information on the outcome of the brigade-level engagements.
- b. Periodically at each echelon an estimate of the situation is made, and, on the basis of this estimate, a mission is selected and resources of various types are allocated to subordinate commands. The sequence continues down to brigade level, where the outcome of each brigade

engagement is determined. The results of such an engagement are a local change in the FEBA and a degradation of the state of the engaged forces. States of forces may also be enhanced, depending on the amounts of resources provided to them from higher echelons. These results are aggregated at the various echelons, where they are used for a subsequent estimate of the situation.

General:

- a. The only forces considered in the model are combat units.
- b. As many battalion types may be permitted as in the CONAF Force structure.
- c. A less than twelve hour average of intelligence is allowed which improves on the TCM.
- d. A periodic output is made of the distribution of engagement types for each type of Blue maneuver battalion.
- e. Combat for a theater-day can be accomplished by the computer in about 10 seconds.
- f. Terrain is played similarly to that in ATLAS and TCM. Significantly, however, linear obstacles such as rivers can be played in CEM.

Limitations:

- a. Close air support squadrons are added as equivalent artillery battalions rather than being allowed to appear as a separate force in the engagement outcome.
- b. The output does not include items of equipment lost in combat. (However, subsidiary calculations can be made to help determine this information.)
- c. Unit movement is considered as moving to combat (commitment of reserve units) or as the result of combat. In neither case does vehicle speed or mobility figure significantly in the assessment.
- d. The model does not properly play penetration and exploitation.
- e. There is no means to inject the effects of lack of maintenance capability directly into the model.

NATURE OF OUTPUT AND PRECISION OF RESULTS: CEM generates engagement situations, for which outcomes are determined and translated into two results:

- a. FEBA movement.
- b. State degradations.

Outputs include:

- a. Distribution of engagement types by type unit participating.
- b. Type and average strength of enemy forces.
- c. Missions decided upon at the various echelons.
- d. FEBA location.
- e. Sector boundaries.
- f. Current status of all forces.
- g. Record of resource units consumed by each type of maneuver battalion.
- h. Casualties can be generated using casualty factors.
- i. Artillery tonnage can be calculated.
- j. Aircraft and air defense artillery information is also determined.

NAME: AMC 71 Mobility Model

TITLE: Army Materiel Command 1971 Mobility Model

PROPOSERS: USATACOM (US Army Tank-Automotive Command) and USAEWES (US Army Engineer Waterways Experiment Station).

PURPOSE: The AMC 71 Mobility Model can predict the cross-country speed of any wheeled or tracked vehicle operated over any geographic area. The model is a particularly useful tool for:

- a. Establishing mobility criteria which ensure a desired level of performance over a specified geographic area.
- b. Determining and comparing the expected performance of various vehicle concepts in a specified environment.
- c. Studying the effect of design changes on the cross country performance of wheeled or tracked vehicles; a requirement for the computer-aided design and engineering of military vehicles (CAD-E).

The AMC 71 Mobility Model is well suited for (1) the assessment of the adequacy of existing vehicle performance prediction technology and hence for the unveiling of important knowledge gaps, and (2) sensitivity analyses to establish the relative importance of various vehicle characteristics which influence field mobility.

GENERAL DESCRIPTION: The simulation consists essentially of four computational modules (in addition to input, output, and control statements): (1) route selection module, (2) stream-crossing module, (3) terrain-unit module, and (4) ride dynamics module.

The route selection module, as discussed earlier, synthesizes data characterizing the vehicle's performance in discrete aerial and linear (streams) terrain units, to derive a comprehensive performance assessment in terms of speed-made-good over the "optimum" route.

The stream-crossing module computes the vehicle's performance, in terms of elapsed time, across both fordable and unfordable streams.

The terrain-unit module calculates the vehicle's average speed across individual terrain units. It incorporates interactive calculation algorithms which take explicit account of all significant mobility impediments save for the vehicle occupants' tolerance to shock and vibration. The latter (important) effect is accounted for on the basis of a limiting-speed comparison algorithm, using limiting speed/ground roughness parameter data derived from the independent ride dynamics module.

No need to do these tables

Table A1

Terrain Description

The terms and values used in describing terrains for use in predicting vehicle performance are given in this table.

Terms Used to Describe Terrain Data

The definitions of most of the important terms used in describing terrain data are as follows:

A. General Terrain Terms

1. Areal terrains - Terrains that can be delineated on a terrain map as a patch with both length and width. For example, a forest is an areal terrain.
2. Linear terrains - Terrains that appear on a terrain map as lines due to their extensive length and narrow width. For example, a river, highway embankment, etc., are linear features.
3. Terrain country - A terrain country is an imaginary or geographic area containing two or more terrain units.
4. Terrain unit - A terrain unit is a patch (areal or linear) of terrain described by a specific terrain factor complex number.
5. Terrain factor complex number - A terrain factor complex number is a combination of two or more terrain factor class numbers chosen for a specific purpose.
6. Terrain factor class number (class No.) - A terrain factor class number is a number assigned to a terrain factor class range. For mobility purposes, the terrain factor class number was assigned in order of increasing effect of the terrain factor on vehicle performance.

7. Terrain factor class (class range) - A specific range of factor values established for a specific purpose. For example, a range of slope from 0 to 1.5 deg.
8. Terrain factor value (value) - A terrain factor value is a specific occurrence of a terrain factor. For example, 1.5 deg is a factor value of the terrain factor, slope.
9. Terrain factor - A terrain factor is any attribute of the terrain that can adequately be described at any point (or instant of time) by a single measurable value, for example, slope and plant stem diameter.
10. Terrain factor family - A terrain factor family is two or more terrain factors grouped together. The terrain factor families used to describe terrains are: surface composition, surface geometry, vegetation and hydrologic geometry.

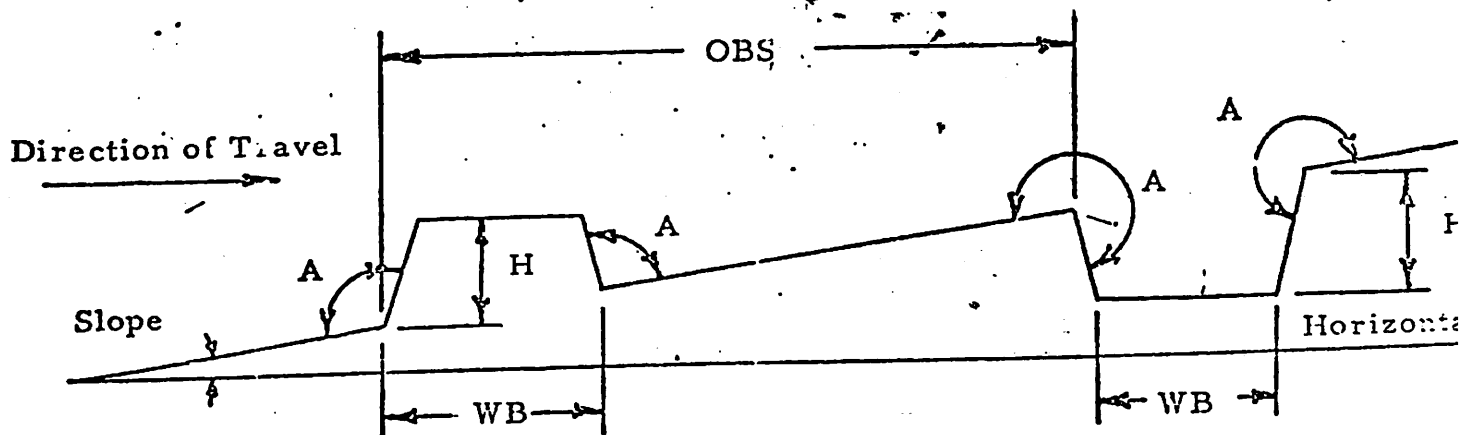
B. Surface Composition Terms

1. Fine-grained soil - A soil of which more than 50 per cent of the grains, by weight, will pass a No. 200 U.S. standard sieve (smaller than 0.074 mm in diameter).
2. Coarse-grained soil - A soil of which more than 50 per cent of the grains, by weight, will be retained on a No. 200 sieve (larger than 0.074 mm in diameter).
3. Organic soils (muskeg) - A terrain surface composed of a living organic mat of mosses, sedges, and/or grasses with or without tree or shrub growth. Underneath the surface there is a mixture of partially decomposed and disintegrated organic material, commonly known as "peat" or "muck."
4. Cone index (CI) - An index of shearing resistance of soil obtained with the cone penetrometer. The value represents the resistance of the soil to penetration of a 30-degree cone of 0.5 sq-in base or projected area.
5. Rating cone index (RCI) - Product of CI and remolding index (RI). RI is the ratio of remolded soil strength

to original strength. RCI expresses the soil strength rating of a soil subjected to vehicular traffic.

C. Surface Geometry Terms

1. Slope (slope) - The angular deviation of a surface from the horizontal, measured perpendicular to the topographic contours. (See sketch)
2. Obstacle Approach Angles (A) - The angle formed by the inclines at the base of a positive or top of a negative vertical obstacle that a vehicle must sense in surmounting the obstacle. (See sketch)
3. Obstacle Base Width (WB) - The distance across the bottom of the obstacle.
4. Obstacle Spacing (OBS) - The horizontal distance between contact edges of vertical obstacles. (See sketch)
5. Obstacle Vertical Magnitude (H) - The vertical distance from the base of a vertical obstacle to the crest of the obstacle. (See sketch)
6. Obstacle Length (OBL) - The length of the long axis of the obstacle.



D. Vegetation Terms

1. Stem Diameter - The diameter of the tree stems at breast height. This value is introduced to the model in centimeters.
2. Stem Spacing - The average distance (meters) between tree stems. This value is computed from the number of stems per unit area, assuming that the stems are arranged in a hexagonal pattern.
3. Recognition Distance - The distance a vehicle driver can see and recognize objects that may be hazardous to his vehicle or himself.

E. Hydrologic Geometry Terms

1. Differential Bank Height (BD) - The difference in elevation of the two banks. (See sketch)
2. Gap Side Slope (THI, RBA) - The angle formed by the bounding incline at the top of the hydrologic feature. The angle is measured with respect to the horizontal. (See sketch)
3. Water Depth (WD) - Maximum depth of water in channel. (See sketch)
4. Water Width (RW) - The width of the stream at water level. (See sketch)
5. Water Velocity (WS) - The maximum velocity of water in a channel.

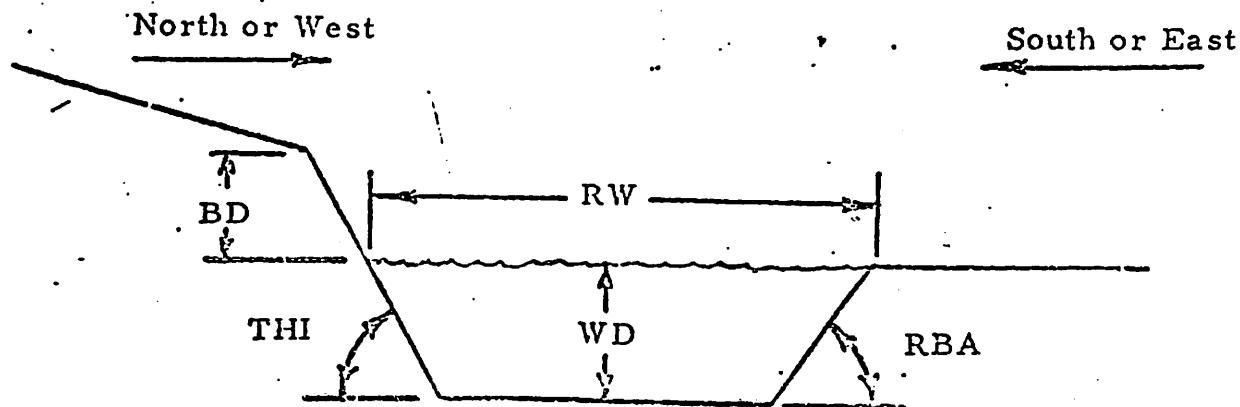


TABLE B1

Vehicle Characteristics Used in Ground Mobility Model

Characteristics No.	Identification	Dimensions	Compute Symbol
<u>General Characteristics</u>			
1	Vehicle type (NVEH = 0 for tracked); (NVEH = 1 for 4 x 4, 2 for 6 x 6, 3 for 8 x 8)		NVEH
2	Gross vehicle weight	lb	GVW
3	Track type (NFL = 0 for nonflexible; NFL = 1 for flexible)		NFL
4	Grouser height for tracks; number of tires for wheeled	in	GT
5	Tire ply rating		TPLY
6	Maximum force the pushbar can withstand	lb	PBF
7	Vehicle swimming speed	mph	VSS
8	Vehicle fording speed	mph	VFS
9	Maximum braking force the vehicle can develop	lb	XBR
10	Auxiliary water propulsion factor (no = .5, yes = .8)		AWPKF
11	Vehicle rated horsepower per ton		HPT
12	Number of people in the vehicle on a normal mission		NCREW
13	Vehicle winch capacity	lb	WC
14	Transmission variety (Hydraulic = 0; mechanical = 1)		ITVAR

TABLE B1 (Cont'd)

Vehicle Characteristics Used in Ground Mobility Model

Characteristics No.	Identification	Dimensions	Computer Symbol
<u>Characteristics Produced by Vehicle Ride Dynamics Subprogram</u>			
15	Number of point pairs in array VOOB (in curve)		NC4
16	Array containing vehicle velocity vs obstacle height at 2.5 g vertical acceleration		VOOB(I,
17	Number of points in array VRIDE		NC5
18	Limited speed due to vibration at the driver's seat for surface roughness Class I		VRIDE(I
<u>Geometric Characteristics</u>			
19	Vehicle width	in.	W
20	Vehicle length	in.	VL
21	Vehicle ground clearance at the center of the greatest wheel span	in.	GC
22	Rear end clearance (vertical clearance of vehicle's trailing edge)	in.	REC
23	Vehicle departure angle	deg	VDA
24	Vertical clearance of vehicle's leading edge	in.	FEC
25	Vehicle approach angle ($\equiv$ AV in FIVEYP); ($\equiv$ VAA in OBSTACL, INPUT)	deg	AAV
26	Track width or wheel width	in.	WID
27	Length of track on ground or wheel diameter	in.	DL

TABLE B1 (Cont'd)

Vehicle Characteristics Used in Ground Mobility Model

Characteristics No.	Identification	Dimensions	Computer Symbol
28	Wheel rim diameter	in.	RDIAM
29	Loaded wheel radius	in.	RW
30	Tire pressure	psi	TPSI
31	Ground contact area	in ²	GCA
32	Height of vehicle pushbar	in.	PBHT
33	Area of one track shoe (tracked) or number of axles (wheeled)	in. ²	A
34	Number of bogies (tracked) or chain indicator (wheeled); (0 = no chains; 1 = chains)		NBC
35	Distance between the first and last wheel centerlines	in.	XLT
36	Horizontal distance from the C.G. to the front wheel centerline	in.	CGF
37	Vertical distance from the C.G. to the road wheel centerline	in.	CGH
38	Maximum span between adjacent wheel centerlines ($\equiv$ DWX in FIVEP, RIVER)	in.	GWS
39	Angle between a line parallel to the ground surface and the line connecting the C.G. and the center of the rear wheel (road wheel or idler). The wheel is used to determine departure angle	deg	ACG
40	Distance from the C.G. to the center of the rear wheel (roadwheel or idler). The wheel is the one used to determine departure angle (in.)	in.	DCG

TABLE B1 (Cont'd)

Vehicle Characteristics Used in Ground Mobility Model

Characteristics No.	Identification	Dimensions	Computer Symbol
41	Vertical distance from the ground to the center of the rear wheel (roadwheel or idler). The wheel is the one used to determine departure angle. (wheeled = RW)	in.	HC
42	Track thickness plus the radius of the rear wheel (roadwheel or idler). The wheel is the one used to determine departure angle. (wheeled = RW)	in.	RWW
43	Maximum vertical step the vehicle can climb	in.	HS
44	Ingress swamp angle of the vehicle ($\equiv$ THD in DIG)	deg	SAI
45	Fording depth or draft height	in.	FD
46	Rolling radius of tire or sprocket pitch radius	in.	RR

Power Train Characteristics

47	Transmission type (ITRAN = 0 for manual; ITRAN = 1 for automatic)	ITRAN
48	Final drive gear ratio	FDR
49	Final drive gear efficiency	FDREF
50	Number of gear ratios in transmission	NG
51	Gear ratio of Ith gear	GR(I)
52	Transmission efficiency	EFF
53	Gear ratio from engine to torque converter	ENTCG

TABLE B1 (Cont'd)

Vehicle Characteristics Used in Ground Mobility Model

Characteristics No.	Identification	Dimensions	Computer Symbol
54	Denotes presence of a torque converter Lockup; no = 0; yes = 1		LOKUP
55	Input torque at which the torque converter curves were measured	ft-lb	TC
56	Number of point pairs in array TNE1		NC1
57	Array containing torque input speed vs converter speed ratio curve		TNE1(I)
58	Number of point pairs in array TTM		NC2
59	Array containing torque converter torque multiplying coefficient vs converter speed ratio curve		TTM(I,
60	Number of point pairs in array TTE		NC3
61	Array containing net engine torque vs engine speed curve		TTE(I,

Characteristics Required for
Vehicle Ride Dynamics Subprogram

62	Mass of Main Frame	lb-sec ² /in	FMASS
63	Mass of Wheel or Bogie Assembly I	lb-sec ² /in	MASS(I
64	Pitch Moment of Inertia	lb-sec ² /in	INRTIA
65	Distance from C.G. to Wheel or Bogie Assembly I	in.	LEN(I)

TABLE B1 (Concluded)

Vehicle Characteristics Used in Ground Mobility Model

Characteristics No.	Identification	Dimensions	Computer Symbol
66	C.G. to Driver Distance	in.	DRVLEN
Initial Displacements:			
67	Vertical C.G.	in.	VAR(1)
68	Pitch	radian	VAR(2)
69	Axle 1	in.	VAR(3)
	Axle 2	in.	VAR(4)
	Axle 3	in.	VAR(5)
	Axle 4	in.	VAR(6)
	Axle 5	in.	VAR(7)
	Axle 6	in.	VAR(8)
70	Horizontal C.G.	in.	VAR(9)
71	Threshold height of wheel segment I	in.	THRSH(I)
72	Segmented wheel spring constant for vertical component of segment I ($K \cos \theta_I$)	lb/in	GAMMA(I)
73	Segmented wheel spring constant for horizontal component of segment I ($K \sin \theta_I$)	lb/in	SIGMA(I)
74	Feeler threshold heights (to portray leading portion of track)	in.	TH(I)
75	Track tension spring constant (between bogies)	lb/in	
76	Track tension spring constant (feelers ahead of first bogie)	lb/in	

The ride dynamics calculation is performed externally to the main terrain-unit module for two reasons: (1) the existing state-of-the-art provides an inadequate basis for taking account of the interactive effects of ground roughness and other mobility impediments such as soft soil or vegetation, and (2) the ride dynamics calculation is very lengthy, and its inclusion in each terrain-unit calculation loop would naturally increase the cost of running the simulation.

The model is structured so that submodels (modules) can be altered, replaced, or bypassed in operation, if desired. This modular structure is employed in the interest of operational flexibility and to facilitate updating as new information becomes available.

The model evaluates the combined influence on system performance of terrain factors comprising four distinct classes, or factor families: (1) surface composition, (2) surface geometry, (3) vegetation, and (4) hydrologic geometry.

The terrain is subdivided into terrain units, areas within which no terrain factor varies beyond stipulated bounds, or class limits. Class limits are selected on the basis that factor variations within these limits produce no significant effect on vehicle performance. The model accordingly assumes that performance is constant throughout a terrain units, and predictions of speed for a given unit are based on nominal, or average, values of each terrain factor within the unit.

Since the model involves a complex system of sophisticated relationships, the list of input data required to characterize the vehicle is extensive; 76 different vehicle parameters must be specified in all. These include, for example, transmission gear ratios, final drive efficiency, tire or track dimensions, suspension compliance and damping characteristics, approach and departure angles, and various dimensions and weight characterizing the magnitude and distribution of masses.

INPUT PARAMETERS AND LIMITATIONS:

Input: 1

Limitations: The AMC 71 Mobility Model is a first generation model; validation is still taking place. This inprocess-validation is of key interest as it demonstrates the ongoing work to accomplish what other simulations in the mobility simulation hierarchy lack--validation. In this first generation status it is especially important that the model is properly applied and interpreted.

a. The river crossing portion of the model cannot satisfactorily simulate water exiting capability. This inability mirrors the Army's lack of understanding of water exiting; research is being directed to overcome this lack of understanding.

b. Similarly, the slipperiness due to water puddles on thin saturated soil layers is not well understood or modeled. This barrier is being explored.

c. Ride dynamics is a complex effect and will require additional research to understand and properly simulate.

d. Speed-made-good is the key mobility parameter modeled. Other parameters such as ton-miles or total covered distance or survivability may be equally important.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: Various output options are available, at the discretion of the user, ranging from map coordinates of a best course (i.e., that course, between specified endpoints, which the vehicle can traverse in minimum time), and time required to cover the best course, to detailed listings and analyses of vehicle speed predictions for individual terrain units.

Expressed in methodological terms, the AMC 71 Mobility Model is a mechanism for calculating the average speed of a vehicle in each of an aggregate of contiguous terrain units, and for synthesizing the derivative speed predictions to provide an objective basis for decisions by vehicle designers, evaluators, and users.

The computer can printout a table of the individual (terrain unit) speed predictions, and list the percentages of the total number of terrain units in which the simulated vehicle can attain speeds in stipulated ranges (say 0 mph; between 0 and 2 mph, between 2 and 4 mph; and so forth). The table of speed predictions and the distribution of attainable speeds constitute a data set which lends itself to various types of meaningful analyses. For example, the characteristics of those terrain units where the vehicle performs badly can easily be established. The distribution of such units in geographical areas representative of the vehicle's intended sphere of operation can be found.

Many important conclusions may be drawn from terrain-unit prediction data, such as: (1) a candidate vehicle is (is not) well suited for a contemplated mission profile, (2) the vehicle's design should be modified to improve

specific facets of performance in order to assure its mission effectiveness, (3) engineering aid is necessary to assure a high probability of mission success in particular areas (e.g., in a riverine environment), and so on. Analyses of terrain-unit speed predictions can be especially useful for comparing the mobility performance of two or more real or concept vehicles. In addition to providing overall mobility evaluations for the vehicle alternatives, such analyses can reveal specific strong and weak points of the candidate vehicle in terms of performance relative to particular types of mobility impediments.

Terrain-unit speed predictions can also be used for parametric design studies. One can vary a single design parameter, such as tire size or gross vehicle weight, and examine the resulting changes in the terrain-unit speeds and in their distribution. One can select a number of typical terrain-units containing, for example, soft soil of decreasing strength, or obstacles of increasing size, and tabulate or plot the speed variations produced by specific design changes.

Questions such as, "what track width is needed to surpass 10mph in 80% of the terrain units" can also be answered. In this sense, one can, in effect, analyze the "cost" of mobility.

It is appropriate at this point to discuss explicitly a crucial feature of the AMC 71 Mobility Model which heretofore has been noted only in passing. This is that the performance assessments produced by the model are comprehensive; i.e., they take account of all significant mobility impediments and their synergistic interaction. This is in contrast to conventional methods for characterizing vehicle mobility (e.g., vehicle Cone Index, V-ride speed, water maneuverability indices), which merely describe the vehicle's performance relative to individual mobility impediments (soft soil, ground roughness, and unfordable streams, respectively).

Even a performance characterization in terms of an aggregation of conventional performance measures fails to take account of interaction effects. And this is an extremely important omission. To give just one illustration, the trafficability of the associated soil surface exerts an enormous influence on a vehicle's ability to climb slopes, to egress from streams, or to surmount, avoid, or override obstacles.

The AMC 71 Mobility Model not only accounts for the interaction of individual facets of mobility performance, it weights their importance according to the distribution of mobility impediments encountered in the mission environment. Weighting mechanisms built into the techniques for calculating and interpreting terrain-unit speed outputs were described earlier. These "built-in" mechanisms do not provide a completely weighted mobility measure, however. One can appreciate their shortcomings by considering a hypothetical comparison of two candidate vehicles for a mission involving the requirement to travel, in the shortest time possible, between two points A and B, separated by some arbitrary configuration of

terrain units. Assume that one of the vehicles is able to proceed slowly but surely along the straight line AB; but that the other, although unable to negotiate AB, can nevertheless get from A to B faster than the first by negotiating some more circuitous route at a higher speed. The example illustrates that consideration must be given to the selection of route, as well as to performance over a stipulated route, in order to make a meaningful mobility comparison. In other words, the missing ingredient in the performance weighting mechanisms discussed previously is route selection. With respect to precision of results it should be noted again that the AMC 71 Mobility Model is currently a first generation model. However, even as a first generation effort it is of enormous value when properly applied and interpreted. The model was an indispensable tool for assisting the recent WHEELS Study Group personnel accomplish their mission. This success was followed by a memorandum of The Army Chief of Staff to complete development of the model and turn it over to the Army Staff (ACSFOR) as a Department of Army Management Tool by 1974.

SUMMARY: The AMC 71 Mobility Model is a good first generation model that is in process of being validated and that is being groomed as a DA management tool. Within the mobility simulation hierarchy it appears to be the most valid simulation, even in its current state, and would appear to be suitable as a base on which to anchor and build the rest of the mobility simulation hierarchy.

NAME: HITPRO

TITLE: Hit Probability (HITPRO)

PROPOSER: US Army Weapons Command (WECOM)

PURPOSE: HITPRO is a firing performance model of an armored weapons system. It was initiated to provide a design tool capable of evaluating tank fire-on-the-move performance.

GENERAL DESCRIPTION: HITPRO deterministically simulates the dynamic gun pointing error of a ground mobile weapon system as it moves over a known terrain.

A firing tank is simulated moving along a test course defined as a series of circular arcs with bumps similar to the Aberdeen Proving Ground Test Course.

In order to provide an accurate gun aim, the stabilization system with gunner response must counteract gun movements due to vehicle motion.

The impact of the terrain on vehicle motion is modeled in two parts: (1) the linear motion including the forward acceleration, velocity and turning rate is calculated based on the input course programmed as a series of constant-velocity, constant turning-rate segments; (2) the three components of angular motion and small amplitude vertical motion are also calculated and consider terrain roughness, recoil forces and torques acting on the suspended vehicle. These vehicle movements require the stabilization system to be responsive in both azimuth and elevation. The simulation includes provision for drive motor characteristics and load torque disturbances caused by friction, unbalance, vehicle angular acceleration, and firing recoil. The stabilization system reacts to inputs from the gunner hand station, gun mounted rate gyros, elevation and traverse tachometers and hull and turret rate gyros.

Currently, HITPRO models the XM10 ballistic computer which is used in the M60 A2 tank. The computer provides lead angle and super-elevation corrections. When the vehicle has no computer, the gunner submodel provides these inputs.

The dynamic response of the gunner when observing gun pointing errors through the reticle is simulated. Also considered are the decision to reset lead angle, the judgment that tracking is smooth enough to make a lead reset measurement and the judgment that aiming is sufficiently close to the target to justify firing. When the gunner commands a firing, the nominal trajectory of the shell and the nominal miss at the target (including target motion during shell time of flight) are computed. The shell dispersion pattern is integrated over the target area to determine a hit probability.

INPUT PARAMETERS AND LIMITATIONS:

Input:

1. Radii of circular arcs along which the firing tank travels.
2. Size of the ramp bumps over which the firing tank must pass.
3. Direction, velocity (constant), and shape, armor etc. of target vehicle. (The target travels in a straight line.)
4. Vehicle characteristics of the firing vehicle.

Limitations: As can be seen from the description of input data, HITPRO has a rather stylized firing trace and a constant velocity target moving along a straight line. Effectively, the mobility/agility of the target vehicle is discounted. This relationship of mobility/agility to survivability of a combat vehicle is unknown and needs to be determined. After determination, the relationship may be incorporated into HITPRO or a new model may possibly have to be constructed. In any case, immediate action is suggested to determine this important relationship and incorporate it into the simulation hierarchy.

NATURE OF OUTPUTS AND PRECISION OF RESULTS: A wide variety of data can be output from HITPRO including the hit probabilities for shots, vehicle speed, gun aiming direction, and sight reticle position as a function of time.

The current model, within the scope of its assumptions, has been validated and produces excellent results. These hit probabilities become key input data for such effectiveness assessment models as DYN-TACS. HITPRO must be considered as one of the candidates for a mobility-related simulation hierarchy.

NAME: CAD-E

TITLE: Computer-Aided Design and Engineering (CAD-E)

PROPONENT AND DEVELOPER: US Army Materiel Command (CAD-E)

PURPOSE: Application of automated techniques to enable the engineer or scientist to accomplish his normal functions in concept, design, and design evaluation, encompassing the use of computers in (1) conceptual design, (2) mathematical modeling and design prediction, (3) design preparation and automatic drafting, (4) prototype fabrication, and (5) automated simulation and testing.¹

GENERAL DESCRIPTION: Army's CAD-E program, as its name implies, includes the full spectrum of computer applications to materiel development. Within this spectrum there are identifiable capabilities that define the extremes involved in this application. These extremes are graphic versus nongraphic and conversational versus nonconversational.

a. The graphic capability of computer systems refers to its ability to display data and information in pictorial or symbolic form. Nongraphic means the input/output devices are alphanumeric rather than graphic.

b. Conversational capability allows the system to accept instructions and guidance from the user and make responses while computations are in progress. Nonconversational implies a computing problem is run from beginning to end without breaking computations into steps involving man intervention or man/machine communication (commonly referred to as "batch processing").

The potential of CAD-E is to allow an engineer/scientist to interact or converse directly with the computer to produce a combination of man and machine that can outproduce either.

INPUT PARAMETERS AND LIMITATIONS: As the above general description implies, CAD-E extends from design through engineering and, therefore, might fit into any echelon of the mobility-related hierarchy. CAD-E is thus more like a family of simulations. However, early in its application and continuing today, one finds CAD-E, at least in the mobility area, finding initial application at the lower echelons of component design--in effect, the very, very high model resolution area. Its successes so far have been in such things as redesign of a U-joint and strengthened wheel design. For these reasons it has been included at the very, very high resolution end of mobility-related hierarchy of simulations.

¹Most of the information included in this section is taken from "CAD-E: A Key to Cost and Time Reduction" by GEN Henry A. Miley Jr., pp 33-39 of January 1973 Defense Mgt Journal.

No matter how else it is viewed, CAD-E is still only a tool similar to the slide rule and desk calculator of yesteryear. It has the potential of increasing productivity and decreasing cost. Since the Army is interested in both areas, interest in CAD-E will continue.

Input: The input to CAD-E is the normal input associated with any design or engineering computations.

NATURE OF OUTPUT AND PRECISION OF RESULTS: The output of CAD-E can span the output of any design or engineering problem. Of possible interest are the experiments at the TACOM to adapt CAD-E to modules of the AMC Mobility Model. Of particular interest is CAD-E and the dynamic side module for improving understanding of this important facet (often the limiting factor) of the parameter speed-made-good.

NAME: TANKSOM

TITLE: Tank Sustained Operations Model (TANKSOM)

PROPONENT: US Army Combat Developments Command

DEVELOPER: US Army Maintenance Agency

PURPOSE: Model tanks in sustained operations and model battalion maintenance of tanks.

GENERAL DESCRIPTION: The TANKSOM interacts with the BONDER/IUA model for the intense phase of combat requirements. TANKSOM can examine tank combat operations at 15-minute intervals spanning 60 days. If there is an engagement decision, the model simulates travel to battle site, battle, and return (if successful). It accounts for all tanks at all times.

Maintenance is played by having tanks fail going to a battle, returning from battle and returning to using unit from maintenance. One tank is failed every MTBF (Mean-Time-Between-Failure) of total tank usage, computed at each 15-minute interval. Since one-half of all mobility and total tank kills are considered repairable, battles also contributes to maintenance requirements.

After failing, tanks to be maintained move, with appropriate delay, to a maintenance unit and enter a queue. If available, a float item is exchanged for the incoming tank. Service time is computed from the Maintenance Ratio and MTBF. The maintenance units are required to move at regular intervals.

INPUT PARAMETERS AND LIMITATIONS:

Inputs:

- a. Results of BONDER/IUA runs:
 - (1) Exchange ratios.
 - (2) Initial Blue and Red battle force sizes.
- b. Mission schedules.
- c. Blue tank RAM.
- d. Maintenance manning and float.
- e. Delay times.
- f. Win/lose criteria.

General:

a. The idea of bringing sustained operations into the combat effectiveness picture is certainly a step in the right direction. In this way the mobility requirements of moving to the attack position can be played.

b. The purpose of the development of the TANKSOM was to assist the recent MBT Task Force in its efforts. However, due to some delays in model development and because there was limited time to do the task force effort, TANKSOM was never exercised and is therefore unproven.

Limitations:

a. Since TANKSOM uses the BONDER/IUA model for its combat situations, the same mobility limitations apply with respect to the intense phase of combat.

b. Since TANKSOM has not been exercised or validated, significant doubt arises as to its current validity.

c. Since maintenance effort and float are played on a battalion slice concept, maintenance priorities, for the better or worse, are not played as they might be were the maintenance resources aggregated at brigade, division, etc.

NATURE OF OUTPUTS AND PRECISION OF RESULTS:

a. 15-minute interval summary including:

Number of tanks available.
Number of tanks going to maintenance.
Number of tanks coming from maintenance.
Number of tanks at organizational maintenance.
Number of tanks at forward support.
Number of tanks at division.
Number of tanks in float.

b. Daily summary including:

Number of Blue tanks killed.
Number of Red tanks killed.
Number of Blue tanks damaged.
Number of Red tanks damaged.
Number of missions turned down.

c. Battle condition summary.

NAME: WHEELS Fleet Model

TITLE: WHEELS Fleet Model

PROPONENT: WHEELS Study Group

DEVELOPER: WHEELS Study Group

PURPOSE:

a. To provide an automated data base of standard TOE vehicle requirements for use in estimating, at unit and fleet level, the cumulative impact of alternative vehicle substitution policies.

b. To provide an automated summary-level, vehicle life-cycle cost data base for generating and displaying life-cycle cost impacts of proposed fleet reductions and substitution policies.

c. To provide visibility to selected Army tactical fleet characteristics to include the distribution of fleet requirements by vehicle type, by location within a type theater of operations, and by function supported.

GENERAL DESCRIPTION: The REVAL-WHEELS model is a computerized procedure for projecting alternative Army vehicle fleet requirements and impacts based upon proposed changes to current vehicle authorization policies and criteria. To avoid confusion, the model as revised and employed during the WHEELS Study effort is termed the WHEELS Fleet Model.

The model was originally developed during the 1968 DA study, Re-Evaluation of the Army Tactical Vehicle Program (REVAL-WHEELS). Significant changes to the model have been made to improve its applicability and utility to WHEELS needs. An overview of the general methodology incorporated in the WHEELS Fleet Model is illustrated in Figure 1. Based upon standard TOE, vehicular task requirements are defined at the unit level and coded in terms of functional descriptions such as:

- a. Task function.
- b. Relative mobility requirement.
- c. Expected duration and frequency of vehicle usage.
- d. Typical area of operations within a type theater of operations.
- e. Body-style requirements (e.g., ambulance, wrecker, dump, van).
- f. Full-time assigned driver requirements.
- g. Associated vehicle-mounted radios.
- h. Currently authorized vehicle types.

General vehicle performance and life-cycle cost data are also coded in parametric form and associated with 120 basic vehicle types, including current standard tactical wheeled vehicles, proposed derated military candidates, and proposed commercial vehicle substitution candidates. Criteria for vehicle deletions or substitutions are specified by the user in terms of selected task and vehicle parameters. These rules are sequentially applied by the model to all defined vehicular tasks. This process, coupled with task density information provided by force structure input data, permits the calibration of fleet vehicle requirements and costs by vehicle type. Model design facilitates the modification of data inputs (such as costs) to update prior alternatives or to perform sensitivity analyses.

INPUT PARAMETERS AND LIMITATIONS:

Input:

Task descriptions.

Vehicle capabilities data.

Cost data.

Force structure data.

Limitations

The model can deal with only one series of a TOE at a time. It is not able, in its current configuration, to move back and forth between TOE series.

Vehicular tasks continually become outdated; a program is necessary to update the individual tasks on a continuing basis.

NATURE OF OUTPUTS AND PRECISION OF RESULTS:

Life-cycle cost impacts of fleet policies or change.

Fleet requirements by:

Vehicle type

Location

Function supported.

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