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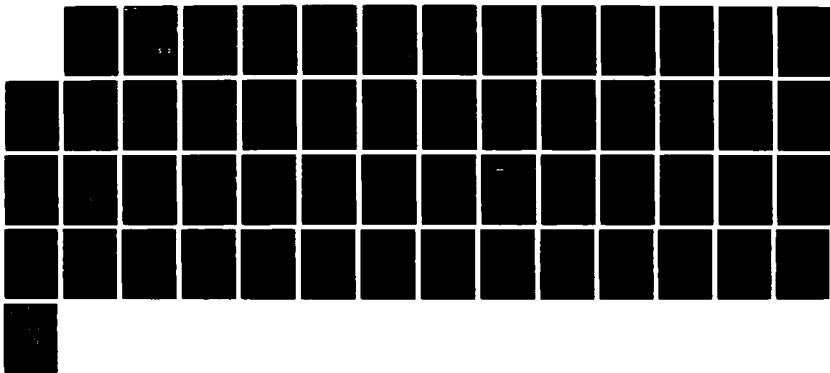
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**Developing and Assessing Concepts for Future
U.S. Army Warfighting: A Progress Report**

Philip J. Romero

April 1988

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→ The U.S. Army's concept-based requirements system stipulates that future materiel requirements should be based on a concept of warfighting that has undergone extensive analysis and refinement. This Note reports on the progress of an ongoing RAND effort to develop a method to help systematize and streamline the process of designing concepts. RAND's model will provide a first-order estimate of the forces and resources needed to meet specified theater success goals for alternative concept designs. The model is meant to be flexible and fast-running, in order to serve as a tool for the exploration of new concept ideas. Analysts using the model will be able to experiment with variations in operational policy, examine the payoffs of improved technical performance, and conduct sensitivity analysis to identify robust concepts.

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PREFACE

The Arroyo Center's "Future Warfighting Concepts and Technologies" project is aimed at developing improved methods for designing and evaluating Army warfighting concepts and forecasting the technical capabilities of future weapons systems. Two of the project's tasks are: to develop a framework for systematically developing new concepts (sponsored by the Deputy Chief of Staff for Doctrine, U.S. Army Training and Doctrine Command) and to design a method for exploring concept ideas and assessing their performance quantitatively (sponsored by the Commander, TRADOC Analysis Center). This Note reports on RAND's progress in performing the latter task, namely, developing an aggregate, theater-level model that will serve as a tool in the design and evaluation of new warfighting concepts. When completed, it is anticipated that the model will be used by the TRADOC Analysis Center as a screening tool in an ongoing study of the Army 21 operational concept, and by RAND as one starting point for its efforts to design improved procedures for the development of future concepts.

This Note should be of interest to specialists in doctrine and operations analysis, and to those involved in military policy analysis methods. The work reported here was performed in the Applied Technology Program of the Arroyo Center.

The Arroyo Center

The Arroyo Center is the U.S. Army's Federally Funded Research and Development Center for studies and analysis operated by The RAND Corporation. The Arroyo Center provides the Army with objective, independent analytic research on major policy and management concerns, emphasizing mid- to long-term problems. Its research is carried out in five programs: Policy and Strategy; Force Development and Employment; Readiness and Sustainability; Manpower, Training, and Performance; and Applied Technology.



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Army Regulation 5-21 contains basic policy for the conduct of the Arroyo Center. The Army provides continuing guidance and oversight through the Arroyo Center Policy Committee, which is co-chaired by the Vice Chief of Staff and by the Assistant Secretary for Research, Development, and Acquisition. Arroyo Center work is performed under contract MDA903-86-C-0059.

The Arroyo Center is housed in RAND's Army Research Division. The RAND Corporation is a private, nonprofit institution that conducts analytic research on a wide range of public policy matters affecting the nation's security and welfare.

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EXECUTIVE SUMMARY

This Note reports on the progress of an ongoing RAND effort to build a tool that will assist in systematizing and streamlining the development of future Army warfighting concepts. In our view, the process of *developing* concepts is hampered because of the absence of a framework that can describe a concept's important characteristics rigorously, and where possible, do so in quantitative terms. The *evaluation* and *refinement* of concepts, particularly those for relatively distant futures (10 or more years), are similarly impeded because (1) there can be a wide variety of *versions* of a particular concept, all of which may require study, and (2) our uncertainty about the future mandates that each version be examined under a *range* of possible future conditions. **RAND's warfighting concept screening model will permit concept developers and analysts to quickly explore and appraise a large number of concepts under a wide range of assumptions. To achieve this, the model incorporates three features:**

- a generalized (but quantitative) *activity-oriented description of "operational policy,"* that can describe a wide range of concepts by varying policy variables;
- an *aggregated treatment of operations* in a theater that uses hierarchical "proxy variables" to represent subordinate components;
- calculations that use *simple equations* organized in a "*spreadsheet*" format on a personal computer, allowing analysts to instantaneously observe the effect on outputs of changes in inputs.

The model produces estimates of the amounts of resources--combat and support units, consumables, and personnel--that would be needed by any specified concept to achieve a minimum level of success in a combat theater. When analysts can project the amounts likely to be available, then **concepts can be "screened" based upon their resource needs.**

Theater success criteria and the size of the threat determine the number of threat units that must be destroyed within some maximum time period or by some penetration distance. Each of six types of units (three combat, one headquarters, and two support) must engage in a set of activities in order to participate in the destruction of a threat unit. These activities together are referred to as the unit's *duty cycle*. Different warfighting concepts can be represented by constraining activities in the duty cycle. Within these constraints, the equations in the model calculate the amount of time each unit would take to perform each of its activities; based upon the time required, requirements for other resources are also estimated. The equations are deliberately based upon simple relationships derived from classical combat theory, simple geometry, or common sense. The resources required per destroyed Red unit can be cumulated for all Red units that require destruction to produce an estimate of the total *forces*, *supply units*, and *consumables* needed.

Besides screening concepts based upon resource needs, the model also permits analysts to examine the leverage that could be gained from alternative performance improvements (such as technologies that could improve mobility vs. those supporting lethality). Because the elements included are of necessity highly aggregated, there cannot be a one-to-one relationship between model inputs and "real-world" attributes. For instance, improved mobility could result from better engines, lighter chassis, or entirely new types of vehicles, all of which are reflected in the "proxy" of unit movement rates. Although the model cannot estimate the payoff of specific system improvements, it can point out general tradeoffs among *classes* of capability improvements, and in particular, note how the payoffs of technical improvements differ for different warfighting concepts.

The immediate use of the model will be in a study of the Army 21 concept under way at the TRADOC Analysis Center (TRAC). The model has been designed to accommodate a wide range of alternative warfighting concepts. When TRAC receives the model in the Summer of 1987, they will be able to use it to further define the Army 21 concept and screen through its many possible versions. At the same time, RAND continues

efforts to develop a more systematic framework for concept development. RAND will use the model experimentally to explore alternative concepts and to appraise the advantages and limitations of its use as a device to increase the rigor and the efficiency of the concept development process.

ACKNOWLEDGMENTS

Several people inside and outside the Arroyo Center have provided valuable assistance to the project. James Hewitt participated in countless hours of blackboard sessions, patiently helping the author think aloud. James Bigelow and Bruce Goeller helped articulate the need for an automated, aggregate method for "screening" warfighting concepts. Finally, Colonel James Pittman, USA, the project's action officer at TRAC, has been generous with his time and insight and has supported the necessary compromises in detail that kept the complexity of the model within practical limits.

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I. INTRODUCTION

A frequently expressed concern of military long-range planners is that the specifications for weapons systems used by the research and development community typically are rarely based upon any coherent, internally consistent concept of how the system might be used in wartime (especially in combined operations with other systems). Often systems designs end up responding to the requirements of the particular Army functional area or branch that will be the system's principal user, without sufficient attention paid to the system's employment in combined operations. Thus, while the design of each weapon in the force may be optimized in terms of its particular measures of performance and its own concept of operations, there can be no assurance that their combined performance is all it can be unless there is some common framework-- i.e., some integrated view of the roles and missions of each system on the battlefield--that coordinates the individual components.

The Army's chosen policy to attempt to establish a common framework from the top down is the Concept-Based Requirements System (CBRS).¹ It stipulates that a concept of operations is a necessary prerequisite to the development of force structure or materiel requirements. Furthermore, CBRS specifies that an overarching or "umbrella" operational concept, which describes in broad terms the sequence of operations of Army forces, should define component roles and missions so as to guide its subordinate mission-area concepts.

The design of any concept of operations involves two fundamental tasks:

- A *forecast* of the conditions under which Army forces might have to fight, including elements over which the U.S. Army has no control (such as threat forces) or incomplete control (such as the performance of future U.S. weapons).

¹CBRS is described in TRADOC Regulation 11-15, "Concept Based Requirements System." The role of operational concepts in the combat developments process is described in TRADOC Regulation 11-16, "Development and Management of Operational Concepts."

- A *judgment* on which of a vast array of possible concepts are *preferred*.

Both of these tasks can be extraordinarily difficult to accomplish. The time required to develop, acquire, and field a major weapons system can frequently exceed ten years, and fielded systems can easily remain in the force for 20 years more. Since the time horizon of the forecast must be in excess of 20 years, there is bound to be great uncertainty about future conditions. Some concepts that perform quite well under one set of plausible future conditions may do poorly under others. A common approach to the treatment of uncertainty is sensitivity analysis. Several analyses are conducted, varying the assumed value of one or more uncertain factors to assess their effects on the outcome. Since it is highly unlikely that any single concept will perform the "best" across all plausible assumptions, the best that can probably be expected is to choose a concept that does "tolerably well" across a fairly wide *range* of plausible conditions. If the process of producing the judgment includes a quantitative component, it is likely to be fairly time-consuming and expensive.

This Note reports on the progress of an ongoing RAND effort to develop a model to assist in systematizing and streamlining the concept design process. The modeling effort is one of three tasks of the RAND/Arroyo Center's "Future Warfighting Concepts and Technologies" project, jointly sponsored by the Deputy Chief of Staff for Doctrine, Training and Doctrine Command (TRADOC); the Commander, Laboratory Command, Army Materiel Command; and the Commander, TRADOC Analysis Center (TRAC).

The modeling task has both an immediate and a farther-reaching objective. Pursuant to the principles of CBRS, in the early 1980s the Army initiated an effort to develop an "umbrella" operational concept for the early 21st century (2005 to 2025), currently known as Army 21.² The concept calls for U.S. (hereafter, "Blue") units to operate

²The most recent unclassified description of the Army 21 concept is contained in U.S. Army Training and Doctrine Command (TRADOC), *Army 21 Interim Operational Concept*, First Edition, Second Coordinating Draft, June 1985.

independently, sometimes deep in the enemy's (hereafter, "Red's") rear area, engaging in offensive operations to attrit, disrupt, and eventually defeat Red ground forces. As mandated by CBRS, the interim concept that was produced in 1985 is scheduled to undergo an extensive quantitative evaluation by the TRADOC Analysis Center. The first use of the model outlined in this Note will be to support the refinement of the Army 21 concept that is integral to TRAC's evaluation. Sections II through V describe RAND's progress to date on the model in terms pertinent to its anticipated use in TRAC's evaluation.

While precipitated by the Army 21 evaluation study, the model's broader purpose is to serve as a tool to assist concept designers in exploring new concept ideas in a more systematic and efficient manner. Section VI illustrates areas where we feel that the model, though initiated with the Army 21 concept in mind, is sufficiently general to reflect a range of concepts. Section VI also describes our preliminary thoughts on the use of this approach in the design of new concepts. Finally, App. A defines the key input variables and performs an illustrative calculation, and App. B summarizes the key attributes of the model.

II. THE NEED FOR A DESIGN/SCREENING METHOD IN THE EVALUATION OF WARFIGHTING CONCEPTS

RAND's most recent involvement in warfighting concept evaluation began in December 1985, when two weeks of working sessions were held with staff members from TRAC/Fort Leavenworth to assist them in developing a plan for their study of the Army 21 concept. While the method described in this Note uses the Army 21 concept for illustration, it is equally applicable to other future concepts. From the outset, TRAC's intent was to make its study as rigorous and quantitative as possible. These approaches are considered TRAC's strengths, and the analysts were skeptical of the value to the Army of a predominantly qualitative evaluation. The study plan embodied a recognition that several methodological challenges, listed in Fig. 1, had to be faced squarely.

AN UNSPECIFIED CONCEPT

The interim operational concept describes a sequence of operations by Army combat units, but remains silent regarding some aspects that are crucial to a quantitative analysis. For example, the concept states that some Blue units will operate under dispersed conditions in the enemy's rear area, then mass to attack a chosen target, before disengaging and dispersing to reduce their vulnerability. Unspecified are:

- What fraction of Blue forces operate offensively in the enemy rear, and what fraction operate defensively in his path?
- What force ratio does Blue desire to achieve when he masses?
- How much Red attrition does Blue wish to achieve in each attack, or how long should his attack last before he breaks off?
- What mix of direct and indirect fire does Blue use in his attacks?¹

¹The Army 21 concept also includes a number of assumptions regarding improvements in the technical performance of Blue equipment;

| <u>Challenge</u> | <u>Implication</u> |
|--|--|
| Concept not fully specified | Need to <i>design</i> concept versions then evaluate |
| Versions can mix a wide range of components (forces vs. operations vs. technology) | Need to be able to examine <i>tradeoffs</i> among components |
| Time horizon far in future | Need extensive sensitivity analysis to find <i>robust</i> versions |

● **CONSEQUENCES:**

- Problem too big and "squishy" for traditional, detailed combat assessment models. Need to design and evaluate *many* concept versions.
- Methods must be "inexpensive" but insightful.

Fig. 1 -- Methodological challenges to the analysis of Army 21

Noting these omissions does no discredit to the designers of the concept, since these are hard questions and any answer given in the absence of analysis would be highly arbitrary.² However, in their

several of them are controversial. Such *assumed capabilities* will also be indirectly influenced by doctrine. They must be treated as uncertain in sensitivity analyses.

²Such specifics would have been arbitrary, but not without value. Eventually they must be provided to give the evaluation a set of starting inputs. In our observation, the concept designers have been reluctant to describe their concept in these kinds of quantifiable terms. It may be due to a fear that an "off-the-cuff" answer will take on exaggerated importance when used by analysts from another organization. Nevertheless, for a quantitative analysis to be performed, these starting points must come from somewhere. They will be

absence it is a misnomer to refer to the operational concept as if it were a unitary, fully-defined entity. Rather, there are many possible *versions* of the concept. The TRAC study is therefore less an evaluation of a *single* concept than it is a *search* among *many* potential versions of the concept to nominate the "superior" versions. Since the differing versions are not specified in the concept document, TRAC will need to *design* them. TRAC must identify the important design variables (such as the example questions on p. 4) and vary them over a sensible range to produce an "envelope" of different possible versions, distinguishing among, as in the example questions above, offense/defense mixes, policies governing initiation and termination of engagements with enemy units, and various uses of combined arms.

TECHNOLOGY AND FORCE STRUCTURE POLICY CHOICES

While the design variables used in the concept study should emphasize operational policy (that is, how the theater commander chooses to *use* a fixed set of resources), they should not neglect force structure and technology. A smaller number of more capable combat units may be able to perform the same job as a less capable larger force. More important, operational policy is shaped by available technology and force structure. It would probably not make sense, for instance, to try to execute a version of the warfighting concept that required combat units to frequently move great distances across the theater to maintain an intense pace of operations if technology only allows moderate rates of movement. Thus the "envelope" will include mixes of technological and force structure policy as well as operational policy.

produced by the analysts responsible for the evaluation if no superior source is forthcoming. TRAC is maintaining the involvement of the concept designers on several of the study's working groups, so that their insight into the concept will be reflected in the study inputs. The study proponent is the Concept Developments Directorate of the TRADOC Combined Arms Concept Development Activity, which wrote Army 21.

UNCERTAINTY ABOUT FUTURE CONDITIONS

Since the concept is intended to apply to the 2005-2025 period, use of a "best estimate" scenario would ignore our large uncertainty about conditions so far in the future. That uncertainty can be taken into account only by defining ranges around our "most likely estimates"-- such as a "best case" and a "worst case" estimate--for each of the variables outside the Blue commander's control (including the performance of Blue systems). Thus there are three combined scenarios: when all variables are set to "most likely" values, to "best case," and to "worst case" assumptions. In practice, there will be interdependencies among the variables that should make the size of the scenario space much larger still. Furthermore, techniques that may be effective in one theater of operations (e.g. Central Europe) might perform differently in another; if the concept is intended for multiple environments, then they too should be varied. To assess how robust any version of the concept is will entail evaluating it throughout the scenario space.

Taken together, these requirements pose a tremendous challenge to the study. Instead of one policy to be evaluated in one scenario, there will be *many* concept versions, each of which could be analyzed under *many* scenarios. Any reader who is familiar with the high-resolution combat analysis methods used in traditional Army studies will recognize that it would be impossible to employ them to evaluate such an enormous set of cases. Resource constraints simply prohibit it.

One element of TRAC's approach has been to organize the study in a series of stages.³ At each stage, the versions of the concept under consideration are subject to increasingly rigorous tests, and only those that succeed pass along to the next stage. Since the analyses at each stage grow in their depth and complexity, this "filtering" process serves to reduce the caseload of concept versions. In this way, the

³The TRAC methodology is outlined in Jeffrey Karhohs, Peggy Fratzel, and Philip Romero, "Evaluating Future Concepts," a paper presented to the 25th Annual Army Operations Research Symposium, 8-9 October 1986. The published proceedings of this symposium are forthcoming.

greatest analytic resources are expended on the *most promising* versions of the concept. In the early stages a spanning set of concept versions will be considered, but necessarily only at a low level of resolution. Those that fail the early tests are filtered out. In later stages, as the analysis becomes more detailed or considers a wider range of scenarios, it need be applied only to the versions that survive the tests in earlier stages.

RAND identified two crucial tasks that needed to be performed in the early stages of the TRAC study:

- A systematic, internally consistent method of describing concept versions was needed. This framework must: (a) incorporate most of the important differences among alternative versions; (b) be expressible quantitatively, so that the different versions could be modeled; and (c) be general enough so that ultimately other concepts quite different from Army 21 could also be described and compared.⁴ We refer to the use of such a framework to develop concepts as the concept *design* stage.
- Once a set of concept versions is described, a method will be needed for conducting a first-order assessment of the likely performance of each concept version. RAND refers to the use of such a method as the *screening* stage of the analysis.⁵ Screening techniques such as simple rules of thumb or cost-benefit estimates have been employed in the past, but the complexity of operational concepts ruled out such simplifications. A screening method must be highly efficient

⁴This framework should at a minimum be capable of capturing the Army's current doctrine (AirLand Battle), so that the performance of a doctrinal base case can be assessed. The Army 21 concept should be compared to that base case to determine not only whether the concept is "good enough," but whether it is *desirable*--that is, improves on current doctrine. One of the later stages of TRAC's study entails such a comparison of different concepts.

⁵RAND's nomenclature departs somewhat from the actual terms used in the TRAC study to preserve generality. However, it is consistent with the essence of TRAC's study plan.

since there would at the early stage of the study be a large number of possible versions; the TRAC study plan anticipated making frequent refinements in the design of the concept. This implied that (a) the screening technique should be an automated, closed-form, deterministic model of some kind (probably *not* a large simulation) and (b) the model should not be designed to produce more than a crude, low-resolution, first-order estimate of the performance of each concept--just enough to allow TRAC to distinguish the promising candidates from the unpromising ones.

RAND's principal task in the TRAC study is to build and deliver a simple, fast-running model that assists analysts in exploring alternative concept *designs*, and provides a first-order performance estimate to permit immediate *screening* among them, based upon their "cost" in resources needed to satisfy specified theater objectives. RAND's modeling effort has used TRAC information on Southwest Asia (since this is the first theater that will be examined in the TRAC study), but the model is intended to be readily adaptable to other theaters.

III. MODELING APPROACH AND OPERATION

Figure 2 illustrates the differences between our "needs" approach and the more typical "prediction" model. In a "prediction" model, the forces that Blue and Red are expected to have available in the theater are specified as inputs, along with parameters describing the performance of those forces and the policy governing their operations (of which doctrine is a component). Such a model produces an estimate of the outcome of combat between the two forces (such as movement of the Forward Line of Own Troops (FLOT)). The analyst compares the predicted outcome to some success criterion to establish if the specified force and doctrine performed sufficiently.

In a "needs" model, the outcome of the battle *required* for success is specified as an input, and the model estimates the amounts of various resources (such as combat units) *needed* to meet the success requirement. Concepts are screened by comparing the amounts of resources they need against the amounts that can be expected to be available.

Our modeling approach has emphasized maximizing the model's efficiency and ease of use after it is transferred to TRAC. Because the screening model will be required to consider very large numbers of concepts, it is imperative, in our view, that it is kept as simple as possible. Furthermore, since the principal responsibility for screening will remain with TRAC analysts, and not with RAND, excess complexity would undercut the model's usefulness.

For these reasons, we have deliberately adopted a highly aggregated structure, using a system of simple simultaneous equations, with aggregated variables used to represent multiple subordinate elements.¹ Similarly, we chose to build a "needs" model because we felt that screening based on resource needs would be less ambiguous and more efficient than screening based on combat outcome. Finally and most importantly, the model is being designed to run on a commercially

¹When aggregate variables are used in a simple model as a substitute for more detailed components, we refer to them as "proxy" variables.

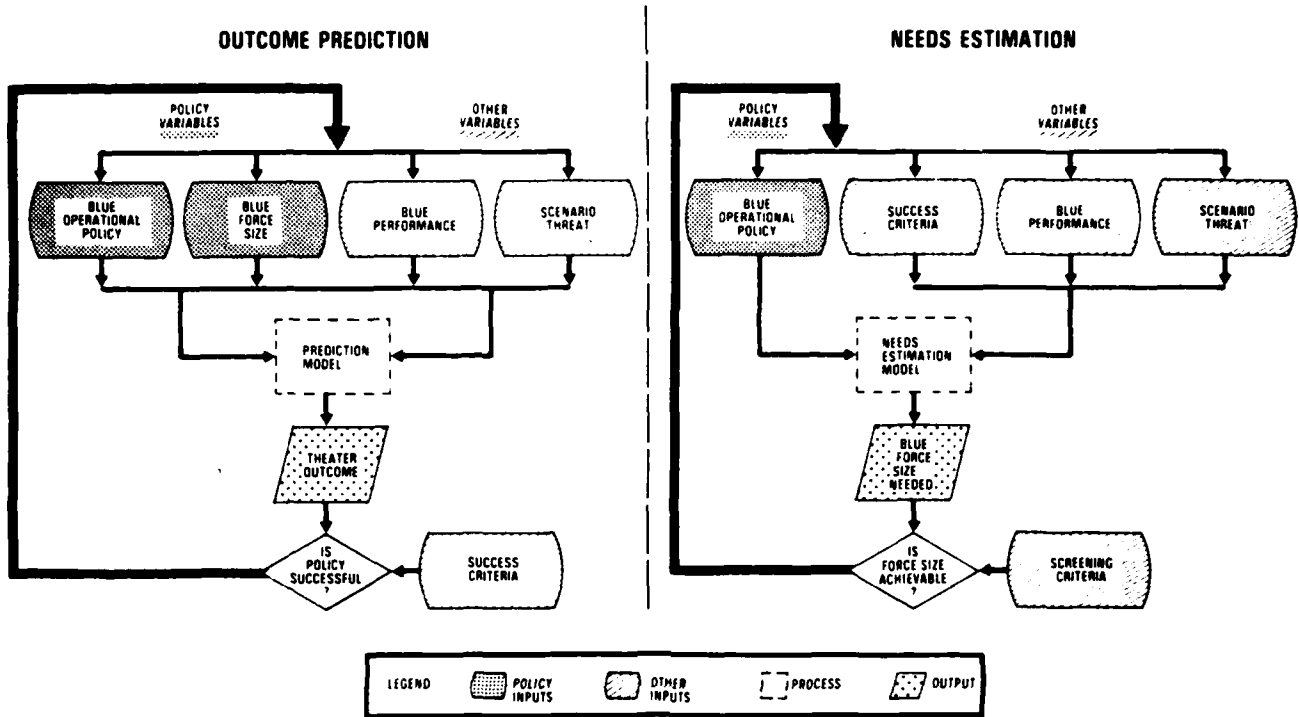


Fig. 2 -- "Prediction" vs. "needs" theater modeling approaches

available spreadsheet software package for a personal computer. The spreadsheet allows analysts to instantly see the effects of changes in inputs on resource needs.

Figure 3 outlines our modeling approach. The model² will estimate the number of units required for each of six unit types:

- Three types of close combat units (known as Heavy, Medium, and Light Close Combat Forces, or CCFs, in the Army 21 document);

²The model is named the Method of Screening Concepts of Warfare, or MOSCOW.

- Higher-echelon units that perform command and control functions and can provide fire support to the close combat units (Land Battle Forces, or LBFs, in Army 21);
- Mobile units that supply the close combat forces (Close Combat Support Forces, or CCSFs); and
- Units that supply the headquarters and its subordinate elements (Land Battle Support Forces, or LBSFs).

It will also estimate the *quantities* of resources consumed in the categories shown. For any concept version that is specified, the model will calculate the forces, supply units, and resources needed to keep the starting force at full strength. The analyst can screen by comparing the amounts needed with the quantities that are projected to be available.

We have adopted an activity-oriented approach to estimating resource requirements (including time). First, we have identified the activities that each unit performs in the course of its mission. (The CCF and LBF missions are to attack or to defend for a specified period of time or to impose a specified amount of attrition on the enemy. CCSF and LBSF missions are to transfer supplies to the CCF and LBF respectively.) We refer to the set of activities as the "duty cycle" for a particular type of unit with a particular mission. Duty cycles are defined for each type of unit. For each type of duty cycle, we have developed equations that estimate the average amount of time required to perform each of the unit's activities. (Figure 5 below graphically represents an Army 21 duty cycle.)

In keeping with our emphasis on transparency and parsimony, the relationships are deliberately kept simple, sometimes relying on established simple formulations, and often upon geometry or common sense, using the simplest form that seems to have the properties desired. For example, calculation of the resources required to move a unit is based on one-dimensional or two-dimensional geometry, whereas the resources required to engage in combat with enemy units are based on a slightly modified version of Lanchester's square law equation (although users will be able to vary its parameters).

- Identify menu of "activities" that CCFs, LBFs, and supply units can engage in
- Develop functions that estimate each activity's consumption of key resources:
 - POL - Vehicles - People
 - Ammo - Subsistence - Time
- Assess sensitivity of each activity's consumption to changes in:
 - Policy variables - Assumptions about threat or technology

Fig. 3--MOSCOW modeling approach

the resources required to engage in combat with enemy units are based on a slightly modified version of Lanchester's square law equation (although users will be able to vary its parameters).

The model first estimates the amount of time that is required in each activity, then estimates requirements for five broad classes of resources: combat and support vehicles, POL, ammunition, personnel, and other materiel based upon the activity's required time.

Figure 4 shows the flow of information in MOSCOW. Inputs that are outside of the control of a Blue theater commander are the size, performance, and operational policy of threat forces, the performance of Blue systems, and the criteria of combat success that the Blue force

offensive and defensive missions and (2) doctrine, which is represented in the model by the mix of direct and indirect fires, the tactical force ratio at which he prefers to attack and to defend, maximum distances that units are permitted to travel per day (if they are less than the units' capacities), and the level of attrition or amount of time per day that CCFs are permitted to expend in combat (i.e., the maximum length of each engagement with enemy units).

Once Blue operational policy and performance are specified, the model computes time required to perform each activity in each unit's duty cycle. (A combat unit's duty cycle is defined as the set of activities necessary for it to participate in combat with a Red unit and reduce Red by a specified amount of attrition or delay Red for a

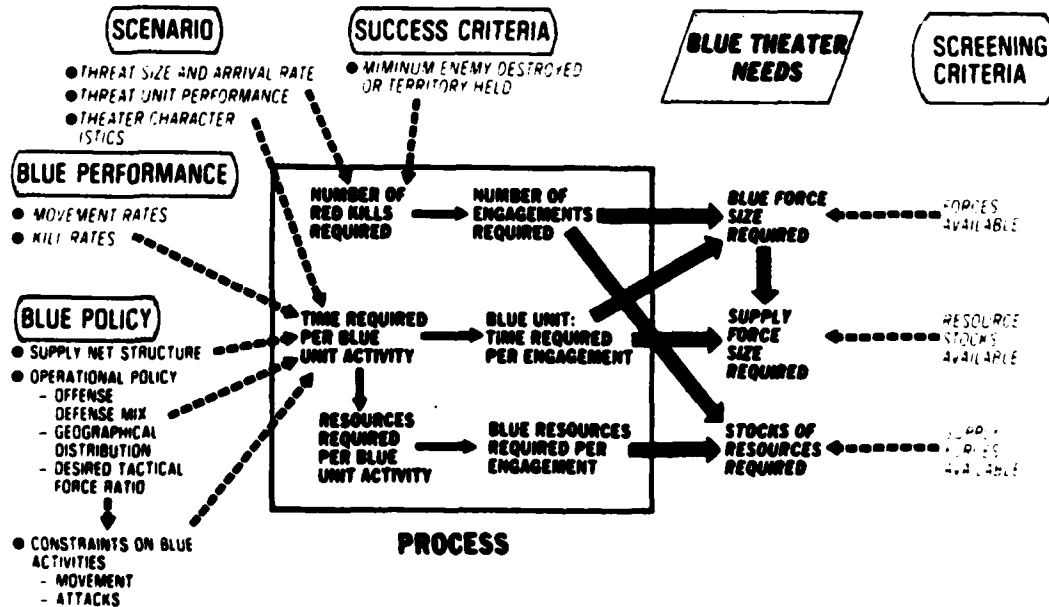


Fig. 4 -- Information flow in MOSCOW

specified length of time. A support unit's duty cycle is the set of activities necessary to load cargo, deliver it to a recipient, and return to its base or depot.) Based upon the time required for each activity, the model computes the resources required for each activity, and combines them to estimate requirements for the cycle. Similarly, times required per activity are combined to compute time for the cycle. The reciprocal of a unit's total time of cycle is the expected amount of Red attrition inflicted by each Blue unit per day.

The success criteria determine the total amount of attrition Blue must impose on Red or the maximum distance that Red can be permitted to penetrate (or both); specified Red force size determines the number of engagements necessary to succeed. Comparing the average number of Red units that must be destroyed per day and the average number that are destroyed per Blue unit per day determines the number of Blue units required. Since we specify by assumption that the supply force and its cargo are required to keep Blue resupplied, the required number of Blue combat units determines the required supply force and the quantities of physical resources needed. Each of these needs can then be compared by the analyst with the amounts expected to be available. If a need exceeds the expected supply, the operational policy (i.e., version of warfighting concept) tested can be considered to "cost" too much and is provisionally screened out.

However, some deficiencies are more important than others, so the screening requires some judgment on the part of the analyst. Also, the forecasts of expected supplies are themselves uncertain, so concepts that are only marginally too "costly" should not necessarily be screened out immediately. Put colloquially, "When in doubt, *don't* leave it out." Additionally, the particular resource constraints that are exceeded can provide valuable information to the analyst--they may suggest potential concept refinements or tradeoffs. For instance, if a version needs substantially fewer CCFs than are available but too many supply units, these two types of units can be traded off; if resources are assumed to be reallocated to permit fewer CCFs but more supply units, the concept might become successful.

Figure 5 illustrates the set of activities in which a close combat unit must engage in order to attack a Red target.³ The sum of the resources required by these activities represents the total amount needed to perform one duty cycle for its particular mission.

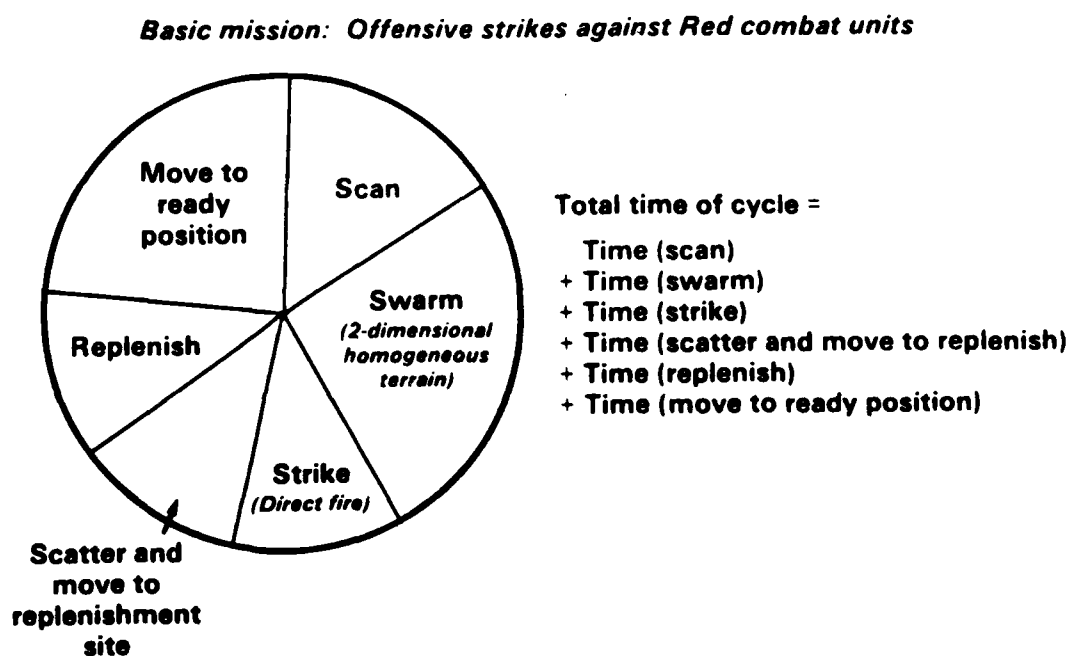


Fig. 5 -- A CCF duty cycle

³The names of the activities are based on the unclassified concept description, which has been superseded by changes in wording in later drafts. Some additional activities were identified by RAND. In the current draft the names have changed, but to our knowledge the basic functions performed by the activities have not. Since the original names have the advantages of simplicity and mnemonic ease, we have retained them in this Note. Different warfighting concepts might use different names, but we expect that those shown here would be the minimum necessary for virtually all concepts. The final version of the model will incorporate a more extensive set of activities, with neutral titles applicable to any concept.

IV. USES FOR MOSCOW

Figure 6 illustrates one of the resource requirements relationships for an activity in a particular duty cycle. In this case, it is the time required to "swarm"--to approach within weapons range of the enemy. The right-hand diagram indicates our rectangular representation of the zone or theater. (Average Blue and Red movement rates are calculated based on the distribution of general terrain types in the theater, to reflect average trafficability.) Blue units are distributed within the theater according to the theater strategy chosen; for this example, they have been distributed uniformly.

One way of distinguishing among versions of a warfighting concept is the tactical force ratio at which Blue chooses to attack Red. To achieve a higher force ratio, Blue must mass units brought from greater distances, which increases the average time that a unit spends swarming. The overlapping circles illustrate this. For specified Blue and Red movement rates, a decision to mass a fairly low force ratio would require moving only those forces in the circle whose center (the point where Blue intercepts Red) is I_1 . (The radius of that circle determines the time required to swarm.) A higher desired force ratio would mandate bringing in all the forces in the larger circle, permitting Red to penetrate to I_2 , and so forth.

The time required to swarm is based on the radius of the circle whose area includes the number of Blue units needed to achieve the desired tactical force ratio (although the usable force ratio will be limited by Red's maximum permissible penetration before interception). For this reason, time to swarm increases in proportion to the square root of force ratio, as shown on the left side of Fig. 6. Note that there is a price to be paid for higher force ratios: it permits Red to penetrate further before he is attacked (to I_2 instead of I_1). If there were a requirement set by theater strategy or by higher authority to ensure that Red be attacked no later than a particular time or depth of penetration, that requirement could constrain the set of acceptable tactical force ratios, and thus the set of potentially promising concept versions.

Time (swarm) = f (Blue movement rate, Red movement rate,
desired tactical force ratio, penetration before
interception)

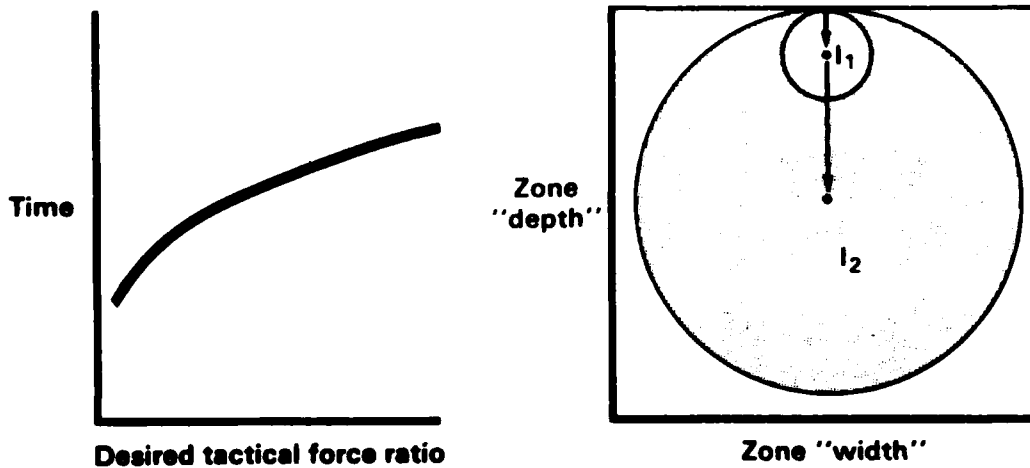


Fig. 6 -- Swarm activity

POLICY ANALYSIS EXAMPLE: IDENTIFYING PROMISING TACTICAL FORCE RATIOS FOR BLUE ATTACKS

If the mix (although not the number) of Blue forces is specified, then the time required to perform each activity can be summed to determine the time needed per Red unit killed--or, more important, its inverse, the average number of Red units killed per day per Blue unit. Once the size of the threat is specified, the number of CCFs required to achieve a given level of combat success can be calculated. For the example shown in Fig. 7, the success requirement was set at "destroy Red units at the same average rate as they arrive"--that is, do not permit any Red units to transit the theater without being destroyed. In Fig. 7, differing concept versions are again reflected as different tactical

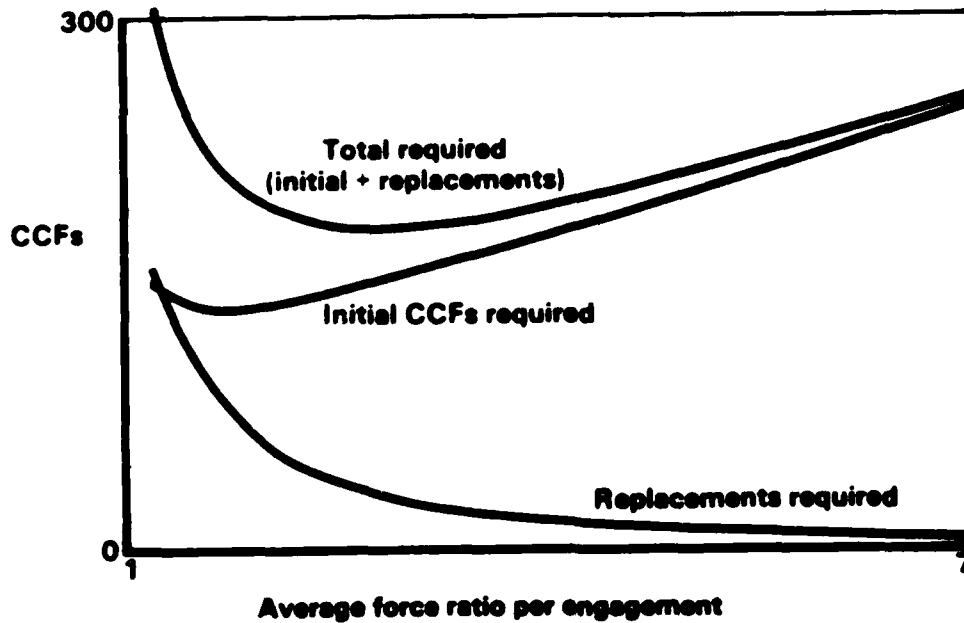


Fig. 7 -- Total CCFs required in a 45-day campaign

force ratios at which Blue chooses to attack Red. As can be seen, an increase in the desired tactical force ratio for the most part increases the required number of CCFs (although there are actually some savings when the force ratio first increases above 1:1). However, higher Blue-Red force ratios will reduce Blue's casualties in each engagement. If the length of the campaign can be specified--based, for instance, on the availability of Red strategic reserves--then the total requirement for Blue replacements (in CCF equivalents) can also be estimated.¹ The total force requirement is the sum of the CCFs needed initially plus

¹A 45-day campaign was the length used in the first scenario TRAC prepared for its Army 21 study.

replacements. The most promising versions of the concept in this example seem to include a Blue to Red tactical force ratio of approximately 2:1 or 3:1.² The feasibility of these versions could be established if the analyst had a projection of the number of CCFs that would be available in the theater.

SENSITIVITY ANALYSIS EXAMPLE: HOW THE PAYOFF FROM A TECHNOLOGICAL IMPROVEMENT VARIES ACROSS DIFFERENT VERSIONS OF A WARFIGHTING CONCEPT

As was mentioned earlier, uncertainty about the future obliges the analyst to perform a sensitivity analysis to determine the robustness of a concept's performance as assumptions about future conditions are changed. Since TRAC intends to continuously refine the concept during its study, sensitivity analysis will illuminate areas for improvement and assist the analyst in sorting high-payoff vs. low-payoff improvements. Figures 8 and 9 illustrate the use of the model as a tool to help set priorities among alternative improvements, either in the concept or (in the case shown) in system performance.

Figure 8 shows how the distribution of times required by the several activities in the CCF's duty cycle is affected by different concept versions, represented here by the desired tactical force ratio.³ The total represents the time required by a Blue CCF to participate in the destruction of one Red unit in direct-fire combat. (We can vary the mix of direct and indirect fire in the model.) At low force ratios, the striking activity--the actual combat engagement itself--comprises the majority of the cycle. As the force ratio increases, the relative amount of time required to attack reduces, but the three activities involving movement (Move to Replenish, Swarm, and Move to Ready

²This figure and others that display resource requirements were produced by an early experimental version of the model, using arbitrary input data to explore general relationships. The reader should not draw any conclusions concerning actual numbers of CCFs required. The examples are provided for illustrative purposes only.

³Tactical force ratio is currently defined as the ratio of *combat power* in an engagement, to include numbers of weapons platforms and their lethality.

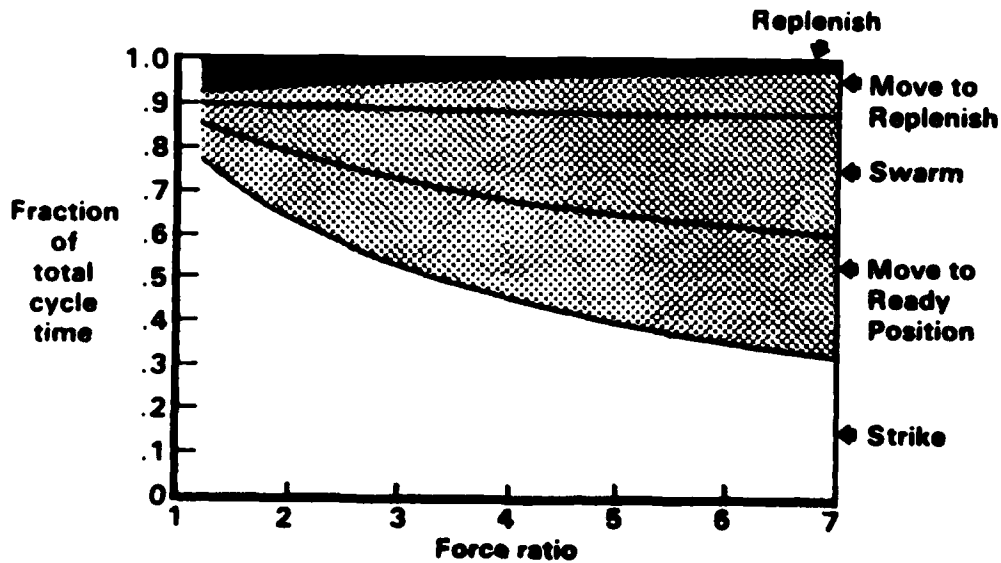


Fig. 8--Components of total cycle time

Position) all increase and eventually dominate the duty cycle.⁴ An analyst interested in setting priorities among possible performance improvements (for instance, alternative technologies) would infer that priorities will *differ* depending upon the concept. The figure suggests that performance improvements pertaining to the strike phase of operations would have the highest payoff under versions of the concept involving low tactical force ratios; at high force ratios the highest payoff would seem to come from improvements in movement.

⁴The absolute amounts of time also increase, although the increase is not reflected on Fig. 8. Strike time reduces as force ratio increases in accordance with Lanchester's law. Movement time increases because in two dimensions the radius of the circle around the target enemy unit increases in proportion to the square root of force ratio.

Figure 9 displays the effects of changes in Blue's average mobility on CCF requirements. These changes could result from lighter vehicles, improved drive trains, or entirely different vehicle designs (e.g., terrain effects vehicles). The horizontal axis shows the average movement rate (in kilometers per day) of a Blue CCF. The vertical axis shows the number of CCFs required to meet the combat success criteria employed for Fig. 7. Each curve indicates the number of CCFs required by a particular version of the concept as a function of Blue movement rate. These results are consistent with the inferences we made based on Fig. 8. A concept version that entailed a relatively low Blue to Red tactical force ratio (such as 2:1 or 3:1) would see little payoff from even a threefold improvement in mobility from 50 to 150 kilometers per day, whereas for a different version involving a higher force ratio (such as 5:1 or 7:1) the payoff would be substantial. Since the lower force ratio concept versions require fewer CCFs, mobility improvements might be seen as of lower potential payoff than some technology alternative that improved performance in the strike activity, such as improved lethality or reduced vulnerability.

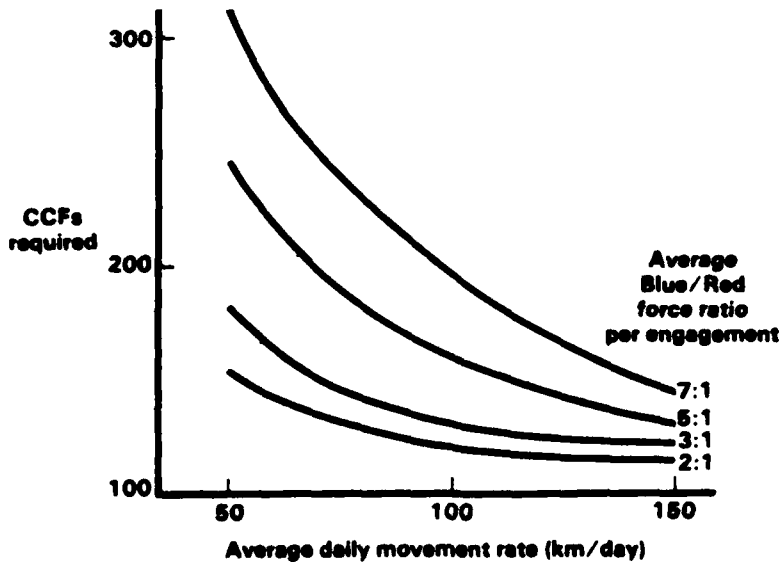


Fig. 9 -- Payoff of higher mobility

V. PROGRESS TO DATE AND FUTURE WORK ON THE SCREENING MODEL IN SUPPORT OF TRAC ARMY 21 STUDY

The initial, exploratory model that was used to generate the illustrative examples used in this Note included only one type of Blue unit (CCF) performing only one type of mission; time was the only resource whose requirements were computed. The version coded in December 1986 includes several types of CCFs that can either attack or defend, as well as headquarters units and a rudimentary supply network. Additionally, the model treats Red in somewhat more detail than before (although still much less than Blue, to limit the model's complexity) and includes parameters intended to allow the analyst to crudely represent the effects of air operations, terrain, weather, and imperfect C³I. For a specified success criterion, the model will estimate the number needed of each of six types of Blue units: heavy, medium, and light CCFs, LBFs, and two types of supply units; and will estimate the total quantities of vehicles, POL, ammunition, personnel, and sustainment needed to keep the units resupplied.

Once the model is completed and debugged, it will be possible to run a number of excursions quite quickly. These excursions should be designed to explore tradeoffs among various components of the concept (such as varying the mix of attacking and defending CCFs, or varying the force mix), with emphasis on potential improvements in performance through changes in operational policy and changes in technology. We anticipate that these excursions will provide useful information to the working groups that TRAC has established to suggest possible operational or technological priorities. Conversely, the model's input formats will impose new responsibilities on the working groups to generate and refine the "guesstimate" data used in our early illustrative runs.

The first phase of the TRAC study concentrated on "visualizing" the Army 21 concept through map exercises in order to identify the important policy variables that define the essential components of the concept and distinguish among its many different versions.¹ The second phase of the

¹RAND engaged in a similar "visualization" process in parallel with TRAC to develop the screening model, using an early version for exploratory purposes.

study will quantitatively evaluate "promising" versions of the concept to assess their "viability" in a Southwest Asia scenario. RAND's model will be used in this phase to screen concept versions, with reduced but frequent use thereafter as possible improvements in operations, force structure, or technology are identified and the concept is refined. RAND demonstrated and briefed the model to TRAC in January 1987. An interim version of the model was delivered to TRAC in the spring of 1987. A final report, including the final model and documentation, will be produced in late 1987.

VI. FUTURE WORK TO SUPPORT THE DEVELOPMENT OF WARFIGHTING CONCEPTS

We chose an activity-oriented modeling approach in MOSCOW because we believed that it offered the potential to represent a wide range of alternative warfighting concepts. For example, something as different from Army 21 as static warfare could be represented by constraining the movement-related activities in the duty cycle to very low values. Similarly, different theater strategies can be reflected, albeit quite abstractly, by changing the geographical distribution of Blue units (including distributions that reflect cross-border operations) and by varying the mix of units with defensive and offensive missions. Furthermore, our emphasis on parsimony, and the use of a spreadsheet format, should limit the cost of "tailoring" the model for any specific concept or theater.¹

The motivation for our inclusion of this flexibility goes beyond simply broadening its scope as a screening tool in the warfighting concept evaluation studies that are mandated by the CBRS. It is our belief, although only a tentative one at present, that this model could be a useful tool for concept *development*. It has the potential to contribute in two areas, as discussed below.

A FRAMEWORK FOR SYSTEMATICALLY DESCRIBING AND COMPARING CONCEPTS

In the discussion of the special methodological challenges faced by the TRAC Army 21 study (Fig. 1), the first challenge mentioned was the degree to which the concept was underspecified in comparison with what is necessary for a quantitative evaluation. Indeed, substantial time

¹We acknowledge that the flexibility of our modeling approach creates the risk that different users might modify different assumptions or input values in different ways, to the point where their "tailored" versions become difficult to compare. The Army analytic community's traditional solution is to use only models that have been "signed off" by the necessary authority, imposing a uniformity that negates the value of "tailoring." A better solution in this instance is a clear input structure and a high standard of documentation, of both the original model as well as later customized versions.

and resources are being spent by TRAC and other study participants to develop a coherent picture of Army 21 with sufficient definition to be susceptible to analysis. The lack of a format for rigorously describing the concept has impeded communications between the concept developers and evaluators, and even among the concept developers themselves.

Because the process of building a model obliged us to be specific about what in our view are the essential elements of the Army 21 concept (that can be quantitatively described), the model--and specifically, the model's operational policy inputs--provides an explicit format for characterizing any version of the concept. Its generality also allows description of very different concepts in the same terms. The framework is a prerequisite for quantitative analysis of any concept, but it also could facilitate systematic qualitative comparisons, hence the design of *new* concepts. The simple existence of a common vocabulary would simplify comparisons of concept ideas, and offer the structure needed to make the creative process of concept development more systematic.

The framework employed in this model has both advantages and disadvantages. That it is relatively general and parsimonious allows concepts to be described by a fairly small number of policy variables (currently about twenty), and still capture a diverse range. However, the price paid for that simplicity and flexibility is that some of the descriptive policy variables are rather abstract proxies for several more tangible subordinate attributes, and represent *average* policies over the whole Blue force (or all of one type of unit) in lieu of describing a policy for every element. The lack of a one-to-one correspondence between "real-world" elements of a concept and the model's variables may trouble many concept designers, especially those less sensitive to the necessity imposed by finite time and resources to make compromises in the amount of detail in the analysis. We feel confident that these compromises could not be avoided if we were to provide a screening tool that would be useful to TRAC's large and ambitious analysis. We anticipate that any attempt to systematically describe concepts using a common framework would out of practical necessity require similar simplifications.

A TOOL FOR EXPLORING AND REFINING NEW CONCEPTS

A warfighting concept is a complex, "squishy" policy with many component variables, and the boundary between its design and its analysis becomes highly artificial. For instance, one of the TRAC study's goals is to "refine" the concept, which is arguably more of a "development" than an "evaluation" task. A fast-running, fairly easy to use model that can distinguish among concept versions and show the effects of design changes could be a powerful tool in the development of *new* concept ideas as well. Concept designers would be forced to be explicit about elements of their design that they might not have considered, and could rapidly gain insights into its strengths and weaknesses to point the way to refinements. Such a model could thus be a valuable *exploratory* tool.² It would also mandate closer coordination between concept designers and analysts in the early stages of the development process. This would, in our opinion, both increase the definition of warfighting concepts and significantly streamline the task of fulfilling the mandates of the CBRS.

This preliminary assessment of the value of the model (or one much like it) to the design of new warfighting concepts cannot be affirmed nor contradicted without further experience. To that end, RAND will be attempting an experiment during 1987. Another task of the "Future Warfighting Concepts and Technologies" project is to develop a framework for systematically designing future warfighting concepts. We hope to draw upon the framework used in this model as a starting point for that effort. As the model is completed and then refined, it will be used in the project's exploration of new concept alternatives. If the model proves as useful as we expect, it should emerge as a tool of substantial power and flexibility. If not, it will have failed under the most

²The relative speed with which concept versions may be explored might encourage analysts to adopt the mistaken belief that the screening model can be used to *optimize* the design of a concept. We make no such claim. Any quantitative model of warfare must make too many simplifications to be trusted to generate an "optimum." This is especially true of the screening model; elements omitted or summarized for the sake of speed, flexibility, and transparency might have unforeseen importance in certain concepts or under certain assumptions.

favorable of circumstances, with a clear diagnosis as to its limitations. Our hope is that the end product will be a methodology for developing and refining concepts that can improve the scope, rigor, and efficiency of the concept development and evaluation process.

Appendix A

AN OVERVIEW OF THE CONCEPT SCREENING MODEL

INTRODUCTION

This appendix provides a technical overview of the concept screening model, known as the Method of Screening Concepts of Warfare, or MOSCOW. MOSCOW is a spreadsheet-based tool designed to be used for either of two purposes: (1) as a *screening aid* in the early stage of a concept study to reduce the number of concept variations to be examined later by other, more detailed assessment tools, or (2) as a *design aid* to help concept developers to organize their concept ideas and gain a first-order appreciation of the resource needs of each idea.

As MOSCOW is still being developed, this appendix cannot provide exhaustive or detailed documentation; rather, the model overview discusses the most important input variables designed to capture warfighting concepts.

GENERAL ANALYTIC APPROACH

MOSCOW is, in effect, a requirements model. It evaluates the efficacy of a warfighting concept by estimating the *resources* that would be needed for Blue forces to successfully complete their designated mission, within the operational boundaries of the concept. The model determines whether the resources needed exceed the maximum amounts available that are specified by the analyst.

Each run of MOSCOW pertains to one "zone," which is essentially one-dimensional. Red forces enter in single formation, moving through the zone to its opposite side, with Blue forces distributed uniformly within a subset of the zone that the analyst can specify. For highly aggregated screening, the zone could represent the entire theater. More typically, a zone will represent all or part of one operational axis of advance. (Deployment of Blue forces in depth can be reflected by setting up several zones in sequence.) If a higher degree of geographical discrimination is required (to represent non-uniform deployments across the width of the operational axis, for instance),

several parallel zones can be constructed. Typically, the Blue and Red units will be of division size (although they can be of any size the analyst desires) and the zone will be on the order of 100-300 km across and anywhere from 10 to 1500 km long.

The analyst first specifies the characteristics of the zone (length, width, and distribution of terrain). Next he sets Blue's mission objectives: generally they are to impose a *specified amount of attrition* on Red by the time Red forces reach a *specified phaseline*. The proportions of Blue units assigned to offensive missions (which impose high Red casualties per engagement but do not delay their movement for long) and defensive missions (which do the opposite) are set. Finally, the analyst can set the levels on a variety of variables which capture "operational policy," such as the mix of Blue units' movement in alternate formations, the tactical force ratio at which units will attack, the amount of attrition that they attempt to impose in each engagement, and the priority given to several types of target units.

Additionally, the analyst can change the assumed characteristics of Blue and Red units (their movement rates, firing rates, etc.) and assumptions about the relative cohesiveness and agility of the two forces.

INPUTS

Inputs are of several types: exogenous conditions, such as the characteristics of the zone and its terrain; Blue mission requirements and operational policy; Blue and Red unit characteristics; resource consumption parameters; calibration parameters; and "budgets" of available resources.

Zone Characteristics

ZONLGTH and ZONWDTH specify the length and width of the zone. A table indicates the effects on defense strength, movement, and target acquisition for each of a number of terrain types (currently 10, but it could be any number). The "average" multipliers are calculated based upon the distribution of terrain types in the zone.

Blue Mission Requirements

The Blue force in the zone is required to destroy a fixed number or percentage of Red invaders (ARRTOT, or total arrivals, minus MAXREDSURV, or maximum permissible surviving Red units) by the time they reach some maximum permissible penetration depth (MAXPEN). For example, a main defensive force might desire to destroy 75 percent of the invading Red units without losing more than 33 percent of the defended territory, while in a different zone a covering force might be willing to settle for 10 percent Red attrition and would be willing to give up the entire zone.

Blue and Red Force Mix

The model can represent three different types of Blue and Red maneuver units--light, medium, and heavy. The analyst specifies the mixture of those three types in the force (%CCL, %CCM, %CCH).¹ For Blue, only the proportions of each unit type are specified (since MOSCOW will calculate the actual number needed); for Red, the number of RCL, RCM, and RCH are entered, yielding a total number of arriving divisions (ARRTOT).

Blue Operational Policy

There are several subcategories of operational policy.

Cross-Country Movement Policy. Each type of unit can move in either of two formations: Administrative (A or ADM), which maximizes speed but is relatively vulnerable when attacked, and Battle (B or BATT), which has the opposite characteristics. The average movement rate for each type of unit (e.g., CCL-MAVG) will reflect the fraction of its movement time in each formation the analyst specifies. Basic movement rates are (for CCLs) CCL-MA and CCL-MB; the proportions are %ADM and %BATT.

¹MOSCOW currently uses unit designators that parallel those in the Army 21 concept. Blue units are close combat forces, or CCFs. Red Units are designated RCFs. The final version will probably use more general designations.

Unit Assignment Policy. Each of the three types of maneuver units can be assigned a mixture of offensive and defensive missions. The proportions (CCL-%A and CCL-%D) reflect the distribution of time that units of this type devote to offensive vs. defensive missions.

Engagement Initiation and Termination Policy. Blue units assigned attack missions will do so whenever they can achieve a desired tactical force ratio (TFR/A). In pursuing the engagement they will impose a specified amount of attrition on Red (RATR/CYC-BA [Blue attack]). (Red may wish to break off the engagement sooner, so the actual length of the engagement will depend upon Blue's ability to maintain the tactical initiative [BLUAGTY, see below]). Blue units whose mission is defensive cannot choose when to initiate an engagement, but they can choose when they would like it to end, again expressed in terms of Red attrition (RATR/CYC-BD).

Operations While Engaged. These portions of the model are being revised and the parameters have not yet been fully identified. Generally speaking, it will be possible to specify the levels of several parameters that will represent tactics very abstractly. For example: Blue can choose the fraction of each type of a unit's vehicles that will fire in direct or indirect fire mode (%DF and %IF). It will be possible to specify the frequency with which Blue vehicles move during an engagement. Blue can set the rate at which his vehicles fire (FTONS/VDF, tons fired per vehicle per day when employing direct fire, and FTONS/VIF, in indirect fire); setting it below the maximum will lengthen an engagement and increase casualties but reduce the rate at which the supply net must provide ammunition to any particular unit.

Unit Characteristics

In addition to those mentioned above, there are several other parameters that affect unit capabilities. The rate at which a Blue unit can destroy vehicles in an enemy unit during an engagement (e.g., CCL-KILL) is based on the firing rate per vehicle (see above), the hit rate per ton of ammo fired (HITS/TON), and the rate of kills per hit (KPH). These parameters can differ for direct and indirect fire, so the average is weighted by their proportions (%DF and %IF). These

parameters assume "proving ground" conditions, and are degraded by Blue C-3 and Intelligence error rates, and Red's ability to deceive Blue targeteers (causing fire to be misallocated to nonexistent or worthless targets). They are further degraded by terrain conditions and Red's ability to conceal targets, which reduce the "availability" of Red targets to Blue gunners, and finally by the hardness of Red vehicles.

The calculations of attrition in engagements use a standard Lanchester square law formulation. Each Blue and Red unit has a nominal strength per vehicle (analogous to a weapon unit value) and a rate at which enemy vehicles in an average enemy unit can be destroyed. To the units' kill rates are added any supporting fire or close air support. Since each engagement lasts a specified length of time (determined by the amount of attrition Blue wants to impose and Red is willing to accept before breaking off), Red attrition is determined, and the Lanchester equation calculates the length of the engagement and the amount of Blue attrition suffered.

Two other parameters will affect the length or the number of engagements in the campaign. First, the breakpoints of Blue and Red (REDBKPT and BLUBKPT) may constrain the length of an engagement below that "preferred" by one side or the other. Second, a "Blue initiative" parameter (currently designated BLUAGTY) determines when, on average, engagements are broken off if one side attempts to end it sooner than the other side desires.

Additionally, the size and composition of each unit and its vehicles can be specified. VEH/CCL indicates the number of combat vehicles in the unit; PERS/CCL indicates its personnel strength; TONS/VEH specifies the weight of each vehicle, and similar parameters determine each vehicle's basic load. Very crude organizational changes could be represented by changing the size of the unit, the characteristics of its vehicles, or by constraining the proportion of the unit capable of firing in direct vs. indirect fire mode.

Resource Consumption Coefficients

For each type of unit, MOSCOW calculates the amount of time and resources it needs to perform the "cycle" of activities pursuant to its mission. Thus there are duty (or engagement) cycles for attacking and defending heavy, medium, and light combat units, and defending duty cycles for headquarters and supply units. Operational policy and unit capabilities will affect the time spent by each unit in its various activities.

The centerpiece of the duty cycle is the engagement itself, but in order for a unit to participate in that engagement it must also partake of a number of "overhead" activities, such as cross-country movement, surveillance, resting, resupply, and waiting for instructions. An equation in MOSCOW estimates the average time each type of unit will need to perform each activity. For instance, the time required for the move-to-within-weapons-range activity is a function of the tactical force ratio that Blue wishes to achieve on attack (TFR/A) and the unit's rate of movement (CCL-MAVG). The time spent in the engagement is a function of the tactical force ratio, Red and Blue kill rates, and the amount of attrition that Blue wishes to impose on Red per engagement. These are fairly complicated equations, based as they are on the two-dimensional geometry of movement around the theater or the Lanchester equations, respectively.

Most of the resource consumption equations are very simple. For example, the time spent resting is simply a specified fraction of total time spent in the field. If the unit as a whole needs to rest an average of 12 hours out of every day, this fraction would be $1/2$; eight per day would make it $1/3$, and so forth. In another example, time spent resupplying is a simple linear function of the amount of material resupplied (i.e., the amount consumed in the other activities of the cycle) and a loading rate.

Once time required for each activity is calculated, the amounts of other items required per activity are similarly estimated. For instance, the unit's vehicles will suffer a certain rate of breakdowns (currently .5 percent) per day of movement. That rate is a "resource consumption coefficient" which multiplies the move-to-weapons-range time

to determine the number of vehicles lost during this activity. In combat, the amount of ammunition consumed is the firing rate per day (see above), plus that ammo lost due to attrition. There is a table of coefficients to calculate the amounts of vehicles, personnel, POL, ammunition, and other materiel consumed per day of each activity. When combined they provide an estimate of the tons of total cargo needed to keep the unit resupplied. While the analyst can set these coefficients to different values for each type of unit, for much analysis it may be more efficient to simply set them at average values for all units.

The sum of the amounts of time required to perform each activity is the "total cycle time," or the amount of time it is unavailable for other assignments. If in the engagement activity the Blue unit had killed or destroyed one Red unit, then its average kill rate per day would be the reciprocal of the total cycle time.

Calibration Parameters

Finally, there are some inputs that have no natural interpretation but are necessary to produce the desired behavior in the model's equations. For instance, the time a unit spends waiting for orders is a function of the span of control of its superordinate headquarters-- the assumption behind the equation is that as headquarters have more units to keep track of, each unit will on average spend more time waiting for the headquarters to give it new orders. The value of the coefficient of this equation should be set at whatever seems to reproduce real-world behavior (whether drawn from historical data, exercises, or intuition). In this example, the units of the coefficient would be "minutes delay per subordinate unit," which is hardly an intuitive formulation. These equations can be readily changed if some better formulation is later identified.

OUTPUTS AND MAXIMUM AVAILABLE RESOURCES

Given a specified threat and a Blue requirement to destroy a specified number of threat units before they cross a phaseline, MOSCOW will estimate the number of Blue units needed (operating under a specified concept of operations). It will also estimate the amount of replacement materiel needed to keep the units at full strength. Based

on these judgments, MOSCOW will estimate the number of headquarters and supply units needed, their materiel requirements, and the strategic lift needed to keep the zone resupplied.

While the maneuver unit and materiel requirement calculations are considerable (and one is outlined below), most of the other calculations are rather simple. For instance, the analyst can specify the span of control of Blue HQ units, as well as their command "radius" (the maximum distance at which they can exercise effective command). Once the number of maneuver units and the size of the area of operations are established, the model will calculate the number of HQs needed under both the span of control and the "radius" rule and take whichever number is larger. Similarly, supply units can carry a specified amount of cargo (in tons), which degrades with distance. Once the cargo requirements of the maneuver units and their average distance from supply bases are established, the number of supply units can be estimated.

Finally, the amounts of replacement vehicles, personnel, POL, etc. required by each type of unit are summed to produce zone-wide requirements for replacements and materiel and for strategic lift to bring it in.

The analyst can enter a maximum amount of each resource projected to be available. MOSCOW then compares each estimated need with its budget to determine if the warfighting concept exercised performs its mission within acceptable "costs." The most salient constraints are probably: (1) the initial number of maneuver units; (2) replacements (in unit-equivalents); (3) vehicle and personnel casualties; and (4) lift. For time horizons where the force mix is constrained, ceilings on specific unit types (such as supply units) might also be important.

A HIGHLY SIMPLIFIED ILLUSTRATION

In this example, we will assume that there is only one type of Blue and Red unit (with equal strengths); that terrain has no effect; and that Blue and Red's strategy can be adequately represented within a single zone. Further, Blue's policy will call for Blue units to destroy one-half of one Red unit per engagement (after taking Red and Blue's breakpoint into account).

Each Blue attack will be at a 4:1 force ratio. All Blue units are assigned attack missions (%CCF/A = 1.00). We will outline how MOSCOW estimates the number of maneuver units needed, ignoring other types of units and materiel.

1. *Theater characteristics:* Assume the zone is the operational axis in Western Iran running from the Soviet border to the mouth of the Persian Gulf, or approximately 1500 km by road. Since it is mountainous terrain, units will be effectively deployed only on or very near roads. Zone length (ZONLGTH) is 1500 km; zone width (ZONWDTH) is 100 km (since there are multiple roads).

2. *Threat characteristics:* The first echelon of the Red Front will enter Iran with 20 divisions (ARRTOT), of equal strength and characteristics as Blue's units. Threat will move (after accounting for terrain and delays imposed by Blue's attacks and air interdiction) at a rate of 50 km per day (RCF-MAVG).

3. *Blue mission requirements:* Blue must destroy 75 percent of the invading Red force, or 15 Red divisions (MAXREDSURV = 20 - 15 = 5) by the time Red has transited the Zagros (MAXPEN = 1200 km).

4. Assume that Blue is distributed uniformly in the area from the Zagros north to the Soviet border, and that each Blue unit's total time of cycle is two days (the resource requirement equations for each activity would actually calculate this in MOSCOW).

5. *Required kills calculations:*

MAXTIME (Time available for Blue to complete mission) =

1200 km/50 km/day = 24 days.

KILLRATEREQ (Average number of Red divisions that must be killed per day) =

15 divisions/24 days = .625 divisions/day.

6. *Kill rate per Blue unit calculations:*

KILLRATE/CCF = .5 divisions killed per cycle/(2 days per cycle * 4

CCFs per engagement) = .0625 divisions killed/day/CCF.

7. *Number of Blue units needed to complete mission:*

CCF - REQ = (KILLRATEREQ)/(KILLRATE/CCF) = .625/.0625 = 10 CCFs needed.

This need would then be compared to the estimate of *available* CCFs to determine if the tested concept was viable.

CONCLUSION

This is a screening model, so its essence is quite simple. Most of the growth in its size and complexity that has occurred over the past six months has been due to the increased number of unit types that are explicitly represented and to the designer's recognition of additional, previously unrecognized, interdependencies among its component variables. (Many of the model's equations, while fairly simple, appear long because they must calculate *average* results over several types of units in several different formations or modes.)

While it would be possible to represent geography and strategy in greater detail, simply by dividing the area of operations into a larger number of zones, the cost of doing so is a proliferation in the number of runs necessary to perform the analysis of any single concept. Since even well-articulated concepts are open to a fair degree of interpretation, it will be necessary to explore a fairly extensive "space" to evaluate and refine any one concept. That is why MOSCOW was designed to be highly aggregated and based on a spreadsheet.

An analytic strategy that compromises between the natural desire for geographical verisimilitude vs. the need for analytic efficiency might be to run MOSCOW representing the entire theater as a single zone, disaggregating only when those less promising concepts could be rejected (or when geography was essential to a particular concept). Although the spreadsheet format might be adequately efficient to make disaggregation less time-consuming than some other models, it will inevitably be somewhat cumbersome and should be used only when required to adequately reflect a warfighting concept.

Appendix B

SOME MOSCOW VITAL STATISTICS

Configuration: Lotus 1-2-3 Spreadsheet on IBM-compatible personal computer.

Approximate size: 50 x 150 cells (approx. 60 kbytes).

Run time: Approximately 15 seconds (to recalculate the worksheet about eight times).

Typical zone size: One operational axis or corps sector, approximately 100 km wide by 20-1500 km deep.

Typical time period covered by a run: Determined by Red movement rate; anywhere from 1 to 60 days.

Unit sizes: Could be any size; typically division for Red; division/brigade for Blue.

Red distribution: Advance on broad front through zone.

Blue distribution: Uniform within any subset of zone (full width x specified length).

Combat resolution: Lanchester square law; based on unit strengths, kill rates based on weapon, C-3I, terrain parameters.

Outputs (required resources to meet mission objectives): Maneuver units (3 types x two assignments); HQ units (2 types); supply units (2 types); replacements in maneuver unit-equivalents as well as vehicles, personnel, POL, ammunition, other; strategic lift required to deliver replacements (in tons/day).

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