A New Approach for the Design and Evaluation of Land Defense Concepts

Philip J. Romero

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PREFACE

Although the development of new concepts for land warfare has been a U.S. Army priority since the early 1980s, few techniques are available that can help design or evaluate concepts in a rigorous, objective way. Indeed, the term "concept" has in the past been used so freely that simply arriving at a suitable definition is a much-needed prerequisite to systematic analysis.

This report contains the results of a two-year effort to develop an intellectual framework for thinking about, designing, and evaluating land defense concepts. The subject is of great importance to the Army because a concept of warfare can have (and under the Army's Concept-Based Requirements System (CBRS) is *supposed* to have) an enduring effect on doctrine, training, organizations, and weapons systems—in short, on virtually every aspect of the Army. The Army is stressing a particular level of warfare (the Operational level) out of a belief in its central importance to planning and in recognition that this level has been substantially ignored in the past. To assist the Army in more systematically developing and evaluating prospective new concepts, this report presents:

- a definition of "concepts" and a *typology* for describing them;
- an *analytic approach* to fully specify and evaluate concepts rigorously and efficiently;
- a quantitative model, the *Method of Screening Concepts of Operational Warfare* (MOSCOW), that permits analysts to describe different concepts concretely and to compare their resource demands at low levels of resolution.

The MOSCOW model is the first attempt to capture a broad range of concepts quantitatively. As such, it is still experimental and will be the basis for further research and development. In its present configuration, it is not proposed for use in Army "production-level" studies.

The research was jointly sponsored by the Deputy Chief of Staff for Doctrine, U.S. Army Training and Doctrine Command (TRADOC), and by the Commanding Generals of the TRADOC Analysis Center (TRAC) and the Army Materiel Command's LABCOM. The work was performed as part of the "Future Warfighting Concepts and Technologies" project within the Applied Technology program of the Arroyo Center. The MOSCOW model is the first attempt to capture a broad range of concepts quantitatively. As such, it is still experimental, and will be the basis for further research and development. In its present configuration, it is not proposed for use in Army "production-level" studies.

An earlier version of this report was submitted to the RAND Graduate School in partial satisfaction of the requirements for a doctoral degree in policy analysis.

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SUMMARY

The U.S. Army has made the development of new concepts for land warfare a priority since the early 1980s. This new emphasis stems from recognition that the military technical advances by possible adversaries (chiefly Warsaw Pact and client states) threaten to undermine its past reliance on technological superiority to compensate for inferior numbers. As the technological margin on which NATO depends for the conventional element of flexible response diminishes, the doctrinal aspect of force quality takes on greater importance.

Unfortunately, few techniques have been available to help design or evaluate concepts in a rigorous, objective way. Indeed, the term "concept" has in the past been used so freely that simply arriving at a suitable definition is a much-needed prerequisite to systematic analysis.

New concepts have the potential to profoundly affect the peacetime shape and wartime prospects of the U.S. Army. They are often at the hub of important political debates regarding security policy, particularly within the NATO alliance. Consequently, the stakes in intelligently developing and choosing concepts are high. The techniques used must be equal to the challenge. They must be flexible enough to adapt to creative ideas, yet rigorous enough to give confidence in their conclusions. They must be broad enough to accommodate a wide range of alternative ideas—including "alternative concepts" born outside the bureaucracy—and efficient enough to address uncertainties about the future. Finally, they must be explicit and—wherever possible—numerical, to allow different concepts to be compared in the same framework, and to measure the benefits and costs of the adoption of new ideas.

This report contains the results of a two-year effort to develop an intellectual framework for thinking about, designing, and evaluating land defense concepts. It is aimed at making the process by which the Army develops and evaluates concepts more rigorous and more efficient. The suggested improvements are of three types:

1. A typology that allows different concepts to be described concretely and compared using a common vocabulary. The raw material for this typology draws from Army doctrine, NATO defense plans, and unofficial NATO defense concepts since the late 1940s.
2. A review of the strengths and weaknesses of the Army's current approach for developing and evaluating concepts (the Concept-Based Requirements System, or CBRS), and a proposed analytic framework to ameliorate some of the shortcomings.
3. A microcomputer-based low-resolution Method of Screening Concepts of Warfare (MOSCOW), which can be used to refine and compare concept ideas in a systematic, quantitative way.

A TYPOLOGY OF LAND DEFENSE CONCEPTS

As the raw material for a typology of defense concepts, official and unofficial concepts relating to ground defense from the late 1940s to the present were reviewed. Historical research concentrated on:

1. U.S. Army doctrine (the Army's official warfighting concept) that most closely approximated the operational level of war, and concurrent divisional organization;

2. Unclassified information regarding NATO's planned main lines of defense;
3. Published material (books and journals) relating to either of these, and other unofficial concepts for NATO defense.

From the end of World War II to the present, the U.S. Army has reissued its capstone doctrinal manual (FM 100-5 *Operations*) six times, at intervals of from five to eight years. Until the 1980s two aspects of the doctrine have been fairly constant. First, it has stressed the conduct of a mobile defense until friendly forces acquired sufficient advantage to convert to the offensive. In the defensive phase of the war, almost all units would be conducting delaying and retrograde battles as they fell back on their final defense line, then with the opening of the offensive phase almost all units would be tactically employed in the attack. In each period specific features varied, but with the exception of the early and mid-1950s, the "mobile defense, followed by broad counteroffensive" concept prevailed.

Second, doctrine did not acknowledge a level of warfare between the strategic and the tactical. The employment of maneuver units at the tactical level would largely mirror the theater-strategic level. As represented by official doctrine, theater campaigns were planned and overseen at the theater-strategic echelon and carried out by tactical units (divisions). Although there might be intermediate levels of command (corps, armies, or army groups), their function was assumed to be limited to coordination of subordinate echelons consistent with the intent of the theater-strategic commander. This intermediate level was recognized to be a managerial necessity (required to limit the theater-strategic echelon's span of control), but had no substantial independent responsibilities.

NATO's concept of defense has in the same period undergone profound changes. First, the alliance's reliance on tactical nuclear weapons for combat power early in a war (which is outside the scope of this report) has been greatly reduced. Second, the area to be preserved by a NATO "mobile defense" has grown equally dramatically. NATO's planned main defense line has moved eastward (from northeastern France in the late 1940s to within 30 to 50 km of the Inner German Border today), as absolute capabilities have increased and political requirements have placed greater emphasis on maintaining the territorial integrity of the Federal Republic of Germany.

Unofficial NATO concepts have been patterned after changing political fashions and technological opportunities. The concepts of the 1950s and 1960s generally attempted to de-emphasize reliance on nuclear weapons and reduce superpower tension as a means of facilitating an eventual German reunification. The unofficial concepts of the 1970s attempted to reduce the costs of forward defense by utilizing precision guided antitank technology, which made its debut in the 1973 Arab-Israeli war, or reducing the number of active forces in favor of increases in nonactive units (reserves, militia, territorials, etc.). A greater variety of technology-oriented defenses have emerged in the 1980s. They generally have emphasized long-range or air-to-ground precision munitions or inexpensive defensive enhancements (fortifications, mines, and obstacles). Also in the 1980s interest has renewed among German political elites in "nonprovocative defense" concepts that reduce or eliminate armored vehicles and ground attack aircraft and in "initiative-oriented" concepts in most military and some American academic circles.

The key dimensions of the typology abstract from the principal distinctions among these official and unofficial concepts. They emphasize different *levels of warfare* from the tactical to the grand strategic, and different *elements*, including the allocation and deployment of forces, their equipment and organization, or their warfighting style. Beneath each of these major dimensions specific attributes are defined in quantitative terms.

USING CONCEPTS AS THE BASIS FOR LONG-RANGE PLANNING: THE CONCEPT-BASED REQUIREMENTS SYSTEM

The Army's Concept-Based Requirements System (CBRS), written in the early 1980s, laid down procedures by which "requirements" (goals) for changes in doctrine, training, organization, and equipment were to be developed. The CBRS regulations stipulate that proposed changes should be justified by a "concept" for employment of forces that provides an intellectual foundation for the proposal. CBRS mandated that new concepts be subjected to evaluation by cognizant Army analytic bodies before the senior Army leadership decided on the proposal's merits. CBRS was intended to apply to all important initiatives and to short as well as long time horizons, but in practice, issues requiring longer time horizons (15 or more years) were emphasized.

The Army has only a limited ability to fulfill the basic intent of CBRS, because of shortcomings in present approaches to concept development:

1. Because there is no framework into which concept ideas can be placed, each one is *sui generis*, and there are no guideposts or tools to assist in comparing or refining them systematically. Also, there is little common vocabulary; so developers and evaluators, who come from different intellectual traditions, are forced to fall back upon generalized slogans or present-day analogs that are familiar to them but of dubious relevance.

2. Under time horizons of 20 or more years, almost any aspect of the problem of choosing a concept is uncertain or variable: both "scenario" variables that are not under the control of friendly decisionmakers and "policy" variables that are. Some policy variables that might be fixed in a short-term study, such as force structure and equipment characteristics, can be variable in a CBRS study—in fact, examining them is the basic motive for CBRS. The tools available for quantitative evaluation generally are limited in the scope of elements that can be varied (omitting, for example, most aspects of warfighting style) and are time- and resource-consuming to use, or both.

3. That same long-term time horizon needed to influence the research and development process is the principal source of credibility problems hampering the direct application of the system requirements (or other long-range requirements) produced by a concept developed and evaluated in accordance with CBRS.

To overcome these shortcomings, the process of designing and evaluating concepts must intermix these two tasks thoroughly, organizing the analysis in *stages* for maximum efficiency. The fundamental elements of the proposed approach are:

- *Concrete* descriptions of the attributes of each concept;
- Consideration of a *wide range* of alternative concepts;
- *Uncertainty* addressed through variations in assumptions; and
- Preferred concepts and systems are those whose performance is *robust*.

USING SENSITIVITY ANALYSIS TO IDENTIFY ROBUST CONCEPTS

The hypothetical campaigns in which operational concepts might be employed are rife with unknowns. Although it is common practice to use "best estimates" for the values of the variables about which we are ignorant or uncertain, in truth we only know a *range* of plausible values. Wide as many of these ranges must be for present-day warfare, the farther in the future we are obligated to look, wider still must they become. Because we do not know—and cannot know, short of war (if then)—the "true" value of these variables, it is necessary to evaluate concepts throughout these ranges to determine how sensitive their estimated performance is to our assumptions. The preferred concepts should be those that are less sensitive and therefore more robust.

For any complex analytic problem, the union of dual challenges—the need to examine a *spectrum* of concepts and the need to look for *robustness* through sensitivity analysis—presents an intimidating problem that has been termed a "combinatorial explosion." Concept development and evaluation studies have finite durations and resource budgets; in all likelihood, no analytic technique (especially the relatively detailed quantitative models commonly used in the defense community) would be efficient enough to handle the caseload. Analyses should be ordered in stages to maximize analytic efficiency. Broad tools should be used in early stages when many concepts and assumptions must be considered, and detailed tools reserved for later stages after the most promising concepts have been identified.

A QUANTITATIVE TOOL FOR SCREENING WARFIGHTING CONCEPTS: MOSCOW

In the research it became evident that there was a need for a broad, quantitative model that could rapidly provide appraisals of a wide variety of concepts with modest data requirements and a consequent low level of resolution. A Method of Screening Concepts of Operational Warfare (MOSCOW) was designed, which provides analysts with broad-brush insights into the viability of alternative concepts.

MOSCOW incorporates three main 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 utilize simple equations organized by spreadsheet software in a personal computer, allowing analysts to instantly observe the effect of changes in policy inputs.

The model produces estimates of the amounts of resources—combat units, personnel, vehicles, and consumables—that would be needed by a specified warfighting concept to achieve a designated level of success in a combat theater. Using this model, researchers can screen alternative concepts by comparing their resource requirements.

There are four levels in MOSCOW's geographic hierarchy: (1) the *war* in an entire theater, (2) the *campaign* in a zone (which can be as small as a corps sector or as large as a theater), (3) the *engagement* between Blue and Red maneuver units, and (4) the *vehicle* hide/dash sequence. The user specifies his campaign objectives in a zone: the number of enemy combat units that must be destroyed and the maximum distance that the enemy can be allowed to advance into friendly territory. MOSCOW estimates the size of the friendly force needed to achieve the objectives, as well as the replacement personnel, vehicles, and major consumables, needed to keep it at full strength. If the amounts projected to be available to the zone can supply these needs, the concept is considered "viable" (or "affordable"). Concepts that are found to be viable over a wide range of assumed circumstances—whose viability is robust—are considered promising and eligible for further analysis with more detailed tools.

MOSCOW differs from traditional approaches by providing a systematic and concrete framework for describing alternative concepts. Concepts can be described in a common terminology, with differences represented by changing the values of key variables. Policy variables are categorized by their function and the level of warfare to which they apply.

MOSCOW differs from traditional models for the analysis of ground forces issues in the following respects:

1. It represents the effects of concepts in part through the mix of activities of friendly forces. This flexible format allows MOSCOW to represent a range of concepts. Similarly, it describes force characteristics in a flexible format that can reflect a wide range of technologies.
2. It evaluates concepts in terms of high-level grand strategy and theater strategy objectives. The model "assumes" that these objectives will be achieved and estimates the size of the force and other resources *needed* to do so.
3. It performs "what if?" analysis quickly, because it was constructed to run on a personal computer.
4. Its computations are readily accessible, and—especially important—easy for a user to customize because it employs the Lotus 1-2-3 (TM) spreadsheet program.

MOSCOW's flexibility and efficiency have come at the expense of certain key simplifying assumptions:

- Terrain/weapon systems and maneuver units are highly aggregated.
- Attrition is represented as a simple Lanchester process.
- Only "steady state" or average conditions are reflected. To represent dynamics, it is necessary to run the model several times in sequence.

MOSCOW provides the user with an analytic "sandtable" into which he may insert his concepts and assumptions. However, because it utilizes a new activity-oriented approach to the description of concepts, users are urged to compare the distribution of activity times calculated automatically by MOSCOW with a reasonable distribution, and modify it as necessary. As in any model, its estimates must be filtered by military and analytic judgment. Its virtue is that the equations and variables can easily be changed to accommodate that judgment.

THE ROLE OF CONCEPTS IN DEFENSE PLANNING

Future concept developers must bear a responsibility to articulate their ideas explicitly within a common intellectual framework. Further development of the typology of concepts described in this report is needed, but researchers must avoid falling into the temptation to add detail in only the tangible areas (organization and equipment, or the tactical level of war), because the greatest need is for analytically tractable definitions of soft elements (such as doctrine).

Future concepts should indicate clearly the limits of their scope—for few concepts are likely to cover every dimension—and demonstrate at least *prima facie* robustness to uncertainty and enemy counters, incorporating promising counter-countermeasures into the concepts themselves. The breadth this implies for design efforts may have to come at the expense of depth and detail, but to the degree that this broadening elevates policy debates to more appropriate levels, that can hardly be a bad thing.

Superficially reasonable as the CBRS may be, the results to date of the Army's attempt to give concepts a preeminent place in planning are less than impressive. The first test, the Army 21 concept, aborted after five years of development and initial evaluation. There is confusion about the proper scope of such concepts, their appropriate time horizons, and even about an accepted definition of the subject itself. Unless certain fundamental intellectual prerequisites are satisfied, it is highly questionable that intelligible, credible "concepts" can influence planning.

Most important, the Army must recognize that design and analysis are effectively inseparable. The separation of these tasks as mandated by CBRS will immensely limit the breadth and richness of any concept development effort. The membrane between designers and evaluators must be fully permeable.

Achieving such fluidity is difficult because the hybrid task of design and evaluation cuts across traditional organizational lines, and across Army cultures. Combat developers use very different mental frameworks than do systems analysts. The hybrid task demands that they communicate well with each other and that they both stretch beyond comfortable styles of thinking: Developers must become accustomed to thinking in quantities, or their ideas will never be widely communicable and susceptible to analysis; and analysts must be willing to grow beyond easily definable problems at high levels of resolution to entertain "squishier" issues of broader scope.

The final cultural change is probably the most difficult. A concept development and evaluation process that considers many concepts under many possible assumptions can succeed only by organizing its tasks in stages. Implicitly, this means analyzing some things early and some things later. The Army has a natural desire to consider every criterion "at the front end" of any study, because each branch or function will have a legitimate claim as to the importance of each criterion. The fundamental compromise that must be made is to acknowledge that deferring harder analytic problems until later, when there are fewer concepts to be considered, indicates only the *cost* of evaluating a given issue, *not* that issue's *importance*. If everything is accorded first priority then the role of concepts in Army will remain as before CBRS: as followers rather than leaders of the Army's future.

MILITARY ANALYSIS AS POLICY ANALYSIS

The methods and paradigms of traditional policy analysis can make a definite contribution to the Army's planning endeavor, but their limits must be recognized. Policy analysis tools make personal judgments explicit and allow analysts to examine the effects of some of the issues about which we are uncertain. They concentrate on a pragmatic goal—finding a concept that appears "good enough" over a reasonable range of circumstances—rather than one that is "best" in a narrow single case. Their best use, however, may be to highlight areas of avoidable uncertainty—issues susceptible to research that are currently ignored or treated by assumption. Their aim should be modest: to manifest areas of ignorance and disagreement, to seek concepts that hedge against the unknowable future.

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At RAND Bruce Goeller originated many of the methodological principles advocated herein, having applied them successfully in previous RAND studies. He identified the need for design and screening techniques in the Army's development of warfighting concepts and suggested these to me as a dissertation topic. James Bigelow identified several of the basic principles used in the early formulation of the MOSCOW model, patiently helped me work through several design issues, and assisted in the derivation of some of its core equations. James Hewitt endured many brainstorming sessions, helped with the mathematics, and introduced me to spreadsheet modeling. Peter Rydell and Richard Stanton took on a large part of the burden of producing supplementary documentation of the model (to be published separately) and suggested several cost-effective simplifications and improvements. Alan Vick and Lee Pleger provided insightful reviews.

An earlier version of this report was submitted as a Ph.D. dissertation at the RAND Graduate School. My dissertation committee chairman, Kenneth Solomon, maintained an enthusiasm that infected his partners, Richard Darilek and James Thomson, and so sustained mine. The Arroyo Center sponsored the research.

Finally, my wife Lita bore up under an indefinite suspension of our normal life with her customary gracious good humor.

The conclusions offered based on my historical research and details pertaining to the formulation and construction of the MOSCOW model are wholly my responsibility, as are any errors of fact, judgment, or arithmetic.

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I. INTRODUCTION

THE CAUSAL CONUNDRUM IN DEFENSE PLANNING

The proverbial problem of the chicken and the egg besets any planner who has ever tried to design a policy for one element of an organization before knowing those of other elements with whom he is interdependent.[1] The problem is not uncertainty per se; any planner must make assumptions about aspects of the environment that are inherently uncertain, because they are out of his control. Small firms without a substantial market share can assume that they will not influence the market price of their product; they can plan based on some presumed price (or range of prices) that is exogenously determined, but large firms cannot. The problem comes when there is simultaneity—when some factor both *influences* and is *influenced by* a planner's decisions.

It is far more difficult to understand simultaneous systems than sequential ones. The complexity rises with the number of organizational functions and with their interdependencies.

The complication that interdependent policies pose is especially pertinent to defense planning and the policy analysis that supports it. To take a very simple example, assume that two separate military organizations are responsible for developing and procuring weapon systems and for developing doctrine for the use of weapons in battle and training troops to execute that doctrine. The doctrine developers need to know the characteristics of the weapons that will be available, yet they also want to influence those same characteristics.

Units of large organizations can plan under such interdependent conditions either by using very short planning (time) horizons or by establishing a hierarchy of plan dominance.[2]

If short time horizons are used, one unit waits until the other units on which it depends complete their planning, then produces a plan based upon their inputs. Using our example, doctrinal planners would wait until weapon planners had made their decisions, then write doctrine assuming that those weapons will be produced. This approach can work if dependencies run primarily in one direction, and there are substantial differences in the length of the units' "planning and execution cycles."[3] If, for example, the doctrinal planning cycle was shorter than the weapon planning cycle, *and* if it was "reasonable" to plan weapons in the absence of a specified doctrine, then doctrinal planning could wait until weapon decisions had been made, designing doctrine that used the specific weapons already chosen.

This approach will unfortunately rarely work in practice. First, there is no a priori reason to expect that logical preeminence will correspond to planning cycle length. Second, the important time comparison is between the implementation of the independent plan and the full planning and execution cycle of the dependent one. The independent cycle must not merely be longer, but its margin must be larger than its component planning time. Obviously, when there are multiple units involved, the required cycle times for the dependent plans may need to

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[1]For example, a firm's marketing director would prefer to know how many units will be produced before hiring new salesmen and buying advertising; at the same time, the production supervisor would like sales projections in order to buy the right quantities of raw materials and lay on a second or third shift on the production line.

[2]With either approach it is possible to facilitate convergence by using multiple iterations. Organizational subunits exchange plans between iterations (perhaps after a provisional review by higher authorities) and use each other's plans to refine their own assumptions.

[3]"Planning and execution cycle" here means the total time needed from the initiation of planning to the achievement of final outputs. The doctrinal cycle would start with the development of new doctrine and end when troops have been trained to implement it. The weapon cycle might start with a decision to initiate development of a weapon and end when the weapon was delivered to the field and had achieved Initial Operational Capability (IOC).

be absurdly short. Finally, the interdependencies may actually be bidirectional, so it may be difficult, if not impossible, to determine which is the dependent and which the independent plan.

Instead, procedures for planning can stipulate an order of precedence among different plans and set deadlines correspondingly. A judgment is made as to the relative logical dependencies of each function and the planning process ordered from the least to the most dependent. In the above example, doctrine was considered more dependent on weapons than the reverse, so weapon planning is completed first and its decisions used in doctrine planning.

Hierarchical precedence establishes to the order in which organizational echelons plan, with "top-down" or "bottom-up" planning being the main prototypes. In top-down planning, the broad choices made first by high-level leaders provide the boundaries within which lower echelon planners must conform. The simplest example is that of a budget. The plans of each division of a company must keep within the monetary allocations made by the company's leadership, the division's budget is in turn allocated among its own subelements, and so on. Top-level input to lower-level planners may be framed in terms of constraints on their planning (e.g. budget ceilings), goals or requirements to be sought, or some mixture of each.

For defense planning, one useful general hierarchical framework distinguishes among several levels of warfare. Table 1 shows Luttwak's typology of levels of warfare, which is frequently used in this report.[4]

Table 1

LEVELS OF WARFARE

Levels of Warfare	Example Definition	Analogous U.S. Wartime Command Echelon
Grand Strategic[a]	Sets global military objectives and allocates resources among multiple theaters of war [e.g., Roosevelt or Marshall, 1941-1945]	National political and military leadership
Theater Strategic[a]	Defines objectives for and allocates resources among several missions or portions of theater [e.g., Eisenhower in France, summer and fall 1944]	Theater Commanders in Chief (CINCs)
Operational[a]	Assigns missions and deploys/positions combat units (e.g., divisions) to achieve theater-strategic objectives [e.g., Patton in Normandy, July-August 1944]	Army group, Army, or Corps
Tactical[a]	Maintains combat units and conducts engagements in which enemy units are attrited or key areas are seized or denied to enemy [e.g., Gerhardt at St. Lo., mid-July, 1944]	Division or brigade
Technical[b]	Establishes effectiveness of weapons and support systems, based only on their characteristics and scientific laws	(No pertinent command echelon)

SOURCE: Luttwak, 1987.
[a]Level of command, planning and analysis.
[b]Level of planning and analysis.

[4]The typology is based on Luttwak, 1987.

Traditionalists may object to this typology or quibble with its example definitions.[5] The specifics are not central to the thesis of this report, but the basic notion of a hierarchy of levels of warfare that provides for organizing military policy planning and analysis is crucial.

Top-down planning is the form often favored by advocates of a national military strategy. Under this approach decisions made at the grand strategic level form the basis for plans involving ever-greater functional specialization and detail that cascade down the military's planning echelons.

Under a top-down approach, plans that emphasize *one* function at one level may have logical implications for *other* functions at subordinate levels. For example, few or no heavy armored divisions allocated at the grand-strategic level to a particular theater would effectively prevent the development of a theater-strategic doctrine that emphasized large-scale offensives. Conversely, with bottom-up planning, operational doctrine and training that placed little emphasis on attacks would eliminate large-scale offensives as an option available to higher-echelon leaders.

For the moment, planning "functions" are distinguished only in terms of the direct and concrete effect that their implementation will have on a military force.[6] At one end of this spectrum of concreteness are plans so long range, or so unspecific, as to stipulate no specific implementation actions. At the other end are plans to develop or acquire specific named items of equipment. In between are functions pertaining to doctrine, training, or war planning that may strongly influence (and even govern) the way the force fights but whose influence is less tangible than equipment plans.

DEFENSE CONCEPTS IN THE MILITARY PLANNING PROCESS

With level of warfare and degree of concreteness established, "defense concept," that amorphous phrase used in the title of this report, can be placed in a larger policy context. According to Webster,[7] a "concept" can mean either of two things: (1) something conceived in the mind; or (2) an abstract idea generalized from particular instances. Table 2 illustrates the different roles that a Type 1 and Type 2 concept play in military planning.

A comprehensive concept would reside in the upper left corner, illustrating an arrangement of both dimensions at once. Each row corresponds to a level of warfare, and the columns distinguish general functions by their degree of specificity. A Type 1 top-down concept sets down broad policy outlines to guide those responsible for more detailed planning (lower levels of war) or more concreteness (greater specificity); planning thus proceeds to the right and down. A Type 2 bottom-up concept, by contrast, merely articulates the consequences of plans already made at lower levels. Planning under this approach proceeds upward and to the left.

The U.S. Army currently attempts Type 1 planning, with mixed results. This report recommends improvements to the process by which the Army designs and chooses the concepts that it intends will govern its long-range plans.

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[5]Naturally, any of a number of typologies is possible, and there is no single "correct" one. Luttwak's version is an extension of the traditional typology employed by Western armies since the early nineteenth century. Since before Clausewitz and Jomini a distinction was commonly made between strategy (equivalent to Luttwak's theater strategy) and tactics. With the rise of mass armies and rail and motor transport, areas of operations became so large that European armies further identified an intermediate level, termed "grand tactical" by B. H. Liddell-Hart, but more commonly called "operational" after German (and later Russian) usage. The grand strategic and technical levels are natural products of, respectively, the capability to wage war in several theaters simultaneously and the growth in technology's importance in warfare.

[6]Section II proposes a typology of defense concepts that explicitly distinguishes among categories of functions and levels of warfare.

[7]Webster's *Third International Dictionary*, 1965.

Table 2

A FRAMEWORK FOR MILITARY PLANNING

Level of Warfare	Concept	"Approved" Concept or Doctrine	Procedures	Organizations and Equipment
	Level of Planning and Implementation			
Grand Strategic	Brookings Defense Budget Pubs. (Kaufmann)	SECDEF Defense Guidance	JCS/General Staff Plans	National Armed Forces
Theater Strategic	Forward Defense, Defense in Depth		CINC Plans	Theater Forces
Operational	Techno-commandos, Active Defense	Field Manuals e.g. FM 100-5	Training Manuals, Field Regulations	Corps to Army Groups
Tactical	Infiltration, Frontal Assault		Army Group, Army, Corps Plans	Squads to Brigades/ Divisions
Technical	"Notional Systems"	System Specifications	Technical Manuals	Equipment

SCOPE OF DEFENSE CONCEPTS

Defining the scope implied by the word "concept" is unavoidably controversial because the word is used quite freely, and inconsistently, by different segments of the defense community. For example, some academic strategists and NATO specialists refer to their "concepts" for NATO defense that involve restructuring active and reserve ground forces (e.g., Canby, 1973); others speak of "concepts" for employing high-tech weaponry (e.g., *European Security Study*, article by Cotter, 1983); and still others suggest the maintenance or abandonment of the "concept" of forward defense (Karber, 1984; and Dupuy, 1983b). Yet the Army's own Concepts Development Directorate[8] tends in its "concepts" to emphasize the organization of future brigade or division-sized combat units, based on general "concepts" of weapons employment. By and large, each constituency has appropriated the word to describe the level of war and elements of deterrence and warfare that most preoccupy them.

There is no general and agreed vocabulary for describing the scope and emphases of defense concepts.[9] Three characteristics that will be part of any concept (whether or not they are made explicit) are the geographic or command scope assumed, the general categories of policy options that are included (or that differ from the present official concept),[10] and the time period assumed. The first is identical to the levels of warfare introduced above. The second requires a classification of the policy elements available to Army and national decisionmakers.

[8]The CDD is part of the Combined Arms Center within the Army's Training and Doctrine Command (TRADOC), located at Fort Leavenworth, Kansas. It is responsible for the development of concepts for the employment of combined arms in land warfare.

[9]Section II will outline a concept typology and vocabulary.

[10]When concepts do not mention some categories of policy options, they must be assumed either to be irrelevant to the concept's authors, or to remain unchanged from current policy.

Obviously, many classification schemes are possible. For simplicity of explication, this report will classify policy elements related to land warfare (and related planning) in three categories:

- Allocation and deployment of friendly forces;
- Characteristics of those forces' equipment and organization;
- Style of warfighting.[11]

The first category pertains to the priorities among geographic locations, targets, or missions of friendly forces. Are they deployed in depth or near the enemy? Are they allocated evenly across the front, or is their distribution nonuniform? The second relates to the organization of those forces and the characteristics of their principal equipment. Are they grouped in large, heavy units or small, light ones? Does their firepower come mainly from hand-held infantry weapons, vehicle-mounted direct-fire weapons, artillery, missiles, or air-delivered munitions? Are their vehicles well-armored and slow, thinly armored and fast, or something else entirely? The third category is the most difficult to define crisply. It relates to the approach to warfare used by friendly forces. Do they emphasize defensive warfare that sacrifices initiative for positional advantage, or a mobile offensive style that does the opposite? What fraction of friendly forces are held in reserve at the outset of fighting? How dispersed are units when moving, and how concentrated when fighting?

These terms are abstractions, but they relate closely to existing groups of planning functions. In U.S. Army parlance, the planning functions shown below correspond to each category:

Category of Policy Element	*Corresponding Planning Function*
Allocation and Deployment	War planning or contingency planning
Equipment and Organization	Force design or force structure planning
Warfighting Style	Doctrine planning or doctrinal development

Exact titles of planning functions will usually include an indication of the pertinent level of warfare and may further indicate the planning horizon.[12]

The third dimension, the assumed time period, can be subsumed within the second dimension. Concepts for a distant future assume a time period far enough away that many elements are free to differ from the present, but near-term concepts will be constrained from varying many policy elements (e.g., equipment).[13] Thus the degree to which each category is constrained to employ present policies is directly related to the assumed time period.

[11]Colloquially, the first category refers to the "Where and When" of friendly forces as assigned on the battlefield, the second refers to "What" those forces are, and the third refers to "How" they fight. (The assumed war scenario—the theater and enemy—provides the "Who".) These categories are further subdivided in the concept typology outlined in Sec. II.

[12]For example, planning pertaining to allocation and deployment at the theater-strategic or grand strategic levels will usually include "strategic" in their titles. The frequent exception is the word "operational," which may refer to the operational level of war or merely to the operation of Army forces. Organizations' titles often also distinguish "long-range planning" from "mid-range programming" and "short-range budgeting." In this report, the word *planning* is used for any time horizon, and the horizons are made explicit.

[13]For example, a concept intended for next year would have to assume as fixed for all elements that could not realistically be changed in that short time. Very likely, the concept would utilize existing organizations and equipment, and probably most elements of existing warfighting style (since any changes must be not only developed, but taught and practiced).

Within the general rubric of "land defense concepts," then, it is possible to make distinctions relating to any concept's level of warfare, time period, and category of policy element included or emphasized. No published "concept" comprehensively covers all of these dimensions. Most emphasize a single level of warfare and a single category of policy lever (or only a part of one category).[14] This restrictive emphasis ignores one of the planning principles mentioned at the outset: that decisions made at one level and for one function or element can have important effects on higher or lower levels and other functions or elements.

For reasons outlined in Sec. III, the U.S. Army has embarked on a substantial effort to develop concepts for the operational level of war, emphasizing warfighting style, for fairly distant time horizons (15 to 30 years). The Army lacks some of the necessary tools to adequately design and evaluate such long-range operational-level warfighting concepts. This report suggests an analytical approach and method to support the concept design and evaluation process. The specific tool (the Method of Screening Concepts of Operational Warfare, or MOSCOW) described in Sec. IV was constructed to address the Army's present priorities, but both the model and the general analytic approach underlying it are adaptable to other emphases as well.

THE CENTRAL IMPORTANCE OF WARFIGHTING CONCEPTS TO AN ARMY'S PLANNING

The Function and Limits of Doctrine[15] (Concepts of War) in a Modern Army

Imagine that you are traveling on an out-of-town business trip. Your plane has arrived late at the airport, so by the time you pick up your rental car you know that you must hurry to reach a scheduled meeting. You have a street map of the city, but no information about obstacles along prospective routes (construction, traffic, flooding, etc.) You must choose a route—quickly—that will allow you to make your deadline.

Now complicate this fanciful example a bit further. While choosing a route, you realize that you have inadvertently switched briefcases with a colleague who has rushed off ahead of you to attend a different meeting in the same building as yours. Now you must not only pick a fast route, but also guess which one your colleague chose in order to intercept him.

In the first situation, lacking any information beyond your map, you would rely on *rules of thumb* to guide your choice. They might be simple and unconditional, such as, "Take the route that has the shortest linear distance regardless of road type," or "Go by the nearest freeway." More likely, these "rules" would be somewhat more complex, such as, "Take the freeway unless the total distance is less than five miles," or "Take the freeway except during rush hour." These rules are based on a mixture of personal experience, hearsay, advice, and folklore. You will probably never know if your rules of thumb are "right" (since you only observe the route you actually take) and will probably conclude they were incorrect only if your journey went spectacularly wrong (e.g., you get stopped in traffic for hours).

The point is that any individual faced with incomplete information or under time constraints will base his decision upon some normative concept—a personal set of principles or "decision rules"—of the best option to choose under different circumstances.[16]

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[14]For the purposes of this report, concepts that emphasize allocation and deployment will be termed *allocation concepts*; those stressing organization and equipment will be *organization and equipment concepts;* and those focusing on warfighting style will be called *warfighting concepts* or *concepts of warfare*--an army's authoritative warfighting concept. Adding an indication of the level of warfare and time period emphasized provides a complete designation.

[15]The distinction between doctrine and concepts is defined below.

[16]Concepts will vary in the range of contingencies they anticipate, or in the range of actions they prescribe, about which more will be said below.

However, when many individuals must act in a coordinated way, as military units must when engaged in any but the simplest combat tasks, and they have little time or opportunity for consultation, concerted action can be greatly facilitated by agreement upon a single concept in advance. All members of a group or organization may hold an identical concept without ever making it explicit, but where unambiguous evidence of success or failure is hard to come by, it is at least as likely that different individuals will favor different (though perhaps overlapping) concepts. One definition of *doctrine*, then, is: *a set of principles that provide broad guides to action* (rules of thumb), *to which members of an organization explicitly agree to conform.*[17]

This pragmatic definition indicates the purpose of doctrine and suggests the limits of and warfighting concepts. For complex tasks involving several participants (e.g., several combat forces in a tactical engagement), doctrine provides the intellectual foundation for coordinated action. To ensure the uniformity of application required to achieve this coordination function, the armed service will use a variety of incentives to induce adherence to the doctrine by unit commanders. Some may be organizational (tests, rewards, and punishments), and others spiritual (instillment of ideological fervor or blind faith in the tenets of the doctrine or the wisdom of its proponents). The rituals associated with instruction and enforcement can cast a mystical aura over the body of the doctrine, obscuring its straightforward function and, as will be seen later, impeding systematic analysis.

The unavoidably generalized nature of doctrinal principles adds to this mysticism. *Plans*, by contrast, specify the exact actions to take—the specific route in the example above—and may include contingencies (branch points and alternative routes) to provide a measure of flexibility. Each plan covers only a small fraction of the universe of possible contingencies that a military force may face, because adding the complexity that would make a plan more general risks confusion, which would imperil its use as a mechanism of coordination. A *concept* applies to a broader range of contingencies and thus must be couched in more flexible language, often so general that its meaning is obscured.

All armies' doctrines (and therefore, their warfighting concepts) must strike a balance between the extreme of bland truisms, which are quite general and easy to understand, but provide no useful guide to action, and the opposite, extensive prescriptiveness, which provides unambiguous guidance, but for only a few situations and in such detail as to be incomprehensible to much of its intended audience. Unlike plans, then, concepts of warfare cannot be "recipes" since such specificity would be self-defeating.

The Wider Effects of Warfighting Concepts on Modern Army's Evolution

All armies have warfighting concepts. In the days of highly personalized leadership and before the creation of general staffs, the "concept" may have been the "scheme of maneuver" in the mind of the leader and perhaps a few of his close lieutenants. With the advent of mass armies and the establishment of additional command echelons (e.g., the division) and general staffs to help the commander control them, some degree of standardization was necessary. One

[17]For the purpose of this report, warfighting "doctrine" refers to the set of normative principles for the conduct of warfare articulated in formal regulations or instructional materials (such as U.S. Army Field Manuals) for current forces. A "concept" of warfare is any normative view of how to fight. "*Concepts*" are thus a *superset* of "*doctrines*" with doctrines different only in that they have explicit official status. A few authors (e.g., Thompson, 1987) make a distinction between an armed force's formal and "revealed" or "implied" doctrine. In this report, the terms "doctrine," "official doctrine," and "official concept" are interchangeable, each referring to an army's formally explicated concept of war. All other concepts of war, including informally accepted principles of "revealed" or "implied" doctrine, and proposed alternatives to the official doctrine, will be termed "concepts." Additionally, "concepts of war," "concepts of warfare," and "warfighting concepts" are synonymous; all refer to concepts that emphasize warfighting style.

manifestation of this was the return of battle drill in the eighteenth century (not practiced in Europe since Roman times), which coordinated fire by musket volley that was far more lethal (and less prone to fratricide) than aimed individual fire. Increasing geographical distances between the commander and his subordinate leaders (without corresponding increases in communications speed) necessitated the advance development of battle plans, and later, operations and campaign plans as well.[18]

A prerequisite to planning was an agreement about the basic principles of how the battle, campaign, or war should be fought. If those who plan and those who execute the plan (leaders of combat units) differ in their fundamental views of, for example, the relative advantages of the offense and the defense, or the value of surprise, or the importance of flank security, they sacrifice any prospect of successful coordinated action.[19]

The first function of a concept of warfare, therefore, is to provide a guide to planning and action in combat, and its first place is in the backs of the minds of the planners and unit commanders who will do the fighting. Concepts can (and usually do) exist for each level of warfare and affect the staff officers and combat leaders at their echelons. To influence the thinking of these officers, a concept must pervade their education and development; it must be written into school curricula and training manuals,[20] used as a standard of evaluation for promotion, etc. This is the second place of a warfighting concept: as one of the foundations of training.

A third place that concepts can affect an army is in its organization for warfare. Before World War II, the French army saw tanks as infantry support or reconnaissance and pursuit weapons, so it did not develop organizations to command large concentrations of tanks (armored divisions) until just before the war. Similarly, the officers of the U.S. Army of the early 1950s interpreted their experience of two years of static war in Korea as calling for emphasis on small-scale infantry formations, based on infantry companies and battalions, and a virtual elimination of integrated larger operations where higher echelons would have more than a purely administrative role.

A fourth place of influence is over weapon systems. Fundamental views regarding the efficacy or importance of different combat missions will affect the allocation of procurement funds. Passive and automated defenses,[21] for instance, have historically received small shares of U.S. Army or Navy budgets. Concepts often underlie the performance requirements that are established to guide weapon development programs, even though the concepts themselves are almost always implicit. The Army is currently attempting to institutionalize the development of warfighting concepts for application to research and development (R&D) requirements setting.[22] This objective is made highly challenging by the need to formalize the role of concepts in R&D, but they have always had an implicit role.

Through the training of junior officers and the choice of the weapons to equip them, a concept of war has the opportunity to prevail for quite a long time—in excess of a generation. Officers are likely to rely on updated versions of principles they were taught in their early

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[18]An excellent survey of the evolution of command techniques, emphasizing the opportunities and limits posed by communications technology, is van Creveld, 1985. Keegan, 1987, is more anecdotal but describes the leadership styles of a few commanders in greater detail.

[19]A classic example can be seen in the execution of the German offensive in the West in August 1914 (the "Schlieffen Plan"). While the bulk of the German armies pushed around the French Northern flank, Rupprecht's Sixth Army in Lorraine had the mission of absorbing the expected French counterattack (Plan XVII), giving ground to pull the French forward. Instead, after a brief withdrawal, Sixth Army counterattacked and drove the French out of the trap into which they had been lured. See Tuchman, 1962, p. 245.

[20]The most widely distributed, and thus among the most influential documents, are Field Service Regulations, or in the U.S. Army's current usage, Field Manuals. These documents are generally cited as the principal sources of official doctrine. Their evolution in the U.S. Army since World War II is outlined in Sec. II.

[21]Engineer equipment, fortifications material, and mines are examples.

[22]These procedures are described in Sec. III.

training, and equipment that remains in the inventory for 20 and more years will limit the ability of their operators to experiment or change.

Finally, concepts are pivotal in broader political debates about security policy. The debate about military reform in the early and mid-1980s (which has roots leading back to at least 1976) manifested widely divergent views on the value and feasibility of "maneuver" and offensive operations in future land warfare. In the politics of several European members of NATO, most especially the Federal Republic of Germany, alternatives to the contemporary official concept for the conduct of land warfare have been staple topics since German rearmament. Their numbers and prominence in NATO security debates have grown in the 1980s, in response first to the introduction of new intermediate range nuclear weapons, and later to the Airland Battle and Follow-on Forces Attack concepts of the U.S. Army and SHAPE Headquarters, respectively.[23] Concepts thus affect the larger political environment in which armed forces must plan in peacetime and fight in wartime.[24]

When and How Should Armies Reexamine Their Concepts of Warfare?

Concepts are largely determined by the presumptions of their proponents concerning the factors that influence who wins and who loses on the battlefield.[25] "Principles of war," the value of surprise, the relative merits and vulnerabilities of defense versus offense, or of concentration versus dispersion, comparative strengths and weaknesses of friendly and adversary weapons systems or branches of service are examples of underlying presumptions. These may stem from any combination of hoary tradition, historical study, direct or vicarious wartime experience, or self-serving dogma.

In principle, armies should reexamine their concepts whenever an event calls any of those presumptions into question. Changes in the force structure or doctrine of probable adversaries, the composition of friendly forces, or the military technology of either side might render formerly promising (or proven) ideas ineffective, or worse. To take examples from the era of World War I, massed infantry bayonet charges were undone by rapid-fire small arms and artillery, the failure to maintain mobile reserves deep in a defender's rear became foolhardy after German introduction of infiltration techniques (and Allied introduction of tanks), and the tactics of the small, professional British Army in 1914 were unexecutable once its ranks swelled with conscripts. In fact, in light of what Luttwak has termed "the paradoxical logic of strategy"—in which every advantage will be temporary as it is met by enemy efforts to circumvent or countervail it—change is likely to be quite frequent as yesterday's concepts stimulate today's competitive responses.[26]

In reality, however, the lifespan of doctrines in most armies tends to be much longer and to change less frequently than the idealized view would imply.[27] Historical accounts have often

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[23] Sec. II outlines the evolution of U.S. Army doctrine and official and unofficial NATO defense concepts.

[24] Several authors have compared the official doctrines or unofficial concepts that govern the planning of several NATO armies, including the two doctrines mentioned above. Quite different conclusions have been expressed depending upon the author's emphasis on official doctrine documents or "revealed" concepts as practiced. See Rogers, 1984; Wolf and Perry, 1986; for examples. They highlight a more important military issue. If coordination of wartime activities is important within armies, should it not be equally important within an alliance of several armies? Counterarguments can be made, appealing to the value of exploiting different nations' comparative advantages and of presenting the Warsaw Pact with a varied opponent. Also, attempts at formal standardization risk slighting the interests of the less powerful members of the alliance in favor of a few dominant ones.

[25] The term "theory of victory" is often used to refer to such presumptions.

[26] See Luttwak, 1987, especially Part I, for a description of the transience of advantage in a military competition.

[27] Except where otherwise indicated, discussions of the pace of change will pertain only to peacetime circumstances. Innovations of all types—in concepts, weapons systems, combat organizations, etc.—tend to occur more rapidly in wartime. Clearly, firsthand experience, especially of defeat, overcomes resistance more than vicarious or hypothetical experience.

cited failure to adapt as a reason why a particular army (e.g., the French army in both 1914 and 1940) lost (or nearly lost) a war; and while they frequently misplace responsibility—too often ascribing failures to generals' obstinacy or ignorance—they are right often enough to suggest that barriers exist to "rational" adaptation of concepts in the face of change.[28] Just as armies must "live with" expensive weapon systems for many years to recover their costs, so they may, deliberately or unconsciously, allow their concepts of warfare to persist nearly as long.[29]

The durability of concepts in a changing world puts a premium on selecting not those that are "certain" to work years in the future—for no one can claim such assurance—but those that are *well-hedged* against *uncertainty*. However, this has not been a priority in the U.S. Army's recent efforts to develop new concepts, because of the absence of tools to support such an approach.

IMPROVING THE CONCEPT DEVELOPMENT PROCESS: THE STAKES AND THE CHALLENGES

The U.S Army is undertaking the development of new concepts for the operational level of war[30] to formalize and rationalize their influence on training, organization, and equipment, which heretofore has been considerably less formal and of questionable salience. It is doing so at least in part out of a recognition that the military technical advances by probable adversaries (chiefly Warsaw Pact and client states) threaten to undermine its past reliance on technological superiority as a means of compensating for inferior numbers. As the technological margin on which NATO depends for the conventional element of flexible response diminishes, the doctrinal aspect of force quality assumes greater importance.

Because new concepts have the potential to profoundly affect the Army's peacetime shape and wartime prospects, and thereby influence larger security issues as well, the stakes in developing and choosing them intelligently are high. The techniques used must be equal to the challenge. They must be flexible enough to adapt to creative ideas, yet rigorous enough to give confidence in their conclusions. They must be broad enough to accommodate a wide range of alternative ideas—including "alternative concepts" born outside the bureaucracy—yet efficient enough to address uncertainties about the future. Finally, they must be explicit and numerical, to allow different concepts to be compared in the same framework, and to measure the benefits and costs of the adoption of new ideas.

PURPOSE AND ORGANIZATION

This report is the product of research aimed at making the process by which the Army develops and evaluates concepts more rigorous and more efficient. The suggested improvements are of three types:

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[28]This is the substance of the aphorism about armies "preparing for the last war."

[29]The escalating costs of major items of military equipment may further encourage inertia. New concepts often are stimulated only by the introduction of new equipment. If high costs limit the frequency with which new equipment is introduced, they will have a similar effect on concepts.

[30]The Army emphasizes the operational level of war because: (1) It has largely ignored this level in the past; (2) the Soviet Army is perceived as placing great emphasis on this level; (3) it is the highest level at which purely military (as opposed to politico-military) planning can occur. For a dissenting view suggesting the Army may have a unique ability to facilitate planning at the grand strategic or theater strategic levels, see Builder, 1987b, especially Secs. VI and VII.

1. A typology that allows different concepts to be described concretely and compared using a common vocabulary. The raw material for this typology draws from Army doctrine, NATO defense plans, and unofficial NATO defense concepts since the late 1940s.
2. A review of the strengths and weaknesses of the Army's current approach for developing and evaluating concepts (the Concept-Based Requirements System, or CBRS), and a proposed analytic framework to ameliorate some of the shortcomings; and
3. A microcomputer-based low-resolution Method of Screening Concepts of Warfare (MOSCOW), which can be used to refine and compare concept ideas in a systematic, quantitative way.

Section II describes the prerequisites of more systematic concept design and analysis. It points out several common errors in past efforts and outlines the proposed concept typology. Section III describes the Army's concept development and evaluation process under CBRS and suggests an improved approach that the army has largely accepted. Section IV describes MOSCOW, the most innovative component of that approach, and illustrates how MOSCOW can be employed to refine concept ideas and to screen among alternatives. Finally, Sec. V summarizes recommendations for improving the Army's concepts and the process by which it develops them.

The appendixes provide supplementary information on MOSCOW's inputs, how it represents concepts and campaign phenomenology, and how it computes the outputs used for comparing concepts.

II. TOWARD AN ANALYTIC TREATMENT OF DEFENSE CONCEPTS

While land defense concepts have been a staple topic of security policy debates since the 1950s, and dozens of concepts for the defense of NATO's central region have been published, there is no cohesive "concept community."[1] Rather, there are many partly overlapping groups with differing interests. Some emphasize improvements in the allocation of resources, advocating changes in weapon systems or in force structure. Others emphasize the peacetime location of forces out of concern for surprise attack. Still others are concerned primarily with the stability of deterrence.

In light of the wide scope of this policy area and the consequent fragmentation of the interested constituency, it is not surprising that little effort has been made to relate individual advocates' ideas systematically. Debates tend to be discussions of the pros and cons of particular concepts as if each were *sui generis*. Rarely are concepts compared in common dimensions. More rarely still do authors suggest "hybrid" ideas based on blends of more than one concept, or explore changes at the margin. Concepts are viewed as unchangeable packages, so the policy debate tends to simplistic yes-or-no assessments of proposed concepts rather than emphasizing new *designs* that try to combine the better features of *several* concepts.

The most important underlying problem is the absence of a framework broad enough to encompass a large variety of concepts and detailed enough to enumerate the essential attributes of each concept in a common vocabulary. Lacking such a vocabulary, policymakers and policy designers have no way of systematically choosing among alternative ideas, or combining the preferred features of each to create a new idea. As long as each concept designer must invent his own lexicon to describe his notion, it is impossible to distinguish substantive from semantic differences among concepts.[2]

The majority of this section is given over to the construction of the most important prerequisite needed for an analytic approach to defense concepts: a framework or typology that enumerates a set of descriptive dimensions intended to be applicable to a wide range of different concepts.

WHAT IS A "CONCEPT"? HOW DO "CONCEPTS" DIFFER?

To fashion the typology, official and unofficial concepts were reviewed that relate to ground defense from the late 1940s to the present. The search attempted to emphasize "warfighting concepts" (those stressing warfighting style, or "doctrine") at the operational level of war, but its scope was expanded because most concept authors failed to specify the functions of the level of warfare encompassing their concept. Ultimately, the following classes of concepts were reviewed:

[1]Although the approach to the design and analysis of land defense concepts presented here is intended to be applicable to a variety of possible theaters of war, virtually all published material regarding concepts pertains to the NATO central region. Consequently, the examples used will emphasize NATO.

[2]Goeller et al., 1973a, provide an early example of a typology of policy options. Goeller et al., 1983, extend the notion by partitioning its typology in a three-level hierarchy of tactics, strategies, and policies. The costs of the absence of a common vocabulary are eloquently presented, albeit in a different context, in Yoder, 1988.

1. U.S. Army doctrine (the Army's official warfighting concept) that most closely approximated the operational level of war, and concurrent divisional organization;
2. Unclassified information regarding NATO's planned main lines of defense;
3. Published material (books and journals) relating to either of these, and other unofficial "concepts" for NATO defense.[3]

Additionally, a few earlier historical cases were examined, mainly emphasizing armies whose ability to adapt their concept to changing circumstances met with reputedly extreme success or extreme failure. These cases were chosen as it became clear that they formed a fundamental and largely misused part of the intellectual foundation underlying many debates over concepts.

The scope of this research was so wide that in the space limitations of this report it would not be possible even to summarize the entire history. Instead, after the briefest of outlines to provide essential context, the sections that follow apply my interpretations of that history to the task of defining the elements of "concepts."

From the end of World War II to the present, the U.S. Army reissued its capstone doctrinal manual (FM 100-5, *Operations*) six times, at intervals of from five to eight years. Until the 1980s two features of the doctrine had been fairly constant. First, the manual stressed the conduct of a mobile defense until friendly forces acquired sufficient advantage to convert to the offensive. Doctrine implied that thus the employment of maneuver units at the tactical level would largely mirror the theater-strategic level: In the defensive phase of the war, almost all units would be conducting delaying and retrograde battles as they fell back on their final defense line, then with the opening of the offensive phase almost all units would be tactically employed in attacks. In each period specific features varied, but with the exception of the early and mid-1950s, the "mobile defense, followed by broad counteroffensive" concept prevailed.[4] Second, doctrine did not acknowledge a level of warfare between the strategic[5] and the tactical. As represented by official doctrine, theater campaigns were planned and overseen at the theater-strategic echelon and carried out by tactical units (divisions). Although there might be intermediate levels of command (corps, armies, or army groups), their function was assumed to be limited to coordination of subordinate echelons consistent with the intent of the theater-strategic commander. This intermediate level was recognized to be a managerial necessity (required to limit the theater-strategic echelon's span of control), but it had no substantive independent responsibilities.[6]

NATO's concept of defense has in the same period undergone quite profound changes. First, the alliance's reliance on tactical nuclear weapons for combat power early in a war (which is outside the scope of this report) has decreased dramatically. Second, the area to be

[3]U.S. Army doctrine and organization provided raw material for the definition of important attributes of warfighting concepts and organizational concepts. NATO plans assisted in defining the attributes of allocation and deployment concepts. Unofficial concepts broadened the sample and helped fill in the gaps.

[4]This phrase is my own invention. The names attached to doctrines varied, but "mobile defense" (leading to a later counteroffensive) was the common theme. With the Soviet acquisition of substantial theater nuclear capability in the late 1950s and early 1960s, the attention paid to the counteroffensive phase waned.

[5]The levels of war defined here follow Luttwak, 1987, and distinguish between grand strategy and theater strategy. Most nations are concerned about a single theater, so to them grand strategy would be largely irrelevant.

[6]This attitude stands in stark contrast to that of the Soviet army, whose improvised "strategic directions" of World War II (where a representative of the Stavka would be assigned to oversee and coordinate the activities of several Fronts) were later codified in permanent wartime command structures. The extent of the U.S. Army's rejection of an operational level is indicated by an article in the early 1960s by Walter Darnell Jacobs, a Sovietologist with strong official connections to the U.S. Army. Jacobs noted the revival of Soviet interest in the "operational" level, which he ridiculed as of "little apparent practical purpose." See, Jacobs, 1961, pp. 60–64.

preserved by a NATO "mobile defense" has grown equally dramatically. As shown in Fig. 1, the planned main defense line (as reported in credible but not authoritative unclassified sources) has moved eastward as NATO's absolute capabilities have increased and political requirements have emphasized the territorial integrity of the Federal Republic of Germany.

Unofficial NATO concepts have been patterned after changing political fashions and technological opportunities. NATO concepts of the 1950s generally attempted to deemphasize reliance on nuclear weapons and reduce superpower tension as a means of facilitating an eventual German reunification. By the mid-1960s, the "forward defense" of Germany had become an established goal of NATO's defense. The unofficial concepts of the 1970s attempted to reduce the costs of forward defense by utilizing precision guided antitank technology, which made its debut in the 1973 Arab-Israeli war, or by reducing the number of active forces in favor of increases in reserves, militia, territorials, etc. A greater variety of technology-oriented defenses have emerged in the 1980s. They generally have emphasized long-range or air-to-ground precision munitions or inexpensive defensive enhancements (fortifications, mines, and obstacles). Also in the 1980s interest has renewed among some German political elites in "nonprovocative defense" concepts that reduce or eliminate reliance on armored vehicles and ground attack aircraft, and in "initiative-oriented" concepts in most military and some American academic circles.

The sections below briefly summarize Army doctrine and NATO's official and alternative defense concepts in each period. The importance of the discrepancies between the Army's and NATO's "concepts" of a war is difficult to estimate. Certainly an army trained to fight in one style would bow to expediency if wartime circumstances required adaptation, but only at some cost—at least a temporary one—to its effectiveness. Additionally, since local commanders can typically adapt—or even subvert—written doctrine or plans for their specific circumstances, actual discrepancies are likely to be smaller than those implied by a naive comparison of written doctrine with reported plans.

The Late 1940s

U.S. Army doctrine emphasized a mobile defense, in which forces in contact with the enemy fought to delay their advance while withdrawing to a planned primary defensive line.[7] The ten active U.S. divisions were organized along World War II lines, although nearly all were manned at 4/9ths strength (with one regiment unmanned and only two of three battalions manned in the remaining two regiments). The defensive line was based on a defensible geographic or topographic feature (a river line, mountain range, or narrow peninsula), usually as far eastward as might be defended (using force-to-space planning factors) with either existing or not-implausible forces.[8] U.S. estimates were more pessimistic than European ones. For example, where the early JCS plans *Pincher, Offtackle*, and *Broiler* anticipated that Western forces might need to retreat to the Pyrenees or even off the European continent entirely, the Western European Union's Long-

[7]Published material on doctrinal issues was scarce in the 1940s. The most useful works are Clarke and Doan, 1952; Department of the Army, 1949; and Doughty, 1979. Doughty's monograph is a useful survey of the historical evolution of Army doctrine since 1946.

[8]The choice of the defensive line varied with the type of plan prepared. Operational plans would designate the defense line that planners believed could be held with standing forces (plus arriving reinforcements). Requirements plans chose a line and estimated the forces required to hold it. Theoretically, that line could be the border, but defending it would require implausible force totals. Generally, the line that protected the most important geography while requiring not-implausible forces was chosen. In a few cases, such as the JCS *Dropshot* plan, several alternative lines were described, but requirements were estimated for only one (the Rhine River).

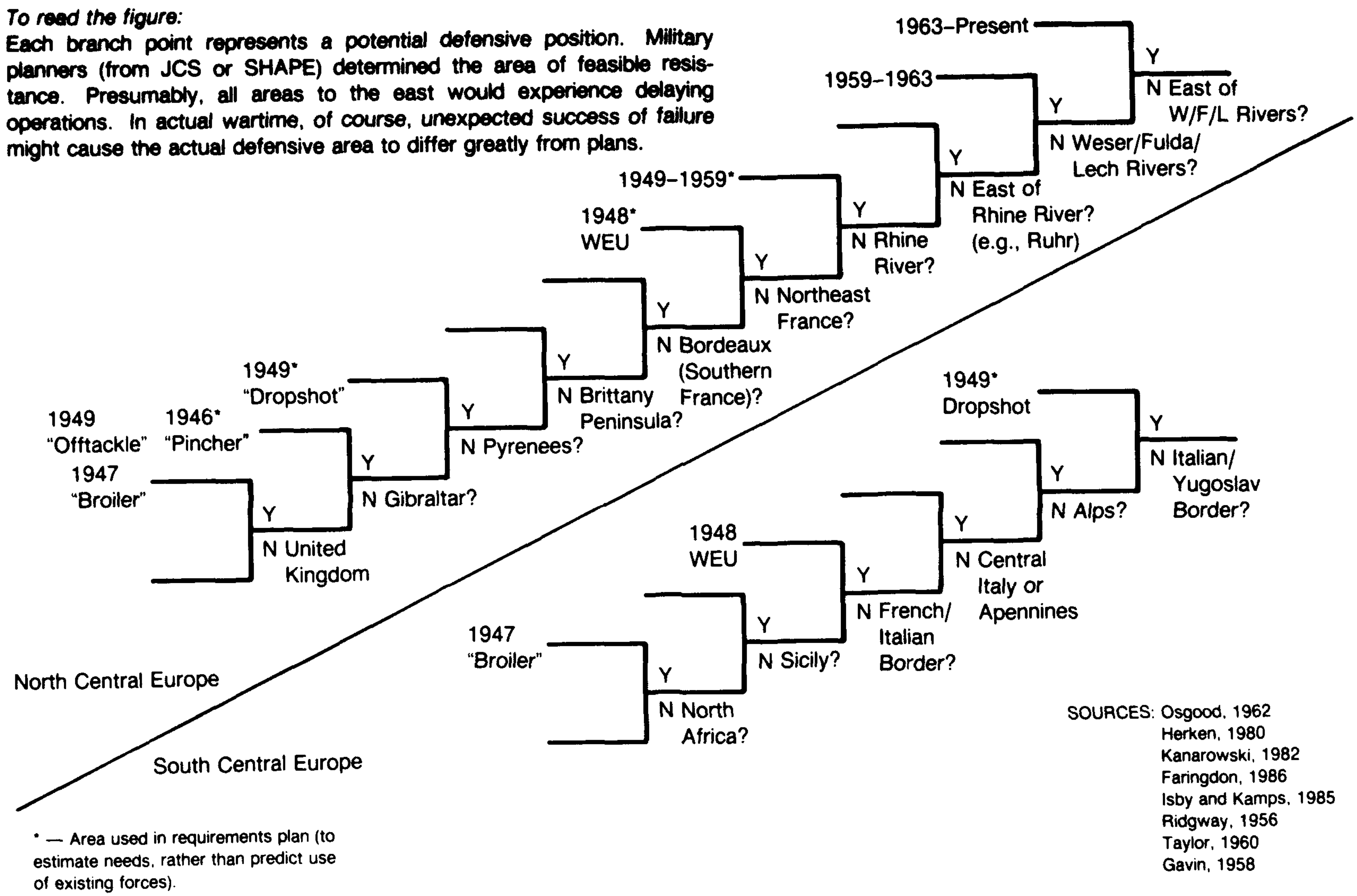

Fig. 1—Planned NATO defense lines, 1947–1960s

Term Defense Plan hoped to draw the line in Northeastern France (in 1948) or even the Rhine/Ijssel basin (in 1949).[9]

There was a disparity not only between U.S. and European plans, but between these plans and Army doctrine. Both U.S. and European concepts for Europe's defense called for a speedy withdrawal to a main defensive line in order to preserve as many frontline forces as possible. Army doctrine, codified in the first postwar Army Field Service Regulations of 1949, by contrast stipulated a fighting withdrawal in which U.S. forces remained in contact with the enemy and gave ground slowly.

The Early and Mid-1950s

The 1954 Field Manual 100-5 *Operations* codified the improvisations in tactics and organization developed during the Korean war. In Korea's broken terrain, against an enemy that infiltrated friendly positions in preparation for an attack, a mobile defense was considered impracticable. Successful U.S. defenses utilized a series of prepared defensive strongpoints; American units might be expected to hold a bypassed strongpoint for hours or days before a counterattack reestablished contact. Such a defense was described as an "area" defense,[10] indicating that friendly forces would occupy prepared positions in two dimensions rather than merely in a line.

The area defense offered few opportunities to exploit armor's mobility, instead relying on infantry to hold strongpoints and artillery to lay high volumes of fire on the expanses between them. Although that approach may have been quite suitable for defending in a dense fixed position (e.g., behind the Rhine, as called for by contemporary NATO plans), if implemented in the early hours of a Warsaw Pact invasion, it would have called for U.S. units to hold in position while allied units were withdrawing. Even a wholesale embrace of the NATO concept of rapid withdrawal and consequent rejection of area defense may have been impossible since, as Fig. 2 shows, it was in this period that the fraction of "heavy" divisions (which in the 1950s meant any organic ground transportation other than light trucks) was at its postwar low. U.S. forces, who discovered the limitations of vehicular transport in Korea, may have learned the lesson so well as to have inhibited the conduct of a mobile defense or even an operational redeployment if called upon to do so in a war in Europe.[11]

The first unofficial NATO concepts were published in 1954 and 1955 by a German journalist (Weinstein) and the chief of the operational plans division (von Bonin) of the predecessor office of the current German Ministry of Defense.[12] Both called for a defense closer to the border (within 50 to 100 km), relying on prepared positions to increase the combat power of defending units. Also at this time the 1955 Carte Blanche exercise, which simulated the use of over 300

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[9]Information on U.S. plans is from Herken, 1980, and Kanarowski, 1982. Kanarowski, 1982, and Osgood, 1962, provide European planners' views. Brown, 1978, has published substantial extracts of *Dropshot*, a declassified 1949 JCS requirements plan. For a fictional but informed contemporary view of how World War III might have proceeded, see Sherwood, 1951.

[10]This tactical concept was often proposed as an operational approach to NATO defense. It was usually termed "area" or "hedgehog" defense. For an example, see Dupuy, 1981.

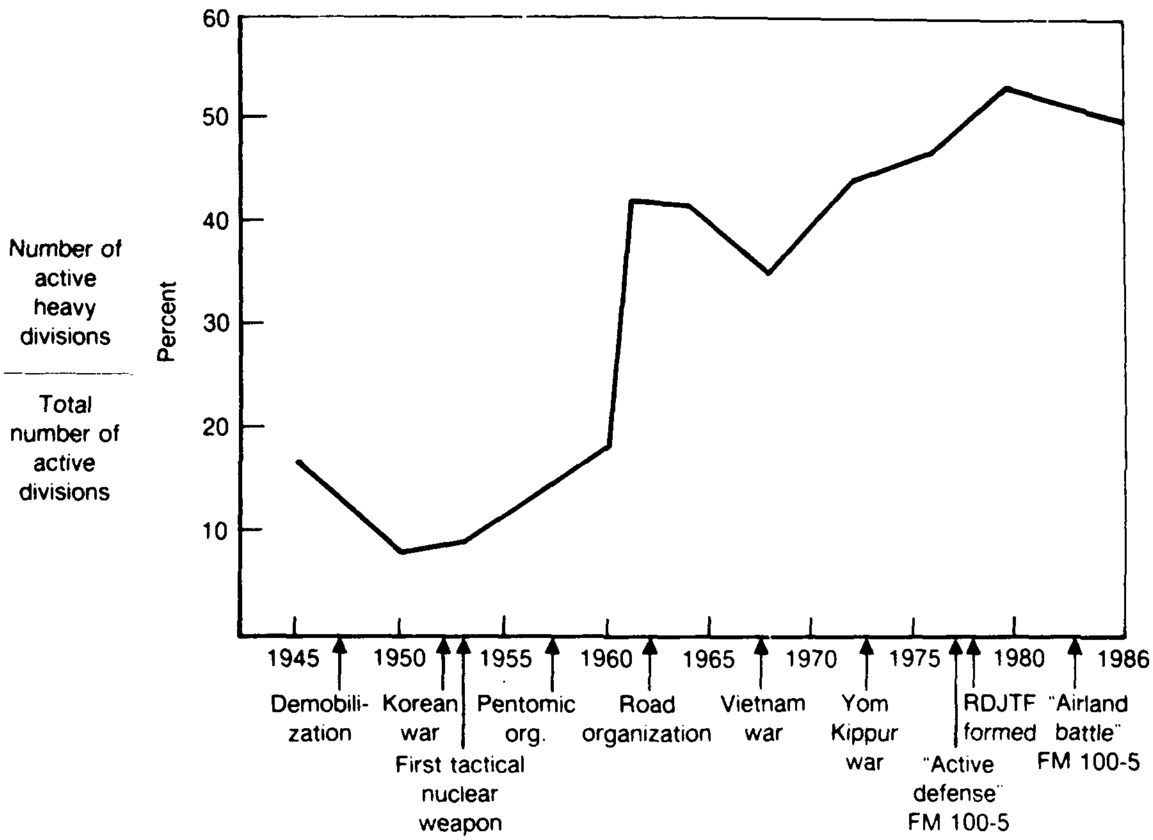
[11]Figure 2 probably exaggerates the situation, because U.S. forces in Europe in the late 40s and early 50s were well-equipped (relative to European counterparts) comparatively and additional forces were sent to Europe in 1951. Thus the Army-wide average may obscure differences between divisions in Korea and in Europe. Also, the figure refers only to divisions and does not indicate the availability of transportation assets from higher echelons. In this period a U.S. infantry division could typically lift somewhat over half of its troop strength at a time in organic vehicles, which in "light" divisions were 3/4 ton trucks. Airborne divisions had very little organic ground transport.

[12]Weinstein's and von Bonin's concepts are outlined in Kissinger, 1957.

atomic weapons, initiated a continuing controversy in Germany over the wisdom of reliance on atomic weapons for its defense.[13]

The late 1950s

While strenuously objecting to the Eisenhower administration's reliance on strategic nuclear weapons (so-called "massive retaliation") at the expense of ground forces—which were reduced from their Korean peak of 20 active divisions to 14 by the late 1950s—the Army



SOURCES: Mako, 1983, to 1980
IISS Military Balance 1986-87, 1986, for 1986

Fig. 2—Heavy/light mix of U.S. active Army divisions, 1945-1986

[13]Carte Blanche is an instructive example of the difficulties of using "signals" to buttress deterrence in a democracy. Member governments gave the press wide access to the exercise in order to convey to the Soviets NATO's willingness to employ tactical nuclear weapons, over which it had a brief monopoly, in Europe's defense. (All of the weapons in "Carte Blanche" were delivered by tactical aircraft.) The effect on the Soviets is unknown, but the unsettling effect on Germans (and some political elites in other European countries, especially the United Kingdom) was considerable. See Kissinger, 1957, for outlines of the early German concepts and German reaction to Carte Blanche. The surveys in Dean, 1988, and Gates, 1987, also mention these early concepts.

embraced the use of atomic weapons as a means of providing long-range firepower.[14] Budgetary motives were not the only ones. In this period the Army was profoundly shaped by the influence of three men, all former airborne division commanders: Chiefs of Staff Matthew Ridgway and Maxwell Taylor, and Deputy Chief of Staff for Research, Development, and Acquisition James Gavin. They emphasized the importance of technological innovation in ground warfare, which meant most of all three things: atomic weapons, missiles, and air mobility. They stressed the importance of lightening infantry divisions to enhance their strategic and tactical mobility, relying on atomic weapons to maintain or increase their firepower.[15]

Belief that atomic weapons would be part of the basic equipment of both U.S. and Soviet ground forces led doctrinal developers to emphasize dispersion on the battlefield as a means of compensating for the enemy's increased lethality. However, if units were to concentrate combat power in a small area to attack or defend against an attack, they needed to mass quickly, achieve their tactical objective, and disperse before the enemy could employ an atomic weapon against them.[16] This suggested to the airborne infantry generals that Army divisions should be lightly equipped and organized in units smaller than regiments to give the division commander greater flexibility.[17] The resulting division was organized in five "battle groups" of five companies each (where each company was somewhat smaller than its predecessor), instead of the contemporary three regiments of three battalions of three companies each. A program of Reorganization of the Combat Infantry Division (ROCID) and Armored Division (ROCAD) was initiated in the mid-1950s; the name given to the new division organization was the "Pentomic" division, which was introduced in 1956.[18]

The Pentomic division was the most controversial issue (after the Vietnam War) inside the Army for the next 20 years. Pentomic units were expected to conduct a mobile defense in which they would alternately mass and disperse, performing each quickly enough to avoid becoming a lucrative atomic target. Internal skeptics doubted the ability of a commander to control five, instead of three, subordinate units, especially in a nuclear environment; they questioned the feasibility of massing and dispersing rapidly enough to stay within what would later be termed the adversary's "decision loop" (or considered that estimates of the length of that loop to be exaggerated); and asserted that the Pentomic organization lacked vehicular mobility—organic trucks could lift only half of an infantry division's troops at a time—and conventional firepower. The latter of these concerns was partly ameliorated in 1958 when the infantry division's allocation of trucks and artillery was increased.[19]

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[14]"Long range" means different things to Army and Air Force audiences, and to different Army echelons, and has changed with technology. To Army doctrinal specialists, in this period, "long range" would mean beyond the line of sight, or perhaps five or more kilometers.

[15]The STRAC (Strategic Army Corps) as a component of Strike Command (STRICOM), an early incarnation of what later became the Rapid Deployment Joint Task Force (RDJTF), was formed in this period and continues today as the XVIIIth Airborne Corps.

[16]General Ridgway formulated many of the underlying ideas during his tenure as Commander in Chief of the Far Eastern theater, where he replaced MacArthur in 1951. The original testbed for these notions was in fact a South Korean reserve infantry division. Trials were conducted during the period between the Korean armistice and Ridgway's elevation to SACEUR in 1954.

[17]By contrast, the Soviet response to atomic weapons was to emphasize armor protection for infantry vehicles as well as tanks. The United States did not adopt this practice until the mid-1960s.

[18]Before the name "pentomic" was concocted, the term used by Taylor to indicate his emphasis on innovation was "Futurarmy." The concept probably suffered because its apellations were too creative.

[19]The best survey of this period is Bacevich, 1986. Taylor, 1956, outlines the Army leadership's essential motives behind the Pentomic concept, and White, 1955 (in an interview with Gavin) supplements this. Gavin, 1958, is a book-length explication of his basic tenets of theater-strategic atomic warfare. Other useful pieces on doctrine are Cushman, 1958; Eddleman, 1956; and Goldenthal, 1957. The Pentomic organization is discussed in Metcalf, 1960; and Shepherd, 1956.

In this period, NATO's plans relied on atomic weapons to destroy or disrupt a Warsaw Pact attack and allow friendly forces to form up on the Rhine. (The main defensive line was moved eastward to the Weser, Fulda, and Lech Rivers in 1959.)[20] The availability of atomic weapons caused SACEUR in 1957 to revise downward the number of divisions he estimated would be needed on M-day.[21] The creation of 12 active German divisions in the late 1950s narrowed the gap between estimated M-day requirements and available forces. U.S. Army doctrine, controversial though it was at home, was probably reasonably consistent with NATO's plans.[22]

The Early to Mid-1960s

With a new American administration committed to "flexible response," and with the retirement of the principal proponents of the controversial pentomic ideas, the Army attempted to adjust to a renewed emphasis on conventional combat. Doctrine and divisional organization was intended to be "balanced," allowing a substantial capability to campaign with purely conventional weapons or with a mixture of conventional and atomic munitions. Yet the legacy of the pentomic concept did not evaporate. In the Reorganization of the Active Division (ROAD), the same objective of improved command flexibility that had pervaded the pentomic idea was addressed by returning to a World War II expedient: the "task-organized" combat command.[23] The intermediate echelon between division and battalion was called a brigade, which theoretically would be assigned forces according to its mission. At lower levels, the practice of "cross-attaching tanks, infantry, and other weapons from several units to form "teams" was fostered. Armored and infantry battalions were standardized, so that an "armored" division merely had a different mix of the two types than an "infantry" division.

The equipment for ROAD divisions emphasized helicopters (for observation, transportation of small units, or air attack) and armored personnel carriers.[24] With these changes in organization and equipment came a new edition of FM 100-5 in 1962, which reaffirmed the importance of being prepared for both conventional and nuclear combat and recast the late 1940s "mobile defense" concept to reflect new weapons and organizations.

Mobile defense diverged from NATO plans in the late 1940s, but they converged in the late 1950s. After 1963 mobile defense again diverged from NATO plans, which shifted the main defense line still farther eastward to within 30 to 50 km of the Inner German border.[25] Army and NATO concepts also differed, at least formally, in their expectations regarding how

[20]Faringdon, 1986, p. 260.

[21]Osgood, 1962. The attrition these divisions were expected to suffer, as well as the eastward move of SACEUR's main defense line, prompted a little-noticed upward revision in the number of divisions required at M plus 30 days. Political realities may have also influenced the deflation of M-day requirements. By 1955, the date by which NATO nations had committed themselves to meet the 1952 Lisbon force goals, there were actually fewer divisions available on M-day than three years earlier. (France and the United Kingdom had each withdrawn forces to attend to colonial responsibilities.) Unreachable as they were, the Lisbon goals were actually slightly lower than the requirements estimated by Montgomery's staff in the 1948 Long-Term Defense Plan.

[22]The pentomic concept of warfare was never codified in an edition of FM 100-5.

[23]In 1944-45 U.S. armored divisions maintained no standing organizations between the division and its component battalions. Instead, three (sometimes four) "combat command" headquarters were maintained, which would be assigned battalions on a temporary basis. Typically two combat commands (A and B) would be in action while a third (Reserve) would administer battalions that were resting or in reserve. The cost of ROAD's flexibility was of course the loss of permanent command arrangements and - in the view of its critics - cohesion and morale.

[24]Unlike the Soviet BMP, which was introduced in 1967, U.S. M-113 APCs were not equipped to protect against nuclear radiation.

[25]Faringdon, 1986, p. 260. Isby and Kamps, 1985, show latter-day corps deployments in three segments: a covering force area of 30-40 km in depth, a main battle area of 40-50 km, and a rear area of 30-60 km.

early in a war nuclear weapons might be employed. Although NATO ministers did not formally endorse flexible response until 1967, informal convergence at the military level had in fact begun earlier.

The Late 1960s and Early 1970s

This period was dominated by the Vietnam war and the need to develop more effective tactics for counterinsurgency warfare.[26] The Army's increased emphasis on airmobility that had first been voiced in the mid-fifties, then given added impetus by the Kennedy administration, crystallized in the conversion of a cavalry division to the 1st Air Cavalry Division in 1965.[27] This was the first Army division to be employed in division-level offensive combat operations in Vietnam.[28]

The inevitable drain of personnel, resources, and doctrinal emphasis into the counterinsurgency effort is symbolized by the 1968 FM 100-5, which was notable for its generality—it was trying to set doctrine simultaneously for counterinsurgency, conventional, and nuclear warfare. Perhaps the purest example of this ambivalence (or more accurately, tri-bivalence) was the creation in the late 1960s of a "TRICAP," or (triple capability) division, which was composed of one brigade each of armor, helicopter-borne (airmobile) infantry, and attack helicopters.[29] This was an attempt to internalize the presumed synergy among these different combat arms in a single division. The TRICAP organization might have been highly useful in a conventional conflict, but it had the misfortune of being tested first in a counterinsurgency, where its attack helicopters and armor were of lesser utility. In this period also came the only dip in a general trend to a heavier mix of divisions that prevailed from 1960 to 1980, a natural consequence of the Army's deployment to Vietnam.

The Mid and Late 1970s

Several trends culminated to provoke a sea change in Army doctrine in the mid-1970s. First, many of the Army's leadership (and others outside) believed that the service lacked a clear idea after Vietnam of what its mission was, an uncertainty that was nourishing the Army's dismal morale. Second, the quantitative Warsaw Pact threat in Europe had grown substantially since the mid-1960s. Five Soviet divisions had remained in Czechoslovakia after the 1968 invasion, increasing the number of Soviet ready divisions near NATO's western border by almost 25 percent, and those divisions were much stronger than before: The number of tanks per division had increased by as much as 66 percent.[30] Third, the qualitative threat had increased, as the BMP armored personnel carrier and the T-64 and T-72 tank replaced 1950s-vintage equipment, and the high state of readiness of Soviet divisions in Eastern Europe raised

[26]All discussions of routine doctrinal adaptation in Vietnam emphasize tactics at battalion level and below. This may reflect a lack of command emphasis on higher levels of warfare, or it may simply be a product of the authors' desire to emphasize whatever is most distinctive about that war.

[27]The Howze Board, the Army's internal study group commissioned in 1962 to assess the Army's aircraft requirements, had recommended that five such divisions be created or converted. In the end, 2-1/3 were so constituted.

[28]1st Cavalry was tested in battle in the Ia Drang valley operation from 18 October to 24 November 1965. See Heller and Stofft, 1986, for a good comparison of peacetime airmobile tactical doctrine and the division's adaptation under fire.

[29]See Norton, 1971, for a glowing description of TRICAP's performance in a contemporary exercise.

[30]Adomeit's chapter in Pierre, 1986, p. 102 (footnote 70), citing figures in Lothar Ruehl, *MBFR: Lessons and Problems*, Adelphi Paper No. 176, International Institute of Strategic Studies, 1982. Ruehl's figures are for the 1965-79 period, but Galen, 1978, data, which cover the mid-1960s to the mid-1970s, tell a similar story. Ruehl estimated that overall the Pact introduced 4.4 new major equipment items per NATO addition.

concerns about the threat of a "standing-start" or short warning attack.[31] Finally, similar growth in Soviet intercontinental nuclear capabilities deepened longstanding concerns about the credibility of NATO's flexible response doctrine. For all these reasons, a doctrinal "return to Europe" made sense to the Army.

The 1976 edition of FM 100-5 signaling this return was unquestionably the most wholesale redefinition of the postwar period of the Army's official view of how to conduct war.[32] The "Active Defense" doctrine, as it was later termed, emphasized "winning the first battle of the next war." A future war in Europe would be different from any the Army had experienced: For the first time it would face a foe that was both numerically superior and qualitatively nearly equal to U.S. forces. Conducting a defense—as was considered imperative, at least initially, in light of numerical disparities—that exploited natural defender's advantages and husbanded losses was considered the first priority. Recent developments in long-range, highly accurate (precision-guided) direct fire weapons heralded in the early days of the October 1973 Arab-Israeli war were viewed as a revolution that could immeasurably assist the defender if they were properly harnessed.

The key propositions of Active Defense were:

- A defender's traditional tactical advantages (concealment, protection, prepared fields of fire, etc.) should not be lightly sacrificed;
- New weapons will magnify those advantages, by allowing the defender to bring an attacker under fire at longer distances, (potentially) before he can return fire;
- To use them to their full potential, the enemy's attacking units must be forced to concentrate, which gave the defender's covering force a new mission of increased importance: to impose attrition and force concentration;
- Numerical disparities were likely to be so great that the defender would probably be obliged to deploy all (or nearly all) of his units forward merely to cover the front line, holding few reserves, then move units from fairly quiet sectors (laterally) to those most threatened as the axis of main attack became apparent.

Each of these propositions has been criticized. The debate over the 1976 FM 100-5 reached apocalyptic proportions, far exceeding the controversy that accompanied the pentomic idea. This report does not argue the pros or cons of Active Defense, or any other concept; There is a voluminous literature available to do that.[33] One salutary aspect of Active Defense, however, is that its propositions are explicit, or at least not difficult to identify. The theory of victory underlying the active defense doctrine is identifiable and thus (theoretically at least) subject to testing.

Criticisms of Active Defense led to the development of two strains of thinking that influenced later doctrine. The most common criticism was that the doctrine exaggerated the

[31]Earlier NATO planning assumptions stipulated that as a best estimate, the Warsaw Pact would not attack until 30 days after mobilization, whose preparations would be detected within seven days (yielding 23 days of warning time for NATO). See Isby and Kamps, 1983, p. 15. Concerns were raised in the mid-1970s that these assumptions might be overly optimistic; although SACEUR Alexander Haig indicated his confidence that preparations could be detected within approximately this interval, the controversy continued. It abated in the mid-1980s largely because other issues (e.g., sustainability) dominated the debate and because Soviet preparations for the invasion of Afghanistan in 1979 superficially called into question the plausibility of a standing start or limited mobilization attack.

[32]Only the pentomic idea, which was never formally documented in a capstone manual, might approach the extensiveness of the 1976 FM 100-5's departure from past codified doctrine. See Department of the Army, 1976a.

[33]Besides the 1976 FM 100-5, the most persuasive defenses of "Active Defense" are DePuy, 1979; and DePuy, 1980b. Criticisms far outnumber defenses. The more thoughtful ones are Baxter, 1981; Blumenson, 1979; Holder, 1985; A. Jones, 1978; Sinnreich, 1979; Romjue, 1984b, offers a good summary of the process of intellectual change regarding Army doctrine from the mid-1970s to early 1980s.

advantages of the defense and in so doing ignored other compensating or even greater advantages accruing to the combatant who held the initiative (usually by attacking, always by behaving "unpredictably.") Around this simple notion the "maneuver warfare" school coalesced. This report will not delve too deeply into the "maneuver" debate, other than to indicate that proponents of maneuver and its stepchild "defense reform" have argued that the American tradition of land warfare excessively emphasizes predictable, slow-moving, conservative, technology-dependent warfighting styles. This misplaced emphasis (in the view of maneuver advocates) so pervaded the military establishment that its correction entails changing basic philosophies pertaining to training, equipment, doctrine, combat and administrative organization, acquisition procedures and organizations, and more. "Maneuver warfare" had strong and capable advocates within the Army, who greatly influenced the succeeding FM 100-5.

The second criticism sprang from a much smaller group, primarily the commander of TRADOC in the late 1970s, General Donn M. Starry, and a few who thought similarly. Starry, who had recently served as the commander of V Corps in Germany, felt that all previous doctrine (including active defense) had had a far too restrictive, tactical emphasis: It focused on what he termed the "close battle" and ignored the "deep battle" behind enemy lines and the "rear battle" behind friendly lines that might be equally important. In essence, he wanted doctrine to impel commanders to recognize the interactions among these three battles and between air and ground operations. In sum, FM 100-5 *Operations* had never truly treated the *operational* level of war.

Active Defense also spawned an abortive divisional reorganization. The authors of the doctrine, chief among them General William DePuy, Starry's predecessor as TRADOC commander, believed that the pace of combat might be so intense as to overwhelm tactical commanders. From this premise the mid 1970s Division Restructuring Study (DRS) had made several controversial recommendations, chiefly intended to reduce the span of control for which company and platoon commanders were responsible (tank platoons, for example, would be composed of three instead of five tanks) and the scope of weapon types over which they exercised responsibility (companies would normally be composed of a single major weapon type). Because in a military organization the number of qualified opinions available on organizational issues is inversely related to the issue's echelon, there was no shortage of published dissent.[34] Ultimately DRS was terminated, but its ideas were incorporated in another organizational study (Division '86) initiated by General Starry in the late 1970s.[35]

Alternative NATO concepts in this period largely mirrored trends in U.S. Army thinking. Their authors were also impressed with the intensity of the 1973 Arab-Israeli war and the demonstrated lethality of precision-guided munitions (PGMs). In the mid-1970s several concepts were published that emphasized a NATO force structure with less flexibility but more defensive capability. Some ideas stressed making peacetime defensive preparations (fortifications and obstacles in varying degrees of political obtrusiveness), such as Tillson, 1979, and others emphasized reducing costs by reducing the number of active forces in Germany and relying more on reserves or militia, such as Hunt, 1973. Still others advocated mixtures in which preparations could buttress the capability of nonactive forces, such as Canby. Horst Afheldt offered one of the first of a series of

[34] Many thousands of Army officers have commanded platoons or companies, but very few have commanded corps, army groups, or theaters. The junior officers also probably have a greater incentive to publish opinion pieces in military journals in order to gain exposure.

[35] DRS proposals are outlined in Foss, Pihl, and Fitzgerald, 1973; and Gibbs, 1978.

suggestions to reduce manpower by deploying very large numbers of anti-tank PSMs.[36] His "teknocommandos" were envisioned as small units manned by local reservists or militia who used their knowledge of the local terrain to conceal themselves and attack invading armored columns as they passed by. Toward the end of the 1970s, general treatises on the importance of the offensive[37] began to appear, largely in reaction to the PGM and enthusiasts.

The 1980s

The two themes of criticism of Active Defense—the need to reemphasize initative and the offense and the need to raise the focus of mid-level officers above the close battle (or tactical level of war) combined in the production of another completely rewritten edition of FM 100-5 in 1982.[38] Because its predecessor had been the center of controversy, it is not surprising that the 1982 "AirLand Battle" was similarly disputed, although the debate was less one-sided.

While agreeing with the authors of AirLand Battle (ALB) that its predecessor, the Active Defense doctrine, seemed to be too unconditional in its support of defense as the preferred tactic, many serving officers felt that ALB erred in overemphasizing the conditionality of *any* prescription, and consequently failed to provide many concrete suggestions. Clearly, ALB reminded the Army—in very general terms—that the offense could have advantages too, but the field manual offered little useful guidance regarding either the magnitude of those advantages or the conditions under which they could be best exploited.

This criticism, then, was a functional one: ALB failed to achieve its objective of providing decision principles that could be used in combat and guide training. The Active Defense doctrine had been quite clear as to its theory of victory: a defender needed to achieve highly favorable rates of exchange with an attacker. Against the attacker's expected warfighting style, and in "normal" circumstances, this could best be done by utilizing the protection of position and by engaging targets at long ranges. That ALB had a quite different theory of victory was apparent by its frequent references to initiative and audacity, which indicated its authors' view that in some circumstances advantages to attacking might be great enough to compensate for the sacrifice of those of the defender. But what exactly were those advantages, and what were the circumstances? And what did this imply about the frequency or type of attacks that should be undertaken? On all these questions the ALB manual and the succeeding publications by its defenders have largely been silent.[39]

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[36]Ahfeldt described his concept in Stockholm International Peace Research Institute (SIPRI), 1978.

The initial success on October 8, 1973, of Egypt's defense against a hasty Israeli counterattack spawned a voluminous and continuing debate about the future of armored vehicles on a modern battlefield. A tank/helicopter exchange ratio of better than 19 tanks lost per helicopter lost was reported in field trials in 1972. This was used as ammunition by those who saw PGMs as the death knell of the tank and NATO's means of securing an affordable, "defensive" conventional defense. On the tactical interpretation of this technological development, see Lennon, 1972; Nihart, 1972; or Ogorkiewicz, 1971; For policy prescriptions, see Kennedy, 1979; Quester, 1978; or Walker, 1978, 1981. The obscurity of the true "lessons" of these experiences, and the flaws in the thought processes underlying these arguments, are suggested below.

[37]Early writings emphasizing the tactical level include Evans, 1977; and Even-Tov, 1979. A discussion of some of the common logical flaws in debates about NATO "offensives" will be found below.

[38]An early, and in many respects less ambiguous, version of AirLand Battle doctrine was published as TRADOC Pamphlet 525-5, *The AirLand Battle and Corps 86* in March, 1981 and in slightly abbreviated form in Starry, 1981, pp. 31-50.

[39]Advocates often refer to the rigidity of Soviet Army plans and command arrangements and ascribe great prospective advantages to their disruption by unpredicted Blue actions. Certainly the reminiscences of German officers who fought against the Soviets in World War II support the thesis that, at the tactical level, individual soldiers and small units (perhaps up to battalion size) sometimes lost all effectiveness when confronted by an unexpected German initiative. See, for example, DePuy, 1980b, or von Mellenthin and Stolfi, 1984. The applicability of this experience to a contemporary war, or to higher levels of warfare, remains to be demonstrated. The basic thesis is quite plausible but demands much more proof than ALB advocates have mustered.

The second criticism was rooted in policy disputes about the appropriateness of "offensive" doctrines within a defensive alliance. Europeans, particularly Germans, were concerned that the potential provocation and exacerbation of the Warsaw Pact's concerns about NATO aggressiveness might harm the stability of deterrence more than any putative increase in conventional capability might help. ALB was published at a time (1982) when intra-alliance tensions over the planned introduction of new intermediate-range nuclear forces in Europe were nearing their peak, and when many political elites, especially in Europe, were questioning the wisdom of "provocative" changes in NATO's forces or defense concept. Concerns were further fueled by publication in 1984 of NATO's concept of Follow-on Forces Attack (FOFA), which aimed to exploit long-range PGMs and improved intelligence capabilities to delay the arrival and reduce the effectiveness of Warsaw Pact operational and strategic echelons arrayed behind the first invading echelon. To this miasma of political controversy a proposed long-range U.S. Army warfighting concept, AirLand Battle 2000 (later renamed Army 21) was added, which gave even greater rhetorical emphasis to attacks than ALB. AirLand Battle 2000, which was an embryonic idea in 1982, unfortunately was released to the press not long after ALB, with predictable confusion.

At about the same time that the ALB manual first began development, in the late 1970s TRADOC undertook to redesign Army divisions (Division 86), later broadened to include higher-level formations as well (Army 86).[40] The primary motivations behind this redesign were to accommodate new models of major equipment items (e.g., the M-1 Abrams tank and the M-2 Bradley infantry fighting vehicle) and to streamline the size and weight of divisions to reduce the amount of lift required to transport them to distant theaters such as Southwest Asia.[41] The experience of concurrently attempting to develop doctrine and to design organizations led Starry to establish a new procedure for long-range planning, the Concept-Based Requirements System, which is described in the next section.

In the 1980s the number of alternative NATO defense concepts mushroomed, and more of the enduring aspects of NATO's official concept came under question. They may be grouped temporarily in four categories:

(1) *Nonprovocative concepts* that stress the reduction or withdrawal from the Inner German border of "offensive" weapons systems, chiefly armored vehicles and ground attack aircraft (such as that of Von Bulow, 1986), or that rule out organized military resistance altogether, relying on passive resistance or guerilla-like insurgencies (such as those of Ebert and of Nolte, but described in SIPRI, 1978);

(2) Concepts that emphasized greater reliance on *terrain preparations* to protect defending units near the border and to delay invading units (such as those of Bailey, 1984, and Canby, 1980);

(3) Concepts that relied on more effective means of directing weapons against targets at *long range*, to destroy maneuver units or delay their advance (such as Hannig, 1986, Cotter, or Sullivan);[42] and

(4) Concepts that placed increased emphasis on *attacks by friendly maneuver units* at some level of warfare (ranging from the theater-strategic level, as recommended by Huntington, 1984, to the operational level, as recommended by a variety of authors, including Gow, 1981).

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[40]Romjue, 1979 and 1980, provide a detailed description of both projects and chronicle the upward revision in division size in the course of the study's several phases.

[41]This latter objective had taken on new importance following the abdication of the Shah of Iran in early 1979 and the Soviet occupation of Aghanistan in late 1979. In the end, little reduction in division size was achieved.

[42]In European Security Study, 1983.

The last two categories were variations on, or specific proposed implementations of, FOFA and of a theater-level version of ALB. The first two generally were European reactions to these notions, ranging widely in the degree to which they would deviate from NATO's baseline concept.[43]

Army 21: An Attempt to Develop the U.S. Army's Concept for the 21st Century[44]

Drawing upon the ALB/Army 86 experience as an indication of the value of concepts in facilitating force design, in 1981 TRADOC initiated work on a proposed new concept. Originally intended to have a short time horizon (eight to ten years) mainly to influence organizations rather than research and development, Army 21's horizon was later extended into the first quarter of the 21st century (nominally 2015 to 2025).[45]

Army 21 redoubled ALB's offensive emphasis while assuming a changed technological environment. Reconnaissance/strike technology was assumed to prevent all but the briefest concentrations of forces (harkening back to the pentomic idea) or logistics. Blue maneuver units would therefore remain dispersed and hidden while awaiting opportunities to engage the enemy and, if required to concentrate, would engage briefly and before breaking off and dispersing again. This style of fighting precluded the use of blocking defensive positions except perhaps for brief ambushes. An invading enemy would be allowed to move forward in corridors canalized by terrain preparation (if possible), and attacked frequently and briefly as he moved. Since Soviet doctrine was assumed to remain unchanged (in spite of this radical change in the doctrine of his opponent), Soviet columns were expected to press on, allowing Blue units to redeploy and repeat the cycle of concentrate, ambush, and disperse—a sequence designated "Scan, Swarm, Strike, and Scatter."[46]

The key features of Army 21's warfighting concept, then, were: dispersed deployment in depth, with rapid concentrations in order to ambush promising targets; brief engagements; a willingness to temporarily cede territory to the invader's advance while attriting him through these ambushes; and an almost complete avoidance of tactically defensive engagements.[47] These last two features met with the vociferous objections of the then-Supreme Allied Commander, Europe (SACEUR), General Bernard Rogers, who correctly insisted that such an approach would hardly be palatable to NATO allies. Many other objections were made regarding the assumed existence of various technological solutions to difficult practical problems, such as the resupply of dispersed covert units behind the enemy's vanguard.

Army 21 did have the great virtue of wearing its theory of victory clearly on its sleeve, almost as manifestly as Active Defense and much more than ALB. This clarity was largely lost, however, in the process of "coordinating" the concept's draft description. Objections—particularly those made by, or expected from, SACEUR and U.S. allies—were met by making

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[43]Some of the issues and some of fallacies often employed in debates about NATO concepts are described below.

[44]The planning context of the Army 21 concept is taken up in the next section. This section summarizes a few of the concept's important features so that it may be included in a general typology of defense concepts.

[45]The story of the development of Army 21 is summarized in Ben-Horin and Schwartz, 1988.

[46]The Soviets might instead choose to stand and fight, or to delay their advance in order to flush out potential ambushers. The Army 21 concept did not address these possibilities.

[47]Army 21 is described in U.S. Army, 1985. Several people in TRADOC's Combined Arms Center Development Activity (CACDA) provided briefings and discussions concerning this concept.

semantic adjustments in early drafts so that Army 21 was both "revolutionary" and "evolutionary,"[48] and therefore neither.[49]

COMPONENTS OF A SYSTEMATIC COMPARISON OF CONCEPTS

Comparing concepts in a common typology, or general framework, requires that we make abstractions and simplifications from the details of each individual concept to determine its essentials and compare them with the essentials of others.

Any attempt to synthesize and generalize must by definition omit detail. Proponents of particular concepts will naturally feel that some essential nuance has been overlooked. The illustrative classification of concepts into particular categories is meant only to indicate a concept's emphasis and in no way implies that concepts cannot fit simultaneously into multiple categories. Because this entire endeavor (the analytic treatment of broad defense and war-fighting concepts) is breaking new ground, the typology laid out here is only a first step. Concept developers and analysts looking for a recipe or checklist will not find it here. They will find, it is hoped, a framework that will help them clarify their thinking and explain their ideas to others.

Some Dimensions of Comparison Drawn from U.S. Army Doctrine and NATO Concepts

How Much Ground to Give?[50] Figure 3 shows the eastward movement in NATO's planned main defense line from the late 1940s until the early 1960s (whereafter it remained essentially unchanged). Figure 4 indicates changes in the number of available and required divisions (as estimated by the U.S. Joint Chiefs of Staff or the Western European Union's planning staff before the foundation of NATO, and by SACEUR afterward) for defense of the Central Region.[51] Concepts that address levels of warfare below that of grand strategy can consider these parameters—maximum ground given and maximum forces available—to be requirements, or the threshhold values of evaluation criteria. Figure 3 shows one of the two most important changes in NATO's official concept:[52] the 40-fold decrease in the amount of ground the alliance is prepared to give.[53]

[48]Participants in the development of Army 21 distinguished among approaches to the design of concepts. They assumed the character of mantras after frequent repetition—soothing and familiar, but possessing little meaning. At their most substantive, "revolutionary" and "evolutionary" were proxies for long and medium time horizons (e.g., 30+ versus 15 years in the future).

[49]The chairman of the Army 21 steering group decided in early 1986 to classify future versions to deny access to foreigners and to excise references to the sequence of "scan, swarm, strike, and scatter" (known colloquially as the "four Ss"). The first act largely ended political controversy over the concept, but the second greatly clouded interpretation of Army 21's essential features.

[50]The following discussion focuses upon the "strategically defensive" phase of a NATO-Warsaw Pact war, which was assumed to last as long as two or three years in the JCS requirements plans of the late 1940s (e.g. *Dropshot*). Naturally, after stabilizing a defense, NATO might elect to counterattack to regain lost territory. That later "strategic offensive" phase of a war will not be treated here.

[51]Disparities between the ambition of the planned defense and estimated requirements can be noted, but a review of the history of NATO planning is beyond this report's scope. Possible explanations for the discrepancies include changing evaluations of the net effect of nuclear weapons on force requirements, increases in combat power per division, or political constraints on "acceptable" requirements estimates.

[52]The other is the alliance's changing reliance on early use of nuclear weapons, which is outside the scope of this report.

[53]Obviously, wartime exigencies will impel commanders to depart from their prewar plans, so NATO might well sacrifice more or less ground. Depending upon the planning context—requirements versus operations, and the degree to which it is used for other political purposes—these planned lines may or may not have been "realistic." If

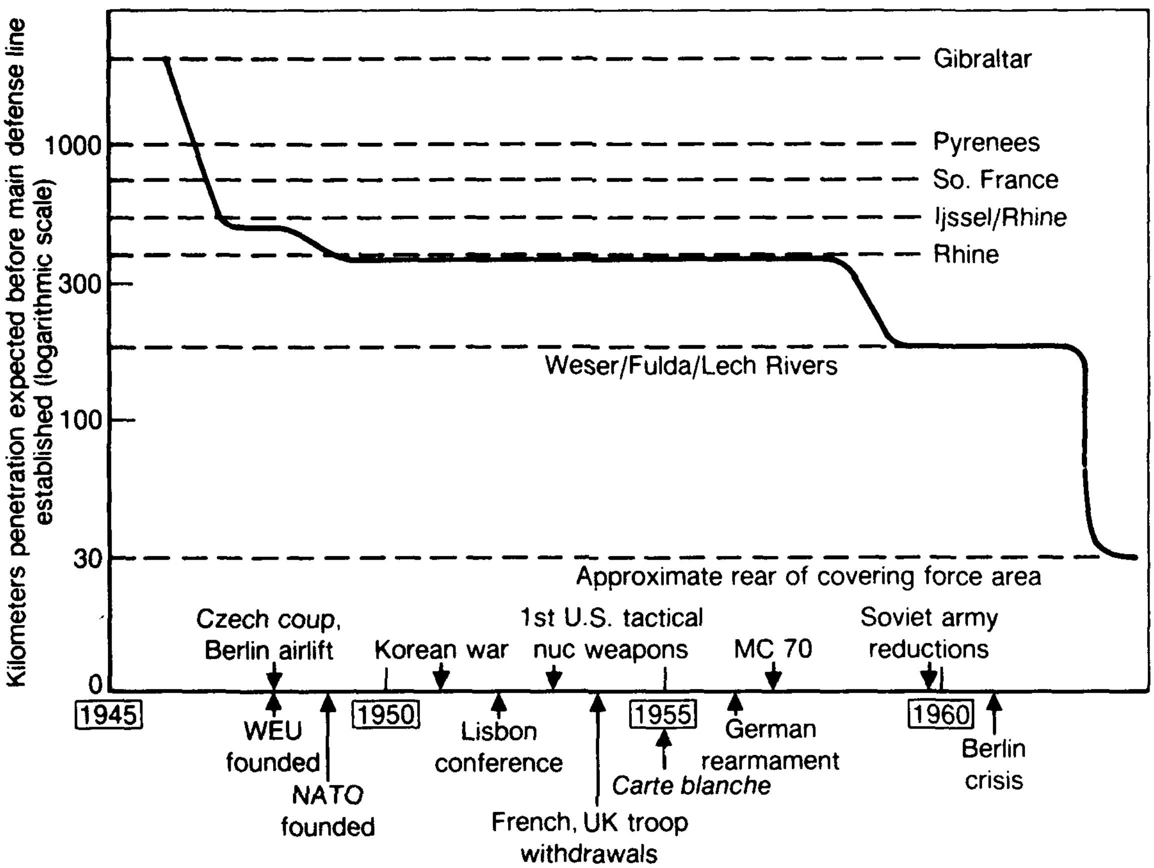

Fig. 3—Eastward movement of planned NATO defense lines, 1947–1963

How Deeply Are Forces Deployed? A forward defense, like the later official NATO concept, requires friendly forces to concentrate, or at least begin defending, near the hostile border. The more ground a concept is willing to cede, the more deeply echeloned friendly forces can be. Table 3 categorizes the deployments proposed under several alternative concepts and the current official NATO concept (termed the Baseline concept).[54] Concepts that recommend steps be made to prepare the border area (beyond those planned under the Baseline) are noted: For example, although von Bonin's concept proposes a fairly deep deployment of forces, he also contemplates fortifying the border area.

How Are Active and Nonactive Forces Deployed? Table 4 indicates how different concepts propose to deploy active forces and notes those concepts that envision changing active forces from predominantly armored and mechanized infantry divisions into "light" forces. In

SACEUR's requirements estimates were accurate, than the gap between available and required forces is a proxy for the plan's "unreality."

[54]Most of these concepts have titles, but many of the titles confuse as much as enlighten. I chose to use authors' names whenever possible to identify concepts unambiguously.

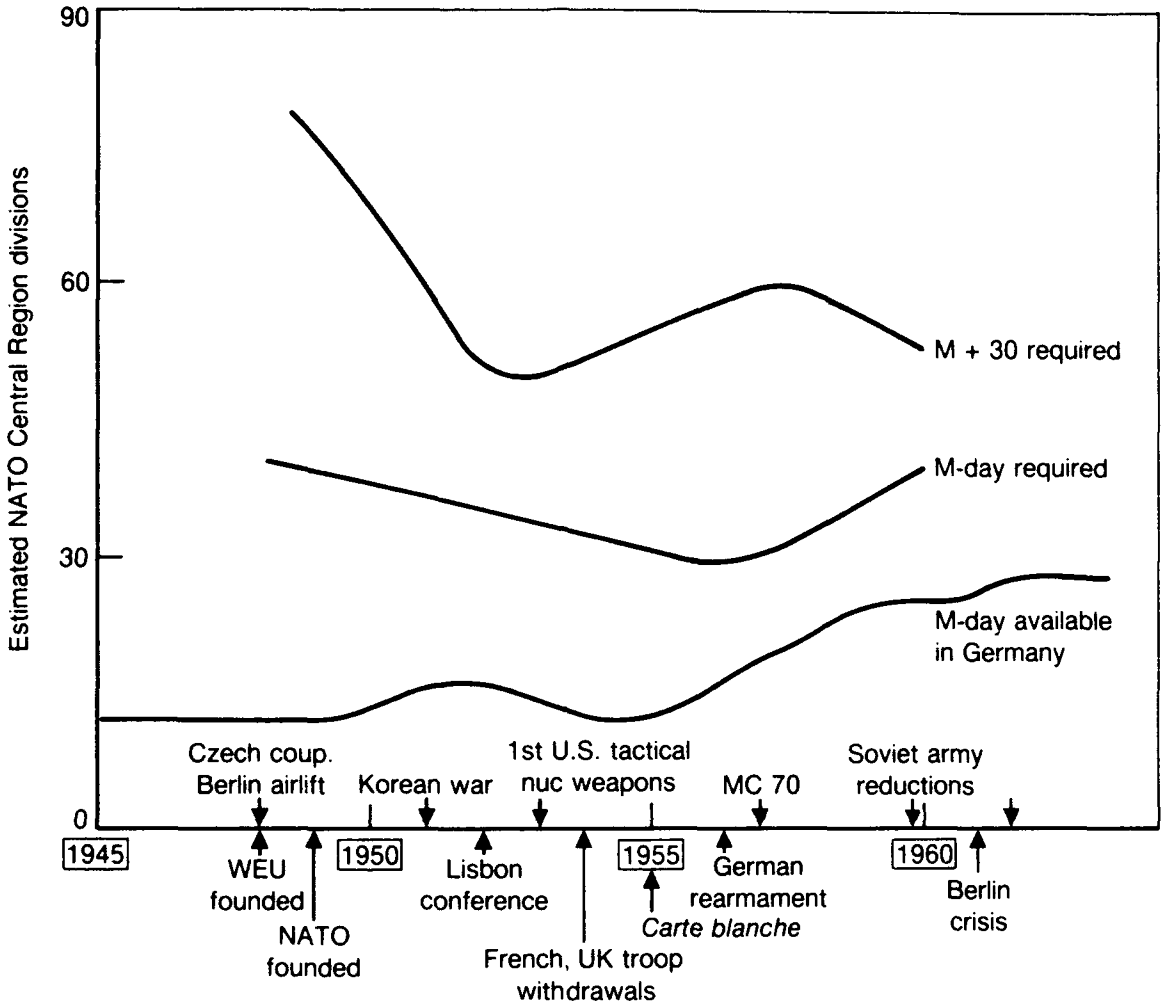

Fig. 4—Divisions required vs. available in the NATO Central Region, 1947-1963

nearly all these concepts, the principal motive for greater reliance on nonactive forces[55] is to reduce costs; consequently, reserves are usually envisioned as lighter than active forces, with equipment assumed to be cheaper than heavy vehicles.

Some concepts envision the forward deployment of actives because they are expected to be the first available (and needed early in the event of a short-warning attack), or are the best trained and equipped to deal with an intense combined arms attack. Others utilize actives to absorb the main blow after it has been channelled and weakened by forward nonactives or in an operational reserve role.

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[55]"Nonactive" in this case refers to any units constituted from other than active duty personnel, to include reserves, territorials, militia, and home guard.

Table 3

DEPTH OF DEPLOYMENT UNDER SOME NATO CONCEPTS[a,b]

<30 km	30-50 km	50-100 km	100-200 km	Most of FRG	Other
Hanning, 1986[a]	Afheldt, 1976	Afheldt, 1983	Loser, 1980		Nunn, 1977: Shift some peacetime forces from CENTAG to NORTHAG
Tillson, 1979[a]	Canby, 1980	Loser, 1980[a]			
Cangy, 1980[a]	von Mueller[a]	von Bonin, 1955[a]	· Dupuy, 1981 ·		
Bailey, 1984[a]		von Bulow, 1986			
		Chaplin, 1975			
		McCaffrey, 1981			

[a]The author has indicated that defensive preparations would be made in this zone.

[b]Concepts not cited in the Bibliography under the names shown may be found in Alternative Defense Commission, 1983; Dean, 1988; Gates, 1987; or Levine et al., 1982.

Table 4

PREDOMINANT DEPLOYMENT OF ACTIVE FORCES UNDER SOME NATO CONCEPTS[a]

Border Area	Main Defense Area	Reserves Area	Rear Area	Few or No Actives Used
von Bonin[b]	Hunt, 1974	Loser		
Baseline	Tillson	von Mueller	—	Nolte
	von Bulow	Carver		Slessor
	Canby	Mendershausen, 1976		Liddell-Hart, 1967

[a]Concepts not cited in the Bibliography under the names shown may be found in Alternative Defense Commission, 1983; Dean, 1988; Gates, 1987; or Levine et al., 1982.

[b]The author proposed that most or all active units be light forces. Nearly all authors recommeded that nonactive units be made up of light forces.

What Changes in Equipment Would Be Needed? Table 5 groups alternative NATO concepts in terms of their principal technological emphases (if any).[56] The three principal categories are air attacks against ground targets, ground attacks against ground targets, and mobility. The first group is subdivided between "nonprovocative defense" concepts, which propose eliminating ground attack aircraft, and those aiming to improve the effectiveness of air attacks. The second group is subdivided between emphasis on direct and indirect fire weapons.

How "Offensively-Oriented" Should Friendly Forces Be? Table 6 shows a simplistic continuum of "offensiveness" from none on the left to complete on the right, with concepts arrayed among the several pure and intermediate categories. The categories also indicate concepts that specifically provided for the maintenance of reserves and their expected role in the campaign. If a concept was silent on reserves or indicated that relatively small reserves (e.g., less than 10 percent) would be withheld from the initial fighting, then it was not listed in a category that indicated a role for reserves.[57]

[56]This grouping omits technologies designed to provide additional defensive protection or degrade an invader's mobility, which were subsumed within "defensive preparations" as part of deployment depth.

[57]While useful, by itself this categorization is insufficient because it gives no indication of the level of war at which attacks would be planned or conducted. Section IV offers a more discriminating definition of offensiveness as a policy variable in the MOSCOW model.

Table 5

TECHNOLOGICAL EMPHASES OF SOME NATO CONCEPTS[a]

Air-to-Ground	Ground Fires	Mobility
No ground attack aircraft	Direct fire PGMs	Uhlewetter
Boserup	Afheldt	Hogarth
Hannig	Boserup	von Senger
SDP SAS	SDP SAS	und Etterlin
von Buelow		
von Mueller		
Attacks behind the FLOT	Indirect fire PGMs	
Baseline (FOFA)	Baseline (FOFA)	
Cotter	Hannig	
Sullivan	Cotter	
	von Mueller	
	Sullivan	
	Both types of PGMs	
	Weiner	

[a]Concepts not cited in the Bibliography under the names shown may be found in Alternative Defense Commission, 1983; Dean, 1988; Gates, 1987; or Levine et al., 1982.

Table 6

DEGREE OF "OFFENSIVENESS" OF SOME NATO CONCEPTS[a]

Passive or Covert	Purely Defensive	Defensive with Defensive Reserves	Defensive with Offensive Reserves	Mixed with Mixed Reserves	Mostly Offensive	Purely Offensive
Ebert	Afheldt, 1976	Afheldt, 1983	Uhlewetter	von Mellenthin	Huntington	Army 21
Nolte	Boserup	von Bulow	Mitzschke	AirLand Battle	Luttwak	
	Chaplin	von Mueller	Canby	Diner and Griffith		
	Active Defense	Hunt	Fisher			
		SDP SAS	Hoag			
		Loser	Connors			
		Active Defense predecessors	Baseline			

[a]Concepts not cited in the Bibliography under the names shown may be found in Alternative Defense Commission, 1983; Dean, 1988; Gates, 1987; or Levine et al., 1982.

What Level of War Is Emphasized? Tables 7 and 8 summarize the seven periods of U.S. Army doctrine as reflected by FM 100-5, authoritative articles and memoirs, and related divisional reorganizations. As indicated in the fourth column, in only one period did the doctrine attempt to address the conduct of warfare from the perspective of echelons above the division or brigade commander. In other words, until ALB, FM 100-5 *Operations* actually emphasized the *tactical* level of war.

Table 7

U.S. ARMY OPERATIONAL DOCTRINE, 1945–1960

Period	Key Dates/ Events	Summary of Doctrine	Level of War Emphasized	Compatible with NATO Plans?	Related Divisional Reorganization
Late 1940s	Demobilization, 1945–46 1949 FM 100-5 Austerity budgets, 1946–50 Korean War, 1950–53	Mobile defense/ fighting withdrawal (dismounted motorized infantry)	Tactical (divisions)	Mostly, no; plans called for speedy withdrawal to static defensive line	Reduced-strength divisions 1946–50
Early-Mid 1950s	1954 FM 100-5	Area defense (positional/ deep defense of successive locations	Tactical (divisions)	No; too static for early NATO defense; required feasible troop densities	1951–53 Korean expedients
Late 1950s	1st tactical nuclear weapons in Europe 1953 Carte Blanche, 1955 Soviet tactical missiles, 1958 "Limited war" critique, 1956–61	Mobile defense (1/2 – motorized infantry, some helicopters) + atomic counterattacks	Tactical ("battle groups" and divisions)	Yes	ROCID (Pentomic) 1956, 1958

Table 8

U.S. ARMY OPERATIONAL DOCTRINE, 1961-PRESENT

Period	Key Dates/ Events	Summary of Doctrine	Level of War Emphasized	Compatible with NATO Plans?	Related Divisional Reorganization
Early-Mid 1960s	1962 FM 100-5	Mobile defense; early conventional phase, then nuclear use nuclear use (mechanized infantry and armor	Tactical (divisions)	Yes; formally after 1967; informally	ROAD, 1962
	Vietnam				
Late 1960s-Early 1970s	1968 FM 100-5	In principle, mobile defense; in emphasis, counterinsurgency (heavy emphasis on airmobility)	Tactical (divisions)	No	1st Cavalry Div., 1965; TRICAP, 1968
	October war, 1973 1976 FM 100-5				
Late 1970s		Active Defense"; forward/area defense utilizing tactical mobility (mechanized infantry, armor, air cavalry)	Tactical (brigades and divisions)	Yes	DRS, 1977
	"Maneuver warfare" debate, 1977–83 NATO FOFA, 1984				
Early 1980s-Present	1982 FM 100-5	"AirLand battle"; tactically mobile area defense, emphasizing early tactical counterattacks, later offensive operations	Tactical to operational (divisions and corps)	Tactically, yes; Operationally, dependent upon timing and risks of counterattack	Division/Army '86, 1978–80

Conclusions: The Uppermost Levels of a Concept Typology

Two principles can be used to try to "bundle" these dimensions at a useful level of aggregation: one pertaining to levels of war or command echelons, one pertaining to the elements (or functions) emphasized in concepts.[58] Table 9 shows the topmost levels of this typology: Level of warfare emphasized (grand-strategic, theater-strategic, operational, and tactical) in the rows, and one of three categories of concept elements (warfighting style, force allocation and deployment, or force organization and equipment) in the columns.

In the matrix itself are two types of information. In roman typeface are typical issues or decisions pertaining to each category and particular levels of warfare. For example, the longstanding debate about the wisdom of forward defense (versus some more deeply deployed defense, shown here as "defense in depth") is a Force Allocation and Deployment issue of great importance in NATO at the theater-strategic level.[59] The degree of "offensiveness" is a warfighting style issue that could pertain at any level of war and in the past has been frequently debated with implicit reference to both the theater-strategic and operational levels.

Table 9

ILLUSTRATION OF TOP LEVEL DIMENSIONS OF CONCEPT TYPOLOGY[a]

	Category of Concept Element		
Level of Warfare	Force Deployment and Allocation (where and when)	Force Equipment and Organization (what)	Warfighting Style (how)
Grand-Strategic	Europe vs. Asia		
Theater-Strategic	Forward vs. in-depth	Active vs. reserve	Offense vs. defense
	CAS vs AI vs. AD vs. OCA *(FOFA)*	*(Canby)*	*(Huntington)*
	(Barriers)		
	(Forward response)		
Operational	City defense vs. avoidance		Offense vs. defense *(AirLand Battle)*
			Mobile vs. fortified *(Tillson)*
Tactical		Loose vs. central control *(Technocommandos)*	Concentrated vs. dispersed
		(Pentomic, Army 21)	
		Heavy vs. light	
Technical	Not applicable	Deep fire systems *(ESECS)*	Not applicable

[a]Concepts not cited in the Bibliography under the names shown may be found in Alternative Defense Commission, 1983; Dean, 1988; Gates, 1987; or Levine et al., 1982.

[58]These dimensions were introduced in Sec. I.

[59]The same issue, phrased in the same or different terminology, could pertain at other levels as well. Space limitations make it impossible to be comprehensive; Table 9 is meant to be illustrative.

A few concepts are shown in italics and are located by the categories and levels of warfare they emphasize. Huntington's "conventional retaliation" concept, for example, relates primarily to warfighting style (degree of offensiveness) at the theater-strategic level. Most technology-oriented concepts, such as Cotter's, stress force organization and equipment (e.g., long-range weapons) at the tactical or perhaps the operational level. Several of these concepts straddle multiple categories or levels of warfare.

No concept discovered in the research for this report addresses all cells in the matrix. Very few even came close to fully addressing a single row or column.[60]

The next step is to define some of the components of each of the three columns. In the interest of ease of comparison through the use of common units, these definitions should be as quantitative as possible. Dimensions that to first inspection "cannot" be defined as quantities are not excluded, but without concreteness it will be difficult to achieve real rigor.

A TYPOLOGY OF DEFENSE CONCEPTS

The absence of an encompassing intellectual framework for the description of ways and means of warfare hobbles attempts (such as those mandated by the CBRS) to make planning more rigorous. Different authors use the same words to mean very different things. For example, some NATO strategists refer to their "concepts" for NATO defense that involve restructuring active and reserve ground forces (e.g., Canby, 1973); others speak of "concepts" for employing high-tech weaponry (e.g., Cotter) in European Security Study, 1983. The Army's Concepts Development Directorate tends to emphasize the organization of future brigades and divisions based on general "concepts" of weapons employment. Comparison of alternative "concepts" is difficult because they address different types of policies (weapons, organizations, deployments, strategy, tactics) at different levels of warfare.

This section proposes an organizing framework and nomenclature to describe "concepts." It encompasses the three dimensions introduced in Sec. I: the element emphasized (weapons, organization, deployment, etc.); the level of warfare; and the degree of specificity and authority of each "concept." For the moment, there will be no new terminology. After the entire framework is outlined, nomenclature will be suggested that is intended to minimize ambiguity.

The typology presented here is meant to be rigorously descriptive, emphasizing numerical or carefully defined qualitative attributes to describe concepts. Many of these attributes, especially those that are most pertinent to the U.S. Army's efforts to develop "operational" warfighting concepts are used in MOSCOW, the Method of Screening Concepts of Operational Warfare, developed to assist in concept design and evaluation. MOSCOW is more fully described in Sec. IV.

Elements of Concepts

Elements of concepts fall into either of two broad categories: those that relate to specific decision variables available to senior decisionmakers, and those that describe general themes. Specific choices are, for example, the allocation of maneuver units among several zones or sectors. General themes are meant to evoke the character or intent of a concept, such as "striking deep." As discussed in Sec. I, they can be grouped in three summary categories:

[60]The concepts developed by Paxson and Weiner, 1978, are among the most complete, balanced, and concrete.

- Allocation and deployment of forces;
- Characteristics of forces' equipment and organization; and
- Style of warfighting.

Colloquially, the first c tegory refers to the "where and when" of friendly forces; the second refers to "what" those forces are; and the third refers to "how" they fight. (The assumed war scenario—the theater and enemy—provides the "who".)

A hierarchy of prospective dimensions for describing concepts is listed below. For each item, a brief definition—numerical if possible—is provided. The intent of each definition is to be as concrete as possible.

Allocation and Deployment of Forces and Their Use of Terrain. Assume that the area of conflict is divided into·a small number of adjacent rectangles (e.g., 3 sectors × 3 depths). Specific choice attributes include:

1. Ground force allocation (specified for each type of ground unit):
   - Horizontal allocation: percent of forces allocated to bands North, Center, South.
   - Vertical allocation: % in bands East, Middle, West.
2. Ground forces' use of terrain:
   - Amount of preparation of terrain (e.g., number of fortifications, mines, obstacles, etc.) This might be defined as the reduction in an invader's lethality and movement rate achieved by the preparations.
3. Air Force allocation:
   - Horizontal allocation: % in bands North, Center, South.
   - Vertical location: % in bands East, Middle, West.
   - Functional allocation of air forces (% allocated to each mission):
     - %Counterair missions
       - %Air defense
       - %Offensive Counterair (OCA)
         - %Airbase Attack
         - %Suppression of Enemy Air Defense (SEAD)
     - %Counter-ground missions
       - %Delay enemy advance
         - %Attack maneuver units
         - %Attack transportation chokepoints
       - %Disrupt enemy command and control
       - %Deny enemy supplies
       - %Attrite enemy ground forces
     - %Near FLOT (Nominal depth)
         - %CAS (0–3 km)
         - %BAI (4–10 km)
     - %Behind FLOT
         - %AI (11–50 km)
         - %"Deep" AI (51–500 km)

Some cross-cutting themes in this category, and possible definitions for each, include:

Traditional Buzzword	Possible Definition
deep strike	Distribution of air and ballistic munitions by the depth behind the FLOT of their targets
forward defense vs. defense in depth	Distribution of ground units by depth behind the border (e.g. %Vertical Allocation, above)
balanced deployment	Variance in force density horizontally or vertically

Table 10 relates several of these attributes to the typical vernacular of NATO concepts.

Equipment and Organization Characteristics. Assume some simple categorization of equipment types (e.g., motorized vs. mechanized vehicles; infantry vs. armor-oriented vehicles; direct vs. indirect fire; missile vs. gun artillery; rotary vs. fixed wing aircraft.) Specific attributes include:

1. *Organization characteristics*

A. Macro characteristics

- % manpower (or vehicles, or tons) in active vs. % in reserves (reserves may be further subdivided by arrival delay or estimated quality, if necessary).
- % "heavy" vs. % "light" maneuver units (heavy and light might be defined by the units' total weight in tons, or their average vehicle weight).

B. Micro characteristics (specified for each type of unit, if more than one):

- size of smallest unit (in men, vehicles, or % of total men or vehicles) that performs "independent" missions; or average number of units reporting to each important echelon.

Table 10

KEY ALLOCATION AND DEPLOYMENT CONCEPT DIMENSIONS
(Category: Force deployment, allocation, and use of terrain)

Dimension	Example Definition and Primary Applicable Level of Warfare	Buzzwords
Depth of deployment and operations	Minimum and maximum distances from Inner German Border within which X% (e.g., 90%) of Blue forces are deployed [TS][a]	Forward defense Area defense Defense in depth
Preparation of border area	Degree to which fortifications, strongpoints, minefields, barriers, or other terrain preparations are carried out in peacetime vs. crisis and wartime [TS]	Barrier zones

[a]Level of warfare codes:
GS = Grand-strategic OP = Operational
TS = Theater-strategic TAC = Tactical

2. *Equipment characteristics*

A. General
- % heavy vs. % light vehicles

B. Combat-related
- % of munitions delivered (or vehicle kills achieved) by means of the following methods:
  - %Air-delivered
    - %rotary-wing
    - %fixed-wing
  - %ground-delivered
    - %direct fire
    - %indirect fire

C. Mobility-related
- % of total distance that ground units are expected to travel within the theater by means of each of the following methods:
  - %ground vehicles own power
  - %transported across ground
  - transported in air by:
    - rotary-wing
    - fixed-wing

General cross-cutting themes include:

Traditional Buzzwords	*Possible Definition*
Heavy vs. light	Average vehicle weight in tons, or % of vehicles weighing > X tons
Capital- vs. Labor-intensiveness	Kills per man, tons per man, or dollars per man in friendly combat force
maneuver by: — fire — ground — air	Percentage of time or distance moved by combat units by each mode, or percentage of total kills achieved by units moved by each mode

Tables 11 and 12 list some key distinctions among concepts in this category.

Warfighting Style. This area is hardest to express analytically. The subcategory titles are especially provisional, as they rely too much on evocative buzzwords and not enough on concrete characteristics. Specific attributes include:

1. *Mission allocations* (specified for each type of unit, if more than one).
   - % of forces (or kills) engaged in offensive missions.
   - % of support assets (or tons, or kills) allocated to each of several maneuver unit missions (e.g. attack vs. defend).

Table 11

KEY EQUIPMENT AND ORGANIZATION CONCEPT DIMENSIONS
(Category: Force equipment and organization)

Dimension	Example Definition and Primary Applicable Level of Warfare	Buzzwords
Active/reserve force mix	Fraction of forces of each category deployed at the IGB and in main defensive positions for several periods in wartime [GS and TS]	Tooth to tail
Heavy vs. light forces	Fraction of force deployed in light (an presumably less expensive) ground or air vehicles versus armored and mechanized infantry vehicles [TAC]	Lightening the force Agility Mobility Technocommandos Defensive defense

Table 12

OTHER KEY CONCEPT DIMENSIONS[a]

Dimension	Example Definition and Primary Applicable Level of Warfare	Buzzwords
Means of delivering munitions	Fraction of munitions delivered by: — Fixed-wing aircraft — Rotary-wing aircraft — Ballistic missiles — Artillery — Ground-maneuver direct fire weapons — Air-delivered direct fire weapons [OP and TAC]	Maneuver by fire Maneuver by air Interdiction zones/belts Forward response FOFA/deep strike

[a]Combines elements of all three major categories. Most authors implicitly assume two of them are fixed (usually force deployment and warfighting style) and make recommendations that pertain to the third (force equipment).

2. *Aggressiveness*
   - degree to which friendly forces attempt to operate in enemy-occupied territory. (A possible definition: average fraction of the campaign that friendly units spend behind the enemy's lead elements.)
   - elasticity of defenders: average time interval between backward bounds made by a defender falling back during an engagement and distance-bounded. An alternative definition would be the casualties friendly forces are willing to accept per engagement (or per hour, or per day) before they bound backward.
   - aggressiveness of attackers: the converse of the above definitions would apply to attackers.
3. *Mobility*
   - % of forces emphasizing terrain to enhance survivability vs. mobility/maneuver.
   - average interval between unit moves.

4. *Intensity*
   - average distances at which enemy targets are engaged.
   - length of average engagement, or some other definition of engagement objectives (e.g., desired or acceptable amount of attrition) that would influence the average engagement duration.

5. *Dispersion*
   - force ratio (or number of units) desired to begin an offensive engagement.
   - average distance between subunits (e.g., companies or battalions) when:
     - %attacking
     - %defending
     - %moving
     - %other

6. *Distribution of Activities*
   - fraction of time spent, on average, in each of several activities—e.g., combat, movement, rest, other.

General themes include:

Traditional Buzzword	*Possible Definition*
initiative shown	Length of orders, words per day or per enemy unit destroyed
audaciousness	Force ratio on attack, amount of time spent preparing each attack, or % of attacks attempted under surprise conditions
agility	Average time from receipt of intelligence report to completion of action

Table 13 lists some of the distinctions among warfighting styles.

Levels of Warfare Emphasized in Concepts

Many of the above features appear in concepts for more than one level of warfare. As was explained in Sec. I, the levels of warfare used in this typology are:

- Grand-strategic: global perspective, emphasizing the relative importance of alternative theaters or strategic objectives. *Decisionmaker*: the national leadership.
- Theater-strategic: theater-wide perspective, emphasizing broad allocation decisions to achieve theater-sized objectives. *Decisionmaker*: theater Commander-in-Chief (CINC).
- Operational: perspective is a large part of a theater, emphasizing translation of theater objectives into specific missions for large field organizations (e.g. army groups, armies, corps). *Decisionmaker*: an army group, army, or corps commander.
- Tactical: perspective is an area of a few or few dozen kilometers on a side, emphasizing the defeat of enemy formations in battle. *Decisionmaker*: commander of a division, brigade, or smaller unit.

Table 13

KEY WARFIGHTING STYLE CONCEPT DIMENSIONS
(Category: Warfighting style)

Dimension	Example Definition and Primary Applicable Level of Warfare	Buzzwords
Staticness of defense	Degree to which Blue units "stand fast" in battles and accept continued casualties rather than withdrawing [OP and TAC]	Positional defense Mobile defense
Means of enhancing survivability	Relative emphasis on prepared positions vs. mobility to reduce enemy's lethality [OP and TAC]	Maneuver warfare Margin of mentality Attrition mentality
Degree of offensiveness	Fraction of engagements in which Blue is attacker or echelon at which offensive operations are principally planned [OP?]	Operational art Initiative Maneuver warfare
Inclination toward risk taking and opportunism	There is no satisfactory definition; roughly speaking, it is the frequency with which Blue will take nonconservative actions to seize or retain the initiative [OP and TAC]	Agility Maneuver warfare
Linearity of battle	Degree of intermixing of friendly and enemy forces at the operational level [OP]	Reactive defense Nonlinear battlefield Amoebas vs. lines

To summarize, *grand strategists* determine the importance of each theater, the resources available to friendly forces, and the broad definition of success and failure there. *Theater strategists* allocate lumps of resources (e.g. divisions, corps, squadrons, or wings) and general missions to operational commanders. *Operational* commanders maneuver and deploy tactical formations to destroy enemy tactical units at desired times and places so as to achieve their strategic mission. *Tactical* commanders assure the ability of their units to implement their operational mission and control their employment in engagements with enemy tactical formations.

Each of the elements listed under Elements of Concepts can be used to describe a concept at each of these levels of warfare. Naturally, precise definitions may vary slightly at different levels.

Degree of Specificity and Authority

The word "concept" has been used to refer to any general idea, while "doctrine" refers to an equally general, but authoritatively sanctioned, idea of how to fight (or arm, or train, or organize). Some indication of a concept's scope, specificity, and authoritativeness is needed. The following nomenclature is suggested:

- *"Idea"* is any general notion not explicitly rendered in conformance with the typology.
- *"Warfighting concept"* refers to the rendering of an idea that emphasizes the "*warfighting style*" element in its description. Where it is explicit, boundary values set for each

descriptive variable, for a specified level of warfare. Similarly, *"Force allocation and deployment"* and *"Force organization and equipment"* concepts imply emphases on analogous concept elements.

- *"Defense concept"* refers to any of the three preceding types of concepts and is used for concepts that emphasize more than one element (e.g. allocation *and* warfighting style).
- Although a *"concept"* specifies only ranges for each descriptive variable, a concept *"version"* specifies points (or narrow ranges).
- *"Doctrine"* refers to any idea or concept that has been *approved* for implementation. In common usage, doctrine emphasizes *warfighting style* but references are also frequently made to "equipment doctrine" or "organization and training doctrine."
- The full name for any concept or idea should include the level of warfare to which it is intended to apply and the features it emphasizes—e.g., "operational warfighting concept" or "theater-strategic defense idea."

Most concepts in the academic literature are theater-strategic defense ideas that emphasize either the deployment/allocation or the equipment/organization categories. Most products of the Army concept community are tactical warfighting ideas that emphasize tactical warfighting style, with implications for organization or equipment noted as well.

Comparing Concepts in Common Typology

Table 14 shows two warfighting concepts, the Army's present AirLand battle doctrine and the draft Army 21 concept. The top part of the table summarizes the essential precepts in words, and the lower part specifies values for some of the typology's descriptive variables.[61]

Clearly this typology is embryonic. Other analysts may find more elegant, more analytic, or more policy-relevant organizing principles. Such attempts should:

- Utilize unambiguous and objective (and, when possible, quantifiable) dimensions;
- Distinguish scale or level of warfare.
- Be comprehensive enough to incorporate short-term and long-term concept attributes (e.g., force employment vs. equipment characteristics).

Without such a framework the rigorous development and comparison of concepts will lack coherence or credibility.

IMPROVING THE POLICY DEBATE ABOUT CONCEPTS

The typology is a prerequisite to a more rigorous approach to the design and analysis of concepts, and its application can considerably clarify and enhance the development of concepts. This section indicates some of the most common mistakes made in past development of warfighting concepts, which the typology helps bring into sharp focus. It also identifies past decisions that have been misdiagnosed as mistakes but that may have more fundamental causes than heretofore recognized.

[61]The warfighting style and allocation and deployment categories are emphasized to correspond with the emphasis of the original sources. Space limitations prevent the display of all variables.

Table 14

TWO WARFIGHTING CONCEPTS COMPARED IN A COMMON TYPOLOGY
(Excerpted)

	AirLand Battle	Army 21
	• Disrupt enemy with fire and airpower • Take tactical initiative whenever possible • Husband reserves to take optional initiative intended to surprise/disrupt/envelop enemy (Initiative/agility/. . . . .)	• Remain concealed while awaiting opportunities to take tactical initiative • Terminate each engagement before becoming over-exposed • Destroy enemy by means of many brief, sharp attacks against flanks and rear (scan/swarm/strike/scatter)
Specifications		
• Force mix (Heavy/Medium/Light	47%/49%/4%	20%/30%/50%
• Unit size/equipment		
— No. of persons (thousands)	18/18/13	8/8/6
— No. of vehicles	1400/1300/800	900/700/600
• Warfighting style		
— Percent attack/move/other	30%/20%/50%	15%/60%/25%
— Engagement start/end conditions	3:1 Combat power/50% Red attrition	1.5:1 Combat power/5% Red attrition
• Force allocation		
— Allocation to axes 1/2/3	33%/33%/33%	40%/20%/40%
— Allocation to depths A/B/C	80%/15%/15%	20%/60%/20%
— Allocation to offense/defense/reserve missions	10%/60%/30%	60%/20%/20%

Confusing or Ignoring Distinctions Among Levels of Warfare

Principles deemed "correct" at one level of warfare may not be correct at other levels. Armies and the civilian academic community commit this type of error frequently. Two examples will illustrate.

France, 1911–1914. Most European armies in the decade before World War I believed that tactical advantage lay in attacking.[62] In the French army the "cult of the offensive" pervaded thinking at all levels of warfare to a remarkable degree. What was desirable at the tactical level was assumed would also be desirable at the strategic level.[63]

In 1913 the French Army committed itself to Plan XVII, which called for an offensive by two-thirds of its field armies to retake the provinces of Alsace and Lorraine and the maintenance of only a very small reserve. It did this in full knowledge of the outlines of the German attack plan, which it had received through espionage several years earlier. Any hesitation regarding the desirability of a strategic offensive could be damaging to an officer's career in an

[62]Howard, 1987, outlines the belief system in several armies and explains how each managed to rationalize apparently contradictory evidence from recent wars outside of Europe. See also Sanders, 1987. The use and limitations of information from proxy wars is taken up below.

[63]Because most of these examples refer to armies without global responsibilities, "strategy" can be taken as synonymous with "theater strategy."

environment that exalted the virtues of attacking. A tactical principle was elevated to a strategic doctrine.

Current Debates About "Defensive Defense" and the Wisdom of Concepts Advocating NATO Attacks. Several of the concepts researched for this report aim to deny, or severely circumscribe, the capability of NATO forces to conduct attacks. Their main focus is technological: In general, they wish to eliminate armored vehicles and ground attack aircraft, which they consider to be "offensive" and consequently threatening to the stability of deterrence and East-West relations.

Adherents of these concepts apparently fail to recognize that most weapons' effect on stability is heavily influenced by the level of warfare considered in the analysis.[64] As an example, a fortification would seem to be as purely "defensive" as a system could be at the tactical level. However, at the operational level, fortifications might offer protection to indirect fire systems that are supporting an attempt to break through an enemy defense, thus becoming an "offensive" system. At the strategic level, fortifications might allow an attacker to economize his forces in quiet sectors to better concentrate on his main axes. Again, fortifications could be considered an "offensive" system. Rarely will it be possible to categorize reasonably flexible weapon systems as unambiguously offensive or defensive when the analytic perspective broadens to consider multiple levels of warfare.[65]

Regardless of the difficulties inherent in classifying technologies, no NATO concept is likely to succeed that allows for negligible offensive capability. Disproving this assertion requires a refutation of several different arguments made in favor of offensives pertaining to each level of war.

First, at the *grand-strategic* level, Samuel Huntington (1984) has asserted that the stability and magnitude of conventional deterrence could be augmented if the Pact faced a credible chance of losing something valuable by starting a war. (Stability is enhanced, of course, only if the threat of a NATO attack is not so persuasive as to convince the Pact that it would be advantageous or necessary to preempt.) The prize usually cited is the political integrity of the Warsaw Pact and the prospect that NATO occupation of some Pact territory could incite one or more eastern European governments to align themselves against the Soviets. Second, at the *theater-strategic* level, without an ability to launch a counteroffensive NATO would be unable to regain by force[66] any territory seized by the Pact, even if NATO were "winning" the war (in the sense that she had stopped the Pact invasion much sooner than expected). Third, at the *operational* level, the absence of any ability to attack prevents NATO from capitalizing on opportunities where the seizure of local initiative might be more effective at stopping an invasion than would pure defense. Finally, at *any* level the absence of a threat of NATO

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[64]Many weapons are inherently flexible—were acquired because of their flexibility—and so can be employed either "offensively" or "defensively" within a given level of warfare. The scope of possible innovations can be vast. For example, tanks are a bugaboo of "defensive defense" advocates. Yet the Israelis in the Golan Heights in 1973 found an ideal defensive weapon in tanks firing from prepared positions. Similarly, an unarmored vehicle armed with antitank munitions could be used with good effect to protect a penetration made in a strategic *offensive*, as the Egyptians did when *defending* against Israeli counterattacks in the early days of the 1973 war.

[65]Defensive defense advocates will argue that the foregoing argument is hairsplitting, that broad patterns will be evident even if there are occasional or implausible exceptions. Unfortunately, their criteria have not been defined specifically enough to ascertain how these broad patterns are identified. The general characteristics most often associated with "offensiveness" are mobility and range. However, several strategic theorists and practitioners (Liddell-Hart, 1967; von Manstein, 1958; Macksey, 1980) have argued that mobility was a quality even more important to defenders than to attackers, and range can be just as useful to a defender facing an echeloned attacker as to an attacker intent upon disrupting a defender's rear. Macksey's book on the hypothetical invasion of England makes the point especially clear: In it, immobile English defenders are unable to cope with even a handful of German medium tanks.

[66]This argument would probably still apply if the war is assumed to be terminated by negotiation, because it will be difficult to win at the bargaining table what cannot be won on the field.

counterattacks greatly simplifies the task of any Red commander. For example, there is no need to hold operational reserves against an unexpected counterattack if the possibility of such an attack could be completely excluded. Similarly, Red units can remain in tactical road-march formation until the moment they are committed to battle, because they would not be concerned about being ambushed.

The correct way to phrase the debate over offensive capability must make reference to the levels of war for which a proponent wishes NATO to achieve or forgo offensive potential. The "defensive defense" adherents are in essence striving to deny NATO the ability to conduct theater-strategic offensives but are suggesting methods that may also prevent operational and tactical offenses, and therefore a robust overall defense.[67]

The "Fallacy of the Last Move"

Edward Luttwak has argued that what makes strategy[68] a separate domain of intellectual inquiry is the existence of a sentient opponent whose aim is to subvert—that is, find countermeasures to—the efficacy of our initiatives (whether of technology, doctrine, organization, or any other type). Any advantage accruing to one side therefore will usually be temporary, as the opposing side develops some response that erodes or even reverses its benefits.[69] The very common error of concept developers is to assume the opponent will not attempt to adapt its own policy to limit or undercut the benefits of the new concept. In other words, they imply that *our* move is the *last* move of the "game."[70]

Examples of this error are legion, and this report has already alluded to two of them: the assumption made by the authors of Army 21 that Soviet practice would remain largely unchanged after the U.S. Army adopted a radical new warfighting concept, and a similar assumption by most "defensive defense" advocates that a Pact attack would continue to emphasize mass (and provide a rich set of targets for NATO ATGMs) and speed (that would be severely compromised by the disruption caused by defenders). Would not a Pact strategy that broke through in a few areas, against which many "defensive defense" concepts envision holding few reserves, seem a logical response to Soviet planners? Might not the maintenance of strong defensive reserves, or raiding parties sent to "search and destroy" Blue Army 21 units operating in Red's rear, be an attractive alternative to present Soviet practice? For the moment, these are rhetorical questions; however, any analysis of concepts ought to be obliged to consider these and other potential adversary responses.[71]

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[67]This judgment would change in the improbable event that Soviet "new thinking" related to "reasonable sufficiency" ever prompted the Soviet army to forsake an offensive capability.

[68]Luttwak (1987) was referring not only to the strategic level of war, but to military decisionmaking at each level of war. His insights appear to extend to non-military competitions as well. For several excellent examples of the process, which had action-reaction cycles as short as a few weeks, see R. V. Jones, 1978.

[69]Obviously, an opponent unwilling or physically unable to compete may be obliged to live with the advantage more permanently.

[70]R. V. Jones, 1978, argues that the advantages of many technological innovations were squandered in the air war during World War II. A new gadget would be tested in prototype on an actual mission, in numbers too small to have any operational effect. The enemy would note the innovation and go to work developing his own counters. Because the advantage gained by any innovation was very temporary, Jones argued that they should have been introduced only in operationally significant numbers and at critical times.

[71]Determining the limits of "plausible" adversary adaptations is a difficult issue. Frequently analysts familiar with Soviet doctrine will assert that a particular response would simply not occur to Soviet planners; it would be too "un-Red" (even if, on the surface at least, that response might be advantageous to Red). For my part, I am skeptical of any argument that relies on an assumption of enemy irrationality as a basis for prediction. It seems more plausible that, given time, institutions can change their concepts even radically, if the marginal benefit of the new concept appears high.

The advocates of new interdiction or deep attack technologies not infrequently fail to consider possible countermeasures that might nullify or even overturn the putative advantages of their proposed systems. Countermeasures are of at least four types: technical measures to (1) reduce the effectiveness of deep attack systems ("hard" or "soft" attacks against sensors or communications), or (2) to attack them directly; (3) tactical measures to reduce the vulnerability of maneuver units to deep attack, or the effects of such attacks (more dispersed formations, more use of camouflage or concealment, stockpiling of bridging and other obstacle-crossing equipment); and (4) operational and strategic measures to minimize the importance of deep attack ("standing start" attacks that rely on a single echelon, long mobilization periods to move all echelons near the start line before invading, or Operational Maneuver Groups that attempt to overrun deep attack systems and otherwise force a capitulation before later echelons are needed). If any of these appeared to be to the Pact's net advantage, then analyses of deep attack concepts ought to consider them. In this instance, many of these responses appear to no longer be hypothetical: The Soviets appear to be exploring several of them.[72] Yet most of the advocates of these technologies present a virtually static adversary.[73]

In debates about a particular concept critics will occasionally offer a damaging countermeasure as "proof" that the concept is flawed. In fact, the appropriate response is to consider whether there might be effective counter-countermeasures within the limits of the original concept. Such measures might be trivially easy and cheap, vindicating the concept,[74] or difficult and expensive, suggesting that the concept lacks robustness.

The only concept elements that have been exposed in the past to any measure/countermeasure/counter-countermeasure logic are those related to equipment, chiefly to weapon systems. A full representation of the sensitivity or robustness of concepts in a dynamic competition must consider *each* concept element and each level of warfare. Figure 5 illustrates a specific, though partial, case. In the mid- and late 1970s, many concepts advocated great reliance on ATGMs, which could be made man-portable (allowing them to be handled easily in urban areas and good defensive terrain, by small units) and fairly cheap (e.g. $10,000 per shot). At what Luttwak terms the "technical" level of warfare (considering only the weapon/target engagement and not allowing for behavioral adaptations), this appeared to be highly desirable for a defender. When the attacker can develop technical and tactical countermeasures, the apparent advantages greatly diminish.[75]

[72]See Sterling, 1986; and Stoecker, 1986; for brief discussions of recent evidence. FOFA is by no means the first concept that has been criticized for inattention to doctrinal countermeasures. For a criticism of Active Defense based on the same theme see Griffin, 1979. Epstein, 1987b; and Luttwak, 1987, have both alluded to the potential benefits to the Pact of a long-mobilization attack with little distance between echelons. Vigor, 1979, has indicated past Soviet flexibility in their employment of echeloning. Rogers, 1984, asserts that NATO's FOFA concept was developed with reference to possible countermeasures, but authoritative sources have offered few details.

[73]It has been pointed out by DeLauer (in Pierre, 1986) and others that this incomplete representation of the adversary often fails to account for possible or projected Soviet *equipment*, as well as ignoring possible changes in Soviet *behavior*. Many of these concepts present mid-1990s NATO systems facing a Pact threat whose equipment and behavior is that of the mid-1980s.

[74]"Vindication" is meant here in the superficial way by which most concepts are debated in international security policy journals.

[75]Luttwak, 1987, uses the man-portable PGM vs. the tank and the patrol torpedo boat vs. the battleship as examples of differing technical and tactical flexibility in opposing platforms. In each case, the smaller platform can achieve very cost-effective kills against the larger one if the equipment onboard the latter, and the tactics it employs, fail to adapt. However, the larger one may have more inherent potential for adaptation, either by changing minor equipment items (reactive armor on tanks, rapid-fire medium-caliber guns on battleships) or by changing the way in which it is employed. The cheap and specialized (and in this case smaller) system may be *less* flexible. On the other hand, Luttwak, 1984, implies that there is some cost-effectiveness criterion that must be applied to assess the wisdom of adapting a more flexible platform at the margin versus building a more specialized one. He points out the decline over time in the number of aircraft available to conduct an aircraft carrier's primary mission, offensive strikes against land targets. The aircraft carrier is arguably one of the most flexible of systems, but the adaptations required to survive new threats have whittled away at its capability to carry out its original mission.

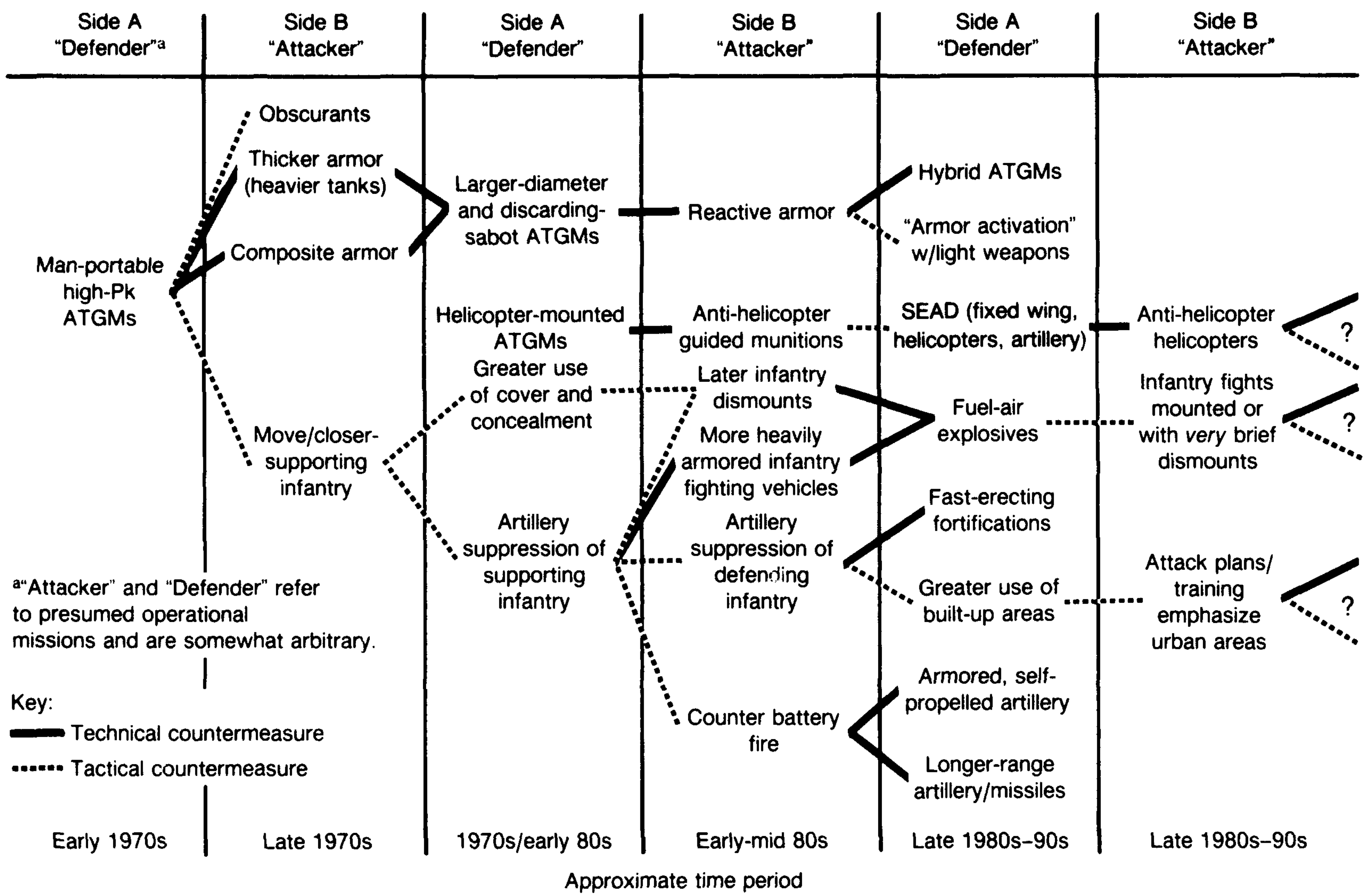

Fig. 5—Illustration of action and reaction at the tactical and technical levels

When the defender can develop counter-countermeasures the picture becomes quite murky, and so on. Including higher levels of warfare can make it even more obscure.[76]

Ignoring the Skill Limits of Available Personnel and Organizations

Simply put, this means that peasant or conscript armies will perform less well than elite forces, but concepts often fail to take this into account.

One historical example of this costly error was the warfighting concept that guided the Soviet army in the early days of the Russo-Finnish War. The "Deep Attack" ideas of Triandifilov and Tuhkachevskii, although no longer official doctrine after the purges of the mid-1930s, still exerted considerable influence when the Red Army went to war in 1939. It had appeared highly promising when first tested in division-level maneuvers by crack units in 1936. However, the troops and tactical level leaders who implemented the concept, which called for great operational agility, were more typical of the Red Army as a whole: poorly trained and drilled in only a limited repertoire of formations and tactics. After suffering terrible reverses in the first two months of the war, a new approach relied on enormous volumes of artillery fire and high infantry casualties to grind down the Finnish defense lines.

Similar adaptations were necessary in the first two years of the war with Germany, as the Red Army experimented to find a concept—their own version of the *blitzkrieg*—that fell within the limitations of a mass army with often only the most rudimentary training (especially in late 1941 and 1942).[77] The continuing tactical rigidity of Soviet ground forces seems well-suited to two-year conscription in a large army. Many similar examples could be cited from the experience of other armies in other periods; it seems common for armies swollen by wartime conscription to be forced to scale back the ambition of concepts that worked well when tested by the professional forces in peacetime.[78]

This problem is especially common among published alternative concepts for defending the NATO Central Front. Many authors have devised concepts that call for changes in force structure to deemphasize active forces and rely on reserve units for a larger fraction of total wartime forces. The rationale for these proposals is either to save money or to reduce the tensions that are assumed to attend large active force concentrations near the Inner German Border (IGB).

In the mid and late 1970s, a common criticism of such concepts was that reserve mobilization and deployment times would be too long to adequately protect the forward areas of the Federal Republic against a short-warning attack. In the 1980s the more frequent criticism has been that the defense of the most forward area (a mission termed that of the "covering force" in tactical and operational-level doctrinal literature) is too stressful for reservists to handle,

[76]Probably the limits of imagination and plausible technology will bound the number of action/reaction cycles that can be examined. In reality, of course, if each side has a doctrine at higher levels of warfare that might call for its forces to both attack and defend in different tactical engagements, they may pursue both measures and countermeasures concurrently.

[77]An interesting compilation of surprisingly candid comments by Soviet generals is in Bialer, 1969. Naturally, "Deep Battle" met with occasional successes even in the early days of the war, as in the raid on Tatinskaya airfield (which was the principal base for the aerial resupply of the encircled German Sixth Army) in late December 1942, by a tank corps operating in a fashion very similar to what today would be termed an Operational Maneuver Group (OMG). See Erickson, 1983; Gay, 1985; and von Manstein, 1958.

[78]Several of the articles in Heller and Stofft, 1986, illustrate mismatches between prewar "school solutions" and the adaptations made by American commanders after the experience of a first battle. Macksey, 1984, comments on the same subject using a hypothetical first battle on the Central Front. Keegan, 1987, in his chapter on Ulysses S. Grant, stresses the differences in command styles suited to a conscript army in a democracy vs. a professional army in an aristocratic society.

because they are assumed to be less well-trained than actives.[79] Counterarguments made by those whose concepts rely on locally raised forces (militia, home guard, etc.) are that no one will be as motivated to defend a particular piece of real estate as a soldier who lives there. These arguments suggest that there is ample room for more systematic thinking.

Confusing Semantics with Substance

The essential ideas inherent in concepts often have surprising durability, but differences in packaging (abetted by the confusion engendered by the absence of a common vocabulary as noted above) often imply that there is more difference between concepts than their substance would support.

One example will illustrate. Concepts advocating "area defense" and those proposing greater use of prepared positions and reserves have distinct although overlapping adherents. In 1963 a RAND study recommended an "illustrative defense" for Germany.[80] It emphasized a mix of static and mobile reserve divisions. In 1977, taking advantage of PGMs to reduce the costs of NATO defense, another RAND study under the same leader proposed a "hi-lo-mix" defense concept.[81]

Table 15 summarizes the suggested allocation and deployment of divisions under these two concepts as separated by 15 years. Although title and description changed, this element was absolutely unchanged. Without such a systematic comparison, differences between concepts by the same author or different ones may be easily exaggerated.

Misusing the Limits of Analogies

In historical hindsight it is cheap and easy to identify "right" and "wrong" doctrines developed in the period before a major war. The French Army of 1911–1914 has been vilified for its doctrine of the remitting offensive; however, seldom is it noted that all major armies espoused offensive doctrines at the opening of World War I for the tactical level of war, and (with the exception of the British) at the strategic and operational levels as well.[82] Ignorance and stupidity have often been invoked as explanations, when in fact the main "rehearsals" for World War I (the Boer and Russo-Japanese wars) were amply observed by highly talented officers of all the principal powers, and their reports carefully scrutinized.

The problem for peacetime combat developers is less often lack of opportunity for study per se than it is the highly specialized conceptual lenses that they must employ. Wars differing in apparently minor details can yield vastly divergent views regarding the utility of a particular weapon, organization, or tactic. For example, the use of entrenchments by Japanese soldiers in 1904–05 was considered inapplicable to a European war in the years before World War I, because better-disciplined soldiers would not be content to remain immobile. Similarly, in the late 1970s many doubted that the lethality of long-range ATGMs achieved by early fighting in the Sinai during the 1973 Arab-Israeli war could be applied directly to NATO because of differences in terrain, urbanization, and weather. In fact, even the same war can

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[79]Certainly professional armies have traditionally been skeptical about the value of reserve units (as opposed to individual reservist replacements). The French army before and after World War I is a good example; see Jacobsen et al., 1985; Sanders 1987; and Tuchman, 1962. The degree to which this view is justified, as opposed to simply a natural organizational attitude, is an open question.

[80]Hoag and Strother, 1963.

[81]Hoag, 1977.

[82]French assault tactics against prepared positions have long been criticized, perhaps unfairly. I used a commercial military simulation (*Soldiers*) to experiment with alternative tactics, but casualties still exceeded 50 percent of French forces.

Table 15

COMPARISON OF ALLOCATION AND DEPLOYMENT UNDER
•ILLUSTRATIVE DEFENSE• AND •HI-LO MIX•

		1963		1977	
Sector	Category	Divisions	Cumulative Divisions	Cumulative Divisions	Divisions
Northern	Defensive zone	9	9	14	14
	Mobile local reserve	5	14	14	0
	Sector reserve (M-Day)	2	16	16	2
	Sector reserve (M+15)	5	21	21	5
Central	Defensive zone	8	8	12	12
	Mobile local reserves	4	12	12	0
	Sector reserve (M-Day)	2–4	14–16	14–16	2–4
	Sector reserve (M+15)	5–7	17–19	17–19	5–7
Southern	Defensive zone	5	5	8	8
	Mobile local reserves	3	8	8	0
	Sector reserve (M-Day)	0–2	8–10	8–10	0–2
	Sector reserve (M+15)	0–2	8–10	8–10	0–2
AFCENT-wide	Defensive zone	22	22	34	34
	Mobile local reserves	12	34	34	0
	Sector reserves (M-Day)	6	40	40	6
	Sector reserves (M+15)	12	46	46	12
	Total		46	46	

SOURCES: Hoag and Strother, 1963; Hoag, 1977.

produce similar divergence of predictions; observers of the 1973 war drew opposite conclusions as to the utility of tanks, depending on which front (the Sinai or the Golan) they emphasized.

In part because of the uncertain applicability of vicarious wartime experience, armies often place exaggerated reliance on their own first-hand combat experience, even if that experience is severely limited (a "small-sample" problem) or is no longer recent. One might speculate that, in the absence of actual wartime experience, an army's views of combat are likely to be quite stable until the last of the "old generation" retires.

Nor is all combat experience likely to receive equal weight. There may be a great deal of organizational and political inertia behind a long-standing concept, making it robust enough to be sustained in the face of all but the most unambiguously contradictory evidence. Even if a concept were "wrong" (for the circumstances in which it might be exercised), victory in battle may make it possible nevertheless to ignore contradictory evidence. Major changes in concepts are far more likely to be precipitated by defeats, by tarnishing the reputation of old concepts and their proponents, and (in many armies) by causing changes in leadership that liberate "back bench" members of the organization from censorship.

The implications of ambiguous data can be summarized as follows:

- Estimates of the utility of alternative weapons or tactics will always meet with great internal skepticism unless based on collective experience;
- In the absence of compelling (directly experienced) evidence to the contrary, most organizations will retain stable doctrines until their adherents leave through natural attrition;

- Wartime defeats are far more likely to produce substantial innovations than victories.

Critics of past doctrines often appear to ignore the difference between hindsight and foresight and ignore considerable differences in available "foresights." They apply yardsticks of omniscience and intellectual flexibility to large, imperfect organizations and not surprisingly find ample opportunity for criticism.

If armies were businesses that daily operated in a market and competed with rival firms, they would have a glut of information available about the effect of their practices on the "bottom line."[83] The pathologies and limitations described above are in large part due to the lack of such readily available measures of performance. The analytic community is partly to blame, however, for failing to develop principles for sorting among competing analogies, and for making inadequate use of available information. Builder makes the point that analysts have become so focused on the evaluation of policies under very narrow and unlikely contingencies (war in Central Europe, or intercontinental nuclear exchanges) that many ignore opportunities to test their premises and techniques in more frequent, but only partly analogous, small wars.[84]

Although some of the attributes of a future war can be estimated, and demand more aggressive efforts to do so, for others (such as the scope of possible enemy counters discussed earlier) we can do no more than guess at a plausible range within they are more likely to fall than not. A concept advocated on the basis of a single point-estimate set of assumptions is the height of analytic hubris.

The proper approach is to recognize the limits of our ability to know the hypothetical future and seek concepts that do tolerably well over a wide range of not-implausible possibilities. The analytic terminology for this is the assessment of the sensitivity of concepts to changes in assumptions, in order to identify "robust" concepts. This theme is taken up in Sec. III, which describes a more rigorous approach to concept developments and evaluation, emphasizing techniques that address unavoidable uncertainty.

A CROSS-CUTTING GROUPING OF ALTERNATIVE NATO CONCEPTS

Although Sec. II has attempted to make a convincing argument for the existence of a common framework for describing concepts, old intellectual habits die hard. For those unconvinced, or uninterested in a framework with more than one dimension, the list below attempts to sort several of the most noted unofficial NATO concepts into a one-dimensional, more "thematic" framework. Very general common themes were used to arrange this grouping. Obviously, any single-dimension sort will be very crude. This is the best argument for a more sophisticated approach.[85]

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[83]Armies and the analysts that support them would probably also be more sensitive to the importance of considering possible short- and long-term counters to their concepts that may be available to competitors—short to think, and to analyze, *strategically*.

[84]Builder, 1987b, pp. 18–19, fn 14. He recounts the lack of interest among RAND analysts in attempting to predict combat outcomes in the Falklands war in 1982.

[85]Concepts not cited under the author's named are described in Alternative Defense Commission, 1983; Dean, 1988; Gates, 1987; or Levine et al., 1982.

Passive/nonbelligerent: Ebert, Nolte

Barrier/fortification: Tillson, Bailey, Hannig, Canby

Interdiction/indirect fire zone: FOFA, interdiction "barrier of fire", Weiner's "Forward response", Cotter, Sullivan

Ambush/sponge: Area defense, Ahfeldt's teknocommandos, Loser's defensive defense, Boserup, Chaplin, territorial defense, stay-behind covering force, PGM belt

Disrupting offensive: von Manteuffel, Airland Battle Army 21, Huntington, "maneuver" advocates (e.g., Luttwak)

Reserve employment: AirLand Battle?, Balck/ von Mellenthin, Von Senger und Etterlin's airmobile reserves, Uhlewetter, Hogarth

III. LONG-RANGE CONCEPT DEVELOPMENT IN THE U.S. ARMY

In the early 1980s the basic outlines of the U.S. Army's next decade had been established in the AirLand Battle concept; the procurement of M-1 tanks, Bradley Infantry Fighting Vehicles, and Multiple Launch Rocket Systems; and the planned divisional reorganization under Army '86. To the proponents of each, which meant to the majority of serving officers who thought about such things, the Army's warfighting concept, procured weapons, and combat organization were blended in a reasonably harmonious combination. The responsibility for this attempt to rationalize concept, equipment, and organization went in large part to the Army's Training and Doctrine Command, led in the late 1970s and early 1980s by General Donn Starry.[1] However, the authors of both AirLand Battle and Army '86, concerned respectively with a concept (doctrine) for the short-term (beginning as soon as practicable after publication) and organization for the medium term (beginning less than five years after publication), had been constrained by time horizons so short that they had little control of, or uncertainty about, the main items of Army equipment (aside from funding uncertainties). They were, in effect, retrofitting a concept and organization onto equipment that had been developed under different assumptions about each.[2] TRADOC's presumption was that better blends could be achieved if it were possible to influence equipment designs as doctrine and organization had been influenced.[3]

INTEGRATING SYSTEMS, ORGANIZATIONS, AND PROCEDURES: THE CONCEPT-BASED REQUIREMENTS SYSTEM

Without diminishing the accomplishments of AirLand Battle and Army '86, the commander of the Army's Training and Doctrine Command (TRADOC) recognized that greater strides could be made if each part could be made responsive to a holistic, unconstrained statement of preferences about the Army of the future (aside, perhaps, from broad constraints as to potential technical and fiscal limits). The centerpiece was to be a description of the *style of warfare* by which Army combat forces would prefer to fight (subject to limits imposed by assumptions about Army missions and U.S. and enemy technological capabilities), which was referred to as a "concept of operations." From this concept of operations would be derived preferences regarding organization and, most important, desirable equipment characteristics

[1]This remark should not be construed as indicating agreement with any specific modernization or reorganization initiative undertaken by the Army in the early and middle 1980s, merely that the Army itself viewed them as reasonably compatible. The military journals showed a marked decrease in criticism of doctrine in the mid-1980s compared with the late 1970s.

[2]In fact, the customary suspicion of the R&D community shared by many in the combat arms caused them to doubt that any coherent warfighting concept underlay the equipment entering the Army's inventory. The commonly voiced concern of TRADOC leadership was that system designs at best responded to the requirements of the functional branch that would be the principal user, without regard to the system's employment in combined operations, and at worst were based on purely technical, rather than tactical, performance requirements. Others, such as Edward Luttwak, have argued that because doctrine changed more rapidly than equipment did, the Army was fielding equipment produced under outdated doctrinal assumptions. His primary example is that of the engine on the M-1 tank, which emphasizes speed over range.

[3]This argument has some intuitive appeal, plus some analytic justification. In most optimization problems the value (in this analogy, the cost effectiveness) of the optimum reduces as more constraints are added. Because the characteristics of Army equipment were fixed, the "feasible set" of organization and doctrine choices was reduced. Planning with a longer time horizon reduced the number of constraints.

(and if possible, priorities among them). The combination of concept of operations, proposed organization, and recommended equipment characteristics was collectively termed a "concept."

From this basic idea came two TRADOC initiatives. The first, the Concept-Based Requirements System (CBRS), laid down procedures by which "requirements" (goals) for changes in doctrine, training, organization, and equipment were to be developed. The CBRS regulations stipulate that proposed changes should be justified by a "concept" for employment of forces that provides an intellectual foundation for the proposal. CBRS laid down procedures for concept development and mandated that new concepts be subjected to evaluation by cognizant Army analytic bodies before the senior Army leadership decided on each proposal's merits. When a change was deemed to be desirable, CBRS decreed that the preferred order was doctrine, training, organization, and equipment, which reflected the authors' assumptions about the relative costs of these alternative innovations. CBRS was intended to apply to all important initiatives and to short as well as long time horizons; but in practice, issues requiring longer time horizons (e.g., equipment) were emphasized.

The second initiative was a project to put the CBRS into practice on the development of a concept for the Army that would field the next equipment generation following the 1980s modernizations: Army 21.[4] Army 21's stated objective was to provide an "azimuth" for future Army planning, particularly as it pertained to the element that required the longest lead time: the research, development, and production of weapon systems. As such, the Army 21 project attempted to prepare a recommended style of warfighting, which in turn was intended to imply preferences among technologies and systems. Recognizing that research, development, and acquisition times for recommended capabilities could be as long as 20 years, Army 21's time horizon was approximately 2015.

CBRS IN THEORY[5]

Figure 6 shows a simplified representation of the tasks required by the CBRS in order to justify new requirements. The specific organizations responsible for each step may vary depending upon the nature of the perceived problem and proposed solution; changes in tactical armored formations would probably be addressed by the Armor school, logistics by the Logistics Center, etc. The discussion below assumes that changes proposed would cut across several Army functions, as Army 21 did, thus involving multiple constituencies and high-level review. The CBRS process uses the *concept* as the foundation of any proposed change. Several tasks must be completed before the concept can become the basis for new requirements.

Definition

Any interested party may outline his idea for solving a perceived problem or deficiency.[6] Generally these ideas are presented to TRADOC in the form of short papers or briefings. For

[4]The precise objective and time horizon of Army 21 varied with its intra-Army political fortunes, so both were in a state of flux in the early 1980s. This discussion of Army 21 objectives is based on the first published Army 21 draft (U.S. Army Training and Doctrine Command, 1985) and conversations with its authors. Ben-Horin and Schwartz, 1988, provide a review of the changing emphases of the Army 21 development effort.

[5]CBRS procedures are outlined in U.S. Army TRADOC Regulations 11-15 and 11-16.

[6]Since the late 1970s the Army has had a formal procedure for identifying, collating, and setting subjective priorities among deficiencies in its ability to conduct its missions. Known as the Battlefield Development Plan, it rank-orders areas where functional experts (drawn primarily from branch centers and schools) perceive needed improvements in equipment, organization, or doctrine and training. Typically the force structure identified in the Program Objective Memorandum, which has a five-year time horizon, is used. Some deficiencies are phrased very generally, but those that are specific tend to emphasize equipment needs.

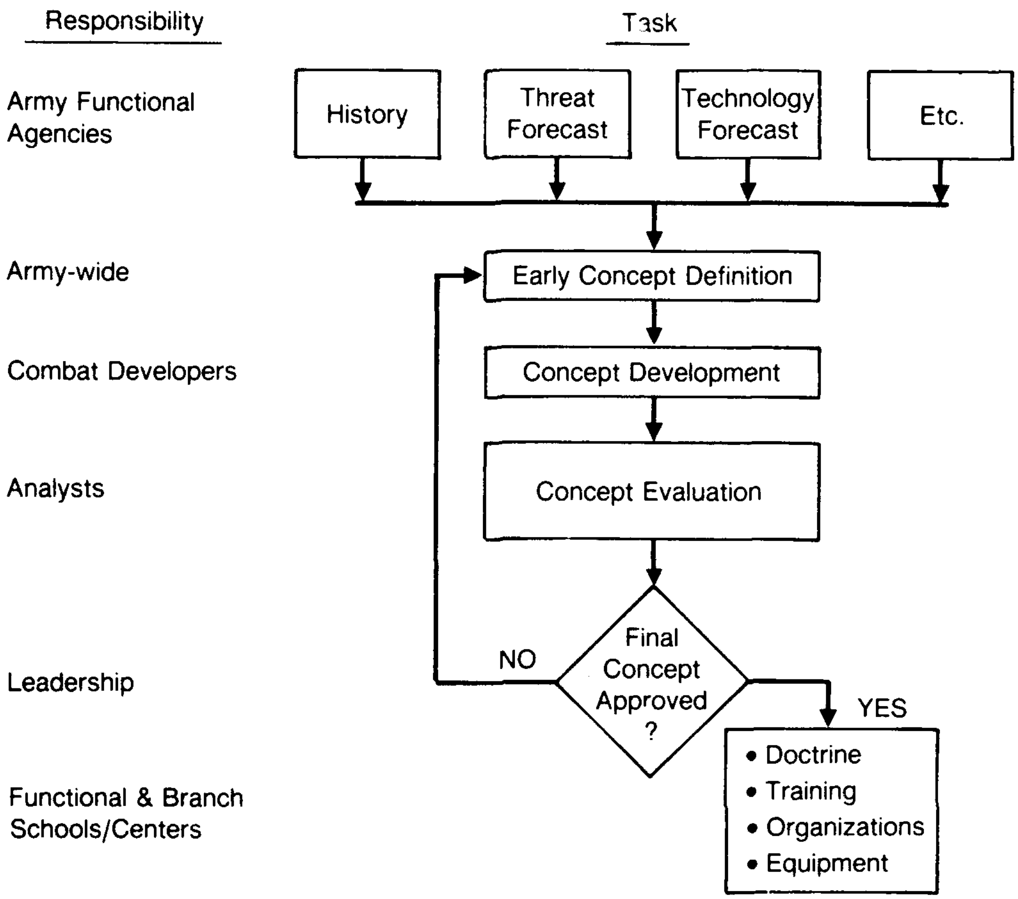

Fig. 6—The Army's concept-based requirements system

combined arms concept ideas, a TRADOC organization, the Concepts Development Directorate within the Combined Arms Center Development Activity, is responsible for expanding promising outside ideas as well as for producing ideas of its own.

Development

The Concept Development Directorate expands the basic idea in a creative effort, using inputs from several outside sources (e.g., a threat forecast from Army intelligence agencies, and a forecast of technologically feasible systems characteristics from the Army technical community). A description of the proposed warfighting style (the warfighting concept) is written, and from it conclusions are derived concerning preferred organizational structures and equipment characteristics. In the case of Army 21, this task took approximately three years (including time to coordinate the concept with various Army constituencies). The product was a roughly 500-page draft "Concept Statement".

Evaluation

The Army 21 concept statement was subjected to an evaluation by TRADOC Analysis Center (TRAC).[7] Analyses performed by the Army analytic community have customarily emphasized the evaluation of combat performance through the use of detailed combat simulation models and computer-assisted games.

Review/Approval Decision

A panel of general officers reviews the concept and recommendations based on its evaluation and approves or disapproves the concept. If the concept is not approved but the panel agrees that some change is needed, the concept developers are instructed to produce a new or revised concept.

Implementation

Changes mandated by the concept are made in procedures, organizations, or equipment. In the case of Army 21, after its approval specific guidance would have been issued to specialized planners for various functional areas (close combat, C3I, logistics, etc.), instructing them to develop long-range plans in accordance with the concept.[8]

The overall theme of CBRS, then, was a methodical approach to planning, grounding new initiatives in a comprehensive, well-developed intellectual foundation. The organizing principle for the entire process was an image of how (within assumed constraints) the Army would prefer to conduct future land warfare.

CBRS IN PRACTICE: THE SHORTCOMINGS

Straightforward and unexceptionable as it may appear in theory, actual implementation of the CBRS idea in a practical setting requires transcendance of several obstacles. The shortcomings noted below are based on observation of the most complete attempt thus far to implement the CBRS planning approach, the development and planned evaluation of the Army 21 concept.[9] They are grouped according to the CBRS task to which they apply.

Problems in Concept Definition and Development

No Agreed-upon Descriptive Framework. As discussed in Sec. II, the absence of a typology for describing concepts in a systematic and comprehensive way impinges on the efficiency of these tasks.[10] First, it is difficult to separate semantic distinctions from substantive ones. Besides engendering pointless disputes, this absence also wastes effort as each concept designer is

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[7] TRAC was fomerly known as the Combined Arms Operations Research Activity.

[8] The Army 21 concept became increasingly controversial within the Army in the mid-80s, as described in Ben-Horin and Schwartz, 1988, and outlined in Sec. II, and in the process its authority as a basis for planning was diluted. While this was in all likelihood unavoidable, it nevertheless was at variance with the basic purpose of the CBRS, which called for approved concepts to guide related planning.

[9] Ben-Horin and Schwartz interviewed several dozen participants in the concept definition and development phases of the Army 21 concept, and I observed the later phases firsthand.

[10] Naturally, there are limits on the extent to which any framework could be imposed on Army developers and analysts from above. Section V outlines an approach for achieving greater coherence in concept descriptions while maintaining latitude for individual creativity.

obliged to invent his own lexicon. Further, there is no assurance that any concept idea is inclusive, and no ready framework for qualitatively exploring minor variations or refinements.

Inconsistencies in Specificity Among Concepts, and Level of Warfare Emphasized Within Concepts. Even a product of an extended development effort, such as Army 21, is highly varied in its concreteness, offering detailed recommendations on the organization of divisions (or even smaller units), but very little that is concrete concerning warfighting style and procedures. For instance, Army 21 emphasizes operations by Blue combat units in dispersed formations in the enemy's rear area, quickly massing for an attack before dispersing again. The concept stays silent about many aspects of this style, including: What is the mix of offensive and defensive missions for Blue forces? How deeply in the enemy rear do they operate? How many forces concentrate before initiating an typical attack? When striking, what are their objectives—attrition, delay, disruption, or destruction of logistics support? How long do they press each attack?

Developers sometimes strive for concreteness by unduly stressing the tactical level of warfare. Army 21, a concept intended to emphasize the operational level of war (Corps, Army, or Army Group activities), was criticized for relying on overtly general slogans to convey a proposed warfighting style. Initial attempts in early 1987 to develop alternative concepts largely compensated by shifting their emphasis to the conduct of the brigade battle (as opposed to the operational campaign). These concepts were accused of merely substituting a larger number of general slogans about tactics for a smaller number of general slogans about operations.

A working definition of concreteness is the presentation of a concept's elements in terms of *quantified* attributes. The illustrative questions about Army 21 listed above are examples.[11] Comparison and evaluation of a concept is not possible until a concept's description is cast in quantitative terms. The failure to be concrete is not confined to Army concepts, being prevalent among most published NATO concepts as well. In most cases, attempts by their creators to specify them has added technical or tactical *detail* without imposing much quantitative *rigor*.

No Techniques for Exploring New Ideas Efficiently. The traditional approaches to the development and exploration of concept ideas—seminars, brainstorming sessions, and tabletop games—are usually time-consuming and personnel-intensive. Consequently the concept development task usually cannot afford to explore a very wide range of ideas, or refine promising ones. If the answer to each "what if . . . ?" question absorbs substantial study resources, then few such questions can be asked.

Problems in the Interface Between the Concept Development and Evaluation Tasks

Although concepts are seldom specified concretely, it can be argued with some justification that further specification of rather vague concepts without supporting quantitative tools would be arbitrary. This would imply that the developers' responsibility ends with the creation of a concept, to be no more specific than the tools of developers allow, while concreteness is up to the evaluators. This can be claimed to be consistent with the division of responsibility laid out in the CBRS, where developers engage in creative activity, while evaluators analyze the developers' products.

In fact, concepts rarely admit of such a neat division of labor. First, the absence of a descriptive framework (typology) means that the developers are held to no particular standard of suffi-

[11]Another example was provided by Lieutenant General Gerald Bartlett, Commander of the Army's Combined Arms Center, in early 1987, when (in commenting on a presentation of the Army 21 concept) he remarked that, "It isn't enough to declare that a Blue force must be 'more agile'; you have to show *how much* more."

ciency in their concept design. Consequently, the evaluators are obliged to interpolate (when details are left vague) or extrapolate (if whole dimensions are omitted) in order to convert the general ideas in the developers' product into a specified product. When the concept is the product of a long and highly visible development effort, as was the case for Army 21, the evaluators will be circumspect about specification, lest they be accused of perverting the concept. Second, even if such a framework did exist, the processes of design and evaluation of policies are difficult to separate and may be inseparable.[12] For example, insights gained in evaluation can suggest improvements at the margin or even wholly new policies. Conversely, the criteria to be employed in the evaluation ought to shape the design process.

Achieving a more permeable membrane between the development and evaluation tasks is complicated by an important difference in the "cultures" of the organizations and people that perform them. Typical analysts in the Army are trained in operations research, applied mathematics, systems analysis, or computer science. Typical concept developers, by contrast, are more likely (and appropriately) versed in strategic studies, military history, or management theory. The two groups have little vocabulary in common, so unless one has been constructed ad hoc,[13] each group finds it difficult to understand the other. CBRS assigns them each tasks appropriate to their comparative advantages but fails to recognize their interdependence.

Problems in Concept Evaluation

The tools and models customarily used by Army analysts for more traditional problems (e.g., weapon system comparisons or balance assessments) generally are ill-suited to the task of concept evaluation. Since most of the policy problems examined by models pertain to the allocation of near-term (five to seven years) resources, most Army models assume corresponding scenarios and force capabilities.[14] Furthermore, their highest practical scope is frequently a single corps. Because they were constructed for other purposes, they do not allow much variation in theater strategy, operational art, or tactics—the essential elements of warfighting concepts. More important, they tend to be quite large, since detail is needed in order to reflect the role of specific weapons systems in the context of a battle or campaign. Therefore the time to run an individual case can be many minutes to many hours. This limits the degree to which alternative concepts or assumptions can be examined.

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[12]The "stages of analysis" approach pioneered by Goeller and described in Goeller et al., 1983, emphasizes explicit hierarchical *design and analysis* of policy alternatives in an integrated process.

[13]In the Army 21 study a tabletop (manual) wargame was used to provide a common base of experience.

[14]Combat or campaign models have not traditionally been employed in the analysis of doctrine and concepts at the operational level of war. The interested community within the Army has relied on manual or man-machine games, which are rich in their ability to reflect command decisionmaking but do not readily provide reproducible results. Balance or requirements assessment, usually assume the tactical or operational practice stipulated in doctrine—changes in doctrine are usually not part of the "policy space" under study. Systems analyses emphasize choices among alternative weapon or support systems, usually retrofitted onto a force also assumed to operate according to contemporary doctrine. Aggregated models that use firepower or combat power scores as the metric of each force's capability embed within those scores assumptions about doctrine and its effectiveness in a battle or campaign and thus make opaque the translation from doctrinal "quality" to force effectiveness. Models used to nominate "superior" concepts must (endogenously or exogenously) reflect the effects of force behavior on force campaign performance, a relationship about which there is little agreement. Recognizing this uncertainty, Posen, 1984-85, manipulates a Blue force's assumed combat power (in armored division-equivalents, or ADEs) to vary the presumed effectiveness of a fixed NATO doctrine.

Problems in Implementation

The objectives of CBRS present those who attempt to apply it with a quandary: to affect long-lead decisions (such as weapons systems), it is necessary to choose concepts for 20 or more years in the future, yet the very idea of projecting so far forward strikes many decision-makers as fanciful. Long-range concepts can therefore have credibility problems, even if they have the backing of senior Army leadership; this can undercut their authority and make their application to planning less binding than CBRS envisioned. Certainly the vacillation of Army 21 proponents as to the concept's intended effect on planning came about largely in reaction to audience incredulity.[15]

To summarize the shortcomings of the CBRS as manifested by Army 21:

1. Because there is no framework into which concept ideas can be placed, each one stands alone, and there are no guideposts or tools to assist in comparing or refining them systematically. Also, there is little common vocabulary, so developers and evaluators, who come from different intellectual traditions, are forced to fall back upon generalized slogans or present-day analogs that are familiar to them but of dubious relevance.
2. With a time horizon of 20 or more years, almost any aspect of the problem of choosing a concept is uncertain or variable: both "scenario" variables that are not in Blue's control, and "policy" variables that are. Some policy variables that might be fixed in a short-term study, such as force structure and equipment characteristics, can be variable in a CBRS study—in fact, examining them is the basic motive for CBRS. The tools available for quantitative evaluation generally are limited in the scope of elements that can be varied (omitting, for example, most aspects of warfighting style), are time- and resource-consuming to use, or both.
3. The long-term time horizon that is needed to influence the research and development process, is the principal source of credibility problems that hamper the direct application of the long-range requirements produced by a concept developed and evaluated in accordance with CBRS.

IMPROVING THE IMPLEMENTATION OF CBRS: A CONCEPT DESIGN AND EVALUATION APPROACH EMPHASIZING ROBUST CONCEPTS[16]

The balance of this section describes an approach intended to ameliorate the above shortcomings. Its point of departure is the mission laid down by CBRS: to develop, evaluate, and choose future warfighting concepts in order to influence Army planning that requires long lead times. As such, it endeavors to graft tools and procedures onto the CBRS process to make it more synoptic, systematic, and efficient, changing CBRS at the margin instead of wholesale. These modifications emphasize the evaluation task, but they have upstream and downstream ramifications for other tasks as well.

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[15]Changes in Army 21's self-described role in the Army's planning process that were intended to insulate the concept from controversy by relaxing its intended authority are noted in Ben-Horin and Schwartz, 1988.

[16]My early thinking concerning improvements to the Army's approach was greatly influenced by a series of workshops held at TRAC in late 1985 and early 1986, informally chaired by Bruce Goeller. The analytical framework proposed draws heavily upon the methods developed in several RAND projects led by Goeller since the early 1970s. I am indebted to Robert LaRocque of TRAC, and Bruce Goeller and James Bigelow of RAND, for leading further discussions on the methodology of concept evaluation.

The fundamental elements of the approach are:

- A *typology* of concept attributes and levels of warfare;
- Consideration of a *wide range* of alternatives;
- *Uncertainty* addressed through variations in assumptions; and
- Concepts and systems whose performance is *robust*.

Application of the Typology of Concept Attributes

Section II described some of the important military dimensions among which NATO concepts differ. These elements of concepts can be grouped into three general categories pertaining to force allocation and deployment, combat organization and equipment, and warfighting style.

1. *Force allocation and deployment* refers to the assignment of missions or targets to forces (air or ground) in specific temporal and geographical locations, including depths of attacks or defenses, allocation of forces to different sectors or echelons, or against targets distinguishable in space or in time.
2. *Force organization and equipment* refers to the characteristics of the force, regardless of use. Are units small or large, heavy or light? Do they rely for mobility on ground or air vehicles? Do they emphasize lethality or survivability?
3. *Warfighting style* comprises employment of forces: their mission objectives, degrees of concentration/dispersion, employment of obstacles and protective shelters, aggressiveness, etc.

Each of these categories pertains *to each level of warfare above the technical level* (because the technical level can by definition apply only to equipment characteristics) and includes subcategories emphasized by various concepts.

Concepts can differ in kind or merely in degree. Figure 7 illustrates the difference. In this example, concepts are distinguished by a single feature, their reliance on mobility, defined here as the average number of hours per day that friendly combat units spend moving in the combat area over the course of a long operation or campaign. Figure 7 displays a distribution of movement times for each concept that might come from exercise or test data and shows the mean movement fraction for that concept. In this example, no unit is assumed to spend more than just over half of their time, on average, in movement; more than that might leave insufficient time for combat engagements or for resting.

Two concepts that are quite different in this dimension, such as the "static" vs. "mobile" concepts, appear far apart on the horizontal axis. But how mobile is "mobile"? Average movement times of eight, nine, and ten hours per day are all "mobile concepts", but all are slightly different. Significant differences, such as eight vs. two hours per day, are *different concepts*, whereas small differences, such as eight vs. nine hours, are referred to as different *versions* of a common concept. Thus a "mobile concept" can be more accurately represented as a *bundle* of mobile concept *versions*, varying the fraction of time spent moving within some range that constitutes the outer boundaries of the bundle. The same is true for any other descriptive attribute.

Concept developers and those more accustomed to a deductive approach than the inductive one suggested by a concept typology may argue that such a framework is overly confining because numbers cannot capture essential differences among concepts. In fact, the purpose of a typology is to supplement, not replace, more traditional formats for describing concepts. There are, however, two powerful counterarguments. Without some device that imposes rigor

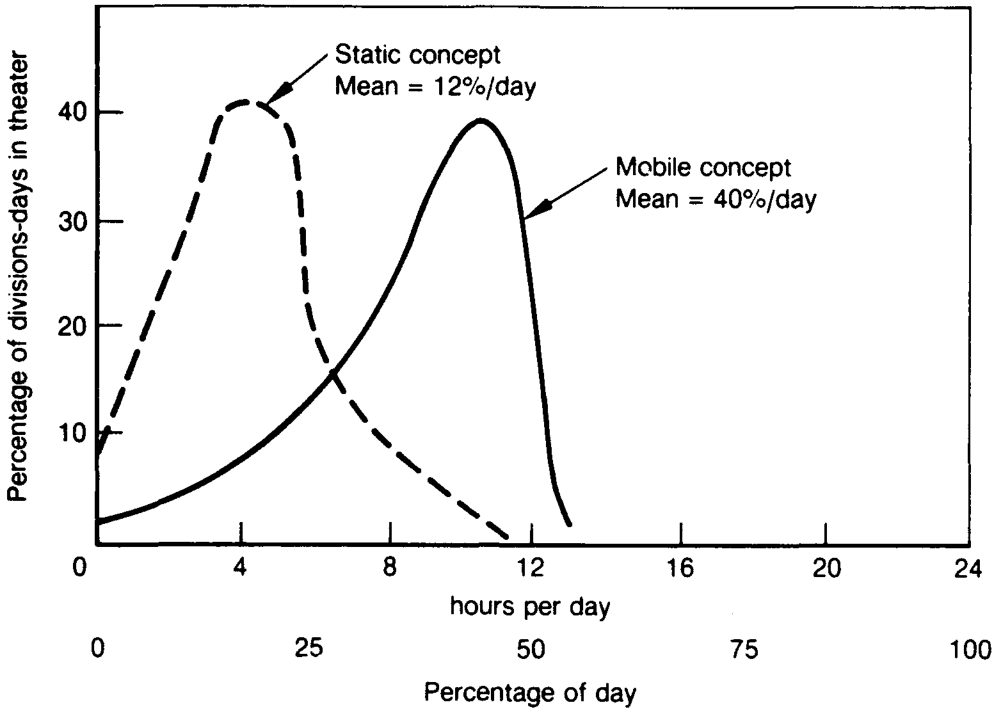

Fig. 7—Differences of degree vs. differences in kind for mobility of two hypothetical concepts

on the concept development task, the evanescence of the concepts produced will undermine their comprehension and acceptance within the Army. More pragmatically, quantitative evaluation of concepts will require putting them in some model's input format in any case. If developers do not quantify, analysts will, and they are less familiar with the concepts' "essence."

A Rich Variety of Policy Choices

Most public policy analyses in both the military and civilian sectors examine and compare a small number of options. In reality, a much wider variety of alternative policies (in the current case, "concepts") are available, but many are not explicitly examined because they are "screened out," usually implicitly. Often discarded at an early stage are options considered to be politically infeasible or too expensive, or options excluded by the study's charter. However, this may remove hybrid, intermediate, or novel options that are worthy of consideration. When a concept is really a bundle of *versions*, care must be taken to assure that the best version of one is not inadvertently compared with the worst of another.

When the number of policy options to be developed and evaluated is large, either of two approaches can be taken, screening or design.

Screening. Each option is weighed against one or a few simple criteria, with only those meeting the criteria retained for evaluation. Criteria might include dominance, cost effectiveness or net benefits minus costs, input measures (such as number of weapon platforms, or combat personnel), or subjective assessments of "feasibility" or "payoff." Depending upon the criteria used, screening might be performed by panels of experts, by simple cost or accounting models, or by "repro" versions of analytic models.

Design. Systematic techniques (usually based on optimization or goal-seeking methods, such as linear programming) are used to identify a smaller number of options or packages of options that maximize one of several possible mixes of goals, constraints, and objective functions. (For instance, one formulation might be to design the minimum-cost force subject to a performance floor, while an alternative formulation, which might produce a different policy, would be to maximize force performance subject to a budget ceiling.)

Whichever of these two approaches is taken—and both could be conducted sequentially—the intent is to choose from a large population of policy options a smaller set of "promising" ones for further analysis.[17]

Coping with Uncertainty Through Sensitivity Analysis

The environment in which future warfighting concepts might be employed is rife with unknowns. In some dimensions, such as enemy theater strategy, operational style, and tactics, we are fundamentally ignorant and cannot avoid remaining so (although doctrinal writings and peacetime exercises are presumed to be suggestive of wartime practice). In others, such as the technical performance of our weapons systems, we are uncertain (unless they have been used in actual combat),[18] particularly about their likely values in the future. Although it is common practice to use "best estimates" for the values of the variables about which we are ignorant or uncertain (e.g., the allocation of GSFG divisions to the NORTHAG vs. CENTAG sectors at the theater-strategic level, or the hit probability of a particular antitank missile at the technical level), in truth we only know a range of plausible values, including a "best estimate." Wide as many of these ranges must be for present-day warfare, as we attempt to analyze wartime situations farther in the future, they must become wider still. Because we do not know—and cannot know, short of war—the value of these variables, it is necessary to evaluate concepts throughout these ranges in order to determine how sensitive their estimated performance is to our assumptions.

Acceptable Performance over a Range of Assumptions Is Preferred to "Optimum" Performance in a Few[19]

Figure 8 provides an illustration of the sensitivity of two hypothetical concepts' performance under varying assumptions. The vertical axis indicates each concept's performance in terms of some measure of effectiveness that we wish to maximize under each unique combination of scenario variables (the variables not entirely under friendly control, and about which

[17]For references that employ or explain the use of screening and design techniques in policy analysis, see Chesler and Goeller, 1973; Goeller et al., 1973a, 1973b, 1977, and 1983; Walker and Veen, 1981; and Walker, 1987.

[18]Uncertainty about performance under "realistic" conditions can be reduced somewhat through well-designed (but expensive) tests and experiments. Several authors, such as Stockfish, 1975, have called for greater efforts to assess the operational, as opposed to the technical performance of weapons and equipment through empirical research and experimentation.

[19]The importance of robustness is emphasized in Abrahamse et al., 1977; Chesler and Goeller, 1973; and Goeller et al., 1977. Arguden, 1982, notes some of the practical limitations and preconditions for the use of robustness as a measure of merit. For a different philosophy regarding treatment of uncertainty that uses a fortiori assumptions to compensate for inputs uncertainties in a balance assessment, see Epstein, 1984. Fisher, 1970, also stresses the importance of sensitivity analysis.

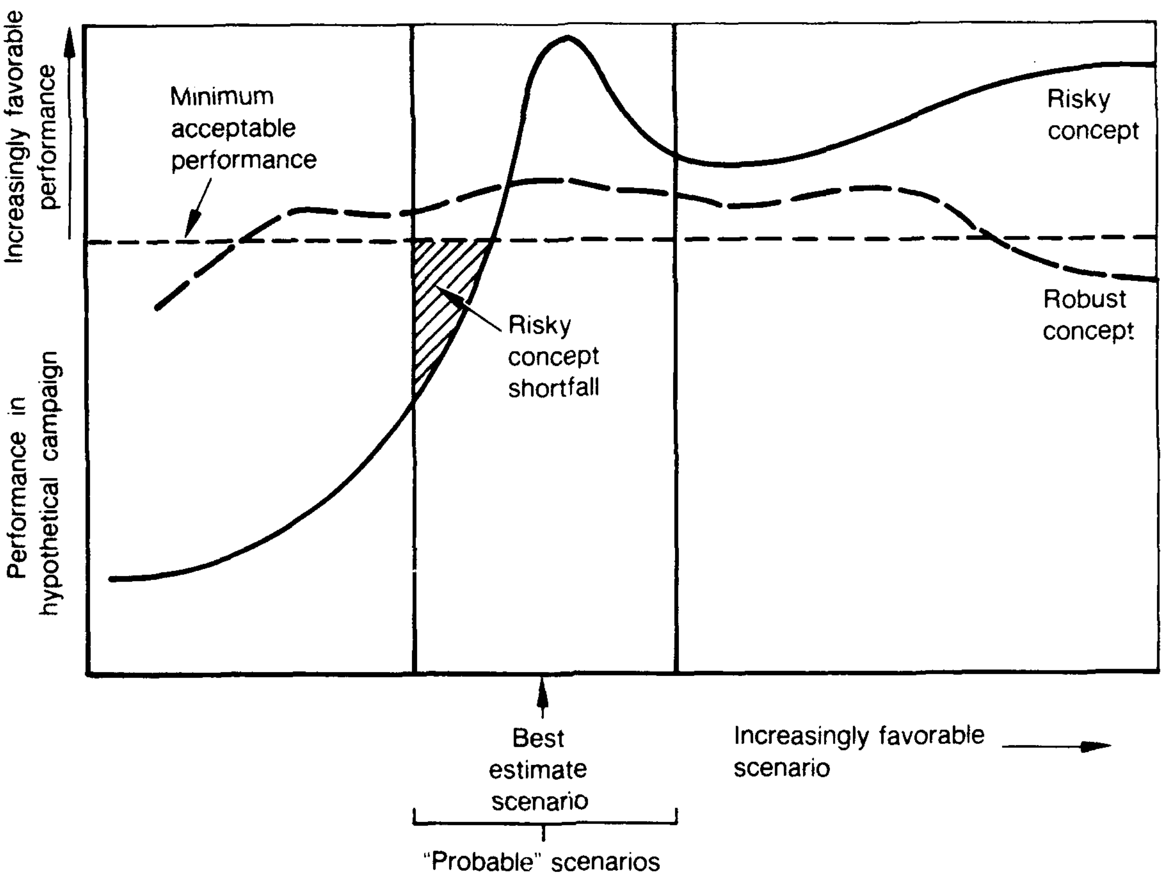

Fig. 8—Illustration of robustness: "Risky" vs. "Robust" concepts

there is quantifiable uncertainty).[20] The "risky" concept performs better than the "robust" concept in the best estimate case, but its performance is quite sensitive to the presumed scenario. In contrast, the "robust" concept performs above the minimum standard throughout the range of more probable scenarios; its variance is lower than that of the "risky" concept. Because these are just estimates of the scenario variables' values, risk-averse people will prefer the more robust concept across a fairly wide range of possible futures over the one that performs best in only a few possible futures.[21] Some of the scenario variables are under the control of Red, who presumably will set his own policies to attempt to minimize Blue's performance, and so influence the scenario probabilities.

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[20]In Fig. 8 input data were assumed to include best estimates for each variable as well as the boundaries of a plausible range as viewed by expert opinion—e.g., the boundaries of an 85 percent confidence interval. Different scenarios combine different proportions of best estimate and boundary values for different variables; "probable" was arbitrarily defined as using best estimate values in more than 50 percent of the scenario variables, and "improbable" using less than 50 percent.

[21]"Fairly wide" was defined as the entire set of "probable" scenarios, but it could be defined in other ways, such as a specific minimum fraction of the entire scenario space (including 100 percent), regardless of prior estimates of their probability. Alternatively, some other principle might be used for choosing the "wide enough" subset of all scenarios, relating to their perceived relevance or importance.

IMPLICATIONS FOR THE DESIGN OF CONCEPT STUDIES AND THE ANALYTICAL TOOLS USED

The union of two challenges—to examine a spectrum of concepts and to look for robustness through sensitivity analysis—presents an intimidating problem: what has been termed a "combinatorial explosion." Concept studies have finite durations and resource budgets; in all likelihood, no analytic technique (especially the detailed quantitative models commonly used in the defense community) would be efficient enough to handle the caseload.

The analytic strategy to respond to this challenge has two basic components. The first pertains to the design of a study and the second to the choice of tools used.

Study Design: Stages of Analysis[22]

A metaphor for the design of the study is a funnel, as indicated in Fig. 9. At the beginning, the largest possible set of concepts and assumptions are considered, but necessarily in only a very cursory way. Several successive filters (simple analyses) identify the concepts that fail to meet absolute standards for a few relevant criteria, such as the screening criteria mentioned above. Only the concepts that pass these initial tests receive further scrutiny. This approach targets analytic resources to the most promising candidates.

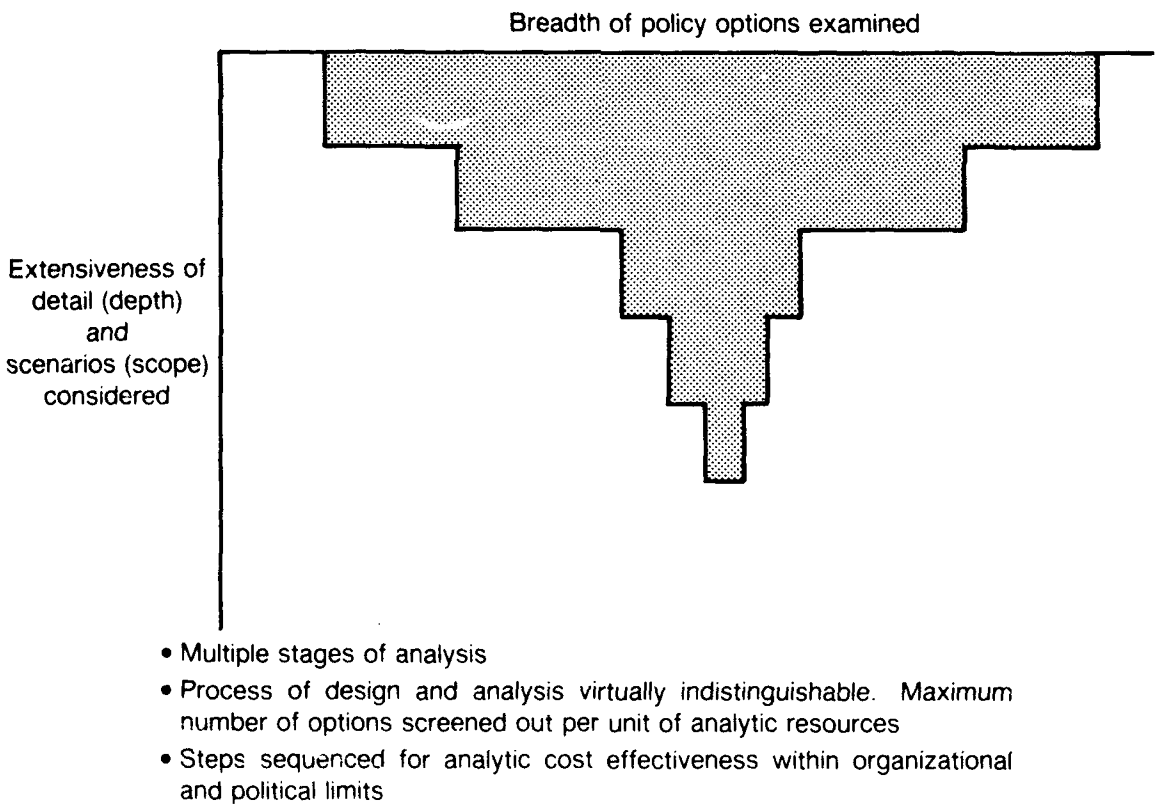
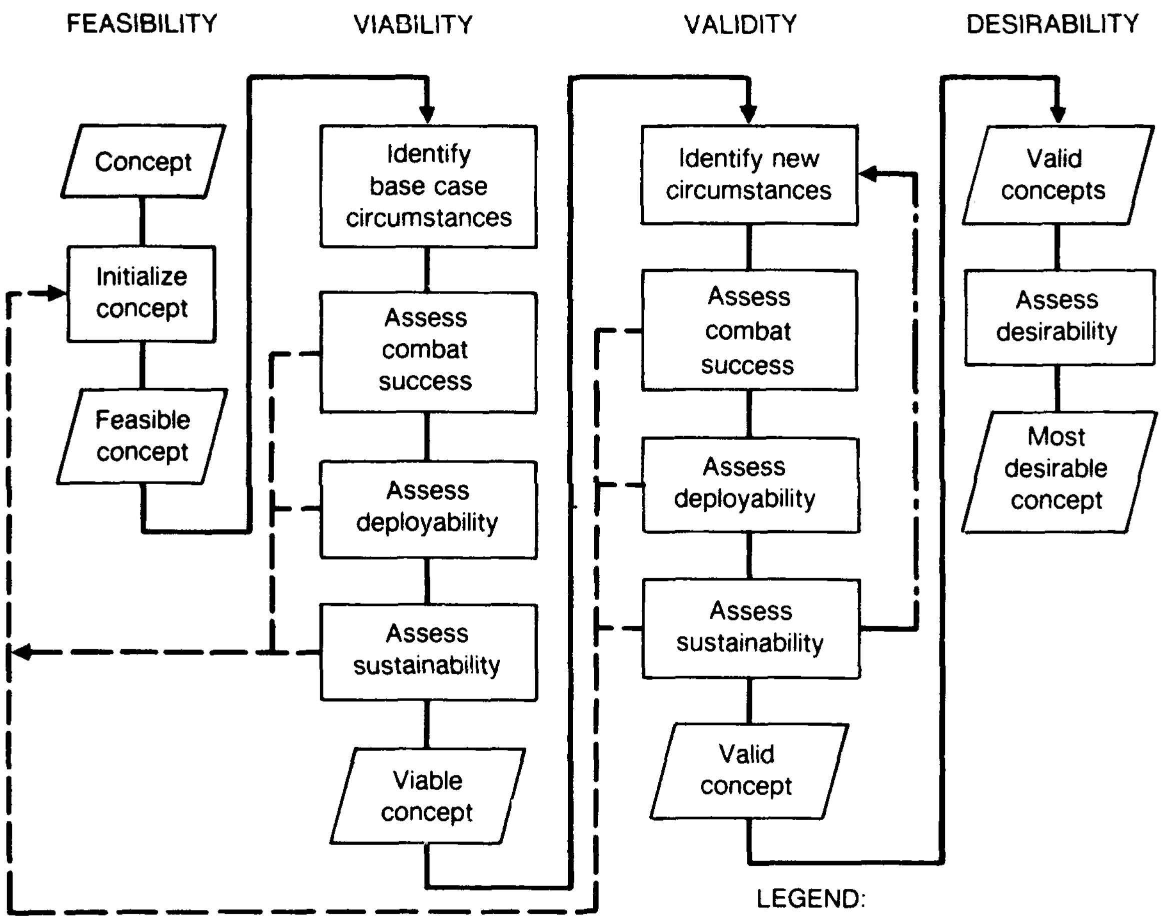


Fig. 9—Stages of analysis: The funnel metaphor

[22]Goeller et al., 1983, provide a good summary description of stages of analysis. See also Goeller, 1973a, and 1985.

If multiple criteria are employed in the evaluation, and different techniques (models) are used to estimate them, the study can have a series of stages. At each stage all concepts that were not discarded in the previous stage are evaluated in terms of that stage's pertinent criteria, with only those that pass muster surviving to the next stage. Successively fewer concepts are thus considered in each stage. Figure 10 illustrates the successive filters originally planned for TRAC's evaluation of Army 21: an assessment first of each concept's prospect for succeeding in combat, then of the prospects of providing logistic support to the survivors of the first stage, and finally of the ability of projected strategic and theater lift assets to deploy the forces assumed in the concepts that survived the second stage.[23]



SOURCE: Karhohs and Fratzel, 1986.

Fig. 10—Planned stages of Army 21 study

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[23]The Army 21 analysis ended after the first stage when two substitute concept designs and evaluation efforts were begun: one with a time horizon of approximately 2005, called AirLand Battle Future, and one for approximately 2020, which retained the name Army 21.

The optimal order in which to array multiple stages depends entirely upon the tools and models available. The study designer's objective is to maximize the ratio of concepts correctly screened out to resources (time, funds, and personnel) needed to do the screening.[24] Tools that are resource-intensive per concept should be used on the smallest number of concepts possible, so their use should be planned for late in the study. There can be no fixed rules about the "right" tools or the "right" sequence in which they should be used.

Hereafter this report will distinguish among three separate CBRS study stages: *Design* will refer to the systematic development and possible early sifting of concepts, preferably using a quantitative design tool, which may be a deterministic model, such as a simulation or an optimizing model, such as a Lagrange multiplier or linear program; *screening*, in which fast, low-resolution tools are used to nominate "promising" and "unpromising" concepts, perhaps using a small number of criteria; and *evaluation*, where specialized and detailed tools are used to assess concepts in terms of each important criterion.[25] Figure 11 interpolates these stages onto the CBRS diagram, indicating the role for a quantitative design support tool in the concept definition/development tasks, and separating the evaluation task into a stage for screening stage, for specification of promising candidates, and for detailed evaluation.[26]

One general principle, however, is clear: At the starting point of a CBRS study there can be many concepts and many scenarios, far beyond the numbers that high-resolution models would be able to accommodate within most plausible study budgets or schedules. Only efficient, low-resolution techniques are feasible in the screening or design stages.

Because a variety of criteria may be applied in the evaluation stage, the ideal tool for screening would be one that provides an approximate appraisal for each, one that efficiently reproduces a subset of the results of the larger, more complex models used in the evaluation stage. Several past RAND studies have constructed such repro models of large simulations using curve-fitting and related techniques, as illustrated in Fig. 12. The repro model sacrifices detail in the name of efficiency, saving its complex parent for use on a smaller caseload.

Analytic Tools for Screening and Design

Screening in a policy analysis is a pragmatic compromise necessitated by the complexity of the parts of the problem that are under a decisionmaker's control (policy variables) and uncertainty about those parts that are outside of his control (scenario variables and other assumptions).

There is no detailed model able to capture the variety of concepts that might be needed in the screening step of a concept study.[27] It is therefore necessary to construct an original model that can meet the *requirements* of screening (easy variation of concepts and assumptions) within its *constraints* (fast run time and simple measures of effectiveness).

The Method of Screening Concepts of Warfare (MOSCOW) was constructed for use by the Army in CBRS efforts. MOSCOW is a commercial microcomputer spreadsheet that asks a user to

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[24] James Bigelow introduced me to "analytic cost effectiveness" as a measure of merit for designing a screening strategy.

[25] Goeller, 1983, used all three stages explicitly. The Managerial Strategy Design Model (for designing water distribution management policies), described in Goeller, 1983, and 1985, was an optimization (design) model. An earlier tradeoff model (for designing pollutant control strategies), described in Goeller, 1973a, employed a mixture of simulation and optimization techniques.

[26] The evaluation stage may have several substages, as was planned for the Army 21 study.

[27] If one had existed, its input structure could have been used as a first approximation of the missing concept typology. Since neither a model with the necessary operational scope and flexibility nor a general typology existed, both were constructed in the course of this research.

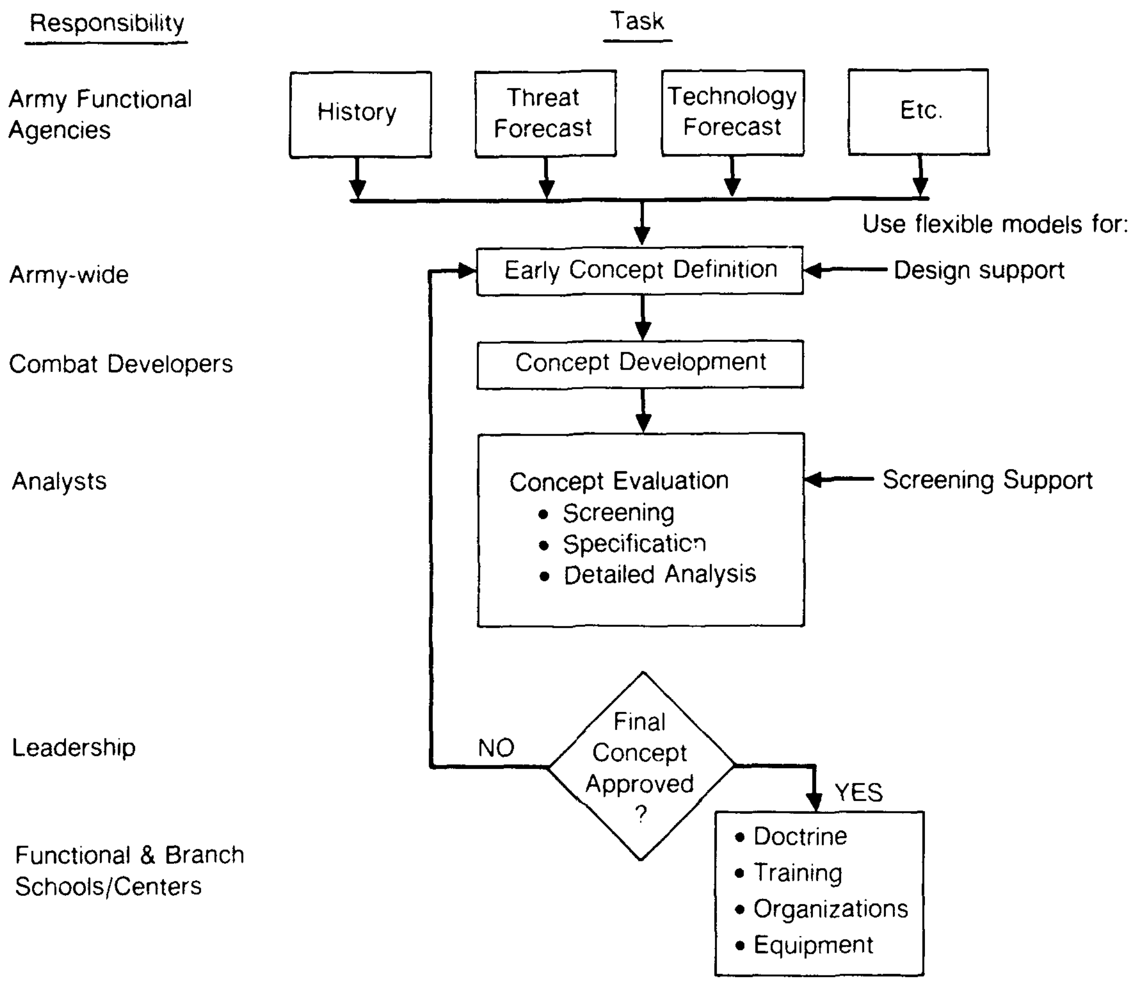
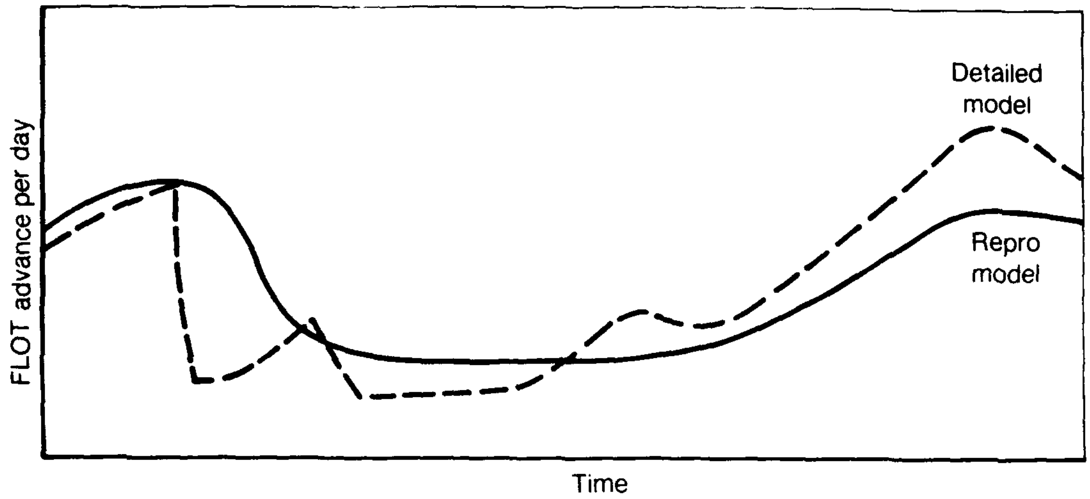


Fig. 11—The role of flexible, low-resolution models in the CBRS process

specify elements of a warfighting concept at the operational level (with additional policy variables to provide basic context at the grand strategy, theater strategy, and tactical levels). The model estimates the resources that would be needed to successfully conclude a campaign utilizing the specified concept. It is described in the next section.



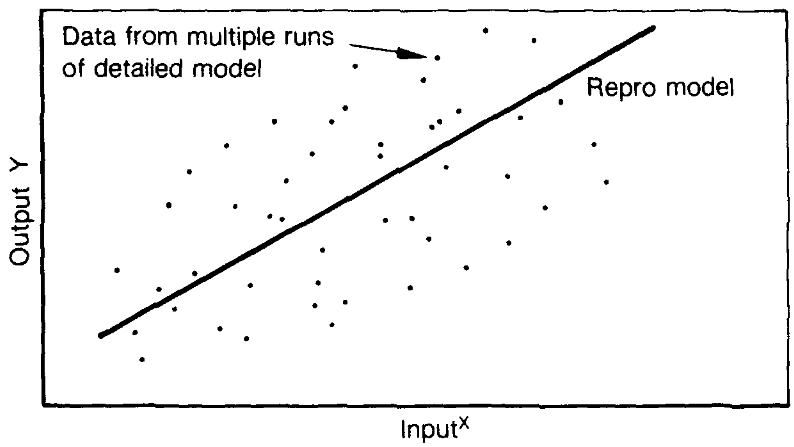


Fig. 12—Examples of repro models of hypothetical detailed models

IV. MOSCOW: METHOD OF SCREENING CONCEPTS OF OPERATIONAL WARFARE[1]

MOSCOW is a microcomputer spreadsheet-based tool to assist concept developers and evaluators gain an aggregate, first-order appreciation of the "promise" or efficacy of a concept, using a portion of the full set of criteria that might be used in the CBRS concept design and evaluation process. It includes approximately 50 policy variables, emphasizing some of the important features of concepts for conducting war at the operational level, with additional policy variables and contextual elements from other levels of war as well. Because a substantial range of possible concepts might be considered in CBRS studies, and the time periods in which they are presumed to be used extend to more than 20 years in the future, these policy variables are necessarily abstract, as are analogous variables describing scenario, capabilities, and the threat.

The original motivation for MOSCOW stems from the planned evaluation of Army 21 in 1986–87. TRADOC developed Army 21 in the early and mid-1980s to visualize the conduct of warfare circa 2015. It emphasized dispersed, covert maneuver by friendly forces, interspersed with brief, intense attacks against enemy forces, taking place primarily behind the enemy's lead advancing elements. After the Concept Developments Directorate (CDD) completed a draft concept statement in mid-1985, TRAC became responsible for its evaluation, which it wished to make as rigorous and quantitative as possible. The description of Army 21 provided by the CDD, however extensive, remained too general to allow its direct translation into the input variables of available evaluation models. Any of several versions of Army 21 were possible, with no a priori means of determining the "right" or "best" one. Because the models available were not well suited to performing an efficient search among these versions,[2] a new model was needed that could capture the essential features of the Army 21 concept, compare them using a subset of the study's evaluation criteria, and appraise each version at low cost.[3]

Because there was little intellectual foundation for representing warfighting concepts in a quantitative model, the development of the policy variables for MOSCOW, which were intended to permit the representation of different Army 21 versions, quickly proceeded into uncharted territory. Because the range of Army 21 versions that the model needed to accommodate was itself large, it might be possible to define the models' policy variables in such a

[1]This section describes the motivation for MOSCOW and outlines in reasonably nontechnical language how it operates. It emphasizes the design philosophy behind the model, and the elements of warfighting concepts that MOSCOW attempts to represent. Readers interested in additional technical model information phould consult the appendixes, which describe the most novel elements of the model: the computation of engagement results, resources consumed, and the model's outputs. Input definitions are provided in Romero, Rydell, and Stanton, 1987. Additional documentation will be forthcoming in a separate user's guide.

[2]Although *screening* many versions of concepts may at first glance seem different from *searching* for the best versions, they in fact are the same. The term *screening* is appropriate when options, or their elements, have been well-defined and filtration is needed to reduce their number. *Searching* implies a less-understood (but finite) space of options. In the case of Army 21, many specifications could each have been consistent with its qualitative principles, although without an accepted framework for describing concepts, the number of meaningfully distinguishable versions was undetermined. The entire evaluation process was described by Army analytic managers as one of "refining" the Army 21 concept—i.e., searching for the best versions and evaluating those. In this context, a screening stage would attempt to "search for" those versions that appear most promising.

[3]Furthermore, because extant models were designed for other purposes, many of the aspects of force employment that are part of concepts could not be readily reflected in them. Table 16 summarizes a qualitative assessment of the suitability of extant tools to the screening of warfighting concepts. I believed that any tool ought to receive a rating of four to five in priority criteria and three in others. Because existing tools had reciprocal strengths and weaknesses, a new tool was deemed necessary.

Table 16

SUBJECTIVE ASSESSMENT OF THE RELATIVE UTILITY OF ALTERNATIVE TECHNIQUES FOR EFFICIENT SCREENING OF WARFIGHTING CONCEPTS

	Technique							
Desirable Feature	Brain-storming and Debate	Judgment Capture (e.g., Delphi, AHP)	Btn/Bde Level Games	Higher Level Games	Btn/Bde Level Simulations	Higher Level Simulations	Informed Curve Fitting (e.g., OJM)	MOSCOW (Self-appraisal)
Provide quantitative results[a]	1	1	2	2	5	5	5	5
Captures military judgment, "soft" factors	5	5	4-5	3-5	1-4	1-3	5	4
Treat different concepts within a common typology[a]	1	2	2	3	2	3	3	5
Describe missions and actions of important entities (e.g., maneuver units)[a]	1	2	3	3	3	3	3-4	4-5
Terrain and timing treated at appropriate operational level of detail	1	2	3-4	4-5	3-4	2-3	2-3	4-5
Efficiently perform many sensitivity analyses[a]	2	2-3	1	1	2-3	1-3	3-4	5
Resonably transparent, portable, user-friendly	5	5	4	4	2	2	4	4-5

[a]Especially important feature.
Rough rating scale: 1 = Poor, 5 = Excellent.

way that some quite different concepts could also be represented. Further, a broad format for describing concepts would be a step toward implementation of the general typology of concepts outlined in Sec. II. MOSCOW, therefore, is intended to be capable of screening a wide variety of concepts.[4] Furthermore, because its structure for describing concepts is intended to be somewhat general, it is intended to assist systematic thinking about alternatives in the concept definition stage and exploration of alternatives in the concept development stage.

MODELLING PRINCIPLES

The general objectives outlined above implied several fundamental principles for the design of MOSCOW. These principles emphasize certain features and capabilities at the expense of others.

[4]In its most recent version, essentially completed in the summer of 1987, MOSCOW's policy emphasis remains on operationally mobile, strategically defensive concepts, reflecting its Army 21 roots, and is therefore designated MOSCOW-M1: Mobile concepts, version #1.

An Abstract Representation of the Elements of Warfighting Concepts

When MOSCOW was initiated there was little precedent for the development of a quantitative description of any concept of warfare, especially at the operational level, that could be made general enough to capture many concepts. Mindful of this deficiency, the designer endeavored to define MOSCOW's variables so that they could describe concepts other than Army 21.

With generality inevitably comes abstractness, and MOSCOW is no exception. Many concepts invent their own terminology and organizing principles to convey their ostensibly unique features, but clearly a model input structure intended to capture different concepts must not be bound by the nomenclature of any specific one. For example, AirLand Battle refers to the importance of seizing the initiative, while Army 21 counsels "striking" as one of its principal elements. In MOSCOW, the policy variable meant to capture both is the fraction of enemy attrition that is to be achieved in engagements in which Blue maneuver units are on the attack. This is a proxy for each concept's emphasis on offensive versus defensive operations.

Some of those familiar with doctrinal issues will be uncomfortable with MOSCOW's deliberate avoidance of familiar jargon (if that jargon is too closely linked with particular concepts) and will consider MOSCOW's terminology too abstract. However, MOSCOW's analytical representation of concepts can hardly be more abstract than the typical concept descriptions that rely on commonly mentioned but undefined characteristics (e.g., initiative, mobility, or intensity) that evoke rather than explain.

An Emphasis on Policy Choices at the Operational Level, Rather than High Resolution of Tactical Detail

MOSCOW was designed for the screening of concepts, not for the analysis of weapon systems, force structure, or military balances. It emphasizes those policy variables that especially pertain to the operational level of war—those choices within the purview of corps, army group, or theater commanders. Although other elements of a campaign must also be represented to place operational concepts in context, MOSCOW endeavors to do so at the lowest level of resolution possible. For example, both Blue and Red can allocate fire support, close air support, and air interdiction assets among seven different objectives, yet the equations that compute platform attrition and weapon effects are very simple, and no attempt is made to distinguish among fire support from different echelons, or battlefield air interdiction vs. deep air interdiction.[5]

Many other models emphasize systemic homological verisimilitude and consequently aim to achieve a consistent level of detail throughout all elements of the system being represented, often with little regard to the policy analyses for which the model is intended. MOSCOW emphasizes those variables deemed necessary to reflect alternative concepts and their high-level effects upon campaign outcomes, supported by the minimum acceptable amount of context.

Figure 13 summarizes the relative emphasis placed in MOSCOW's design on each element of concepts at each level of warfare indicating its stress on issues pertaining to warfighting style at and near the operational level. Concept design and evaluation studies whose emphases correspond to MOSCOW's (as was expected for the Army 21 evaluation study) will

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[5]Users cannot, for example, allocate indirect fire weapons directly (to reflect, for example, counterbattery fire), but only through proxies that are described in App. C.

	Major Attribute of Defense Concept		
Level of Warfare	Force Deployment and Allocation	Force Organization and Equipment	Warfighting Style
Grand-strategic	L	—	—
Theater-strategic	M	—	M
Operational	H	L	H
Tactical	L	L	M
Technical	—	L	—

LEGEND:
H, M, L = Relative emphasis in MOSCOW
[dotted shading] Strongest emphasis [hatched shading] 2nd strongest emphasis

Fig. 13—MOSCOW's relative emphasis among concepts

probably not find any single tool extant that is equally suited to all of their requirements. Studies emphasizing other levels of warfare (e.g., tactics) or concept elements (e.g., force design) will find MOSCOW more limited.

Flexible Representation of Environment, Scenario, Force Capabilities, and Military Phenomena

The TRAC Army 21 study plan called for an evaluation of the concept in several different theaters (using 2015 scenarios). CBRS time horizons can vary depending upon the ambition of their planning objectives; those less concerned with influencing system research and development (but still interested in procurement or organization) might project only 10 or 15 years in the future. Clearly, MOSCOW needed to have the flexibility to represent varied theaters, threats, and technologies. Again, this required highly general definitions of the input variables, to avoid constraining the range of situations that the model could accommodate. For example, the effects of air attacks on ground targets are expressed in terms of kills per ton (with aircraft loads in tons designated elsewhere) to allow the representation of different types of air munitions.

Similarly, MOSCOW needed to be able to accommodate the different "theories of victory" underlying different concepts. For example, Army 21 called for dispersed maneuver, followed by concentration to initiate an attack. Its presumption was that concentration would increase vulnerability to air attack, which implied that no more forces should concentrate than necessary to achieve their tactical objective. Army 21 was trying to balance the benefits of greater concentration (more weapons in range of their targets, leading to higher tactical lethality) against the costs (greater vulnerability). The "right" balance depends on the relationship between concentration and each of these. Although the concentration/lethality relationship is believed to be well understood (dependent essentially on two-dimensional geometry), the concentration/vulnerability relationship is not, because the increase in vulnerability because of concentration is more likely to be caused by improved target acquisition probabilities (and perhaps by an increase in perceived target value) than by weapons effects *per se*.[6] Different concepts may implicitly assume different functional forms and magnitudes for the concentration/vulnerability relationship. Unless empirical data can provide some guidance, MOSCOW must be flexible enough to allow users to change the functional forms of any equation.[7]

Transportability

Nothing in CBRS prohibits the development of more than one concept simultaneously. In early 1987 TRADOC instituted a program known as the Army's "Architecture for the Future," which is slated to develop at least one concept each for a 15-year and a 30-year time horizon and initiate definition of several concepts for horizons of approximately 40 years. To aid in design and screening of concepts by several different organizations, MOSCOW had to be readily transportable. Furthermore, because not many concept designers are modelers or programmers, it had to be written in a computer language that was reasonably well-known or easy to learn. For these reasons, MOSCOW was designed to run on IBM-compatible personal computers with the most widely used commercial spreadsheet package, Lotus 1-2-3®.

Low Time Cost per Analysis Run

The potential combinatorial explosion cited earlier mandated that MOSCOW must permit rapid analyses. Although that is commonly interpreted as the time required to run one case through the model, the meaning is broader. MOSCOW typically takes anywhere from about 30 seconds to under three minutes, depending upon the model of microcomputer and the input variables being manipulated. "Time per analysis" includes both model run time and the time required to change inputs and examine outputs.

With its capability to display the results of computations onscreen instantaneously and to compare several runs using simple graphical displays, the spreadsheet greatly reduces the time needed for the latter task. However, the spreadsheet format requires that the simultaneous equations in MOSCOW be solved iteratively to converge on a solution, and this need for multiple iterations increases run time, yielding the above estimates.[8] Subsequent versions of MOSCOW may utilize more efficient means of computing results while preserving the spreadsheet interface to maintain its accessibility. Nevertheless, with MOSCOW-M1 it is still possible to compare several concepts (or versions of one concept) and produce summary graphics in well under a half hour.

[6]This would be less true for nuclear weapons or new conventional weapons with large effects radii, such as submunitions dispensers or fuel-air explosives.

[7]MOSCOW was written on commercial spreadsheet software permitting the user to see and edit equations onscreen because it was recognized that users might wish to customize it for their own purposes.

[8]The spreadsheet's ready interface also imposes a run time penalty compared with compiled programs. Spreadsheet compilers are becoming available and may be used in subsequent versions of MOSCOW.

What Was Given Up

MOSCOW's approach gives up "realism" and detail. To achieve the efficiency mandated by its screening purpose, the model must emphasize breadth rather than depth. For example, MOSCOW-M1 represents only one type of *average* ground maneuver unit on each side, which is composed of only one type of *average* vehicle.[9] Similarly, Blue maneuver units can have only two combat missions (out of four total missions): *attack* or *defend*. MOSCOW computes the results of an *average* attack and *average* defense engagement, which are applied to all maneuver units with the respective mission.

MOSCOW tremendously simplifies combat, but to a great degree so do all military models. The lack of a one-to-one correspondence between real-world elements of a force or concept and MOSCOW's variables will undoubtedly trouble many concept designers, especially those less sensitive to the necessity imposed in any analysis by finite time and resources to make compromises in the amount of detail desired. Although this deliberate intent to err on the side of simplification is at odds with long traditions in the Army analytic community, more complex models are not likely to be consistent with the model's efficiency and transportability objectives.

Consistent with its operational level emphasis, and to avoid restricting analyses to a limited range of scenarios, the formats of some MOSCOW variables differ from those of traditional ground force modeling.[10] For example, the user sets the campaign requirements that a Blue force must achieve: to let no more than some number of Red maneuver units survive by the time the Red force has penetrated some distance into Blue territory (which the user specifies). By contrast, tactical-level analyses often express objectives in terms of fraction of the enemy's starting force surviving; but MOSCOW's emphasis on high-level command perspectives (corps, army group, and theater) throughout a *campaign* (not only a battle) suggested that ultimate campaign objectives were more appropriate, which arguably relate more to the absolute amount of enemy residual force that can be permitted to survive than to a percentage attrition figure (90 percent Red attrition might appear to be a tremendous success unless several Red armies remained in the field).

Finally, MOSCOW is designated a "method" to emphasize that it is a *tool of good and thoughtful analysis, not its sole embodiment nor its substitute.* MOSCOW's relative accessibility (because of the spreadsheet format) may lull users into naive analytic strategies, but the quality of the results hinges upon understanding the limits of the model's ability to represent the effects of particular policies. For example, MOSCOW computes the time Blue maneuver units spend performing each of several activities, as affected by the Blue's warfighting concept.[11] Different concepts are expected to have different distributions of activities. To determine if MOSCOW is implementing a concept "reasonably," a user must check the distribution computed by MOSCOW against his previous assumption (and adjust MOSCOW's distribution if he believes it is necessary). Similarly, users must make explicit judgments about several factors, to set calibration parameters such as the one affecting the concentration/vulnerability relation-

[9]The vehicle type and unit type are assumed to be composites and can be synthesized from more heterogeneous structures using a simple averaging spreadsheet. The EQUIP.WK1 spreadsheet mentioned below computes the average characteristics of a combat unit's vehicles based on those of individual vehicles.

[10]Others are identical; the design principle used was to keep variable definitions consistent with common practice in the Army analytic community unless doing so would add uneconomical complexity or obscure operational-level policy issues.

[11]The "activities" of Blue units are explained below.

ship mentioned above. With MOSCOW as with any other computer model, its results must be leavened by judgment.

MODEL SIMPLIFICATIONS AND OMISSIONS

All models simplify and abstract the events and entities they represent. Being a screening model, MOSCOW does so as much as or more than most models used in defense analyses.[12] This is an unavoidable cost of achieving flexibility and efficiency. However, many people judge models more on the basis of their homological verisimilitude (the number of factors they purport to cover and the degree to which "real-world" factors can be mapped one-to-one to model variables) than on more pragmatic analytical criteria. This section lists the most important omissions and simplifications in MOSCOW. The general reference model against which it is compared is a time-driven, closed-form simulation, such as RAND's CAMPAIGN, CAA's FORCEM, Vector Research's VECTOR II, or TRAC's VIC.

The first column of Table 17 lists the key features that MOSCOW omits or abstracts—its treatment of geography, abstraction of maneuver unit, vehicle, and support platform types, lack of time dynamics, and types of weapons omitted. The second column, which indicates how MOSCOW treats or could treat each item, shows that many of these omissions are more apparent than real. Greater resolution of time, space, or entities can be achieved by proliferating the number of zones used to represent a single campaign. To do so, however, has two costs. First, it multiplies the number of MOSCOW runs needed to examine any particular concept, thus reducing the model's efficiency, which is one of its principal comparative advantages. Second, MOSCOW's outputs are computed on the basis of activity cycles, a "steady state" notion that begins to break down if zones become so small that the calculated duration of the campaign is greater than the time Blue units spend in their "cycle" of activities, and the model estimates that less than three to five Blue maneuver units are needed.[13] If a high level of resolution is important to the user, then MOSCOW is the wrong model to use.

Each of the items listed in Table 17 was the result of compromises among the desired principles of verisimilitude, policy emphasis, concept and scenario versatility, speed or efficiency, and ease of use and modification. Table 18 identifies the choices that were made among these goals. It lists the features that were emphasized, the price paid for that emphasis (what other goal was diluted), and the implications of the choice for MOSCOW's use in analyses. For prospective users of the model, the most important conclusions are:

- MOSCOW is appropriate for *operational-level* concept exploration and comparison, but probably not for balance assessments, and *certainly not for weapon system or force design* (organizational) *analyses.*
- *MOSCOW should be used to represent wars or campaigns, not battles.* Individual zones should be large enough that the length of the campaign exceeds the length of activity cycle times, and at least three to five Blue ground units are required.

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[12]This applies especially to ground force analyses, which customarily use open- or closed-form simulations that are quite large (many hours of run time on main frame computers).

However, many of these other models may (by overemphasizing combat and largely ignoring other activities) actually be *narrower* than MOSCOW.

[13]This MOSCOW terminology is defined below. It is included here to alert the reader to the model's limitations.

Table 17

CAPABILITIES NOT AVAILABLE IN MOSCOW

Capability	Closest Analog Available in MOSCOW	Limitations/Disadvantages of Analog
No map (zone is a rectangle)	Can represent geography using multiple zones in 1 or 2 dimensions	MOSCOW's aggregated approach inappropriate for very small zones (e.g., where campaign length $<$ cycle time and MVRs required $<$ (3 to 5))
No time steps	Multiple zones in sequence	"
No dynamics or distributions: All calculations made for "average" unit, engagement, activity, sortie, day	None, except distributions of time and losses among activities. Can construct unit-specific, time-limited zones	" "
No specific terrain resolution	Effects of several terrain types averaged for zone, but can construct terrain-specific zones	"
No distinctions among maneuver unit types (one "average" type per zone)	Unit's characteristics can can be weighted average of multiple vehicle types; or threat in zone be split into several spreadsheets, one for each Blue unit type	Increases number of runs required per concept
Individual divisions/brigades not identified	Can resolve higher echelons by setting zones = corps or army group sectors	"
One composite vehicle type in maneuver units	Vehicle's characteristics can be weighted average of multiple vehicles types	Implies uniform allocation of fire and damage among vehicle types
No explicit air war	Can vary CAS and AI attrition as proxies	Can't fully vary air doctrine (no explicit OCA, AD, SEAD)
Non-organic support grouped as Fire, CAS, or Air Interdiction, with one composite weapon type each	Platform weapon effectiveness is a weighted average of multiple types	Implies uniform attrition among platform types
No nuclear or chemical use	Can increase lethalities, decrease activity rates	Ignores denial effects
Forces execute campaign plan with no adaptation	Can vary assumptions to search for "wiser" behavior; constrain to reflect deception	Increases number of runs required per concept
Full Blue resupply assumed	None needed; assumption is consistent with requirements approach	None

Table 18

DESIGN TRADEOFFS IN MOSCOW

MOSCOW Incorporates:	But at Expense of:	This Feature Implies:
Analytical formulation of important elements of operational-level concepts	Detailed treatment of individual units, tactics, or geography	Users must think quantitatively about concepts usually expressed as general principle
Emphasis in inputs on policy choices, rather than scenario or force structure	Homologic representation of a "map," "order of battle," etc.	MOSCOW appropriate for comparisons of policies (concepts), not for balance assessments or force structure/ weapon systems analyses
Flexible treatment of maneuver units composition and technology	Representation of specific weapons or their tactical advantages/disadvantages	Detailed TO&Es must be aggregated to construct MOSCOW inputs
Flexible formulations of uncertain military phenomena (e.g., effect of HQ workload on C^3 errors)	Traditional pretense of precision because poorly understood phenomena were ignored	Users must review suggested calibration factors and relationships which are conjectural
Approach that explicitly represents 15 maneuver units' activities ("activity cycle") besides combat	"Steady-state" formulation limits model's value when considering very small zones or short time periods	Users must filter distribution of activities computed by MOSCOW with judgment, and eschew shallow zones, short campaigns, or small forces
Near-symmetric Red input structure, allowing examination of alternative responses	A single, hard-wired, "approved threat"	Need to assess concepts' robustness to threat assumptions through sensitivity analysis
On-screen display of all inputs and computations	Ultra-fast run times ($\leq$ 10 seconds instead of $\leq$ 3 minutes)	MOSCOW useful for screening at campaign level, not battle level
Spreadsheet format allows easy display and editing of any equation, to encourage user customization	Uniformity of models because one organization monopolizes it, or bars elements from being changed	Need procedural solutions, rather than denying access to source code

- Because MOSCOW represents composite maneuver units, vehicles, and support weapons or platforms, users who need to explicitly consider heterogeneous force structures must either set up one zone for each type, if possible within the minimum zone constraint just mentioned (and less efficiently), or aggregate components into averages.[14]

[14]One method of aggregation is the EQUIP.WK1 aggregation spreadsheet described in Romero, Rydell, and Stanton, 1987, which combines the individual vehicles in a maneuver unit into a weighted-average composite vehicle. Users can build one for each unit type, then another to combine unit types into a composite unit. For the illustrations below,

- Because MOSCOW treats a subject without a quantitative tradition, its representation of concepts is crude and embryonic. It is highly likely that the activity cycles MOSCOW computes for some concepts will fail to represent them properly. Users, however, will have no way of checking the model unless they have reference cycle times and activity distributions in mind. Such reference values might come from historical studies (such as the Chir River example described below), map studies or manual gaming, staff officer's planning factors, or exercise information. Only in this way can values for calibration factors be set or activities redefined and equations rewritten to conform to empirical evidence.[15]

LIMITATIONS OF THE ILLUSTRATIONS

To produce the illustrations of MOSCOW applications in this report, unclassified data on current NATO and Warsaw Pact forces and concepts were collected—or when necessary, inferred—and calibrated in a base case outlined in App. A.[16] These data are approximate, and *none have been approved by the Army, nor should these illustrations be considered authoritative in any way.* MOSCOW has not yet been systematically verified; at present RAND and the Army are jointly planning these tasks. Thus the illustrations presented here should not be construed as having definitive policy implications, but rather as providing indications of MOSCOW's general capabilities, insights concerning tradeoffs among concept attributes and policy objectives, and an illustration of how the process of design and screening can be made more rigorous through use of quantitative tools (where MOSCOW is the example tool).

WHAT MOSCOW DOES

Figure 14 sets the geographic context represented in MOSCOW. There are four levels in MOSCOW's geographic hierarchy: (1) the *war* in an entire theater, (2) the *campaign* in a zone (which can be all or a large subset of the theater), (3) the *Engagement* between Blue and Red maneuver units, and (4) the *vehicle* hide/dash sequence. The discussion below begins at the campaign level.

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one aggregation spreadsheet each was used to represent a mechanized and an armored division for Blue and for Red. Then a third spreadsheet was used to combine these two division types per side into a single composite division per side. Weights used were based on frequency of each vehicle or each type of division.

Aggregation of inputs becomes less of a challenge (and more of a benefit) as the time horizon of the analysis advances. Near-term analyses have vast amounts of detailed data available, which must be summarized to conform to MOSCOW. Analyses with longer time horizons (15 or more years in the future), which are MOSCOW's principal intended applications, suffer from too few data. For these analyses MOSCOW's aggregation and modest data demands should be virtues rather than liabilities.

[15]The calibration factor settings in MOSCOW-M1 are based on the following items in order of their influence: experimentation to produce outputs within the calibration tolerance ranges identified in Appendixes A, brief historical examination of a few World War II battles based on secondary sources, discussions with military analysts, and my own hunches and intuition.

[16]Calibration emphasized intermediate measures, such as casualty and resource consumption rates, for which historical data are available, rather than output measures that could be compared only against other theater models, such as advance rates.

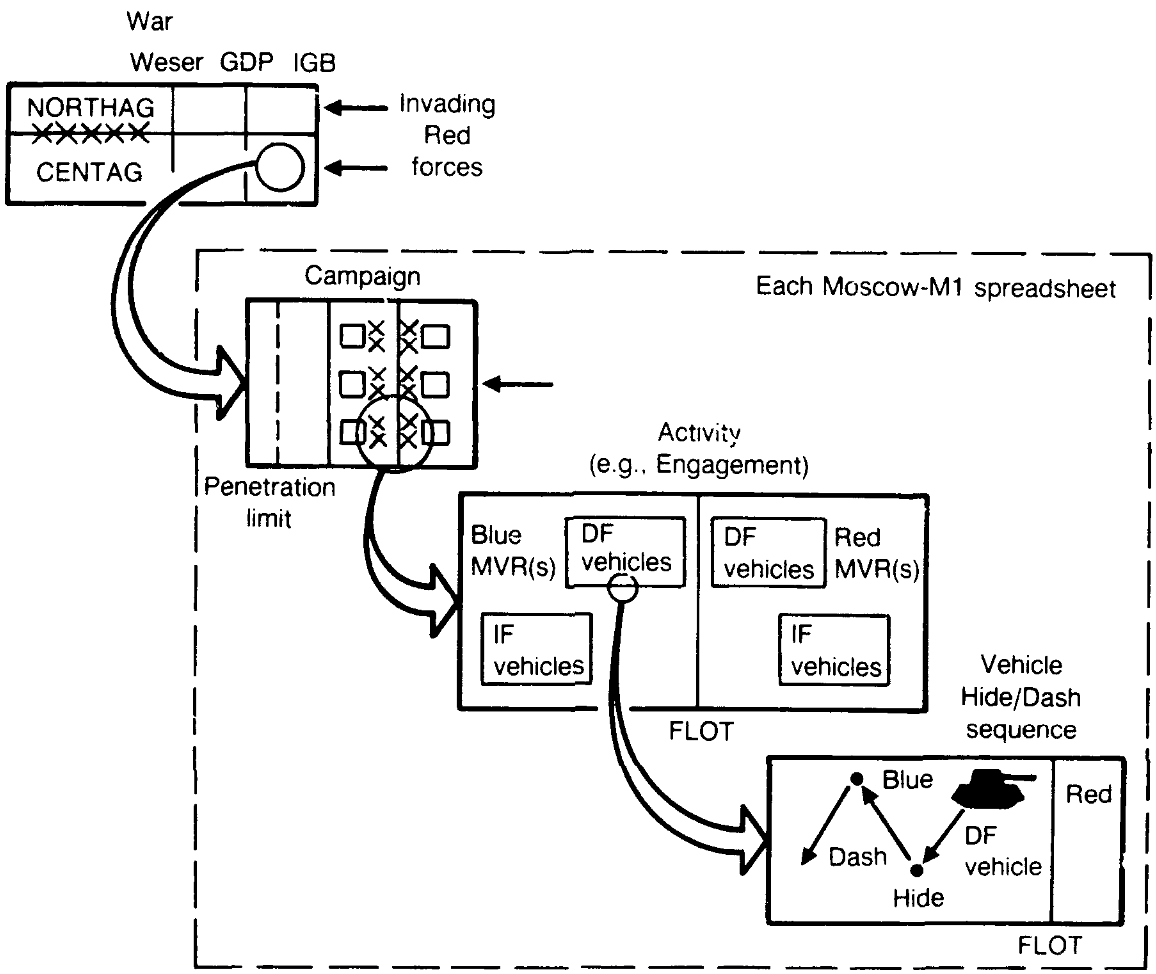

Fig. 14—Hierarchy of geographic levels in MOSCOW

The Campaign in a Zone

A zone, such as the one illustrated in Fig. 15, is a rectangle whose width and length are specified by the user. Typically it will represent an entire theater, but it can be a single avenue of approach for a Red formation of several armies (approximately Front size) or larger.[17] Terrain is considered to have homogeneous average characteristics affecting movement, vulnerability, and attackers' lethality, based upon a distribution of terrain types. Frontage to be defended is the average of the zone's effective width in areas with and without choke areas.

Red maneuver units (in present-day terminology, they would typically be divisions) enter the zone in a single operational echelon, although the effects of a second tactical echelon can be crudely represented, with the objective of crossing the zone and leaving at the other end.

[17]There is no physical bar to setting a MOSCOW zone to be much smaller, but it might depart too much from the steady state representation of the campaign used in MOSCOW.

AD-A254 277 A NEW APPROACH FOR THE DESIGN AND EVALUATION OF LAND DEFENSE CONCEPTS(U) RAND CORP SANTA MONICA CA P J ROMERO 1991 RAND/R-3643-A XD-DA 2/3

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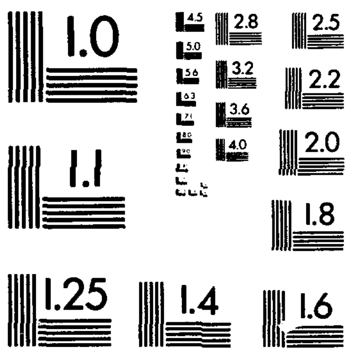
IMAGE EVALUATION TEST TARGET (MT-3)



150mm

6"

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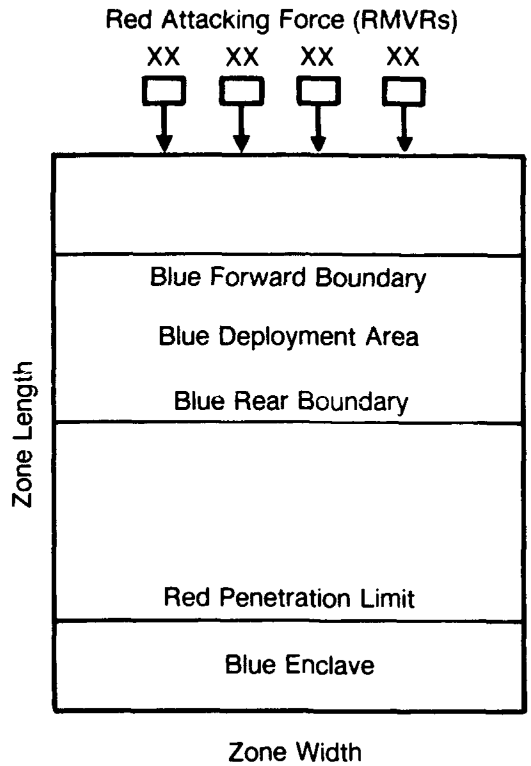


Fig. 15—MOSCOW's representation of the campaign zone

Red policy and capability variables allow the user to indicate Red's march velocity and tactical formation, as well as the degree to which he is willing to delay his progress when attacked by Blue maneuver units.

The user sets Blue's campaign success criteria: to let no more than *X* Red maneuver units survive by the time the Red force has penetrated *Y* kilometers into the zone. Blue forces are deployed uniformly within a rectangle whose forward and rear boundaries can be set by the user (allowing Blue forces to concentrate in a thin line or disperse throughout the zone in depth). Proportions of Blue maneuver units are assigned to attack Red units, to defend against Red units, or to remain in reserve. (Providing Rear Area Security is discussed in App. E.)

Each of the Blue maneuver units (referred to as MVRs) assigned to the attack and defend missions is assumed to go through a series of activities in the course of participating in combat—up to 15 in all. Besides combat engagements, these activities include movement, reconnaissance, loading supplies, and resting. Attack and defend MVRs have different sets of activities.[18] Each attack or defend MVR must perform certain noncombat activities to be ready and available for combat; thus each MVR must go through a *cycle* of activities, for every attack or defend engagement in which they participate.

[18]Definitions of activities and a description of the attack and defend cycle are in App. B.

Policy variables set attack and defend MVRs' engagement objectives and therefore their activity cycle objectives. Attack MVRs attempt to continue the attack until a desired amount of attrition is imposed on the enemy MVRs. Defend MVRs attempt to occupy their Red attackers, blocking their advance or delaying access to territory, until the defenders have suffered a maximum acceptable amount of attrition. In every attack and defend activity cycle, a calculated amount of *average* attrition will be imposed, requiring a calculated amount of *average* time for the engagement activity and other activities. The attrition imposed (in Red MVRs, or RMVRs) per cycle divided by the time required for the activity cycle is the average rate at which an attack or a defend MVR can kill RMVRs in the course of a campaign, and is known as the *campaign kill rate*.[19]

The most important MOSCOW output is the *number of MVRs needed to destroy the required RMVRs within the time available before they reach the designated penetration limit.* This is done by comparing Blue attack and defend MVRs' campaign kill rates to the rate at which RMVRs must be killed to satisfy the campaign objectives. The *required kill rate* is computed in the following way: Given Red's rate of advance (calculated in MOSCOW but taken here as an input), Red's time to reach the penetration limit is [Penetration limit / advance rate]. Blue's required kill rate is [Kills required / Red's time to reach the penetration limit].

Computing Requirements: The Agincourt Example. The general approach taken by MOSCOW to estimate MVR requirements can be illustrated with a historical example, showing how MOSCOW would compute the number of archers needed at the battle of Agincourt in 1415.[20]

In the first phase of the battle, French cavalry charged the English line, with the aim of breaking through it to allow exploitation by followup infantry. The English first line of defense were archers, whose mission was to destroy the cavalry charge before it reached the English position. Figure 16 indicates the situation at the time of the French charge.

Instead of asking "Can X archers kill Y horsemen in time?" estimating an *outcome* based on fixed inputs, MOSCOW formulates the problem as: How many archers would be needed to kill Y horsemen in time, and how does that need compare with the X archers available? In other words, what are the *requirements* based on a *specified desired outcome.*

The mission is defined as: Kill 50 percent of the charging horsemen before they reach English lines (believing that such high casualties will cause many of the survivors to retreat, thus disrupting the following infantry; this transpired in the battle). The cavalry must cross 250 yards, at an average speed of 5.30 yards per second; thus the archers have 250/5.30 or 46.80 seconds to kill 500 archers, a required kill rate of 10.67 horsemen a second.[21]

What is the average kill rate per archer? Assume that each archer requires 10 seconds to aim and fire each shot and another 20 seconds to step back, reload, and step forward again. Thus on average each archer shoots 1/30 arrows per second. Assume each arrow has a 0.10 probability of hit and a 0.75 probability of kill; each archer would therefore kill on average 0.0025 horsemen per second.

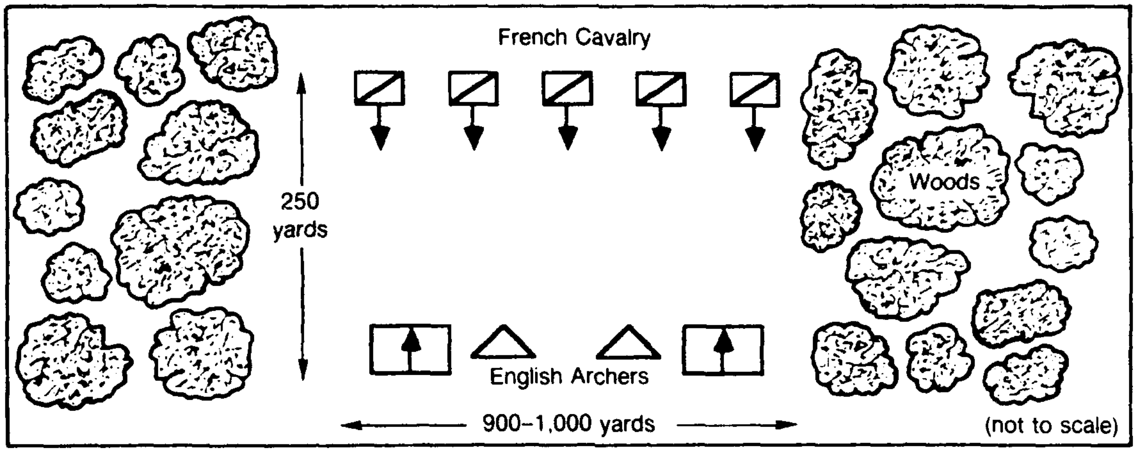
Finally, MOSCOW represents command, control, communications, and intelligence (C3I) in a simplified way. If all archers performed their tasks without panic, false targets, or fatigue

[19]If more than one MVR is involved in the engagement, which can be specified by the user as part of the concept, then the campaign kill rate will be deflated by this number. The units of the campaign kill rate are [RMVRs killed per day per Blue MVR].

[20]MOSCOW itself was not used to generate these results, as the problem formulation and available data did not require extensive calculations. However, the basic computations in the Agincourt example are identical to their analogs in MOSCOW.

[21]All input estimates, except for error rates and activity times, are derived from Keegan, 1976, pp. 87-95.

English archers' mission: kill "enough" French horsemen (e.g., 50%) to incapacitate the attack by the time they reach the English line.



Inputs

Starting French cavalry: 1,000
Required kills by archers: 500
by advance distance of 250 yards
Cavalry advance rate: 5.3 yards/sec

Archer lethality:
— 10 sec to fire
— 20 sec to reload
30 sec or .033 shots/sec

Probability of hit = .1
Probability of kill = .75

Archers not firing because of poor visibility = .1
Archers not firing because of panic = .05

Process and Output

Kill rate required: $\frac{500}{250/5.3} = 10.67 \ \frac{\text{Horsemen}}{\text{sec}}$

Kill rate/archer: .1 × .75 × .033 = .0025 horsemen/sec/archer

Archers required: (10.67/.0025)/[(1 − .1) × (1 − .05)] = **4993.5**

Agincourt, Phase I — Illustration of activity-based requirements estimation

SOURCE: Keegan, 1976, pp 82–95.

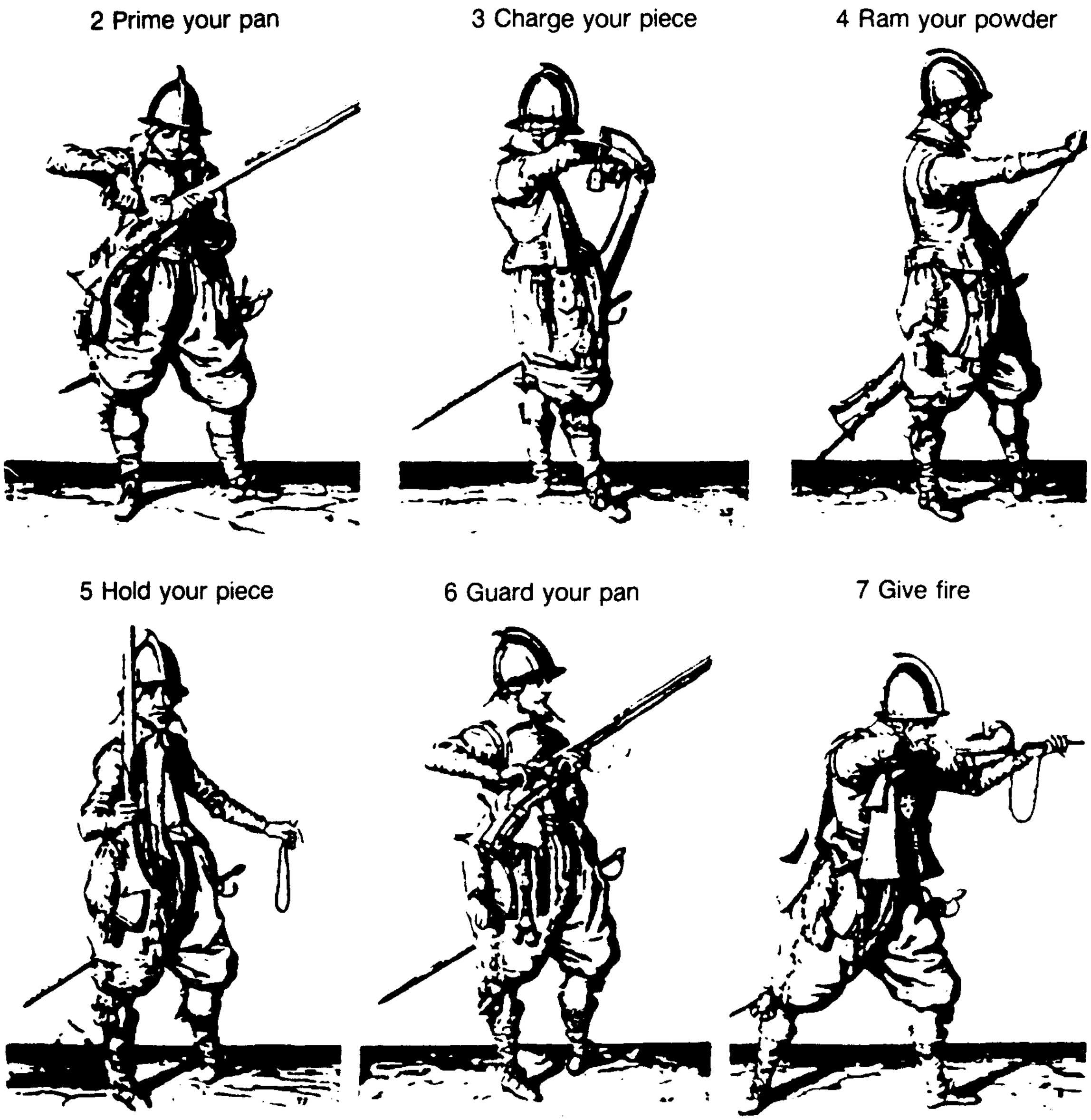
Fig. 16—Requirements estimation illustrated: The Battle of Agincourt, 1415

(there were no command and control or intelligence errors), 10.67/0.0025 = 4268 archers would be needed. In all likelihood, some archers would panic and fail to fire (e.g., a probability of 0.05) and some would not be able to see a worthwhile target (e.g., probability of 0.10). The required number of archers must therefore be inflated to reflect this wastage due to C3I errors. In that case, the final requirement is 4268/[(1 − .05) × (1 − .10)] = 4993. This squares nicely with Keegan's estimate that 5000 English archers were available at Agincourt.

The Activity Cycle. The Agincourt example considered only two activities: firing and other. Military texts of the seventeenth century distinguished among up to 42 activities in the firing cycle of musketeers, some of which are illustrated in Fig. 17.[22] The efficiency of the force was measured in terms of its kill rate per archer. This would be increased if the time required for either activity were reduced. From this perspective, one can see why the reforms

[22]The identification of up to 42 activities is noted in Keegan, 1987.

imposed by Gustavus Adolphus in the seventeenth century had such profound tactical effects: The introduction of new types of muskets and systematizing of the battle activities of musketeers through drill increased their firing rate by a factor of three (time per shot reduced



SOURCE: Montgomery, 1968.

Fig. 17—Example musketeer activities, seventeenth century

by two-thirds), permitting Gustavus Adolphus to achieve with six ranks of musketeers what other armies needed 18 to accomplish.[23]

The campaign kill rate in MOSCOW is the basic measure of merit of a force and of its concept of warfare. Doubling Blue's campaign kill rate will (with minor exceptions) halve the number of maneuver units required to meet a campaign objective. In the limit, if technology, organization, or warfighting concepts made Blue maneuver units very efficient killers (had a very high campaign kill rate), then very few MVRs would be needed. Conversely, reductions in campaign kill rates will require increases in the number of MVRs needed to compensate.

More important, in MOSCOW equal reductions in the time of an MVR's cycle will have the same effect on MVR requirements, regardless of which particular activity is foreshortened.[24] For example, improvements in lethality will reduce the time needed to achieve a desired amount of attrition, reducing the time required for engagement activities; but an improvement in mobility that produced the same reduction in movement time would have approximately the same effect on MVR requirements. The effect of percentage reductions in activity times will depend upon the *fraction of the overall cycle spent in those activities.* A 50 percent reduction in an activity in which little time is spent (e.g., engagements by a highly lethal MVR) may produce only minor reductions in MVR requirements, whereas the same 50 percent taken out of a dominant activity (e.g., movement in a maneuver-oriented concept) might make a substantial difference.

In the Agincourt example, the archers performed only two activities, so there is little opportunity for varying their "concept." Suppose, however, that the time required for each of these two activities was dependent upon other behavioral variables. For example, suppose that some concepts called for archers to spend only five seconds aiming and firing (instead of 10), but at the cost of a reduction in their probability of hit per shot from 0.10 to 0.066. Alternatively, a concept might call for each archer to spend only 15 seconds reloading but involved use of a less lethal arrow that reduced the probability of kill per hit from 0.75 to 0.50. In this activity framework, different concepts will be manifested in different proportions of time spent in each activity and may yield different campaign kill rates.[25] MOSCOW allows users to set variables intended to reflect some of the important aspects of concepts and computes the time required for each activity in the attack and defend cycles. Thus the *distribution of MVR's activities* is one important way of distinguishing among concepts.

Activities can be identified and tabulated for operational campaigns in a manner analogous to the tactical example of Agincourt. The principle will be illustrated with the example of a brief campaign on the Eastern front in World War II, the German XLVIIIth Corps' defense of the Chir River line in December 1942.[26] The theater-strategic situation is shown in Fig. 18.

The Soviet double envelopment of the German VIth Army at Stalingrad in mid-November was but the first phase of a planned two-stage offensive (Operation *Saturn*). Plans for the second stage called for three Soviet fronts to continue to attack in the direction of Ros-

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[23]See Montgomery, 1968, and Dupuy and Dupuy, 1986, for a discussion of Gustavus Adolphus' innovations.

[24]It will not have identical effects on losses or consumption, as will be explained below.

[25]Depending upon the complexity of the system, it may be possible to formulate an objective function (to maximize the Blue campaign kill rate) and solve for the optimal concept. However, because parameter values are uncertain, there may not be a determinate optimum.

[26]The Chir campaign was chosen for three reasons. First, there are similarities between German operations and those sugggested by AirLand Battle doctrine. Second, day-by-day summary information on the locations and activities of the key maneuver unit was readily available for this campaign in secondary sources (the writings of the corps chief of staff, Von Mellenthin, 1956). Third, a lone unit participated in the critical actions, which simplified analysis and exposition.

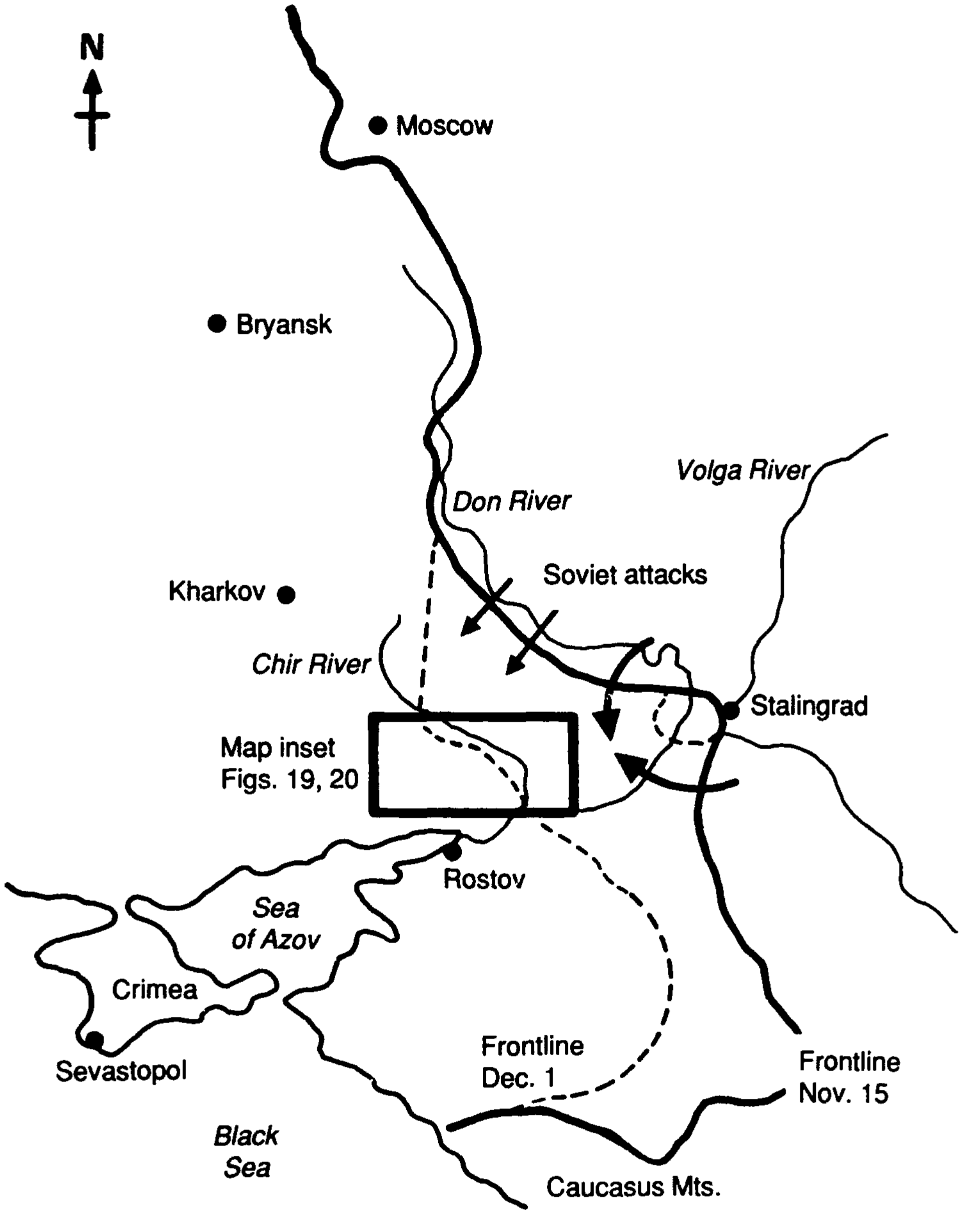

Fig. 18—Theater-strategic situation in southern USSR, December 1942

tov to cut off three additional German armies (two panzer, one infantry) in the Caucasus, while elements of two fronts reduced the Stalingrad pocket.[27] In early December, the mission of the XLVIIIth Corps (whose area of operations is inset in Fig. 18) was to block further Soviet

[27]See Erickson, 1983, Ch. 1.

penetrations and divert forces from the south, where a German counteroffensive to relieve Stalingrad was launched on December 7.[28]

The corps front ran along the curve of the Chir River and was manned entirely by infantry. On the 7th the Soviets effected their first breach in the line, penetrating as far south as State Farm 69, approximately 20 km south of the river, before being enveloped and destroyed by the newly arrived 11th Panzer armored division, which had marched directly to battle from army group reserve. For the next eleven days, 11th Panzer acted as a mobile reserve, marching to the site of Soviet penetrations and counterattacking to seal them. Figures 19 and 20 indicate the activities of the division. The 11th Panzer division's mission and tactics bore substantial similarity to the precepts of AirLand Battle doctrine: The corps' operational concept was defensive, but the division's tactics were entirely offensive (in all recorded engagements during the period 11th Panzer attacked rather than rely on tactical defensive advantages). The division typically allowed Soviet spearheads to penetrate before counterattacking to pinch them off and enfilade their flanks. Sometimes this was by design and sometimes because multiple penetrations were made simultaneously; on the 12th and again on the 17th through 19th the division had to counterattack penetrations on opposite ends of the corps sector without rest. This intensity is not unlike that described in the AirLand Battle doctrine, as well as Army 21.

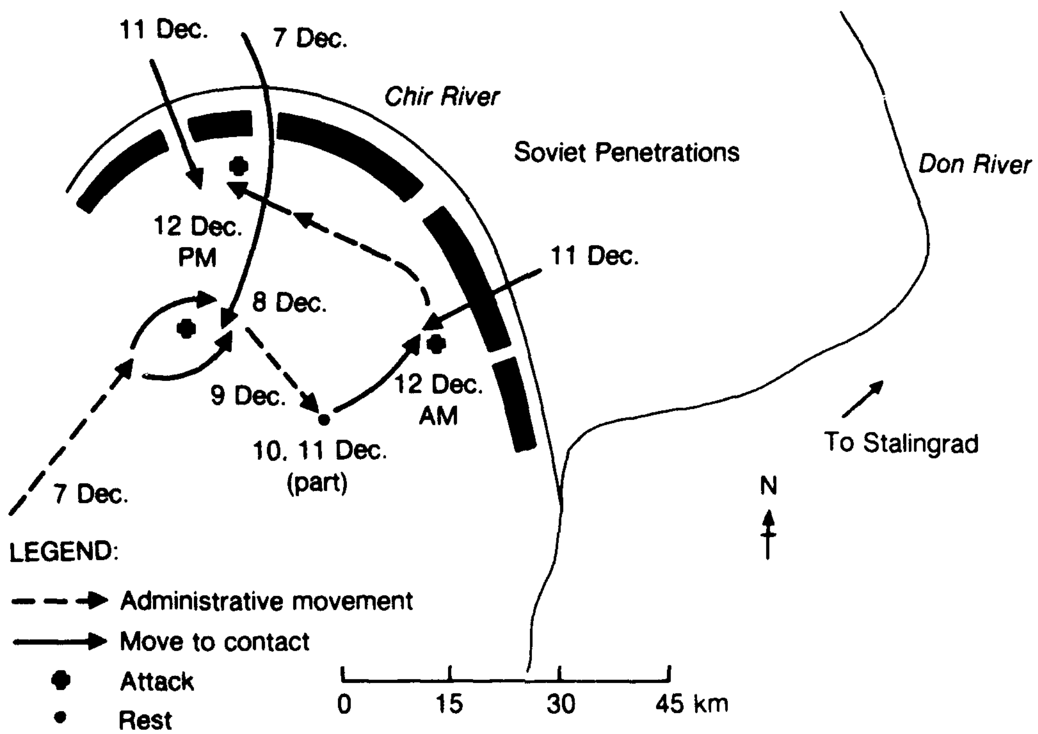

Fig. 19—11th Panzer Division's activities in the Chir River battles, early December 1942

[28]This description of XLVIIIth Corps' activities draws primarily upon Von Mellenthin, 1956; and Von Mellenthin and Stolfi, 1984.

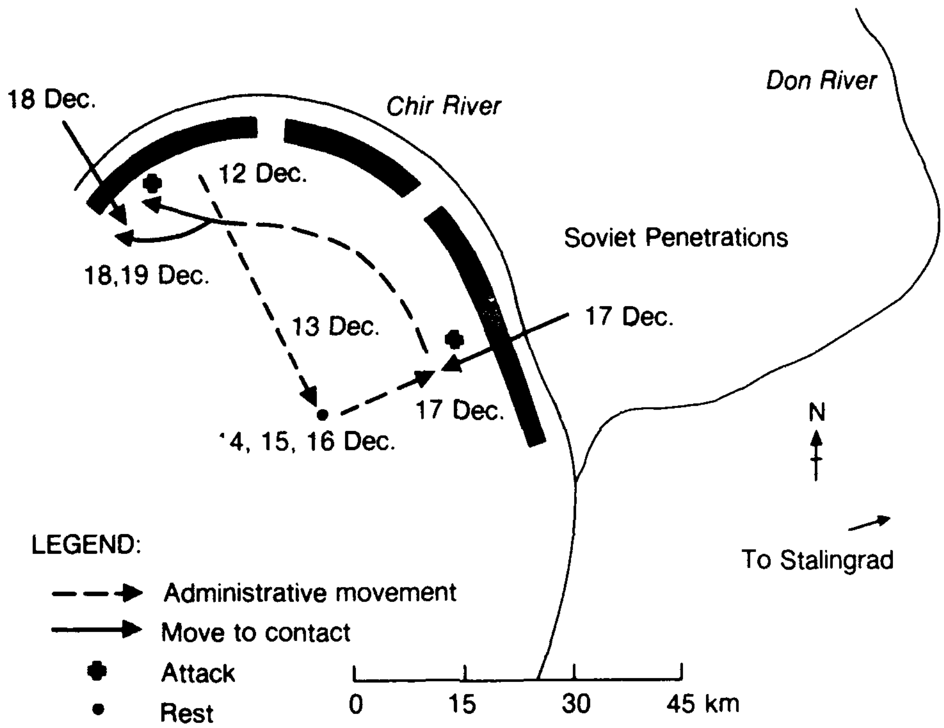

Fig. 20—11th Panzer division's activities in the Chir River battles, mid-December 1942

Table 19 displays estimates of the portions of each day that 11th Panzer devoted to each of six activities between December 7th, when the Soviets first penetrated, and the 19th, when the last penetration was destroyed.[29] The rightmost column indicates the estimated number of Red divisions killed in each engagement activity.[30] The bottom row shows the average fraction of time 11th Panzer devoted to each activity and its revealed campaign kill rate for that period.

What insights can be drawn from such information, and how does it help in making useful distinctions among concepts? Several items are suggested:

1. The *mix of attack and defend engagements* is an indication of the tactical or operational "offensiveness" of a concept. In this case, 11th Panzer relied entirely on attacks to destroy Soviet divisions, but only after they penetrated German territory.

[29]*Administrative movement* is defined as movement entirely within friendly territory where no enemy maneuver units are contacted. *Move to contact* is movement to a position where enemy units will be engaged. *Defend and attack* are engagements where friendly units do or do not rely on superior (but not necessarily immobile) positions for tactical advantage. *Rest* pertains to personnel rest and minor equipment maintenance. *Other* is everything else, such as repairing major damage, conducting reconnaissance, loading supplies, etc. No mention is made of the last two activities in the source material, so it is arbitrarily assumed that on days when 11th Panzer was not in combat and made no change in position, its activities were evenly split between *rest* and *other*. On December 9th, the activity (administrative movement to a rest area near the divisional HQ) noted in the source would have required only part of that day, so the balance was assumed to be devoted to rest. On days split among multiple activities, the fractions shown are based either on clock times noted in historical sources, or travel time estimates based on study of a map of the corps sector.

[30]Sources generally do not give specifics, but it appears that the five successful counterattacks each destroyed at least one Soviet division.

Table 19

11TH PANZER'S ACTIVITIES AND KILLS, 7 TO 19 DECEMBER 1942
(Percent of day spent in each activity)

Date	Activity						Soviet Divisions Killed
	Administrative Movement	Move to Contact	Attack	Rest	Other	Defend	
7 Dec.	100					0	
8		50	50			0	≥ 1
9	25			75			
10				50	50		
11				50	50		
12		40	60				≥ 1
13	50			50			
14	40			60			
15				50	50		
16				50	50		
17		30	70				≥ 1
18		60	40				≥ 1
19			100			0	≥ 1
	16.5	13.8	24.6	29.6	15.4	0	≥ 5

Campaign kill rate = $\frac{\geq 5 \text{ kills}}{13 \text{ days}}$ = 38.5 percent Red divisions killed/day

2. Even in an "intense" concept, there will probably still be time needed for rest, maintenance, repair, and other "overhead" activity. In this example, rest + other amounted to 45 percent of 11th Panzer's activities.
3. This "overhead" requirement limits the time available for combat and movement, in this case to about 25 percent and 30 percent of total time respectively.[31] Thus, even a fairly "mobile" concept—one in which maneuver units are expected to travel substantial distances in the course of the campaign—may imply a small fraction of time spent moving.
4. The notion that the division could go through a repeating "cycle" of activities seems to be generally borne out, insofar as there appears to be some broad regularity in the order of 11th Panzer's activities before and after attacks (movement to contact first, then attacks, then administrative movement to a rest area, rest and other, then movement to contact again, etc.). Naturally, there will be individual exceptions: The order of activities may vary, or some units may participate in multiple attacks before they are able to catch up on needed rest. But in this example, the "steady state" simplification of a campaign kill rate based upon the time required for a cycle of activities seems plausible.
5. For any particular force and situation, there probably are natural limits on a division's feasible campaign kill rate, beyond which further conceptual improvement may be counterproductive. For example, if 11th Panzer had not rested at all, its

[31] Obviously, improvements in 11th Panzer's mobility—higher movement rates—would decrease the time needed to march fixed distances, and similarly increases in lethality would decrease the time needed for combat to achieve fixed attrition objectives.

campaign kill rate theoretically could have been 5 kills / 9.15 days = 0.55, instead of its actual 5 kills / 13.00 days = 0.38. In practice, lack of rest beyond some limit (which was nearly reached, according to von Mellenthin) would have reduced its effectiveness in engagements, increasing the time required for attacks (and because of this, the attrition suffered in attacks) and possibly its mobility, increasing the time required for movement. If the extension of these times exceeds the rest time saved, the net effect might even be actually to reduce the campaign kill rate.

Figure 21 displays the activities in the attack and defend missions estimated by MOSCOW. Of the 17 activities shown, two do not apply to maneuver units but are reserved for subsequent versions of MOSCOW that may compute activity cycles for noncombat units. Four activities pertain only to attack cycles, two only to defend cycles, and nine pertain to both.[32]

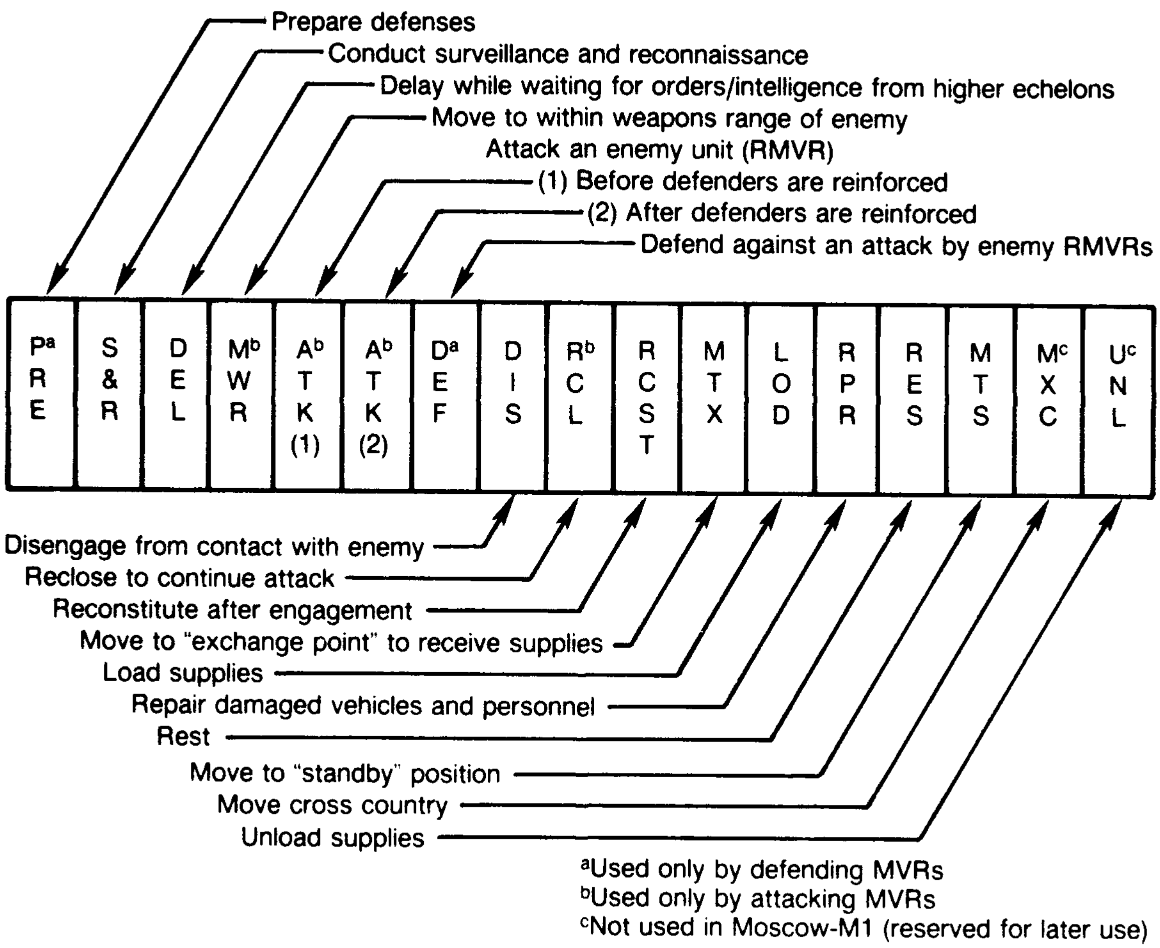

Fig. 21—Activities in MOSCOW

[32]Definitions of each activity, and explanations of the equations used to compute time consumed in them, are contained in App. B.

Equations in the model estimate the average time that would be needed to perform each activity. Blue's technical and organizational capabilities largely determine these, with some relationships well-established (e.g., the time required to move a fixed distance is simply the distance divided by Blue MVRs' movement rate), and some hypothesized (e.g., the time required to delay movement while waiting for higher echelon orders is affected by the number of MVRs for which the higher echelon must be responsible). They are also affected by the warfighting concept, which is captured through Blue policy variables. For example, as part of the concept the user specifies the amount of attrition each average Blue MVR is willing to impose on a Red MVR in each attack, and how much Blue MVRs are willing to endure when on defense. The time required to attack or defend is determined by a version of the Lanchester square equation,[33] using these attrition goals as inputs.[34] Similarly, as part of the concept the user specifies the degree to which Blue MVRs, on average, choose to concentrate before initiating an attack, expressed in terms of a desired combat power ratio.[35] Because MVRs are assumed to be uniformly distributed within their deployment area, higher combat power ratios will require them to converge from longer distances, increasing the average time needed to move within weapon range.[36]

Some policy variables affect more than one activity, often in opposing directions. The combat power ratio desired to initiate an attack is an example. Increasing it will require more distant MVRs to converge on the engagement, thus raising average movement time.[37] However, for given MVR lethality and engagement attrition objectives, increasing combat power ratios will decrease the time needed to complete the attack. Their relationship, for particular assumptions about mobility and lethality, is shown as curve R in Fig. 22.

We will prefer the ratio that minimizes the *sum* of movement time and attack time if no other activities are affected by the choice of desired force ratio. For the nominal assumptions about Blue mobility and lethality, the "optimal" combat power ratio appears to be roughly 3:1. However, mobility and lethality are uncertain, especially for a future force, so it is important to determine how *stable* this "optimum" is. Curves 3/4, 1.5, and 2 indicate the sum of attack plus movement time as mobility changes from 3/4 to double the nominal case. The apparent

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[33]The computation of engagement attrition is described in App. C.

[34]Analysts familiar with traditional modeling and use of the Lanchester equations may be puzzled by a formulation that sets attrition as an input and time as an output. Its rationale relates to policy relevance. Units participating in engagements generally continue until one side achieves its tactical objective, which will usually be based on terrain or attrition, or reaches its tolerance limit (attrition constraint). Rarely does time per se enter into a unit's objective. Because in MOSCOW the campaign objective is the destruction of some number of enemy units within some territory limit, the dominant objectives for Blue MVRs are either attrition or delay. Thus, attack MVRs have a Red attrition objective, while Defend MVRs have the objective of sustaining the engagement up to a Blue attrition limit.

[35]Setting a desired combat power ratio as a general precondition for initiating an attack is common in many armies, receiving special prominence in Soviet doctrine. Units of account vary, with the main distinction being between raw counts (of divisions, men, tanks, or artillery tubes) vs. indexes that attempt to reflect force quality or the tactical situation. The designer consulted TRADOC officers regarding the most useful expression of combat power, with the majority favoring a quality-adjusted approach. MOSCOW defines combat power as the number of vehicles engaged times the square root of the rate at which an MVR can kill an RMVR (or vice versa). Throughout this report, "force ratio" and "combat power ratio" are used interchangeably.

[36]The desired combat power ratio and amount of attrition per engagement are also referred to respectively as the criteria for *initiating* and *terminating* an engagement.

[37]MOSCOW embodies a system of simultaneous equations solved iteratively by the spreadsheet to converge on a solution. Typically 12 to 15 iterations are needed. The movement activity is one of the reasons for this simultaneity, because the distance that an average MVR must move to accumulate the desired combat power ratio is inversely related to the assumed density of MVRs per km^2 in the zone. This density is a function of a model output (estimated MVRs required in the zone), so the model's output depends on itself; hence the simultaneity. Note, however, that an increase in MVRs will increase MVR density, other things equal, thus decreasing movement time, which will in turn decrease cycle time and campaign kill rate, and decrease the number of MVRs required. Therefore, this simultaneous system will converge.

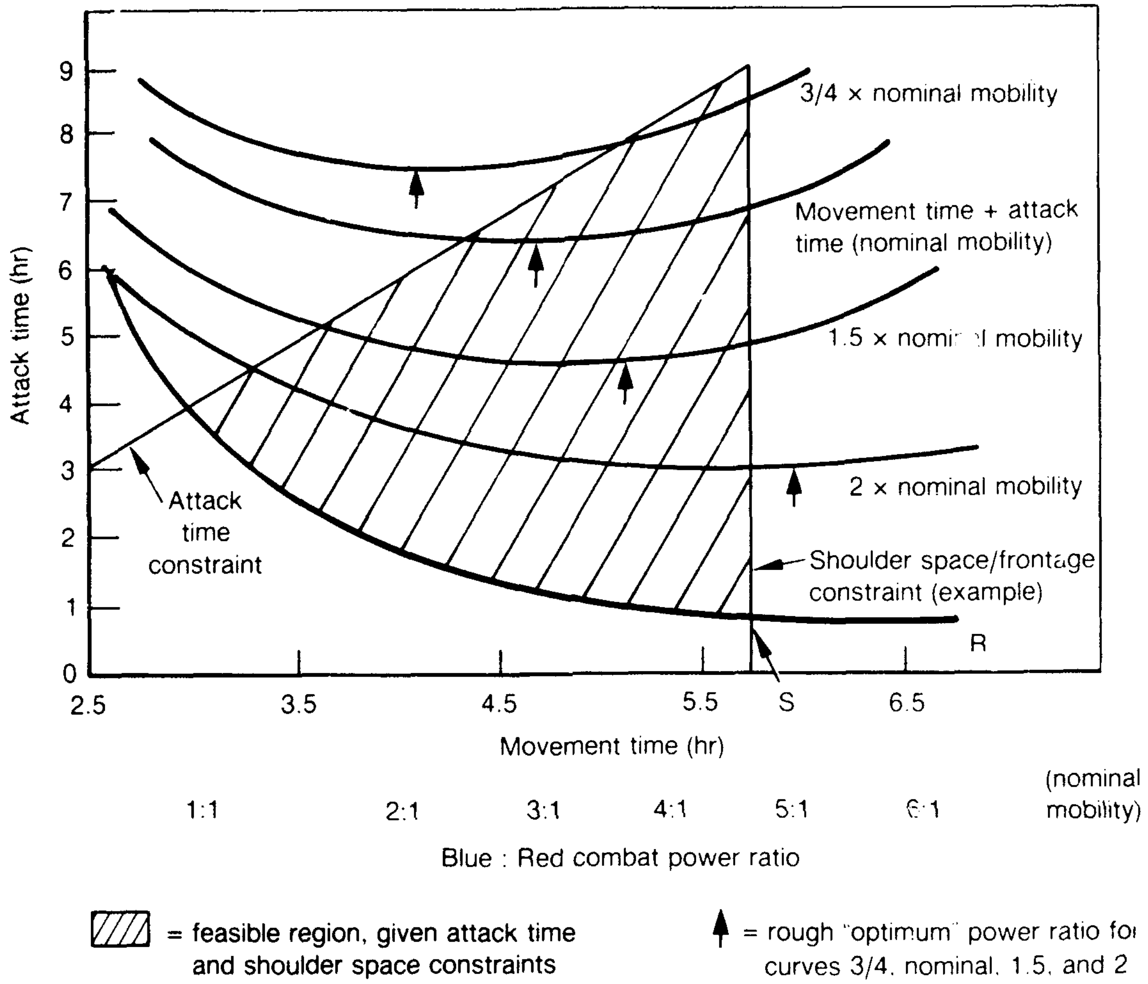


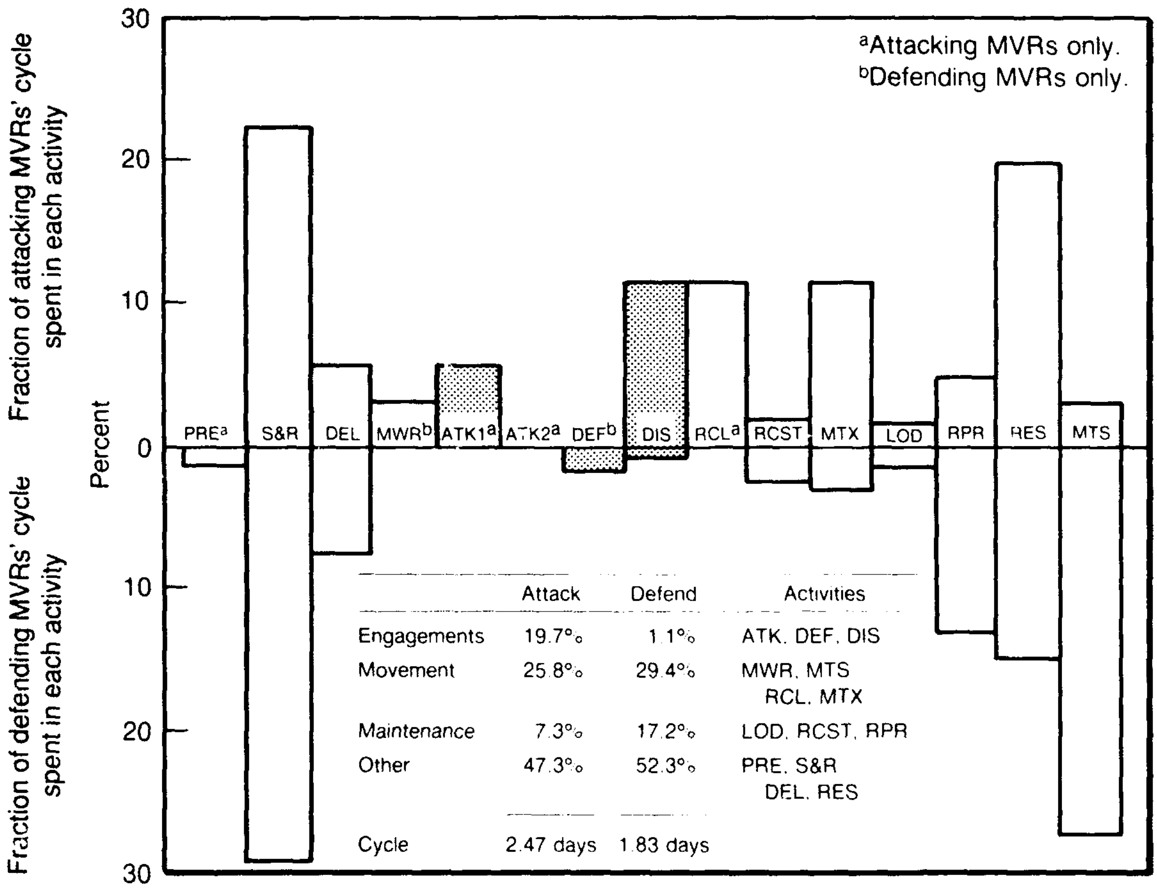
Fig. 22—Example relationship between time in movement activity and time in attack activity: Tradeoff between massing and total time required

"optimum" shifts substantially as mobility assumptions vary. When Blue is less mobile (Curve 3/4), massing beyond about 2:1 becomes increasingly expensive (in total time required), but as Blue becomes more mobile (Curve 1.5 and Curve 2) he can afford to mass to higher force ratios before time costs begin to rise.

Not only is the "optimum" force ratio strongly dependent upon assumed Blue capabilities, but other factors may prevent Blue MVRs from implementing it. Line S and Line A illustrate two constraints on the feasible tactical force ratio. Line S represents a limit on concentration that might be imposed by terrain (e.g., shoulder space). Line A represents a limit on attrition that a Blue MVR is permitted to suffer in an attack. At higher force ratios, Blue can afford to spend more time in combat before reaching the attrition constraint, so it is sloped upward (reaching infinity at infinite force ratios).[38] The area bounded by Lines S and A and the x and y axes represents the feasible set of force ratios and attack times. The "optimal" force ratio is outside the feasible set under some Blue mobility, ruling out the 5:1 "optimum" when mobility is double the nominal case and the 2:1 "optimum" when it is 3/4 of the nominal case.

MOSCOW does not find "optima" for any concept variable but computes time requirements for the concept specified by the user. An example of the times for activities in the attack and defend cycles is shown in Fig. 23. This distribution reflects a maneuver-oriented concept in which engagements are brief (attrition objectives are low) and little reliance is placed on prepared positions. The total time required for each cycle and a tabulation that groups related activities are also shown.

Representing activities explicitly, as MOSCOW does, offers two great advantages over traditional low-resolution campaign models. First, *different concepts will manifest different mixes of activities.* As suggested by the example illustrated in Fig. 23, a change in the amount of massing required will change the duration of maneuver and engagement activities. (Other activities may also be affected.)



	Attack	Defend	Activities
Engagements	19.7%	1.1%	ATK, DEF, DIS
Movement	25.8%	29.4%	MWR, MTS RCL, MTX
Maintenance	7.3%	17.2%	LOD, RCST, RPR
Other	47.3%	52.3%	PRE, S&R DEL, RES
Cycle	2.47 days	1.83 days	

Fig. 23—Example distribution of time among activities in MOSCOW

[38]Under the Lanchester formulation, Line A would in fact be curvilinear and concave (with increasing slope), but it is drawn here as a line for simplicity.

More important, MOSCOW *will calculate time and resources consumed in noncombat activities as well as in engagements.* Many other models treat noncombat activities implicitly or omit them entirely and consequently are criticized for underestimating losses. MOSCOW calculates consumption *separately* for *each activity.* In Fig. 23, for example, only the shaded activities relate to combat engagements. In an example reported in App. B, the proportion of total resources that are consumed in noncombat activities are (percent):[39]

- Vehicles: 69
- Personnel: 39
- Ammunition: 50
- Fuel: 94
- Other: 95

These proportions are clearly too high to omit, as many other campaign models do.

Outputs: Forces and Resources Needed. The time available for Blue MVRs to destroy the requisite number of Red MVRs is largely determined by the depth of penetration that Blue is willing to allow.[40] Red is attempting to cross the zone and leave the other side and has an inherent rate of advance that is input by the user. However, that advance is slowed by terrain, rest delays, barriers, air interdiction, or ground opposition—the last three affected by Blue's concept.[41] The rate at which the entire Blue force must destroy Red MVRs (the Required Kill Rate) = [RMVRs to be destroyed / Time available], where Time available[42] = [Red penetration limit / Red advance rate].[43] The number of Blue MVRs needed to achieve this in the time available is thus:

Required kill rate / Campaign kill rate = Blue MVRs needed.

This required number of MVRs is compared with the number projected to be available to determine if the concept can be executed successfully within the limits of available forces.[44]

Figure 24 shows a much-simplified numerical example of the MVR requirement calculation in MOSCOW. It is assumed that the MOSCOW zone represents the entire theater. Concept inputs (policy variables) are arrayed according to their corresponding level of warfare. The national leadership establishes that a budget of 27 MVRs (defining MVRs as brigades in this example) will be available for the campaign, while the theater commander determines the requirements for campaign success: 10 RMVRs (defined as divisions in this example) must be

[39]Estimates shown are derived from Fig. B.6, which illustrates the consumption estimated by MOSCOW for a maneuver-oriented concept such as AirLand Battle. See App. B for a definition of each activity and of the methods used to estimate resource consumption.

[40]In the Agincourt example, Blue could have made do with fewer archers if the French cavalry had been required to charge farther.

[41]MOSCOW's representation of how Red's advance is degraded by Blue efforts is shown in App. D.

[42]MOSCOW refers to Time available as the Campaign Length.

[43]The role of support forces in delaying Red's advance, and thus extending the time available, is the second prime cause of simultaneity in MOSCOW. Support, such as interdiction, can impose an average amount of delay per day. However, some support assets attrite over the course of a campaign, so that in a longer campaign the average delay per day that a fixed starting stock of aircraft can impose will be less than in a short campaign. Campaign Length depends upon itself. Increases in Campaign Length will, other things equal, decrease average delays to Red's advance, thus increasing Red's advance rate and decreasing Campaign Length. This system is also convergent.

[44]If substantial Blue or Red forces are expected to arrive in the zone after the start of the campaign, several zones can be established in sequence to reflect changing force budgets. Specific procedures for reflecting arrival schedules are described in App. F.

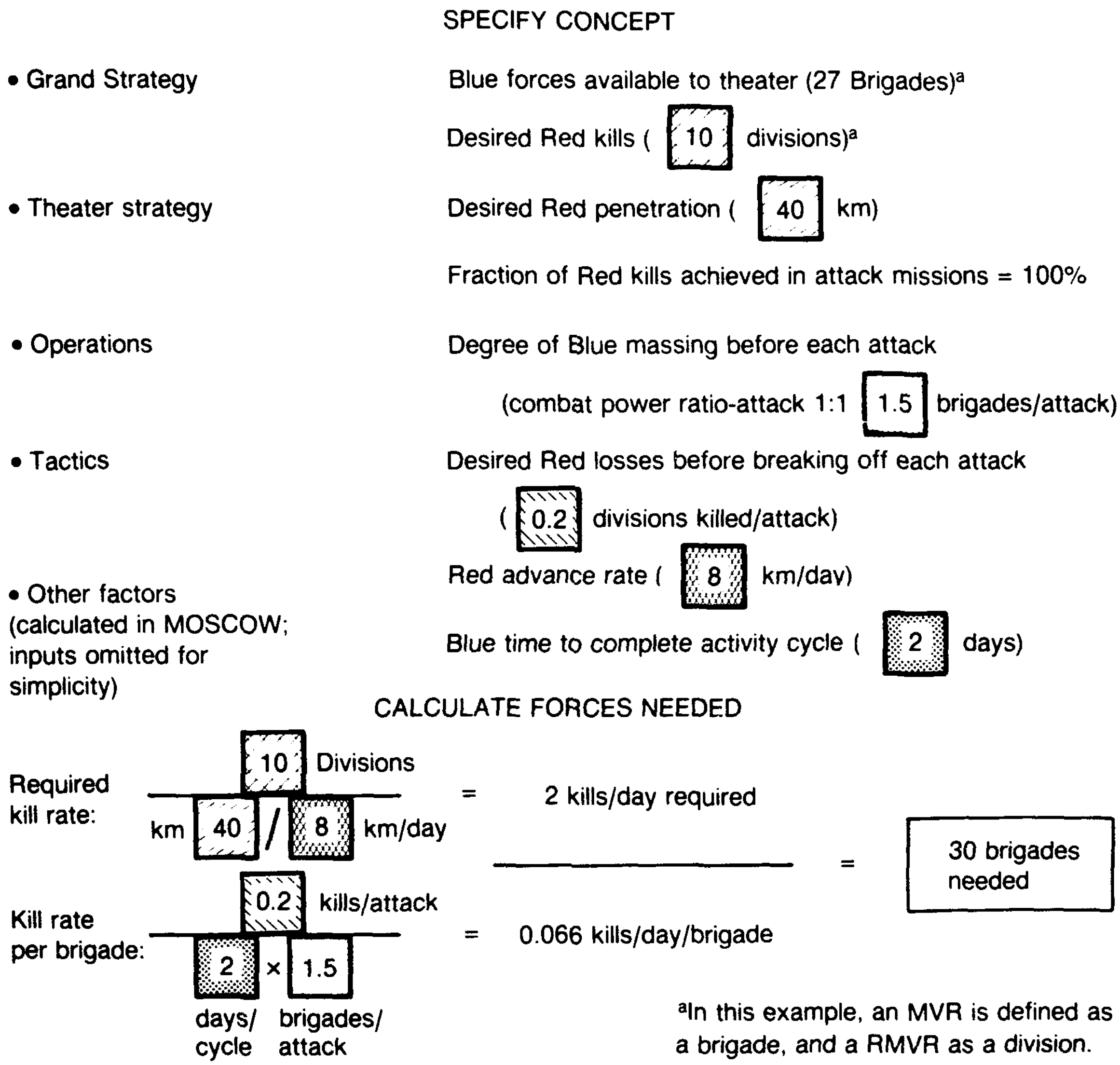


Fig. 24—Force requirements computation in MOSCOW (simplified)

destroyed by the time Red has penetrated 40 km into friendly territory.[45] The operational commander may determine the mixture of offensive and defensive tactics MVRs will employ (in this case, like 11th Panzer's operations, all kills are to come from counterattacks) and the force ratio to which MVRs must mass before initiating attacks. The average attack has the tactical objective of imposing 20 percent losses on the defending RMVR before the attack is broken off.

[45]In MOSCOW the user inputs the size of the invading Red force and the maximum number of RMVRs he is willing to have survive at the penetration limit. Desired kills are the difference between the two. This number is actually the number of Red kills required of Blue MVRs, net of the Red "kills" caused by air interdiction, breakdowns, and rear-area security needs. To keep the example simple the number of kills desired is shown as an input.

The "other factors" are simplified here to two numbers, but their computation actually consumes over 50 percent of MOSCOW's space. The Red advance rate accounts for Red's choice of formation,[46] degradation caused by terrain and command and control (each a multiplier of the basic advance rate), and delays imposed by obstacles, air interdiction, and engagements. Cycle time is the sum of time required for each activity.

As Fig. 24 illustrates, the number of brigades required to meet the campaign objectives are equal to the required kill rate divided by the campaign kill rate. To assess the viability of the concept in terms of this criterion, this estimate of 30 brigades is compared with the projected number available, 27 brigades. This concept therefore requires 11 percent more brigades than are available in the budget.

After computing the time required for each activity in the attack and defend cycles, MOSCOW computes consumption of each of five types of resources: *personnel, vehicles*, rounds of *ammunition*, gallons of petroleum, oil, and lubricants *(POL)*, and pounds of *other* commodities (e.g., food and water).[47] Coefficients provided by the user represent the average loss or consumption of each commodity per day of each activity.[48] Once the time required for each activity is computed, the other resource requirements are computed as well and added to those from other activities to produce resource requirements per *cycle*. Since the number of cycles required is known (in the above example, the number of cycles needed is 10 division kills required / .20 divisions killed per cycle = 50 cycles), total *campaign* requirements of each resource are computed. These estimates are converted to average daily requirements by dividing each by Campaign Length. By converting personnel and vehicle losses into MVR-equivalents, replacement MVR-equivalents needed are also computed.

Finally, the number of MVRs required determines the number of headquarters units needed to command them. The daily required number of tons of commodities needed determines the number of supply vehicles needed.[49]

Figure 25 shows a slightly summarized version of MOSCOW's output screens. In each row, the leftmost column with a numerical entry shows the quantity of that resource required to implement the concept and conform to the campaign success criteria. The next numerical column shows the amount of that resource projected to be available (which is an input provided by the user). The final numerical column shows the ratio of the amount required to the amount expected to be available. In the "AFFORDABLE?" column each ratio is tested to determine if it falls within tolerance limits set by the user; if it does, the concept is deemed "affordable" within the available "budget" of that resource. By scanning this column a user can quickly develop an impression of which resources are stressed by the concept. In the example, Blue has ample forces available, and a great surplus of replacements stocks, but the daily *rates* of casualties, vehicle losses, and ammunition consumption exceed the rates at which they can be supplied. A user could attempt to vary the concept to lengthen the campaign, which might bring loss rates within the limits of supply capacity.

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[46]Blue and Red MVRs can move in either of two formations: "Administrative," which is assumed to emphasize speed at the expense of lethality and survivability, and "Battle," which does the opposite. The user sets the fraction of time spent in each formation, thus affecting mobility and combat power.

[47]Each of these is converted into a common weight measure (tons) to also estimate the total *lift* needed to resupply this consumption.

[48]Details on the calculation of resource consumption are in App. B.

[49]Appendix E provides a more detailed description of MOSCOW's outputs.

BLUE REQUIREMENTS FOR SUCCESS				
Resource	Required	Available	Reqd/ Avail	Afford- able?
MANEUVER UNITS				
Initial stock	20.9	21.8	96%	YES
Maximum replacement equivalents	3.5	8.6	41%	YES
Initial + Repl Equivs. (grand total)	24.4	30 4	80%	YES
Replacement equivalents per day	0.86	0.29	302%	*NO*
INITIAL STOCKS				
Personnel	209250	217826	96%	YES
Vehicles	29307	30508	96%	YES
AMMO (tons)	9.8E+05	1.0E+06	96%	YES
POL (tons)	1.5E+07	1.5E+07	96%	YES
Other commodities (tons)	5.9E+06	6.1E+06	96%	YES
REPLACEMENTS				
Personnel	22724	200000	11%	YES
Vehicles	4880	12000	41%	YES
AMMO (tons)	1.5E+05	7.0E+05	21%	YES
POL (tons)	3.8E+04	5.0E+06	1%	YES
Other commodities (tons)	1.0E+04	1.0E+05	10%	YES
REPLACEMENTS PER DAY				
Personnel	5634	4000	141%	*NO*
Vehicles	1210	400	302%	*NO*
AMMO (tons)	3.7E+04	2.0E+04	183%	*NO*
POL (tons)	9.5E+03	4.0E+05	2%	YES
Other commodities (tons)	2.6E+03	4.0E+03	65%	YES
LIFT (tons of personnel, vehicles and commodities)				
Total during campaign	3.5E+05	1.5E+06	23%	YES
Average per day of campaign	8.7E+04	1.1E+04	791%	*NO*
CASUALTIES				
Total during campaign	46199	250000	18%	YES
Average per day during campaign	11455	5000	229%	*NO*
Max daily rate (%) to an MVR	39.4%	15.0%	262%	*NO*
SUPPORT FOR MANEUVER UNITS				
Supply vehicles	1.2E+05	1.0E+05	115%	*NO*
Headquarters	3.7	8.0	47%	YES
CAMPAIGN LENGTH				
	Achieved	Desired	Desired/ Achieved	Afford- able?
Days Red delayed	3.25	3.00	92%	YES
Days Red advance unimpeded	0.78	0.78	100%	NA
Total Campaign Length	4.03	3.78	94%	YES

Fig. 25—MOSCOW output screen

The War in a Theater

For simple screening the MOSCOW zone could be defined as the entire theater.[50] There are instances, however, in which a user might prefer to divide the theater into several zones:

- If there are widely separated "subtheaters" (axes of advance) with few forces between them. An example might be a campaign in Iran, where two key strategic objectives (the headwaters of the Persian Gulf and the Straits of Hormuz) lie at opposite ends of the Iranian coastline and would probably be assigned to different Red Armies or Fronts.
- If a nonuniform distribution of Blue forces (either across the FLOT or in depth) was an important element of the concept being screened. For instance, some NATO concepts—e.g., Nunn in Levine et al., 1982—suggest changing peacetime deployments to move forces from the Central Army Group (CENTAG) area to the Northern Army Group (NORTHAG). Figure 26 shows an estimate of the forces that could be shifted from the reinforcement of CENTAG to NORTHAG under a "Maximum NORTHAG"

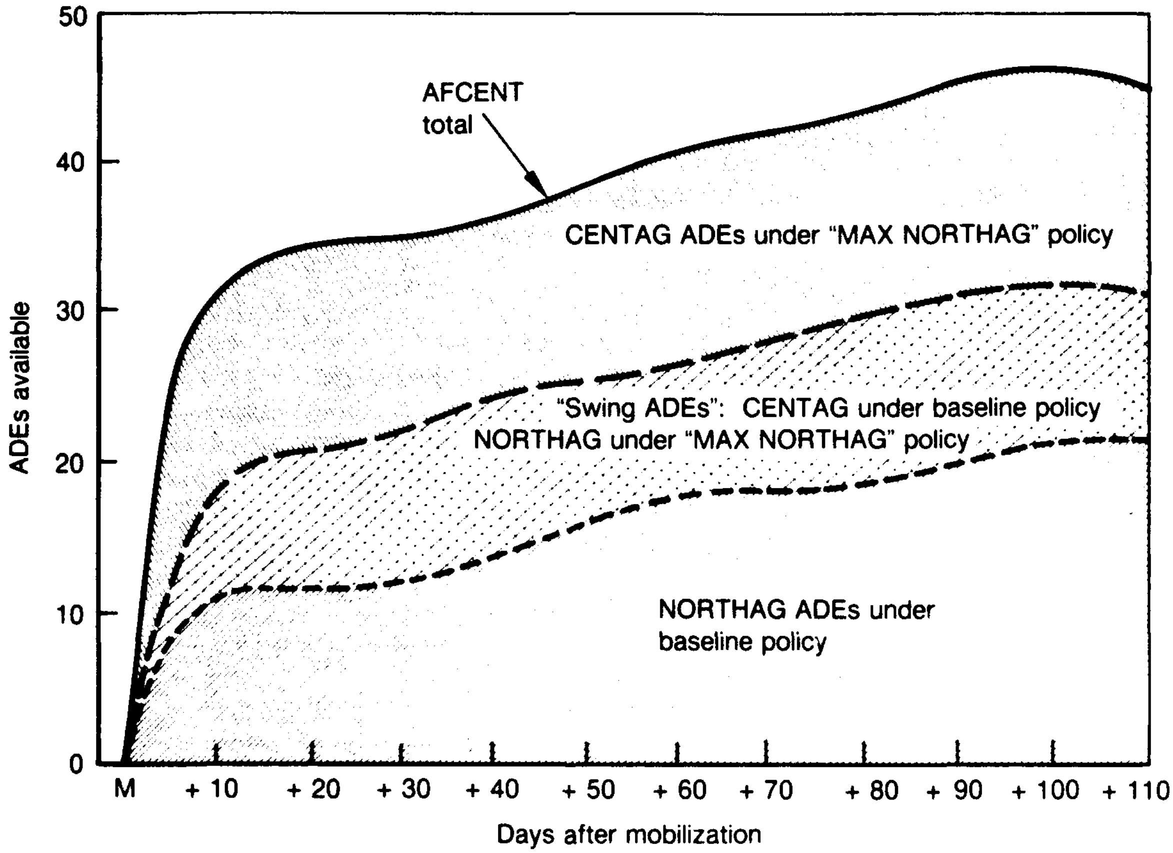

Fig. 26—Alternative allocations of arriving NATO reinforcements: Baseline vs. "maximum NORTHAG" policies

[50]The illustrations below treat the entire NATO Central Region as a single zone.

policy.[51] Other concepts recommend the creation of operational reserves, which presumably would be withheld through the initial (covering force) phase of the campaign.

- If users were interested in examining the sensitivity of a concept's requirements to changing Red theater strategies, in keeping with the discussion in Sec. II. For example, the user might vary Red's allocation of forces among several axes of advance, or Red's mix of first echelon and follow-on forces.
- If differentiation of subtheaters by general terrain type were considered necessary for realism, or because specific terrain features were important to a concept.

Figure 27 shows several alternative representations of the NATO AFCENT (Central Front) area utilizing different numbers of zones. Each MOSCOW run will estimate Blue requirements to destroy the portion of the total Red force in the zone specified. If more than one zone is used, Red forces (and Blue Headquarters and aircraft) must be allocated among them by the user, and MOSCOW's estimates of the Blue forces and resources needed in each zone must be combined to estimate overall theater requirements.

Setting more than one zone in sequence allows the user to crudely represent the sequenced arrival of Red or Blue forces. Many concepts call for greater reliance upon reserve forces, which might not be fully available until after the beginning of the campaign (depending upon assumptions about warning, decision, and mobilization times).[52] The user might establish two sequential zones, the first representing the initial phase of the campaign involving only active forces, and the second involving active plus reserve forces. Similarly, concepts that call for the creation of additional operational reserves can be represented with two (or more) sequential zones, the first in which only frontline forces are available, followed by a second in which reserves are also available.[53]

Similarly, echelonment of arriving Red forces can be represented by setting sequential zones, the first representing the battle of the first echelon, and the second representing the battle of the second echelon plus any surviving first echelon forces.[54]

Greater resolution comes at the price of a larger number of model runs (each run of MOSCOW-M1 represents a single zone),[55] which undercuts the efficiency that is one of MOSCOW's principal advantages. Additionally, there are limits to the minimum appropriate zone size. The use of activity cycles to represent "average" maneuver unit behavior—a "steady state" abstraction—implies a reasonably long campaign. The preferred zone size is still under study, but as a provisional minimum, the zone should be large enough that the length of its campaign (calculated by MOSCOW) is at least as long as the length of the attack and defend cycles.

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[51]Force estimates are denominated in armored division equivalents (ADEs). Reinforcement schedule information is drawn from Posen, 1984/85, p. 95; and Mako, 1983, p. 134.

[52]This same treatment could be used to represent operational reserves withheld from the first phase of the campaign.

[53]To give the use of reserves its full meaning as a theater-strategic decision, more than one horizontal zone would be needed to represent multiple corps or army group sectors. Blue operational reserves would be available—with delay times to reflect intelligence, decision, and movement times—to second zones in each sector, based on Red's allocation of forces among sectors. At least two horizontal zones and two zones in depth would therefore be needed.

[54]A description of procedures for representing multiple echelons is in App. F.

[55]Future development of MOSCOW may include automated routines to link several zones (spreadsheets) in a single run.

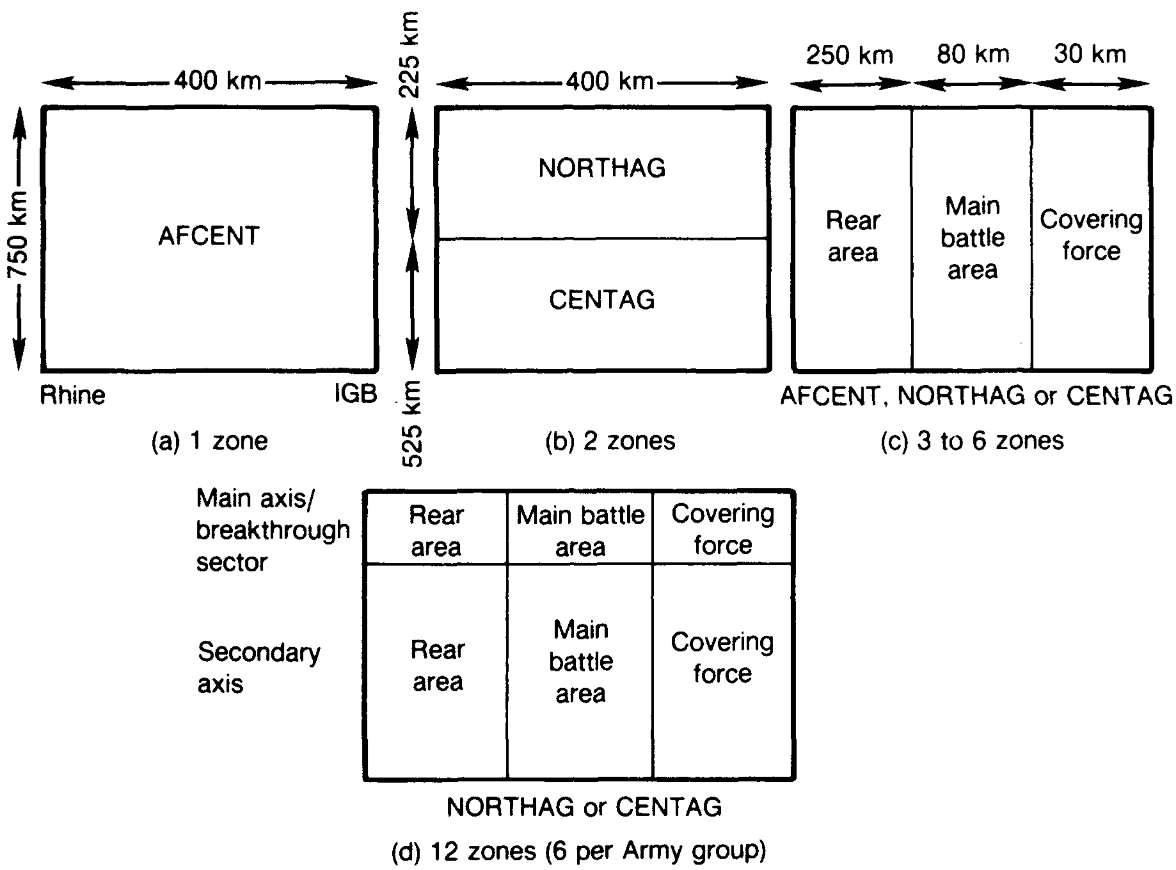

Fig. 27—Alternative representations of AFCENT in one or more MOSCOW zones

The Engagement

The *engagement* refers to the three activities in which Blue MVRs participate in combat with RMVRs. Two of the activities (Attack1 and Attack2) pertain to attack cycles, and one (Defend) pertains to the defend cycle. In each engagement one defending MVR or RMVR is attacked by a user-designated number of enemy MVRs, so the area represented is a small part of the campaign's zone (delimited by the range of each unit's weapons).

Engagements are the activities in MOSCOW that use the largest number of calculations to compute their outcome, but for the most part they play the same role as other activities in the cycle: They consume time and other resources. The difference, of course, is that engagements are the activities in which RMVRs are attrited, without which Blue cannot achieve its campaign objectives. Thus the policy and capability inputs to these activities are more detailed than most others, and the calculations to compute time and resource consumption are much more extensive.[56]

[56]Details of the engagement activity calculations are provided in App. C.

In attack engagements one RMVR is attacked by the number of Blue MVRs needed to achieve a desired combat power ratio.[57] Blue and Red each designate the amount of attrition they prefer Red to suffer in an average Blue attack before they would choose to break off. If these preferences differ, as is likely, the amount of attrition that Red will actually suffer will be set within the range between them, its proximity to each side's preference based on each side's ability to dictate the point at which it successfully disengages.[58]

Once the amount of attrition that Red will suffer in the engagement has been established, and given the starting vehicle strengths and lethalities of each side,[59] Lanchester's equations are used to compute the duration of the engagement, then Blue attrition.[60]

Although MOSCOW-M1 uses homogeneous Lanchester to compute engagement time and attrition, the model is neither firepower-oriented nor wedded to Lanchester.[61] Engagements may constitute but a small fraction of cycle time and thus have only a proportionate effect on force requirements. Lanchester's equations were used because they are well known, *but analysts may replace them with any other function that produces engagement duration and attrition.*

MOSCOW computes the lethality of MVRs and RMVRs in two general stages: First, it estimates the number of enemy vehicles that the MVR could kill per hour under ideal conditions (clear terrain, no enemy attempts to conceal, all targets in range, etc.), then it degrades that "ideal" lethality to account for the incomplete availability of enemy targets, their hardness, and other "friction."

Each side's MVRs are made up of composite vehicles that are assumed to fire in either direct or indirect fire mode.[62] For each mode, the user can specify with policy variables some tactical behaviors, in particular the rate at which vehicles fire, the high and low ranges at which they fire, and the maximum and minimum distances these vehicles are deployed behind an imaginary line dividing Blue and Red vehicles referred to as the "Initial FLOT."[63] Figure 28 illustrates MOSCOW's representation of the deployment of Blue and Red Direct Fire (DF) and Indirect Fire (IF) vehicles. MOSCOW assumes each vehicle type to be uniformly distributed within the segment bounded by its minimum and maximum distances from the Initial FLOT.[64] Fire from vehicles is assumed to be uniformly distributed within the line segment bounded by their weapons' high and low ranges. The fraction of a vehicle type (either DF or IF)

[57]Combat power is a "lethality-adjusted" measure of force size in an engagement. In MOSCOW it is defined as the number of combat vehicles participating in the engagement (e.g., one average Blue division may contain 1399 combat vehicles) times the square root of the expected number of enemy vehicles killed per hour per vehicle (or expected fraction of an enemy MVR killed per hour per friendly MVR). These two terms are the size and lethality components used in Lanchester's attrition equations (square law version).

[58]This input is defined as the fraction of attack or defend engagements in which Blue is able to impose its preference. A setting of .5, for example, would indicate that each side was on average equally able to control the duration of the engagement.

[59]Vehicle strengths are known because one RMVR always defends, and Blue's combat power ratio criterion determines Blue's vehicle strength. Lethalities are computed, as will be outlined below.

[60]This is an inversion of the normal formulation of Lanchester, in which engagement duration is input and Red attrition is output. Here Red attrition is an input and duration is output. See App. C for details.

[61]Homogeneous Lanchester was chosen because it is analytically tractable—i.e., does not require a separate simulation—and is well-known to military analysts.

[62]The fraction of MVR vehicles firing in each mode is input by the user.

[63]FLOT is forward line of own troops. The user can input each weapon's maximum and minimum ranges and maximum firing rate. The variables should of course fall within these boundaries, but MOSCOW does not force them to do so.

[64]Note that using a homogeneous Lanchester process assumes that fire is distributed uniformly throughout its target area (i.e., it is not possible to differentially allocate fire against different targets), and that targets expose themselves at a uniform rate throughout the engagement. These are simplifying assumptions made for the sake of model efficiency.

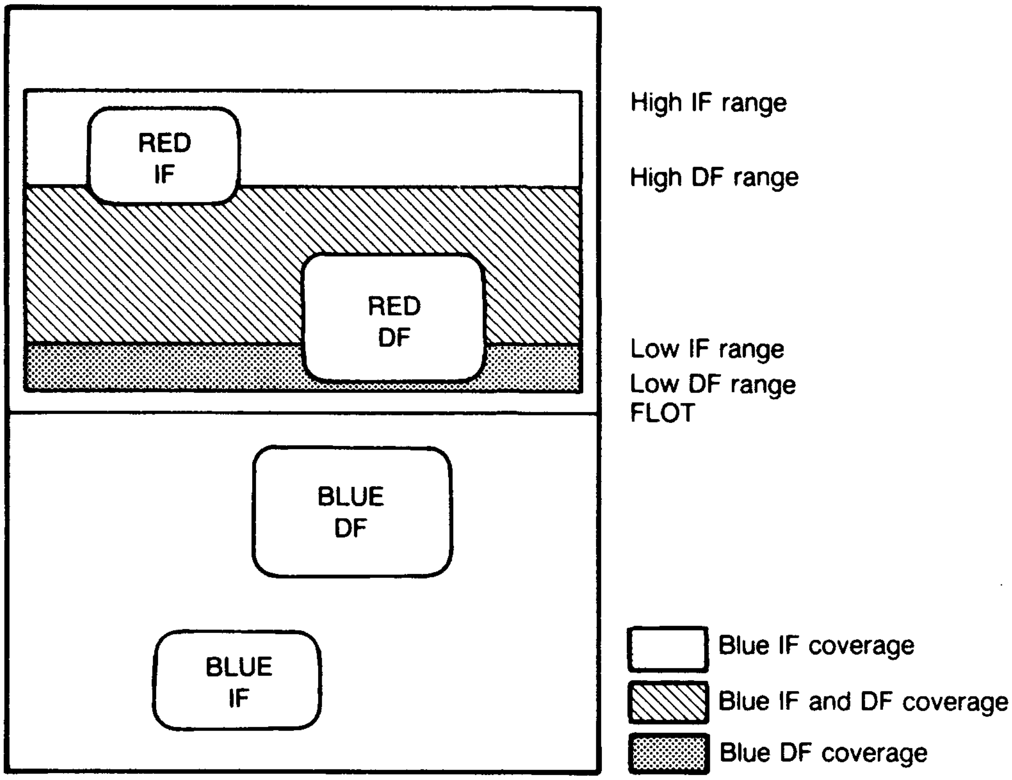

Fig. 28—MOSCOW's representation of the engagement

"available" as a target is computed as the fraction of its vehicles within the coverage of each weapon type. Four availability estimates are made: DF and IF vehicles' availability as targets to DF and IF weapons. In Fig. 28, Red IF vehicles are 100 percent available to Blue IF weapons and about 15 percent available to Blue DF weapons. Red DF vehicles are 100 percent available to Blue DF weapons and about 33 percent available to Blue IF weapons. Red coverage of Blue vehicles is omitted for simplicity. Such factors as terrain, enemy concealment, and command and control errors will further reduce average target availability.

"Ideal" lethality is computed in a fairly traditional way. Each firing mode has probabilities of hit and kill. The number of weapons actually able to fire is affected by the mix of movement formations chosen by the user. Kill rates are further degraded by terrain, command and control errors, intelligence errors, enemy vehicle hardness, lack of rest, and distance to target. Deploying a fraction of the MVR's personnel as dismounted infantry can increase its lethality but also increases personnel losses.

The product of "ideal" lethality and target availability is the MVR's or RMVR's organic lethality. To that is added kills achieved by supporting fires from higher echelons and from Close Air Support aircraft (both fixed and rotary-wing).[65] This sum, expressed as the fraction of an enemy MVR that can be killed by a friendly MVR per hour, is used in the computation of engagement duration and attrition noted above.

[65]Lethality in an attack and in a defend engagement are computed individually, and the relevant variable is used in the Lanchester equation. Fire and air support can be allocated unevenly to attack vs. defend MVRs.

The Vehicle Hide/Dash Sequence

MOSCOW includes policy variables to allow the user to represent a concept's tactical mobility during an engagement in a simplified way. They are implemented in the vehicle hide/dash sequence and affect vehicles' availability and lethality.

Each vehicle in an engagement is assumed to proceed in a sequence of tactical dashes (or bounds) between stopping points (which typically will be areas where cover is available). To represent this, the user inputs the average length of a dash and the average time between dashes—the average period in which the vehicle is stationary (and hiding). With the speed at which the vehicle dashes as another input, MOSCOW computes the average fraction of the engagement in which vehicles are stationary and moving (dashing). MOSCOW similarly computes the stationary/moving distribution for enemy vehicles.

When computing lethality, the user inputs hit probabilities for each element of the joint distribution of friendly and enemy vehicle states: Firer stationary / Target stationary; Firer stationary / Target moving; Firer Moving / Target stationary; and Firer moving / Target moving. Average hit probabilities reflect the frequency with which firers and targets are in each of these four states.

MOSCOW allows for the possibility that there will be a delay in locating (acquiring) an enemy vehicle after it stops moving (presumably at some hiding place). This delay could be determined by either the innate capability of friendly sensors to acquire a hidden enemy vehicle, or the enemy vehicle's revelation of its position by firing from it. Inputs indicate the delay before a hidden vehicle is acquired automatically and the number of shots it must fire before being acquired. The actual delay is the minimum of the two delays implied by these inputs. During this delay targets are assumed to be completely hidden, so hit probabilities against stationary targets are reduced in proportion to the fraction of a vehicle's stationary (hiding) period taken up by this target acquisition delay.

As part of a concept, the user can indicate the degree to which each side in an engagement attempts to close with or retreat from the enemy.[66] These "aggressiveness" inputs specify the average fraction of each vehicle dash that causes a net displacement toward enemy vehicles.[67] When set to 1.0, each dash is aimed directly at the enemy; −1.0 aims each dash directly away from the enemy; and 0.0 moves parallel with the FLOT (no net change in distance from the enemy). Values between 0.0 and 1.0 or between 0.0 and −1.0 represent partial closure. Figure 29 illustrates several alternative settings for this aggressiveness input. In most cases, the aggressiveness of attack MVRs or RMVRs will be greater than 0.0, and that of defend MVRs or RMVRs will be between 0.0 and −1.0. Note that aggressiveness does not refer to the degree to which vehicles rely on *mobility* in engagements—the period they are stationary and the distance they dash capture that—but to *their change in relative positions* with enemy vehicles.

This representation of tactical mobility provides a third source of simultaneity in MOSCOW's equations. Recall that target availability and weapon lethality, which influence the duration of engagements through the Lanchester equations, are both affected by the average distance between weapons and targets. If vehicles' relative distance can change, as this formulation of tactical mobility allows—drawing nearer or farther apart as the engagement proceeds—then lethality and availability can change, and so affect the engagement duration. Some means is needed of computing an "average" distance between vehicles. MOSCOW uses

[66] When applied to a defending force, this is sometimes referred to as its "elasticity."

[67] Setting the aggressiveness of the attacker to be positive will (assuming no change in the aggressiveness of the defender) increase his lethality due to reduced range and greater target availability, and simultaneously increase the defender's lethality.

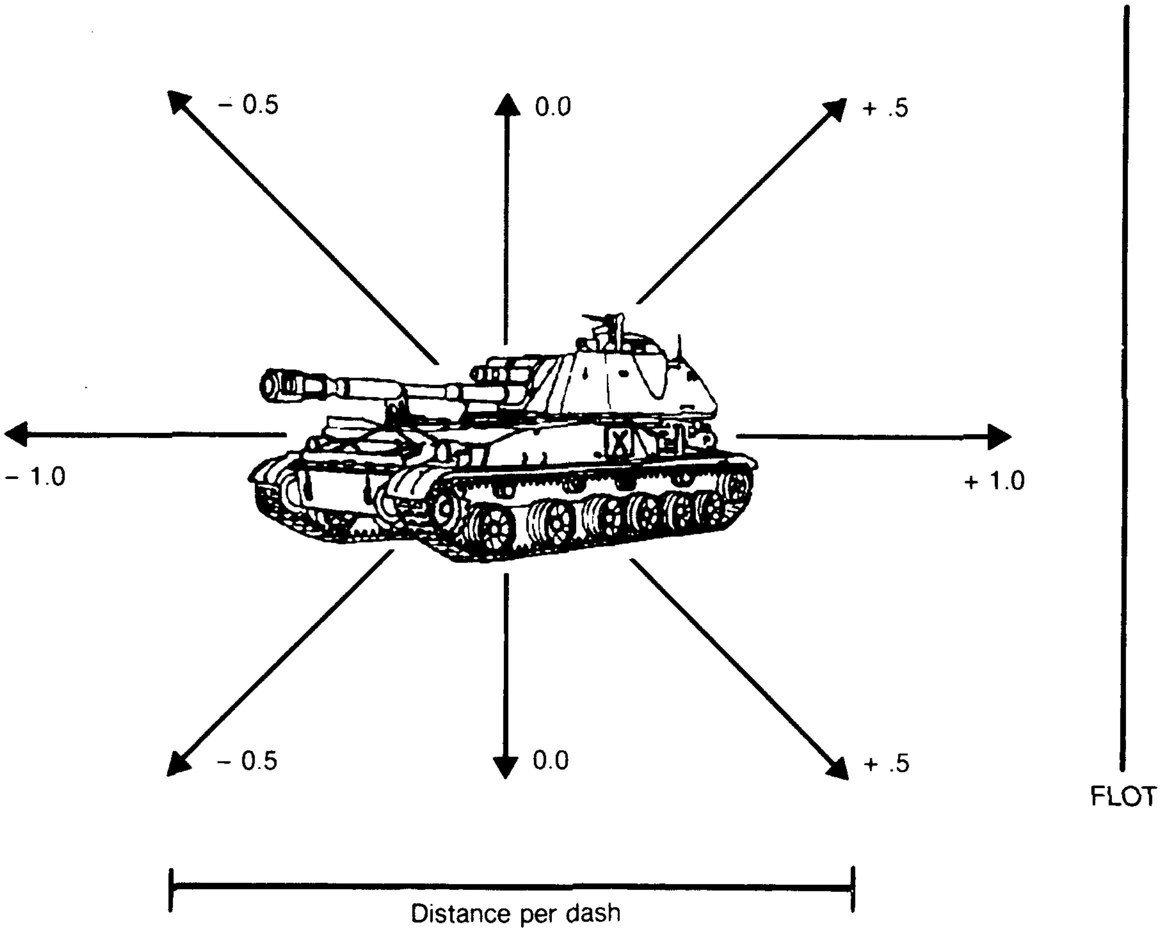

Fig. 29—Illustration of different values of aggressiveness parameter

1/2 of the engagement duration. Therefore, engagement duration depends upon itself. Fortunately, the spreadsheet's estimates of these parameters converge as it is solved iteratively. The following example will illustrate.

Assume that the distance between attacker and defender vehicles narrows as the engagement proceeds.[68] Holding other factors constant, the attacker will be more lethal and the time that is needed to impose the specified amount of attrition on the defender will be reduced. This shorter engagement duration increases the distance between vehicles, reducing attacker lethality and increasing engagement duration. The spreadsheet will oscillate in tighter ranges as it iterates to converge on a solution, as illustrated in Fig. 30.

Because the positions of both attacking and defending vehicles may change during the engagement, the overall FLOT for the campaign may move. MOSCOW takes the FLOT advance or retreat into account in computing Red's average advance rate. Red's advance rate

[68]In other words, [Attacker dash distance × Attacker dashes per hour × Attacker aggressiveness] is greater than [- (Defender dash distance × defender dashes per hour × defender aggressiveness)].

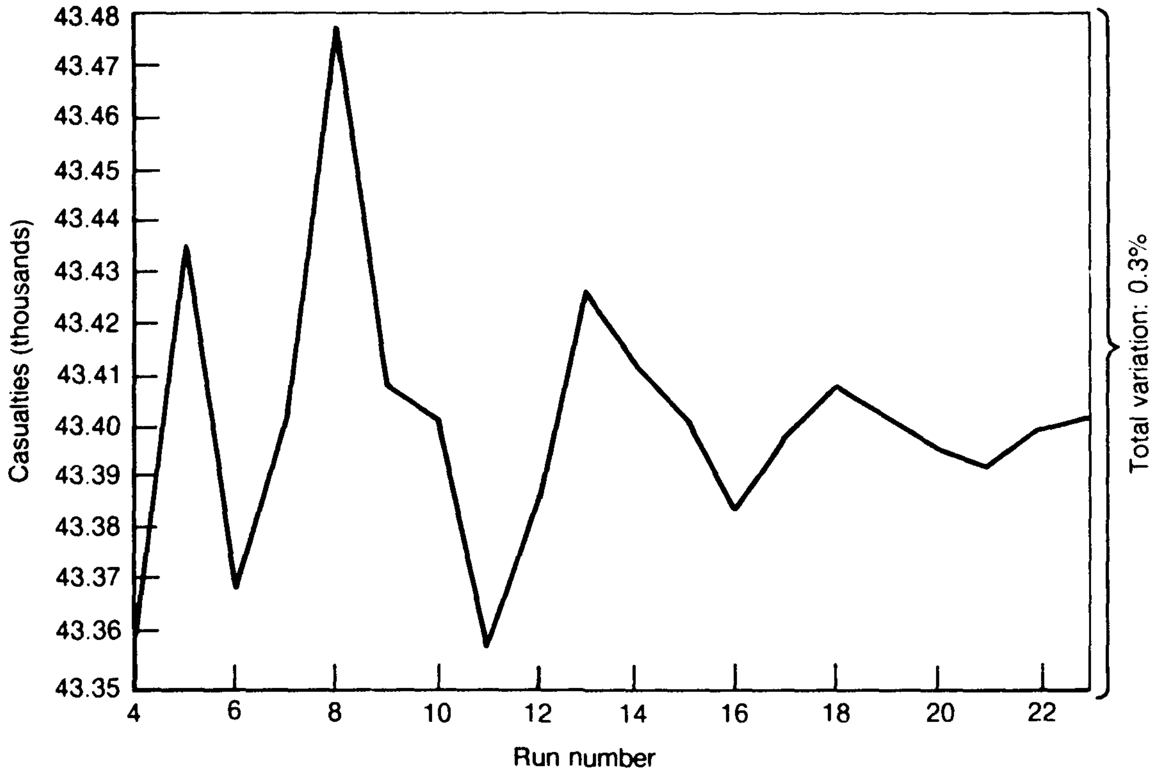

Fig. 30—Convergence of output value through multiple spreadsheet iterations

is composed of three components: (1) his rate of advance as delayed by all factors except ground combat, (2) the delay caused by ground combat; and (3) FLOT displacement during ground combat.

Summary

Figure 31 summarizes the key information flows in the system represented by MOSCOW. Four levels of geographic hierarchy are identified: the vehicle sequence, engagement activity, campaign (including nonengagement activities), and war. For each level, four types of information are shown: Blue policy inputs, scenario inputs (shown primarily as Red capabilities or behavior), process computations, and outputs. Naturally, this diagram cannot be comprehensive, because MOSCOW has over 50 policy inputs alone, but it portrays the model's essentials.[69]

Vehicle Sequence Level. The vehicle sequence establishes the lethality and availability of Blue and Red MVRs. Because engagements utilize the combat power ratio desired by the attacker, these together determine the number of vehicles on each side in engagements (and therefore their combat power as well).

[69]Arrows indicate information flow. In several cases, flow is in both directions (because of simultaneity). Numbered "go to" boxes indicate backward flow.

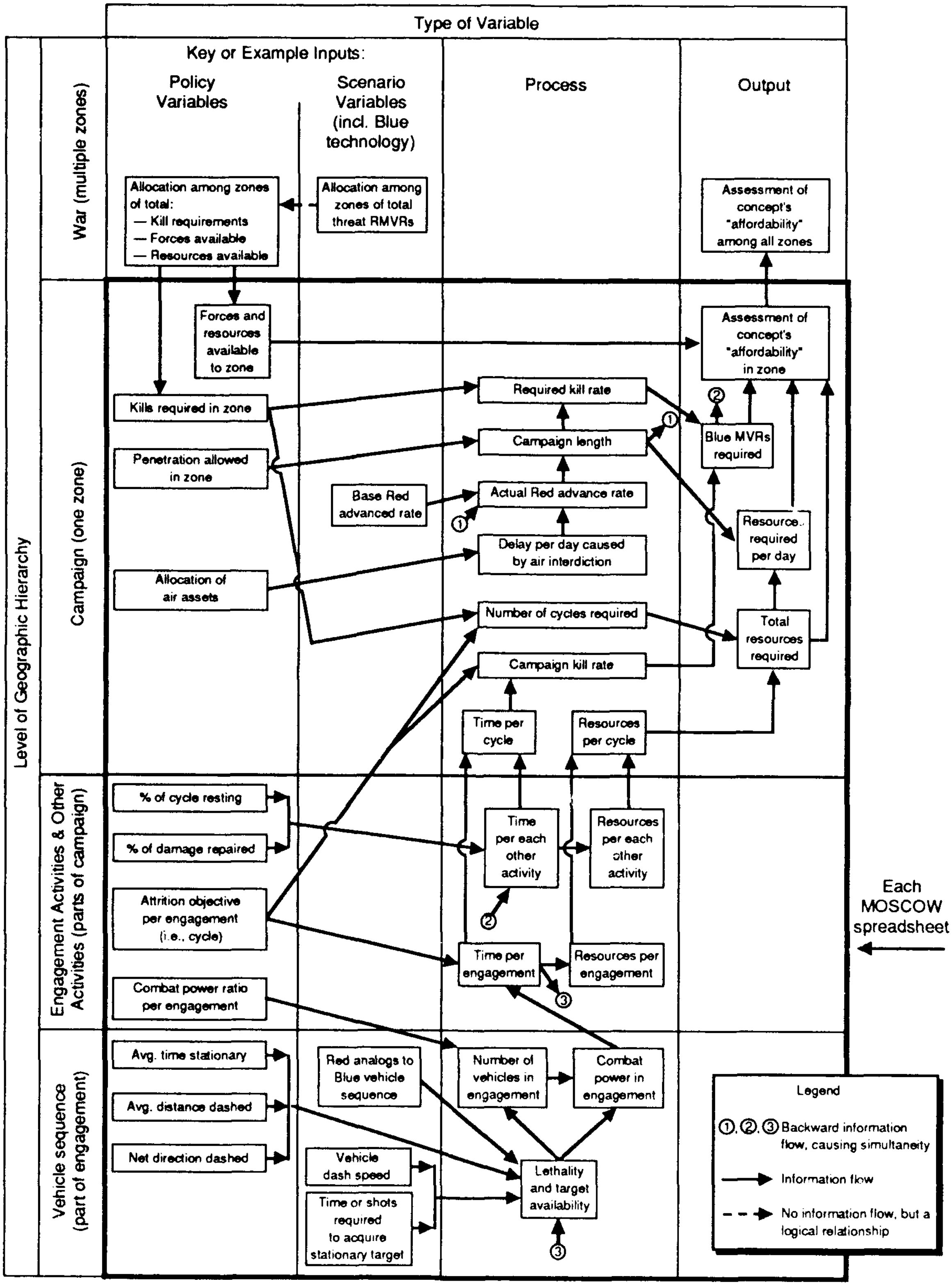

Fig. 31—Key information flows in MOSCOW

Engagement Level. Utilizing the engagement attrition objective and each side's combat power, the Lanchester equation computes the time required per engagement. Engagement time and combat power determine attrition and other resource consumption during the engagement activity.

Nonengagement Activities. Utilizing policy variables that affect specific activities (such as the rest or the repair activities), the time required for each nonengagement activity is computed. When added to the time required for each engagement, total time per cycle is computed. Similar computations are made for the consumption of each physical resource per cycle.

Campaign Level. Blue MVRs' average Campaign Kill Rate is the attrition achieved per engagement divided by cycle time. The time available for the desired amount of Red kills (Campaign Length) is Red's actual advance rate (as degraded by Blue air and engineer support) divided by the allowable penetration. Blue's required kill rate is thus Red kills required divided by Campaign Length. The number of Blue MVRs needed to achieve this desired number of kills is Blue's required kill rate divided by the average MVR's Campaign Kill Rate.[70]

The number of cycles needed is Blue's campaign kill objective divided by Red attrition per cycle. This number times the resources required per cycle determines total resource needs (including replacements). Total resources needed divided by Campaign Length determines average daily resource requirements.

The principal requirements—for standing MVRs, for total MVRs, for total resources in the campaign, and for average daily flows (and the lift to transport them)—are compared with input "budget" limits to assess the concept's "affordability" in the zone.

War Level. Any single MOSCOW spreadsheet will represent a campaign in a single rectangular zone of any size. If a user wishes to distinguish among campaigns (in space, in combatant types, or in time), multiple MOSCOW spreadsheets can be used to represent more than one zone. In this case, Red must allocate resources among zones, and Blue must allocate his overall resource budgets. A concept may be found to be affordable (in terms of the physical resources it requires) in some zones but not in others, and the user will wish to experiment with alternative budget allocations to determine if the zones' needs can be jointly satisfied.

FUNCTIONAL BREAKDOWN

The MOSCOW spreadsheet is organized in a series of blocks, each block performing a set of like model functions, or holding like inputs. There are five categories of blocks: *inputs*, *input conversions*, computations relating to *engagement activities*, computations relating to *nonengagement activities*, and *outputs*.[71] Within the blocks in the Input category variables are further subdivided into those reflecting Blue or Red behavior, those reflecting Blue or Red capabilities, or those determined by exogenous circumstances.

[70]In MOSCOW's output, this is referred to as the "standing" or "initial" force required. This force plus replacements needed is referred to as the "total" force required.

[71]Input conversions are computations made directly from input information to convert them into different units of measure. For example, air interdiction effects against enemy vehicles require the user to input the number of tons of munitions carried per sortie, expected hits per ton, and expected kills per hit. The corresponding input conversion converts these into expected kills per sortie.

Inputs and Input Conversions

Each of the following types of inputs is included. An example of each input block is displayed in App. A.

Terrain. Although MOSCOW does not distinguish among terrain features within a zone, its "homogeneous" terrain can reflect a distribution of terrain types. Currently 22 types are represented, but more could be added quite easily. Terrain affects mobility, combat power on defense, and target availability.

Red Threat and Zone Geography. This block includes the number of RMVRs, headquarters, and engineers, their allocation between attack and defend missions, and the aggressiveness of the RMVRs on attack and defense set the basic parameters of the Red threat at the zone (operational) level. The length and width of the zone and the fraction of it taken up by "choke areas" (limited shoulder space, which may constrain attacking force ratios) are specified.

Success Criteria and Operational-Level Policy for Blue. Blue's basic campaign objectives are specified—the number of RMVRs that can be permitted to survive after a specified amount of penetration into Blue territory. Here Blue also specifies his delay objective, if any (which is a goal that he is not assured of meeting), and the forward and rear boundaries of the rectangle within which Blue is assumed to be uniformly distributed. Additionally, Blue's allocation (in percentage terms) to attack, defend, and reserve missions are specified, as is the aggressiveness of Blue MVRs.

Limits for Blue. The budget of MVRs, personnel, vehicles, consumables, and lift that Blue has available for the campaign is input here. These can be recorded as both stocks available for the entire campaign and average daily flows (which may be limited by logistics throughput capacity). Limits on the number of available supply vehicles (that provide intratheater resupply) and on the number or average daily rate of acceptable casualties may also be provided.

These limits are not necessary for MOSCOW's operation—the model can still estimate requirements without them—but they are needed in order to assess the limits of affordability. Without them, analysts can still compare among concepts (to identify those that have the lowest resource demands),[72] but they have no benchmarks for assessing whether even the least-demanding is feasible.

Fire, Air, and Engineer Support. Four types of support are included. Headquarters are assumed to be all long-range artillery and missile forces not organic to MVRs; they can provide direct fire support to MVRs in engagements, or can suppress enemy headquarters. Close Air Support refers to all fixed and rotary-wing aircraft not organic to MVRs that operate during engagements in the vicinity of friendly MVRs (near the FLOT). They assist MVRs in a manner identical to headquarters. (The kill rate of this support is added to the MVR's organic kill rate when computing MVR lethality.) Air Interdiction aircraft operate in areas distant from friendly MVRs (usually presumed to be behind the FLOT), and can kill enemy vehicles, delay enemy MVRs, disrupt enemy MVR command and control, suppress enemy headquarters fire, or kill enemy supply vehicles.

Each function is treated identically for Blue and Red supporting forces, except for engineers. Blue engineers are presumed to delay RMVRs (through the construction of obstacles), and Red engineers attempt to ameliorate this delay. (Red engineers cannot "accelerate" Red's advance

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[72]Because multiple criteria are used to assess affordability, any summary assessment would require a means of translating different resources into a common unit of measure (such as dollar costs), except in the unlikely event that one concept dominated across all resource categories. Dollars are reasonable proxies for most of the resources estimated by MOSCOW, except for personnel casualties. MOSCOW-M1 does not currently include costs, but if unit cost data were available, it could easily calculate total cost demands.

beyond the rate that would be possible in the absence of Blue engineers.) Headquarters and engineers each have a specified capacity per unit per day, so their effects increase as Campaign Length does. The effect of CAS and AI aircraft can change because they can suffer attrition with each sortie, so MOSCOW computes their average effectiveness per day, accounting for attrition.

Maneuver Units. This block describes the characteristics of Blue and Red maneuver units. It is subdivided into the following sections: General; Mobility; Lethality; Vulnerability; Command, Control, Communications, Intelligence, and Electronic Warfare (C3IEW); and Basic Load and Logistics. Each section distinguishes between variables that describe the maneuver units' capabilities that stem from its organization and technology, such as the number and capabilities of their vehicles, and those that derive from policy choices (norms in Soviet vernacular), such as their mix of movement formations, or the average fraction of time that they rest.

Consumption Coefficients. These coefficients reflect the relative resource demands of different activities. For example, vehicles performing the activity *Move to Weapons Range* may have a higher probability of breaking down per day than vehicles resting or loading supplies. There are similar coefficients for each resource in each activity.

Calibration Coefficients. These coefficients allow users to vary (or nullify) relationships among inputs that are used in computing components of several activities. In each case, the designer nominated a conjectural, but plausible-appearing relationship in lieu of empirical information or well-established theory. For example, the average time an MVR must delay to wait for instructions from higher echelons is assumed to be a function of the number of MVRs each headquarters controls. (The assumption is that headquarters bog down as they must control more MVRs.) Even if this relationship seems plausible, there can be disagreement about its shape: Is the exponent of MVRs per headquarters greater than, less than, or equal to one? The calibration coefficient for this relationship allows the user to choose, and its counterpart nullification coefficient allows it to be omitted entirely.

Proportion Constraints. If the user is not happy with the distribution of activities computed by MOSCOW's equations, he may constrain the time of one or more activities to be a fixed proportion of total cycle time. For each activity, MOSCOW uses its "unconstrained" (computed) time unless a constraint is set.

Engagement-Related Activity Computations

In this block the lethality and target availability of MVRs and RMVRs in attack and defense engagements are computed.[73] Using the Lanchester equations, the duration and attrition suffered in Attack1, Attack2, and Defend engagements are computed, then provided to the lethality and availability computations for additional iterations. Using resource consumption coefficients pertaining to these activities, consumption of other resources is computed.

Computations Related to Activities Other than Engagements

Time and resource demands for all nonengagement-related activities (all activities except Attack1, Attack2, and Defend) are computed.[74] Most are not part of MOSCOW's simultaneous system and can be computed directly from inputs. For example, time and resources required by defending MVRs to prepare defenses is simply the percentage of maximum preparations chosen as a policy variable × the MVR's preparation rate. A few activities, however, require

[73]The equations are derived and explained in App. C.

[74]The activity cycle is described and activity equations defined in App. B.

variables that are computed in the output section and must iterate to converge on a solution. For instance, the time required by an MVR to move within weapons range depends upon the density of MVRs in the zone, where the numerator of density is the number of MVRs in the zone, an output.

Time and resource requirements for all activities are summed to yield cycle time and cycle resource demands.

Blue Requirements

In addition to the outputs mentioned in the section on the computation of campaign requirements additional computations are reported to assist in model calibration and to check results against several common benchmarks (e.g., exchange ratios, average daily casualty rates, or pounds of resources required per man). More information on these supporting calculations is contained in Apps. A and E.

POLICY VARIABLES

MOSCOW emphasizes the operational level of war to allow users the freedom to represent a wide range of concepts, but it includes policy variables at other levels as well.[75]

As the time horizon for a decision extends, constraints relax, and some scenario variables become policy variables.[76] Similarly, the higher the decisionmaker is in the policymaking hierarchy, the more that formerly scenario variables become policy variables. A platoon commander may have little choice about his sector, but a company or battalion commander may have a great deal. A corps or army group commander may have a choice among whole provinces, a theater commander among countries, and the NCA among theaters.

When MOSCOW refers to *scenario variables*, it means only those things not in the direct control of any Blue decisionmaker, such as the characteristics of the threat or the terrain in the zone. *Policy variables* can be arrayed in a hierarchy according to the level of warfare or echelon of decisionmaking to which they pertain. Thus, the number of MVRs available to a theater is a grand strategic (NCA) policy variable; on the other extreme, the distance IF weapons are deployed behind the FLOT is a tactical (brigade or division commander) policy variable.[77]

Similarly, criteria used to evaluate concepts will often differ among different decisionmaking echelons. Obviously, higher echelons will probably use more aggregated measures than lower, and those with combined, joint, or national perspectives will be concerned about a wider array of command organizations, service branches, or nationalities than those with more limited responsibilities. MOSCOW emphasizes the essential concerns of the Blue commander responsible for the zone—how much territory can he afford to cede and how many surviving Red units at that penetration he can tolerate to be considered a "successful" campaign, and the upstream resource needs they imply.

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[75]For those not familiar with the term, policy variables are numerical proxies for those elements of a decision that are within the control of the decisionmaker relevant to the analysis. Scenario variables are those elements outside of the decisionmaker's control. If a study were concerned with the best place to deploy elements of a corps, for example, the corps sector's terrain, the threat, and the corps' equipment would all be scenario variables, but the geographic distribution of men and equipment within the sector would be among the policy variables.

[76]This of course was the primary motivation behind Army 21's long time horizon.

[77]One of doctrine's purposes is to influence the choices made by tactical commanders. Therefore *tactical* policy may be an aspect of *operational* warfighting concepts.

Principal Policy Variables		Success Criteria (Alt-S)	Fire, Air, and Engineering Support (Alt-F)	Limits on Blue "Budgets" (Alt-L)	Maneuver Unit Description and Policy (Alt-M)	
		Section of MOSCOW — M1				
Level and Warfare (and corresponding decision echelon)	Grand-Strategic (National)			• Total and avg. daily availability of MVRs, HQs, supply vehicles, personnel, vehicles, ammo, pol, other lift • Acceptable casualties		
	Theater-Strategic (CINC)	• Red penetration limit • Red survivors allowed • Maximum Red penetration prior to interception	• % CAS assigned to ATK MVRs • % Fire support assigned to ATK MVRs • % Fire support assigned to suppress HQs • % Air interdiction Missions assigned to — Attrit — Delay — Disrupt — Attack Fire support			
	Operational (Army Group Army, or Corps)	• Forward Boundary • *Rear* Boundary • % of attack operations that employ linear avenues • % of zone width screened • % of MVRs — ATK KILLS *and* DEF KILLS			• Combat power ratio chosen for attacks • Desired Red attrition in Blue attacks • Desired (maximum) Blue attrition in Red attacks • *Distance MVR disengages* after battle	• % of movement in "administrative (road march) formation • Fraction of maximum defensive preparations made before each battle • Fraction of time spent resting • Distance from battle to depot • Fraction of losses repaired by MVR
	Tactical (Division or Brigade)				• Typical interval between tactical moves (bounds) by weapon carring vehicles • Distance moved in tactical bounds by direct fire vehs • Fraction of above moved by indirect fire vehicles • Distance between vehicles when attacking	• Weapons firing rates — Indirect and Direct Fire — Stationary and moving • Distance from FLOT (min. and max.) • Fraction of vehicles firing direct fire • Fraction of personnel dismounted • Fraction of attack vehicles in first tactical echelon
	Technical		• HQ Firing Rates • CAS, AI sortie rates • Kills (or other effects per hit • Air attrition per sortie		• Weapons Ranges (min and max.) • Hits per round • Kills per hit	• Hardness • Vehicles breakdown/day • Movement rate/hr • Pol consumed/km

Fig. 32—Key policy variables in MOSCOW

Most of the important policy variables are shown in Fig. 32, grouped by their block in MOSCOW and the level of warfare to which they pertain.[78] Not surprisingly, there is reasonably close mapping between MOSCOW blocks and levels of war, because this was a key dimension of the typology of concepts described in Sec. II.

Many of these policy choices are about allocation: of time spent in each of two movement formations; of air interdiction aircraft among five missions; of MVRs among attack, defend, and reserve missions.[79] MOSCOW will not seek optimal allocations of any of these. It estimates resources needed for any allocation the user specifies.[80]

There arc too many policy variables (over 50) to discuss the role of each in representing elements of concepts. However, Table 20 summarizes some of the critical dimensions among which concepts differ, and identifies the principal MOSCOW variables that can correspondingly be manipulated.

To provide a flavor of how MOSCOW can be used to represent different concepts, the next two subsections illustrate how MOSCOW represents some of the elements of concepts and provide some insight as to the model's behavior.

The data on forces and terrain used in the examples reflect current-day NATO and Warsaw Pact forces, converted into U.S. or Soviet equivalent divisions.[81] Some illustrations pertain only to individual maneuver unit activities, but most show campaign-level results. Unless otherwise specified, the illustrations treat the requirements for a campaign in NATO's central region[82] against the first operational echelon of a Warsaw Pact attack. Blue forces have the objective of destroying 15 of 30 Red divisions by the time they have penetrated 30 km. The MOSCOW zone represents all of AFCENT: approximately the Federal Republic of Germany and most of the Benelux countries.

EXAMPLE POLICY VARIABLES IN MOSCOW

Should Units Slow Down Their Operations to Repair Damage? [TAC]. MOSCOW's activity cycle includes a repair activity, in which damaged vehicles and personnel can be repaired. The user specifies the number of vehicles that can be repaired per day (and the relative rate at which personnel casualties can be "repaired"), and the fraction o: losses that are repairable at the MVR level and at higher levels (referred to as the "theater" level).

The policy variable here is %REPRD-M, the fraction of vehicles repairable by the MVR that the unit chooses to actually repair. The tradeoff is time for vehicles: A high %REPRD-M

[78]Assigning variables to levels of warfare is an inexact science. Practice varies with armies and command philosophies; what might be within a tactical commander's purview in the Israeli army might be decided by an operational commander (or by inflexible norms) in the Soviet army. Many of the assignments shown in Fig. 32 were close calls, particularly when choosing between the Tactical vs. Operational or the Operational vs. Theater-Strategic levels of war. The assignments are unimportant unless analysts (foolishly) drew some arbitrary upper limit to the level of warfare that their study would consider. Even if this were done, excursions should be undertaken to ascertain what the "shadow price" of an imposed policy constraint would be. It may be possible to make a case to higher authorities that there is a marginal benefit to the relaxation of the constraint.

[79]Reserve MVRs cannot participate in a zone campaign and do not consume any resources; they are simply added to the required number of attack, defend, and rear-area security MVRs. Including them in the model may seem to offer little. However, if more than one zone (spreadsheet) is used to represent phases of a campaign, MVRs held in reserve in the first phase can be committed to the second (or later) phases, thus allowing the user to represent different policies regarding allocation and employment of operational or strategic reserves.

[80]Because multiple criteria are used in MOSCOW to assess concepts, until a means is developed of combining them into a single measure of utility (such as money), "optima" may be unstable under alternative utility functions.

[81]Orders of battle have been normalized using the estimates of NATO and Pact strengths in Armored Division Equivalents (ADES) in Mako, 1983; and Phillips, 1987.

[82]Allied Forces, Central Europe, or AFCENT.

Table 20

VARIABLES IN MOSCOW AVAILABLE TO REPRESENT ELEMENTS OF DEFENSE CONCEPTS

Dimension	Example Definition and Primary Applicable Level of Warfare	Buzzwords	Pertinent MOSCOW Variables
	Category: Force Deployment, Allocation, and Use of Terrain		
Depth of deployment and operations	Minimum and maximum distances from IGB within which X% (e.g., 90%) of Blue forces are deployed [TS][a]	Forward defense Area defense Defense in depth	FORW BNDRY and REAR BNDRY (in 1 zone) % of total force available to each of several zones (if multiple zones used)
Preparation of border area	Degree to which fortifications strongpoints, minefields barriers, or other terrain preparations are carried out in peacetime vs. in crisis and and wartime [TS]	Barrier zones	Movement, defense, and concealment multipliers for terrain type Red vehicle (VEH) Breakdowns/km
	Category: Warfighting Style		
Staticness of defense	Degree to which Blue units "stand fast" in battles, and and accept continued casualties rather than withdrawing [OP and TAC]	Positional defense Mobile defense	TAC STA PD-DEF DIS/TAC MV-DEF MVRAGGRESSV-DEF BLU ATTR-RATK *RED PENETRATION* FOWR or REAR BNDRY
Means of enhancing survivability	Relative emphasis on prepared positions vs. mobility to reduce enemy's lethality [OP and TAC]	Maneuver warfare Maginot Attrition mentality	TAC STA PD-DEF DIS/TAC MV-DEF DEFENSE PREP%
Degree of offensiveness	Fraction of engagements in which Blue is attacker — or — Echelon at which offensive operations are principally planned [OP?]	Operational art Initiative Maneuver warfare	% MVRs—ATK KILLS (if several zones used, this can differ among zones to represent main secondary counterattack axes)
Inclination toward risk taking and opportunism	There is no satisfactory definition: roughly speaking it is the frequency with which Blue will take nonconservative actions in order to seize or retain the initiative [OP and TAC]	Agility Maneuver warfare	C-3 ERR (to reflect command competence) REDATTR-BLATK TAC PWR RA % REST
Linearity of battle	Degree of intermixing of friendly and enemy forces at the operational level [OP]	Reactive defense Nonlinear battlefield Amoebas vs. lines	% ATKOPNS-LINEAR (if multiple zones used:) Some zones can be friendly territory in one period, enemy the next

Table 20—continued

Dimension	Example Definition and Primary Applicable Level of Warfare	Buzzwords	Pertinent MOSCOW Variables
	Category: Force Equipment and Organization		
Active/reserve force mix	Fraction of forces of each category deployed at the ICB and in main defensive positions for several periods in wartime [GS and TS]	Tooth to tail	(If several zones used:) Different MVR capabilities in each zone; Different amounts available over several periods (reflecting mobilization time)
Heavy vs. light forces	Fraction of force deployed in "light" (and presumably less expensive) ground or air vehicles versus armored and mechanized infantry vehicles [TAC]	Lightening the force; Agility; Mobility; Technocommandos; Defensive defense	MVMT/HR-ADMIN and BATTLE; HARDNESS-ADMIN and BATTLE; Enemy probability kill/hit
	Category: Any[b]		
Means of delivering munitions	Fraction of munitions delivered by: Fixed-wing aircraft; Rotary-wing aircraft; Ballistic missiles; Artillery; Ground-maneuver direct fire weapons; Air-delivered direct fire weapons [OP and TAC]	Maneuver by fire; Maneuver by air; Interdiction zones/belts; Forward response; FOFA/Deep Strike	% IF; MVMT/HR-ADMIN and BATTL; Tons of munitions available from: CAS, AI, fire support

[a]Level of warfare codes:
GS - Grand-strategic OP = Operational
TS - Theater-strategic TAC = Tactical

[b]This dimension combines elements of all three major categories. Most authors implicitly assume two of them are fixed (usually force deployment and warfighting style) and make recommendations that pertain to the third (force equipment).

reduces the number of replacement vehicles needed but reduces the MVR's Campaign Kill Rate (by adding to its repair time, thus lengthening cycle time), increasing the number of standing MVRs required for the campaign.

Figure 33 shows how repair is treated. For a given number of vehicle losses (here, 100), some fraction (10 percent) is repairable by the MVR, some fraction (30 percent) by theater assets, and the remainder are unrepairable.[83] Of the 10 that could be repaired by the MVR, 20 percent will be repaired according to the policy variable %REPRD-M. Therefore, two are repaired and eight are added to the "replacements required" group. If the MVR's repair rate is ten vehicles per day, the time required to repair is 2 / 10 = .2 days. Because the rate at which

[83]The "repairable by theater assets" (%REPRBL-T) input makes an assumption about the length of the campaign. If the calculated Campaign Length varies significantly from this, %REPRBL-T may have to be adjusted. It is not in MOSCOW's simultaneous system, so only one further iteration would be necessary to recompute Blue requirements.

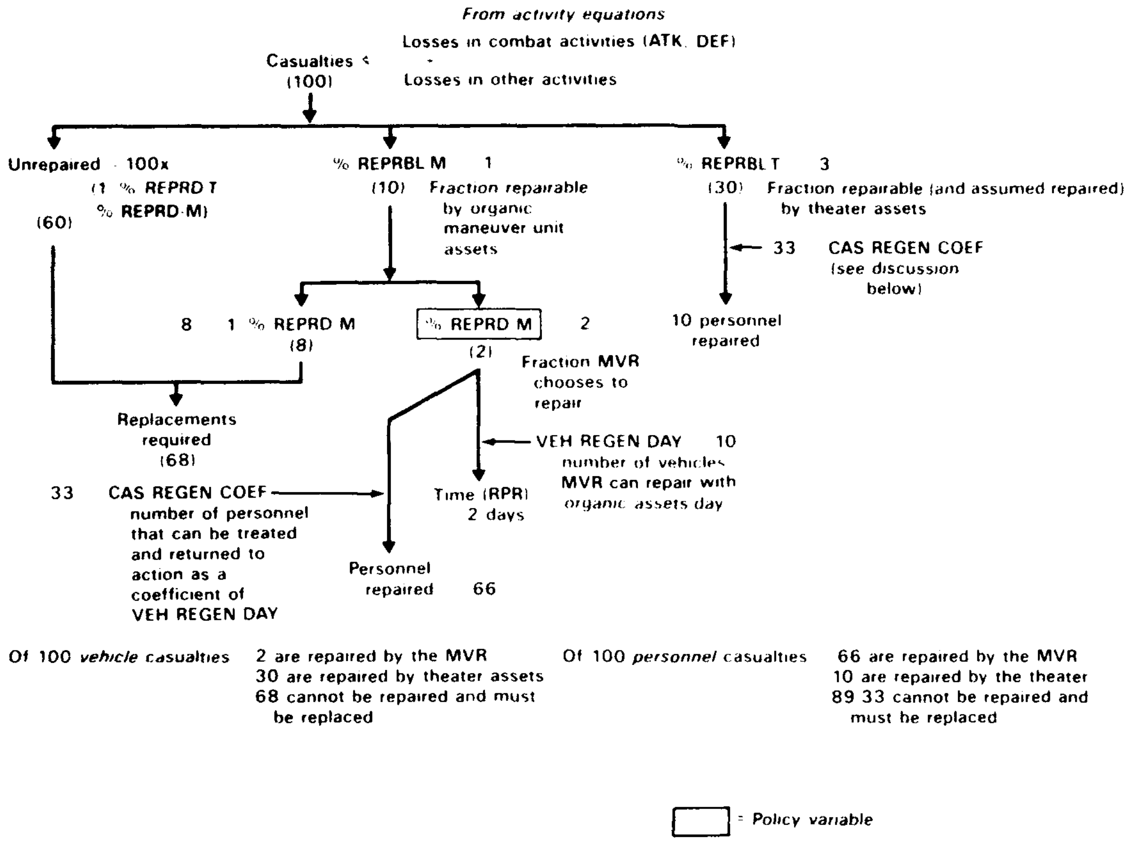

Fig. 33—Treatment of repair in MOSCOW

casualties can be "repaired" is 33 percent of the vehicle repair rate, 0.66 people will be repaired during the Repair activity. The bottom of Fig. 34 summarizes the distribution of vehicles and personnel, and the time required to repair based on the repair policy specified.

How Far Should Surviving RMVRs Be Allowed to Penetrate? [TS]. Other things being equal, allowing Red to penetrate farther (RED PEN LIMIT) will increase the CAMPAIGN LENGTH (the time available to kill the required number of RMVRs), as illustrated in Fig. 34, reducing the number of standing Blue MVRs required. The number of Red kills actually required of Blue ground forces shrinks (because there are more days in which Red vehicles break down and Blue air intediction can attack Red units). However, as CAMPAIGN LENGTH increases, so too does Blue noncombat attrition. Therefore, Blue's MVR requirements decrease at a decreasing rate. Figure 35 shows how the distribution of Blue losses changes as allowed Red penetration increases.[84] (In this case MVRs are defined as battalions.)

The intersection of the requirements curve with the horizontal line denoting Blue's force budget in this example or about 30 battalions, 3-1/3 divisions, indicates the minimum penetration that Blue would have to accept in order to keep the concept "affordable" in MVRs.

[84]The precise shape of this function depends on Blue's air interdiction policy and effectiveness, and Red's breakdown rate. If either of these is fairly high, then the rate at which Blue requirements reduce with penetration allowed may actually increase.

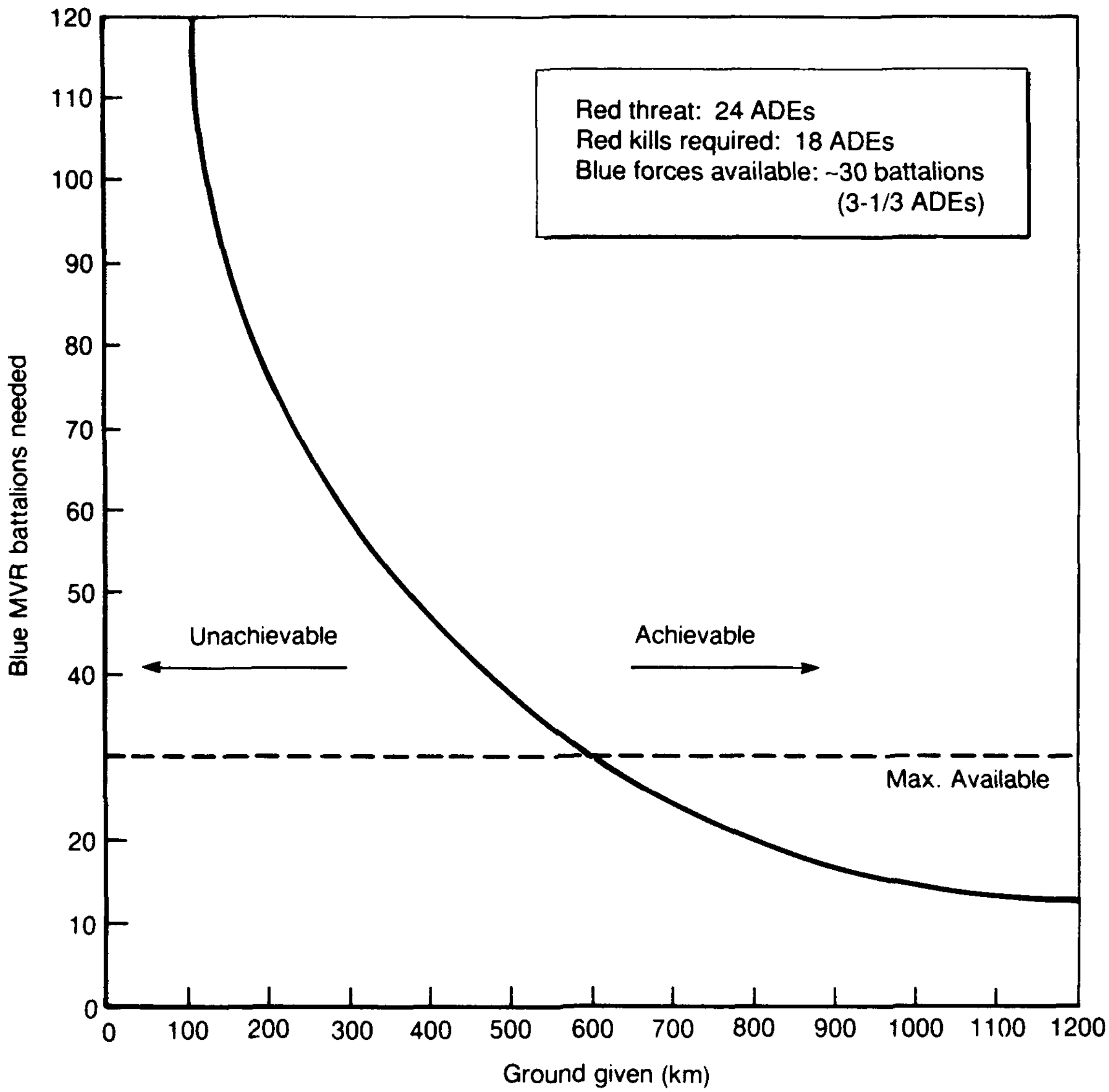

Fig. 34—How MVR requirements are affected by ground given

Naturally, if kill requirements increased, penetration allowed would need to rise to keep the MVR requirement constant, or the number of MVRs would have to rise to keep to the same penetration. Figure 36 shows a NATO example. Here 30 RMVRs are invading NATO territory in a standing start or very short warning attack; the analyst has varied the allowable penetration and number of RMVRs that must be killed. For any fixed penetration limit, the marginal cost (in terms of higher MVR requirements) of more RMVR kills increases; for a fixed number of kills, the marginal benefit (in reduced MVR requirements) of allowing more penetration decreases. To stay under NATO's budget of 21.8 MVRs (armored division equivalents, or ADEs) available on short notice, Blue could allow as little as 16 km penetration

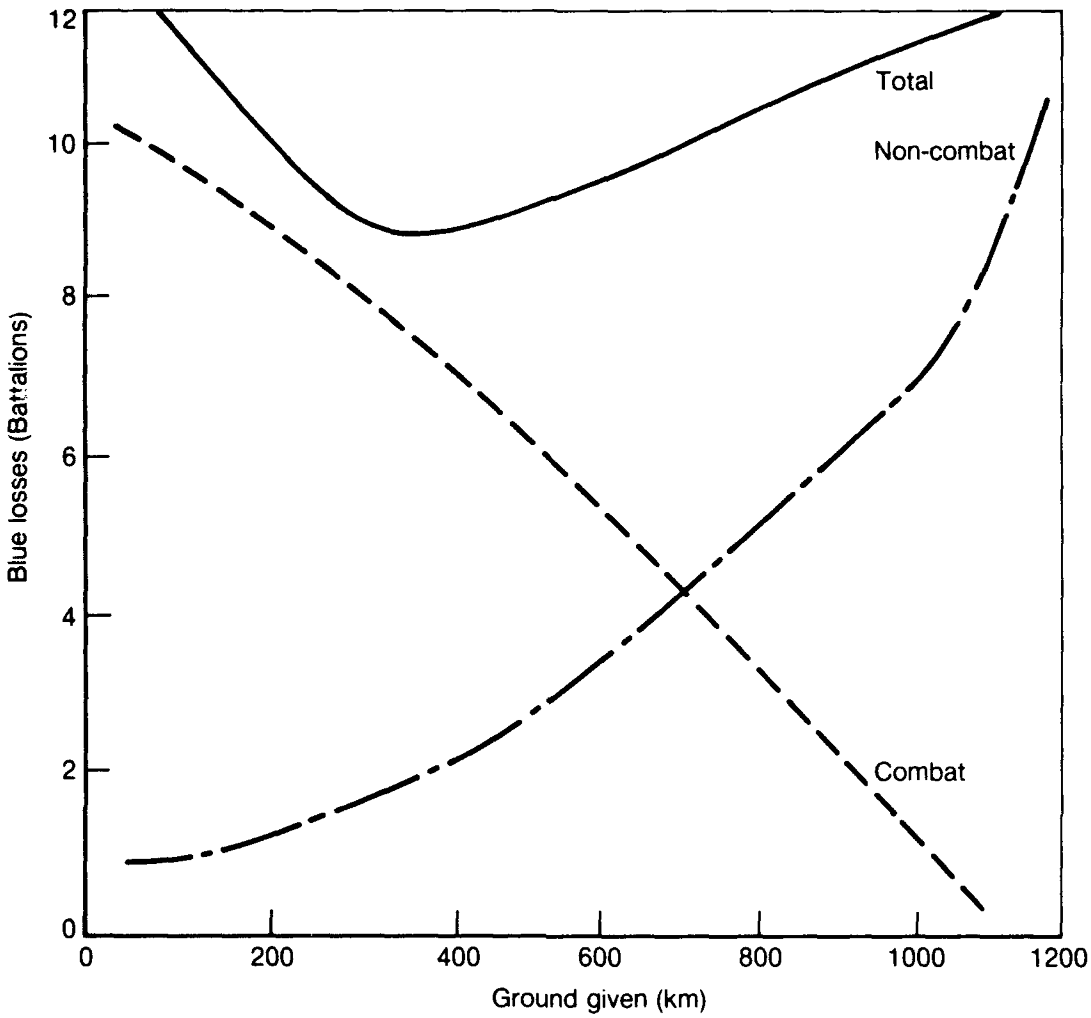

Fig. 35--How distribution of Blue losses changes with ground given

if 5.5 RMVR kills were sufficient, but if 15 kills are needed, about 28 km would need to be sacrificed.

To Which Force Ratio Should Blue Mass Before Attacking? How Much Attrition Should be Imposed Before Disengaging? [OP or TAC]. Recall that attackers choose the combat power ratio at which they initiate each attack engagement and specify the amount of attrition they wish to impose on the defender before breaking off.[85] The joint effects of these two policy variables are highly interdependent, as Fig. 37 shows how the number of Blue survivors of an engagement (enumerated as the fraction of the number of vehicles that began the engagement) is affected by these two variables. Each line shows the effect of desired Red

[85]These policy variables are termed engagement *initiation* and *termination* criteria. The defender also specifies an acceptable amount of attrition, so the actual amount will fall between each preference.

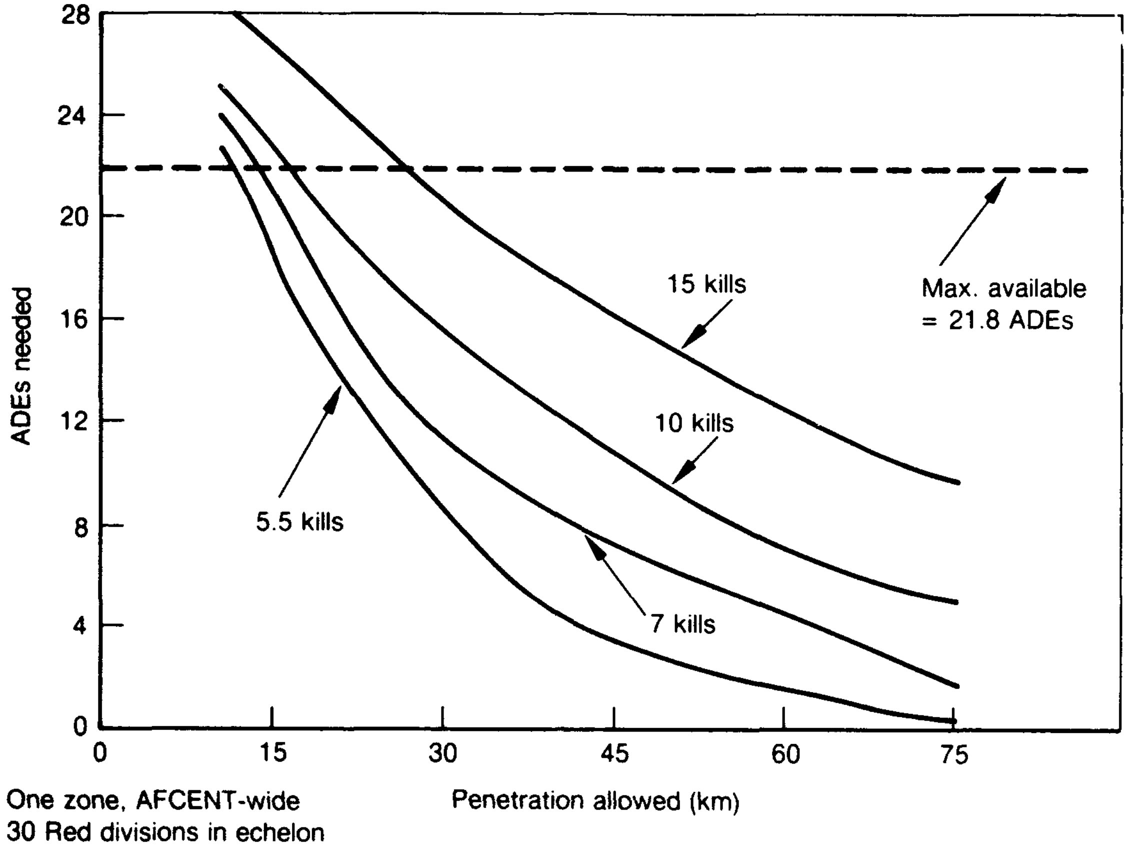

Fig. 36—NATO-wide force requirements against Red's 1st echelon

attrition (which ranges from 0.1 to 0.9 of starting Red vehicles in the engagement) on Blue survivors for a Blue:Red combat power ratio. When the odds are essentially even, Blue losses are about equal to Red's (the slope of the 1:1 line is about −1.0), but even a modest increase to 1.5:1 narrows Blue's losses considerably, and at higher combat power ratios, the marginal cost (in Blue attrition) of imposing greater attrition on Red is slight.[86] Figure 38 tells the same story, with Blue attrition shown across combat power ratios for several levels of desired Red attrition; again, at high combat power ratios, the curves converge.

If the requirements estimated by MOSCOW were influenced solely by combat-related activities, then it appears that the "optimal" engagement initiation and termination policies would be to attack only at high combat power ratios, and to press each attack until the defending RMVR were destroyed. Not only is the marginal cost of more persistent attacks low at high combat power ratios, but the marginal time cost *in the engagement activity* also decreases with combat power ratio. Why then are real attacks rarely pressed so relentlessly? There can be several possible explanations. In real life there may be constraints on the combat power

[86]This is equally true when Red is the attacker. Of course, the number of MVRs or RMVRs each side would need in order to achieve these combat power ratios depends upon relative combat power per MVR and RMVR.

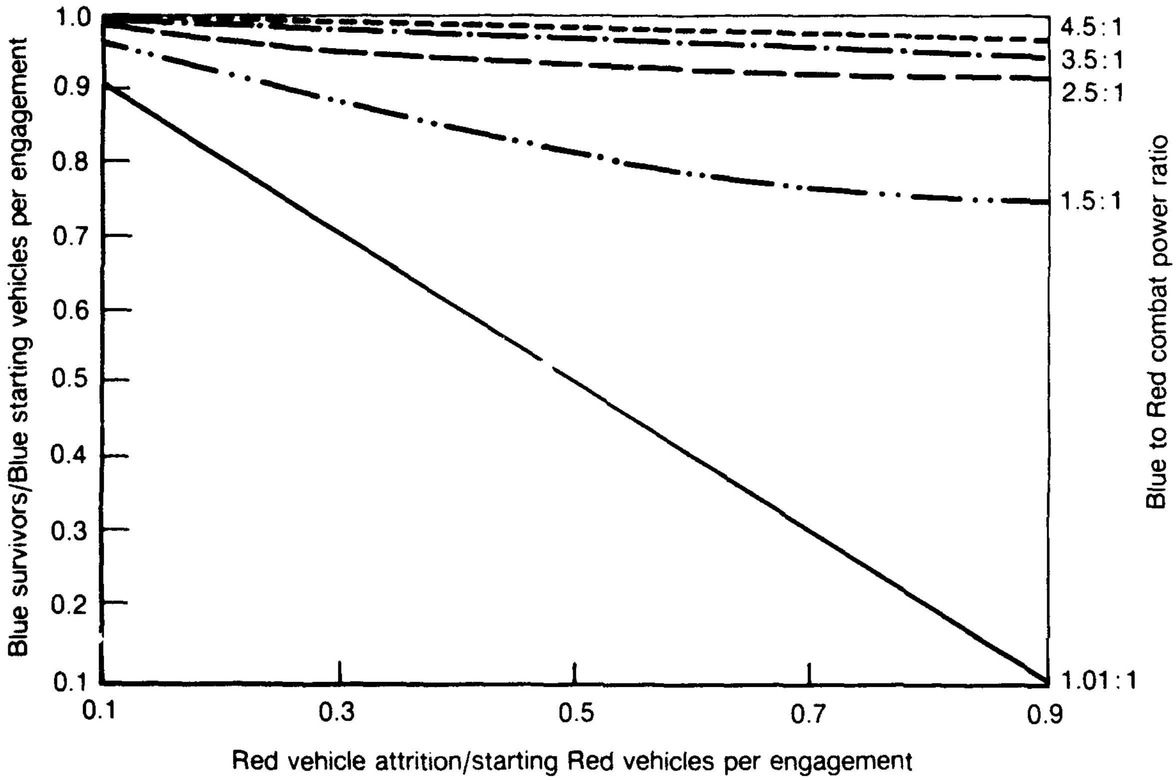

Fig. 37—Effect of engagement initiation and termination criteria on Blue surviving fraction

ratio that can be practically achieved, because of limited resources, shoulder space, endurance, an uncooperative defender, or loss of surprise (which allows a defender to anticipate an attack and counter-concentrate). Some aggregated ground combat models reflect a few of these constraints.[87] MOSCOW allows for another possibility: there is a tradeoff between gains in engagement activities vs. costs in other activities. (Recall Fig. 22, illustrating the tradeoff between movement time and engagement time as affected by the attacker's chosen combat power ratio.) The net effect is hard to predict intuitively, as it depends on the Blue capabilities that affect the countervailing activities.[88]

How Many RMVRs Should Be Allowed to Survive at the Penetration Limit? [TS]. As the standards of campaign success become more demanding and fewer RMVRs are permitted to survive at the specified penetration limit, more engagements will be needed and therefore, presumably, more Blue MVRs. However, MVR requirements may increase at a less than linear rate with increased kill requirements.

[87]MOSCOW allows the user to set shoulder space and endurance constraints if he chooses.

[88]In the earlier example, the relevant capabilities were Blue's mobility and lethality. See Fig. 23 for an illustration of the effects of mobility on the sum of movement and engagement times.

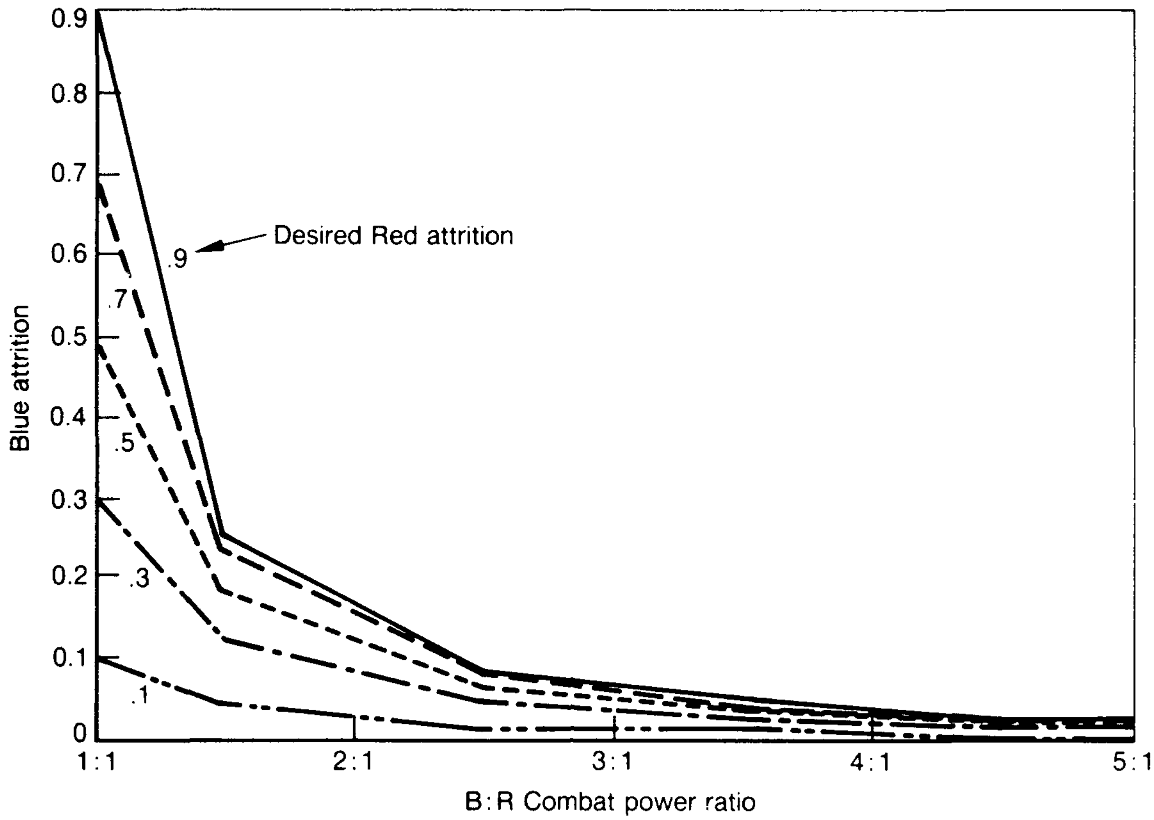

Fig. 38—Effect of engagement initiation and termination criteria on Blue fraction attrited

The cause stems from the indirect effect on Red of engagements with Blue: delay.[89] Red's advance is assumed to halt while engaged with Blue MVRs,[90] for some multiple of the engagement time (reflecting time needed by Red to prepare for and recover from the engagement before proceeding further). The more engagements Blue has with Red, the more aggregate delay Red suffers. This increases the length of the campaign, causing higher Red losses from breakdowns and Blue air interdiction. Figure 39 shows that campaign length increases slightly faster than the required number of kills.[91] Consequently Blue casualty rates per day rise at a less than linear rate, so MVR requirements taper off, as illustrated in Fig. 40.

Therefore, there appear to be economies of scale in kill requirements, if the campaign kill rates of the MVRs themselves are not decreased by increasing MVR density. Figure 41 illustrates the effects of MVR density on campaign kill rates. In this example, the defend kill rate decreases by about 3 percent over the range shown, and the attack kill rate increases

[89]The direct effect is the attrition imposed on the advancing RMVRs.

[90]An exception occurs if Blue's "aggressiveness" is set at less than zero, so that Blue retreats during defend engagements. Then Red will be slowed rather than halted.

[91]In other words, the second derivative is slightly positive. Although the line looks nearly linear, a comparison of its slope at extremes will demonstrate that it is not. Between 20 and 30 kills Campaign Length rises from 1.20 to 1.72 days, a marginal increase of 0.052 days per kill required. Between 55 and 60, kills Campaign Length rises from 3.11 to 3.4 days, a marginal increase of .058 days per kill.

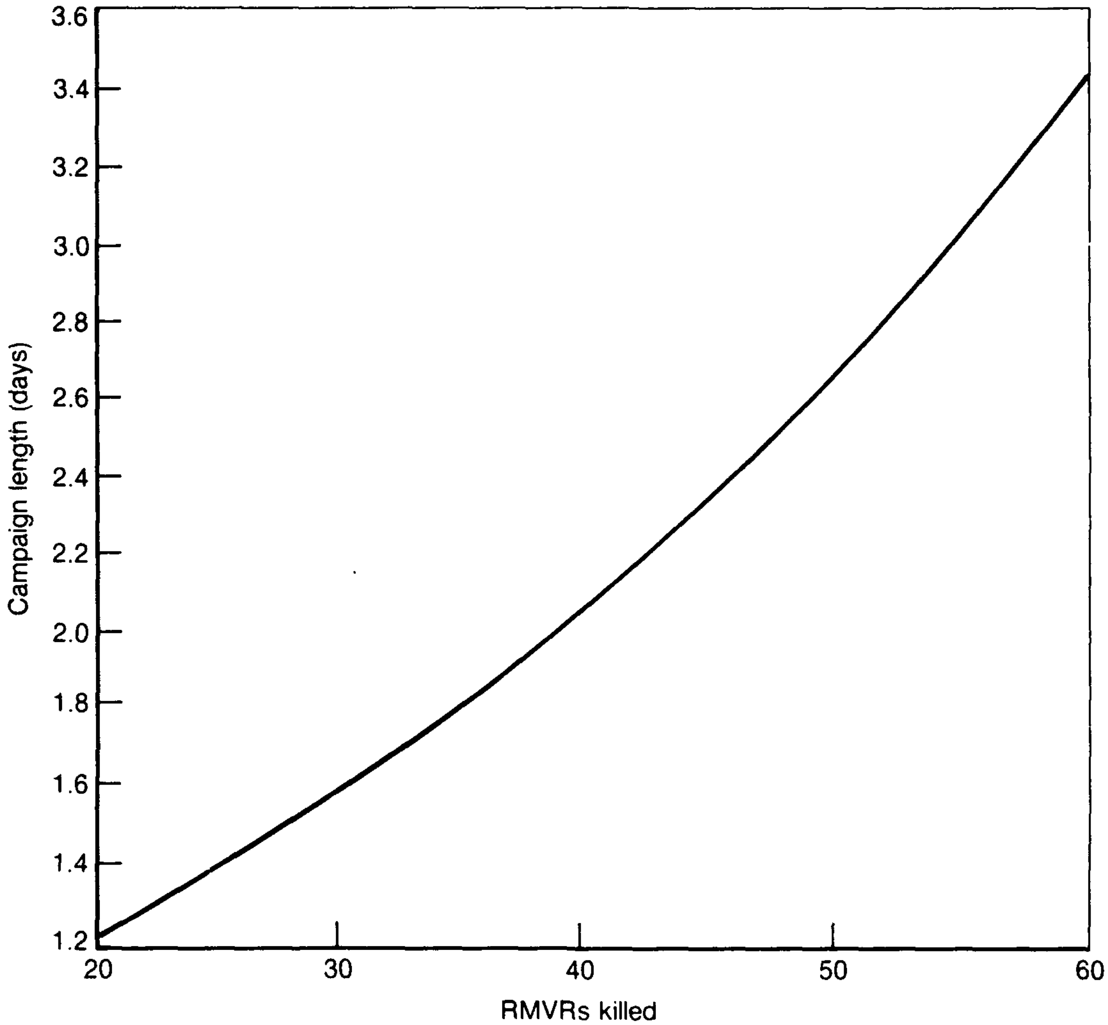

Fig. 39—Effect of kill requirement on campaign length

sharply—about 25 percent—before tapering off. Unless the fraction of kills from attacks were set close to zero, the average kill rate would, in this example, at least hold steady as density rose, and would probably go up, thus magnifying the scale economies. Of course, at some very high densities, crowding would cause campaign kill rates to drop. MOSCOW includes calibration factors that will cause average MVR performance to decrease with density, but this specific effect has not been checked.

The magnitude of these returns to scale will depend on Red loss rates from nonengagement causes (primarily breakdowns and interdiction): If they are fairly high (e.g., several percent per d y), then returns to scale will be considerable.

How Should RMVR Kills Be Allocated Between Attack and Defend Missions? [OP]. The degree to which a concept is considered "offensive" is one of the most controversial and elusive aspects of many NATO debates about operations planning. MOSCOW allows the Blue MVRs assigned to destroy RMVRs in ground engagements to do so in attack or defend

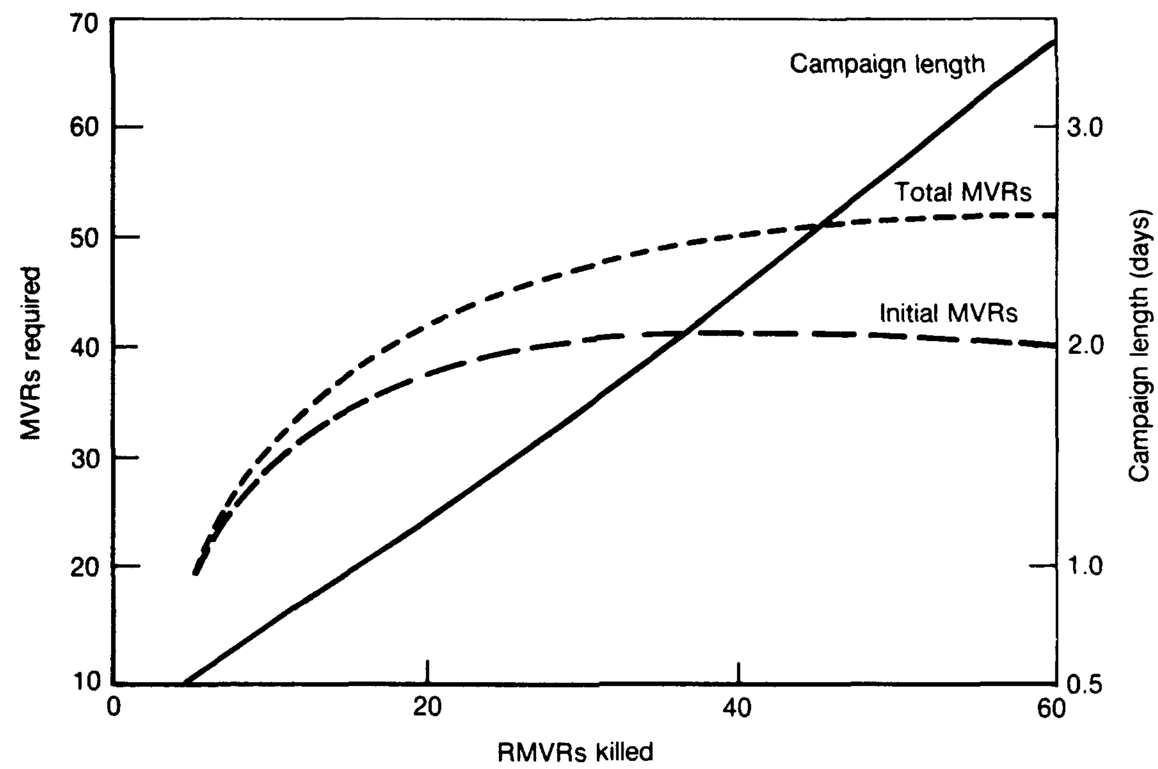

Fig. 40—Effect of kill requirement on MVRs needed

engagements. Policy variables designate the *fraction of ground kills to come from each type*. The user can thus explore variations in the offense/defense mix.

For any single criterion, there will always be an optimum mix of missions, but that may vary across multiple criteria. In the example just mentioned, the defend campaign kill rate was over five times as high as the attack rate. Therefore, a concept that minimized the required standing force size would allocate 100 percent of the required kills to defend engagements. However, in the example shown in Fig. 42, defend cycles consumed six to eight times as many personnel and vehicles per day as attack cycles, so attack cycles would be favored if the sole criterion was to minimize these resource demands.[92] Concept analyses, however, will probably never rely on a single criterion. Most concepts, even operationally defensive ones, implicitly recognize these tradeoffs and will assume *some* offensive action even if only at the tactical level; therefore very few prudent concepts are likely to use only attack or defend engagements.

How Should Air Interdiction Aircraft Be Allocated Among Alternative Missions to Attack 2nd-echelon Targets? [OP or TS]. The geographical flexibility of airborne weapons platforms makes them a very important policy variable at the operational and theater-strategic levels. MOSCOW concentrates on the three air allocation decisions that most directly affect the ground campaign. The first decision concerns the number of aircraft assigned to CAS versus AI

[92]Similarly, daily demands for POL and ammunition *both* fall as the example concept is made more defensive, but because of the reduced maneuvering of Defend MVRs, daily POL demand drops *more quickly*, as indicated in Fig. 43.

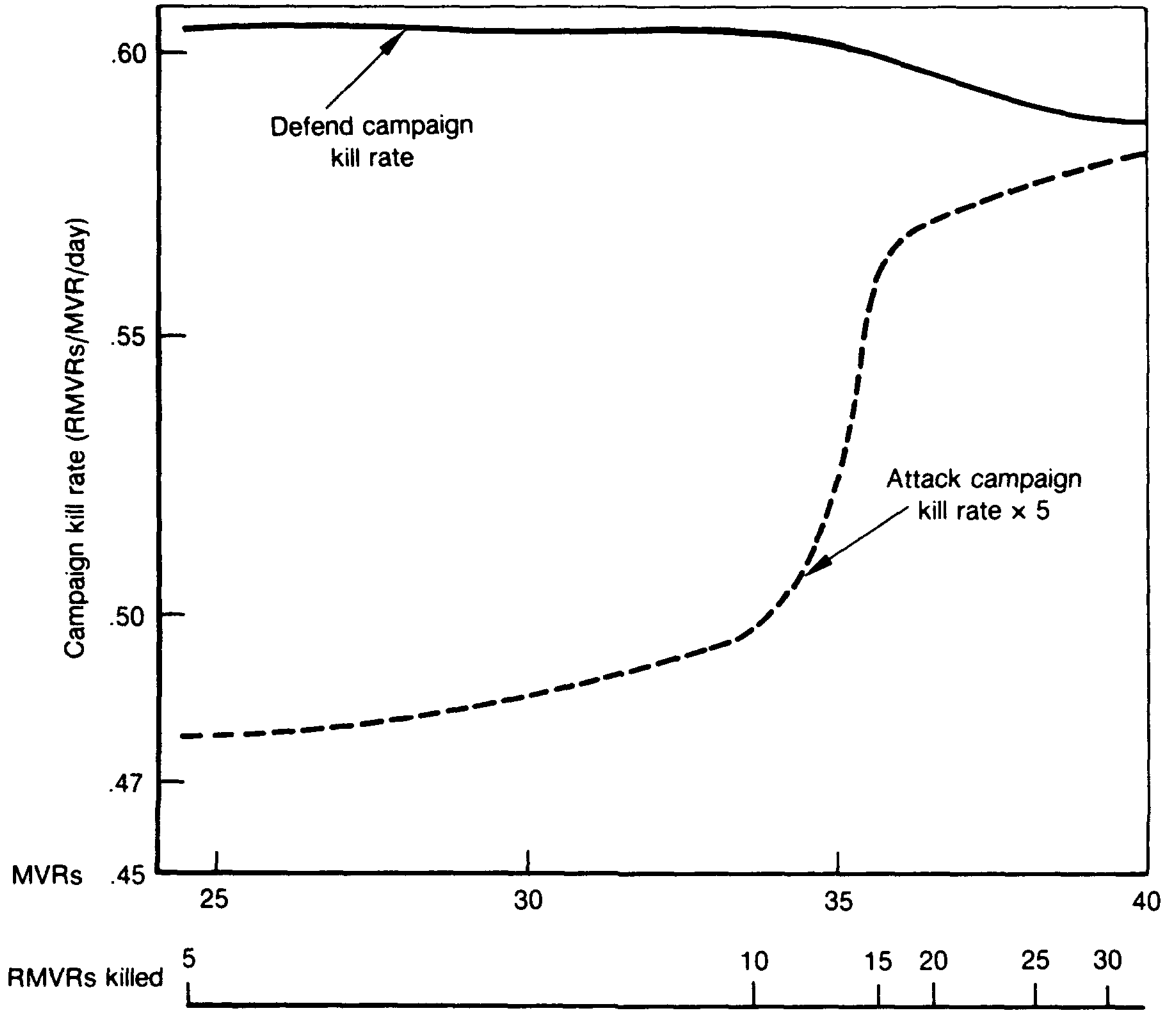

Fig. 41—Effect of MVR density on campaign kill rate

missions (within any constraints established by aircraft capabilities).[93] Within each mission type, assigned aircraft are allocated to one of several tasks. The fraction of CAS aircraft assigned to support attack versus defend engagements is a second decision.

For AI aircraft, more choices are available. AI missions can emphasize (1) delaying RMVRs by attacking transportation chokepoints, (2) disrupting their command and control by harassing their movement and attacking command vehicles, (3) destroying combat vehicles, (4)

[93]As with any other resource, the user will need to allocate aircraft among multiple zones if more than one is used in the analysis.

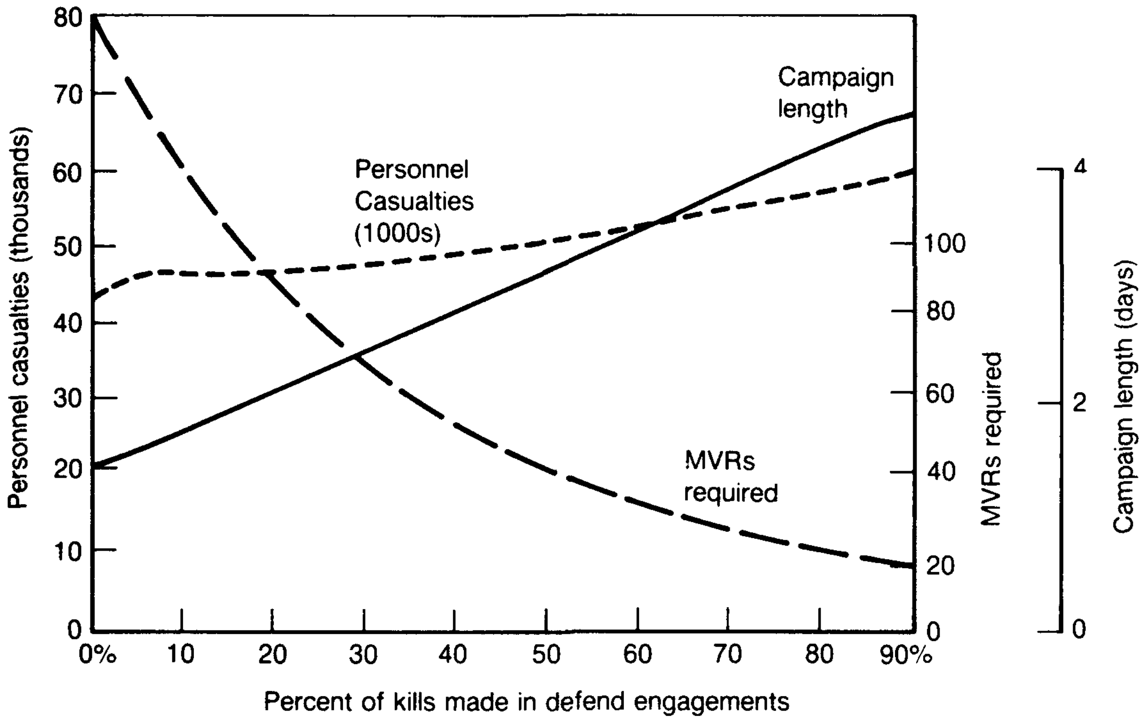

Fig. 42—Effect of defensiveness on replacements required

suppressing headquarters supporting fires, or (5) attacking supply vehicles.[94] Policy variables allow the user to specify the fraction of AI aircraft devoted to each task.

The following example will illustrate one aspect of air decisions. All policy variables related to CAS are omitted and a fixed initial stock of AI aircraft is assumed. Blue is defending against the first Red operational echelon, with a follow-on echelon several days behind the first. Blue's concept is assumed to include some variation of NATO's Follow-on Forces Attack (FOFA), and Blue desires to damage and/or delay the follow-on echelon before it reaches the FLOT.

Representing a second echelon required a MOSCOW spreadsheet for each of three phases: (1) the campaign of Blue MVRs against the first echelon; (1a) the interdiction of Red's second echelon by Blue AI; and (2) the campaign of Blue MVRs against the survivors of Phases 1 and 1a (after the second echelon arrives at the FLOT).[95]

What is the best way to use Blue's AI aircraft in Phase 1a? There has been a great deal of debate regarding the most efficacious use of FOFA to assist in NATO defense. In MOSCOW's terms, should aircraft try to maximize the attrition, delay, or the disruption they cause to second-echelon RMVRs? Attrition will most reduce the size of the arriving second

[94]Currently, the effects of each type of sortie are "pure"; e.g., delay sorties do not kill any vehicles or cause any disruption. The capability to allow the user to reflect "bonus" effects in other damage categories of sorties of a particular category can be readily added. In the meantime, users can approximate these bonus effects through their sortie allocation.

[95]Further explanation of how to use MOSCOW to represent Red or Blue echelons is in App. F.

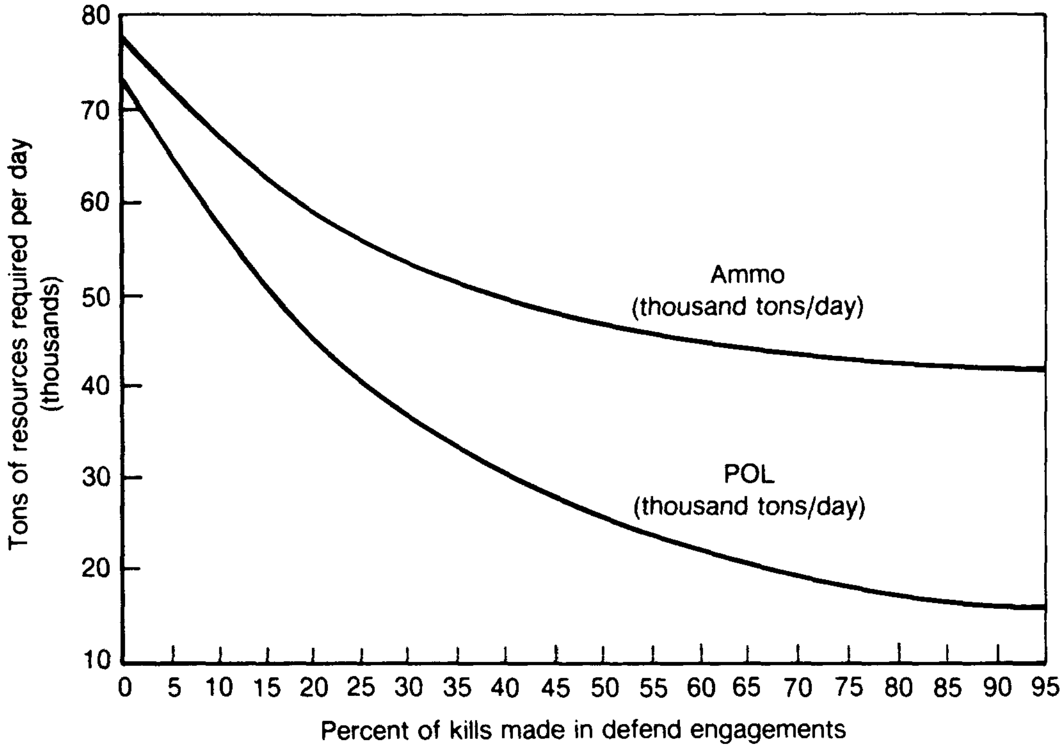

Fig. 43—Effect of defensiveness on daily POL and AMMO requirements

echelon but have the least effect on its schedule. Delay will do the opposite, and disruption may be a compromise between them. Obviously, mixes of these are also possible (and likely). For this example, the options are represented simplistically: allocation of 100 percent of AI aircraft to each of the above three alternative tasks.

Figures 44 and 45 show the consequences of these alternative interdiction policies in Phase 1a in terms of intermediate-level measures: the attrition or the delay imposed on the second echelon. These might be appropriate criteria for an air commander, but they do not capture the *campaign* effects of these options. A criterion that allows us to compare these dissimilar alternatives is the MVRs (standing and replacements) needed to destroy a fixed number of RMVRs within a specified penetration.

Figure 46 shows Blue's requirement for standing MVRs and replacements in order to destroy a fixed number of total RMVRs (about two-thirds of the combined strength of the 1st and 2d echelons arrayed against CENTAG) within the first 50 km. The stacked bars distinguish casualties in the Phase 1 campaign (against the 1st echelon only) from those in Phase 2 (against the combined 1st and 2nd echelons). The length of the campaign varied from 4.3 days (under the Attrition AI option) to 11.5 days (under the Delay AI option). Although the initial number of MVRs required under the delay and disruption options are virtually identical, those for the attrition option are considerably lower. Blue ground units need destroy fewer RMVRs under the attrition option than under either alternative (because AI aircraft are destroying more). Because of this lower workload, fewer standing MVRs are needed, and fewer casualties

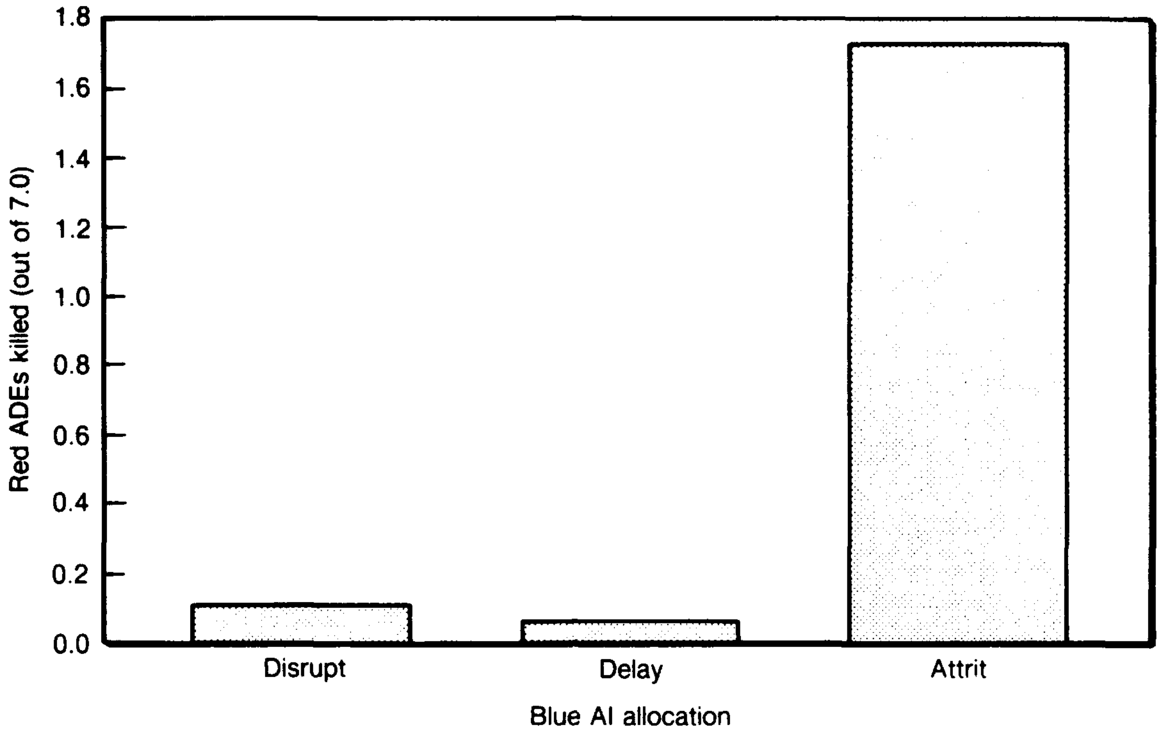

Fig. 44—Attrition to Red second echelon under three interdiction concepts

are suffered in Phase 2 (because the arriving second echelon is smaller than under the alternative concepts).

Obviously, this example is arbitrary, and the air to ground phenomenology is extremely simplified. The relative values of the three alternative AI policies will change under different assumptions about the effectiveness of AI aircraft to delay, disrupt, or attrite RMVRs. Mixes of AI missions should also be investigated. MOSCOW allows users to reflect different air mission priorities inherent in different concepts, with primary emphasis on the effects air policies have on the ground campaign.

AN ILLUSTRATION OF MOSCOW'S COMPARISON OF SIX NATO DEFENSE CONCEPTS

Although it is possible to explore some alternative concepts by varying only one or two policy variables, very different concepts will require the analyst to change many settings at the same time. This section illustrates a comparison of six NATO defense concepts that are representative of many of the published ideas. Each is thematically similar to a general type, but no attempt has been made to faithfully represent the ideas of any particular author.

For this example the assumed setting will be NATO's Central Army Group (CENTAG), which in wartime will have command of at least four corps (two German, two U.S., with an additional Canadian division and possible French reinforcement) responsible for the defense of approximately the southern three-fifths of the Federal Republic of Germany. For simplicity,

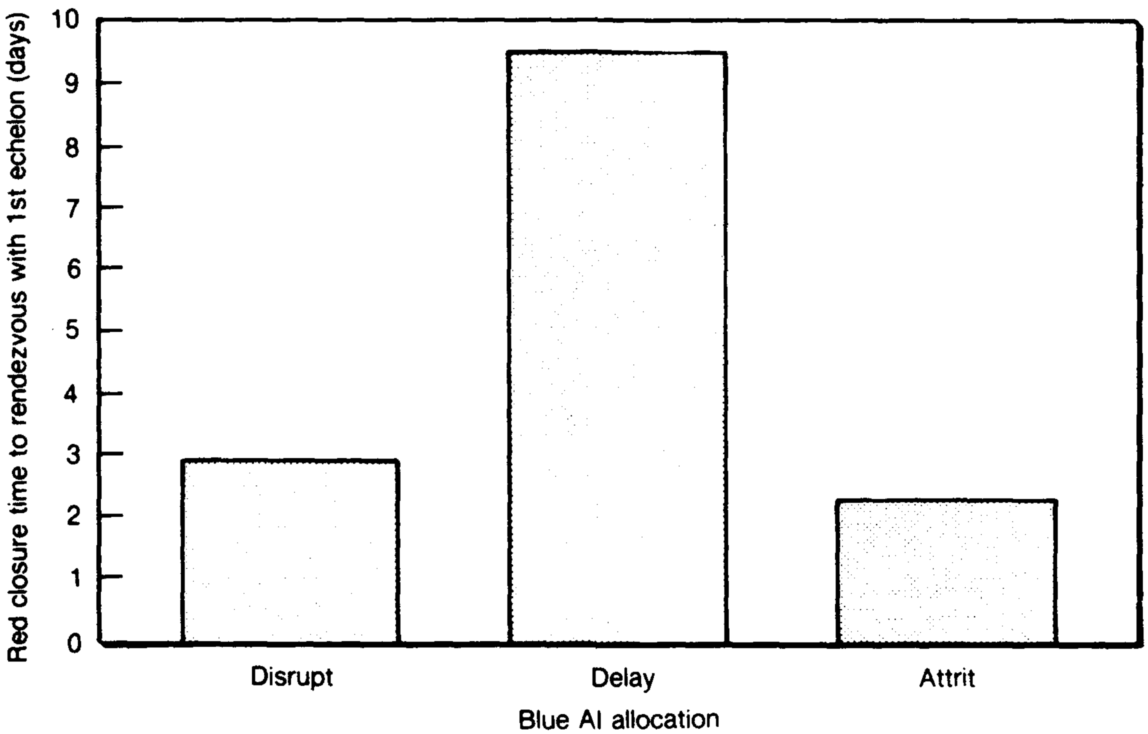

Fig. 45—Delay to Red second echelon under three interdiction concepts

only the campaign against the first Red operational echelon will be considered. One or two MOSCOW spreadsheets will be used to represent each of six general concepts.

The six concepts are illustrated schematically in Fig. 47.

(1) The *forward mobile defense* (FO) concept begins defending at the IGB and relies on mobile defensive operations to destroy approximately 2/3 of invading RMVRs before they penetrate beyond 50 km inside of the FRG.[96] (This concept is a simple representation of NATO's current official defense concept.)

(2) The *static linear defense* (SL) defends largely in place in a prepared defensive belt within the first 30 km. Defending Blue MVRs "stand fast" rather than giving ground. (This is loosely patterned after ideas of Tillson, 1979, and others.)

(3) The *mobile defense in depth* (DD) is a more extreme version of forward mobile defense. Blue forces are deployed farther west of the IGB, give ground more readily, and are willing to cede 150 km of FRG territory. (Although few authors have publicly proposed such an idea, because of the FRG's natural disinclination to surrender so much of its territory, deeper deployments are usually the unstated aim of critics of forward defense.)

(4) The *linear defense with counterpenetration reserves* (LR) concept provides a zone of mobile defensive reserves behind the defense belt of the SL concept to meet RMVRs

[96]Penetration limits vary among the six concepts, but the attrition objective is fixed at roughly 2/3 of the Red first echelon. This generally reduces the surviving Red force size to be equal to or less than that of Blue. This is meant to represent the objective of "defeating the first echelon."

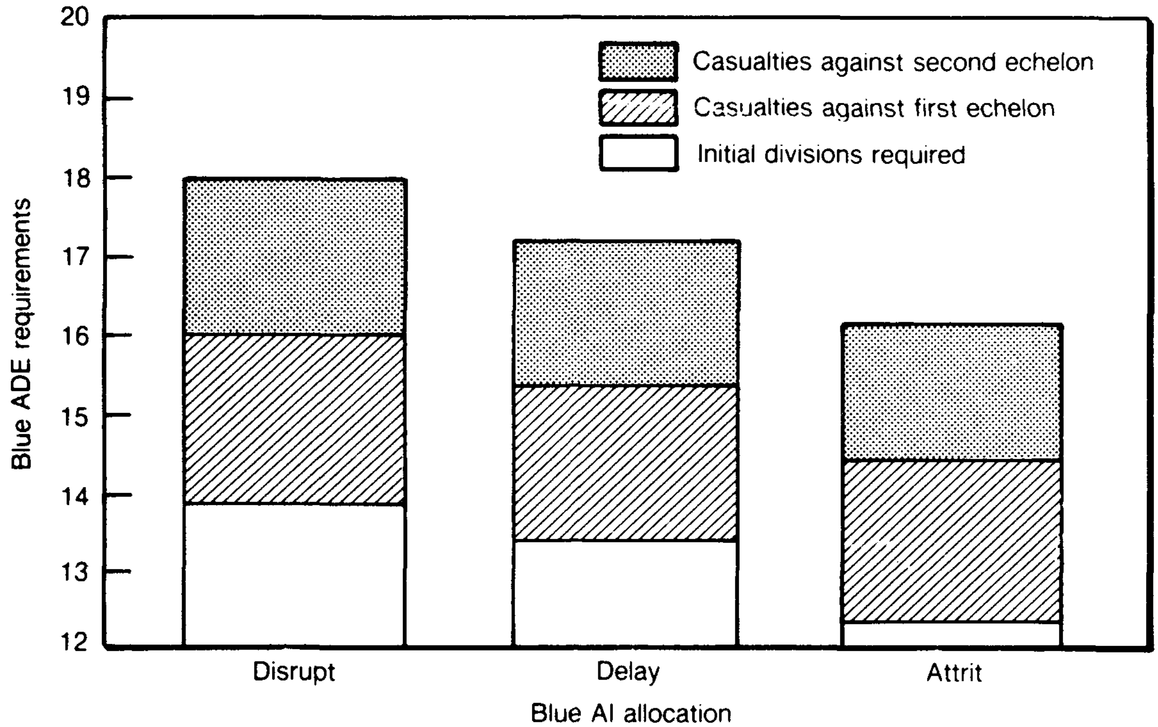

Fig. 46—CENTAG ADE requirements under three interdiction concepts

that break through. (Canby, 1980, and others have suggested that defensive preparations could allow reserves to be formed from units withdrawn from border areas.)

(5) The *"technocommando"* (TR) concept assumes that forces near the border have been restructured into small (2 to 20 men) units mounted in light vehicles and armed with ATGMs. These units would attempt to ambush Red armored formations, fight brief engagements, then withdraw into cover. Traditional mechanized forces stand in reserve behind the technocommando zone. (Several German authors have proposed versions of this idea, which originated with Ahfeldt (summarized in Alternative Defense Commission, 1983), and Weiner has published several studies of the possible composition of such a force, such as Weiner, 1984.)

(6) The *"barrier of fire"* (BF) concept attempts to impose most of its attrition near the IGB through high volumes of indirect fire. Terrain preparations and mines would canalize attacking vehicles, providing dense target arrays. Few ground forces would operate inside the barrier zone, except perhaps to designate targets. A zone of traditional reserves would again back up the barrier zone. (This idea is a natural extension of NATO's FOFA, using indirect fire artillery and medium-range missiles as a supplement to manned aircraft.)

Representing each of these concepts in MOSCOW required the manipulation of a number of policy variables. Table 21 lists some of the most important ones in five categories: success criteria; force allocation, deployment, and use of terrain; equipment and organization; warfighting style; and MOSCOW administration. The first row lists settings for several important policy variables under the baseline (FO) concept. Each succeeding row shows highlights of the changes needed to represent each other concept. (A blank cell indicates that no changes were made relative to the baseline concept.) Key changes included:

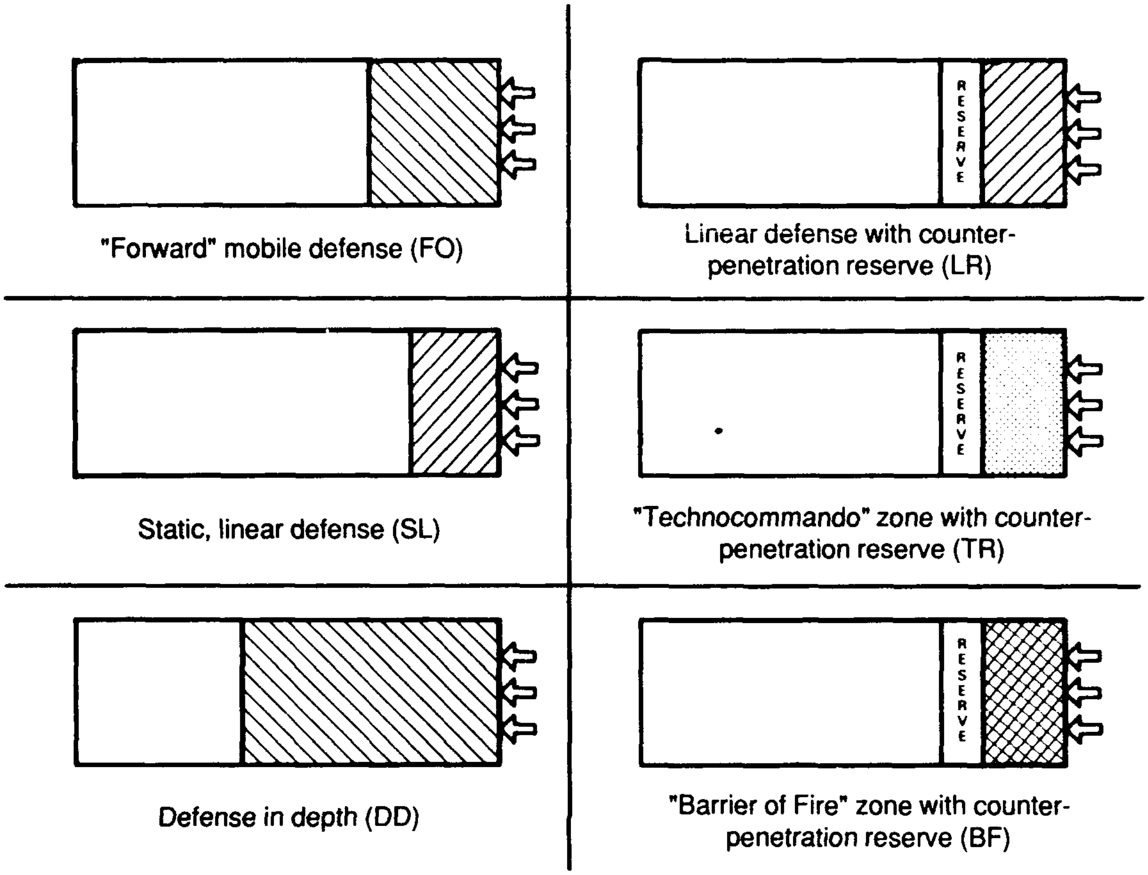

Fig. 47—Schematic of six illustrative concepts for defense of CENTAG

- At the *theater strategy* level: the penetration allowed, and the boundaries of Blue's deployment;
- At the *operational* level: the fraction of kills achieved by defend engagements;
- At the *tactical* level: the aggressiveness of Blue defenders and the degree of defensive preparations they made in each cycle.

The SL, LR, TR, and BF concepts involved assumptions about the efficacy of untested Blue systems: in SL and LR, the protection offered by preplaced defensive positions or fortifications; in TR, the characteristics of technocommandos; and in BF, the rate of fire and lethality of medium-range indirect fire systems. These assumptions can be thought of as "technology policy variables" at the technical level of war that affect the equipment characteristics of Blue forces.

Figure 48 compares the MVR requirements of the six concepts.[97] The top portion of each bar shows the number of replacement MVRs (measured here in ADEs) needed to maintain the

[97]Since the concepts have not been fully specified by their authors, other versions of each are entirely possible. It would be more correct to refer to each example as one *specification* or *realization* (out of many that are possible) of each of the six concepts.

Table 21

HIGHLIGHTS OF CHANGES IN MOSCOW'S INPUTS TO REFLECT BASELINE AND ALTERNATIVE CONCEPTS

Concept	Success Criteria	Allocation Deployment, Terrain Use	Equipment and Organization	Warfighting Style	MOSCOW Administration
"Forward" mobile defense (FO) [NATO Baseline]	Penetration allowed: 50 km	Forward boundary = 0 Rear boundary = 50	Mid-1980s mix of forces 47% Armor 53% Mech	% Kills-Defend = 70% Defend Aggressiveness = −.25	—
Static, Linear (SL)	Penetration allowed: 30 km	Rear boundary = 30		% Kills-Defend = 90% Defend Aggressiveness = 0 % Defense Prep = 100	—
Defense in depth (DD)	Penetration allowed: 150 km	Rear boundary = 80	—	Defend Aggressiveness = −.75	—
Linear defense with counterpenetration reserves (LR)	—	Rear boundary = 30 Terrain defense multiple × 1.5	—	—	2 Zones: Defense line, reserves
Technocommando zone with counter-penetration (TR)	—	—	Technocommando MVRs mobility increased hardness decreased	Technocommandos % Kills-Defend = 0 Defend Aggressiveness = − 1.0	2 Zones: Technocommandos, reserves
"Barrier of fire" zone with counterpenetration	—	All interdiction sortie allocated to "barrier" zone	Hit probability and firing rate of HQs × 2	AI allocation to attrition mission = 100%	2 Zones: 20 km Fire zone, reserves

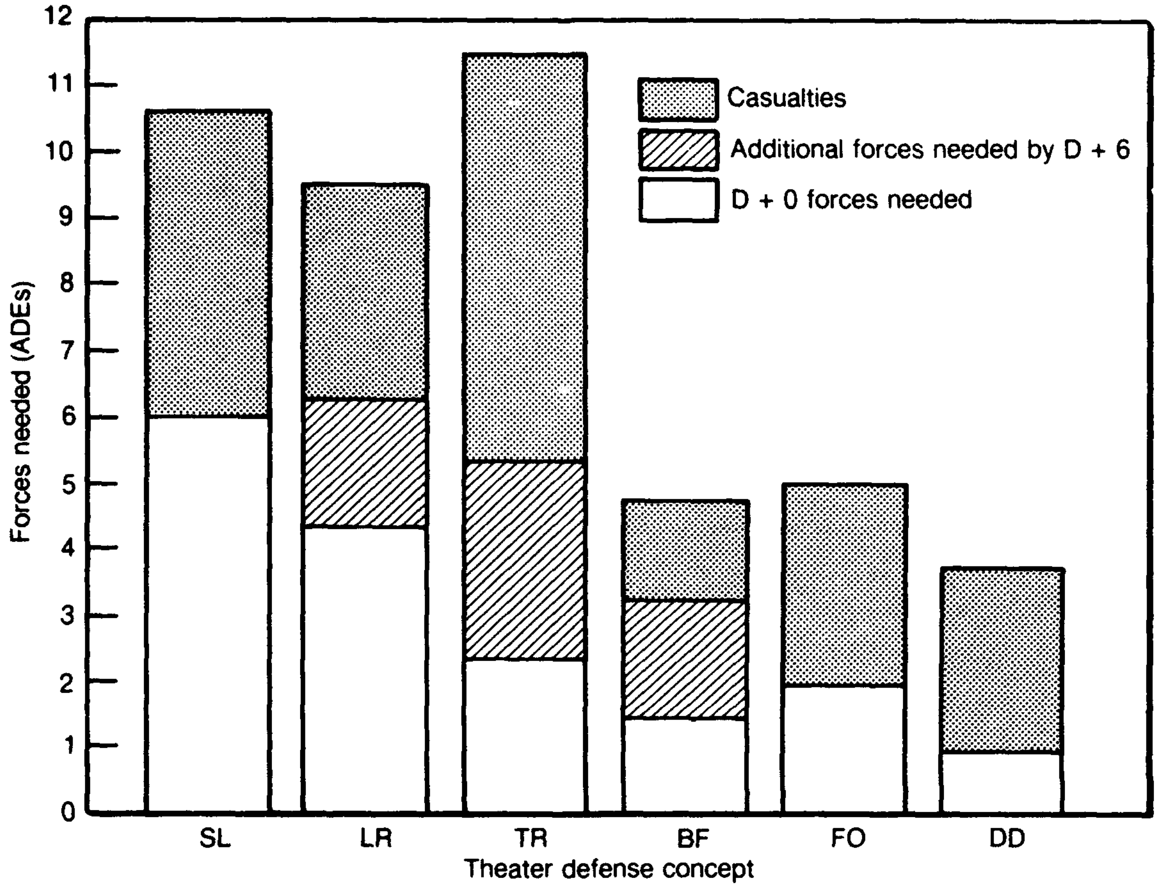

Fig. 48—Force requirements for six illustrative CENTAG concepts

required standing MVR force indicated by the lower portion. The LR, TR, and BF concepts involve defensive reserves deployed behind a border zone, so the MVR requirements for each zone are indicated in separate bars. In each case, Red's advance through the border zone took six days or longer, so the reserves would not need to be in place until then.

The Static Linear concept gives the least territory, so it is not surprising that the SL and LR concepts require the highest standing MVR force; the DD concept, which gives the most territory, required the smallest. The TR concept, which utilized highly vulnerable technocommandos (when they could be acquired), suffered the highest casualties; while the BF concept, which required almost no MVR contact with RMVRs in the fire barrier zone, suffered the lowest. The height of each entire bar indicates total requirements if equal weight is assigned to each kind of MVR required (Standing on D+0, Standing on D+6, and Replacement).

In the absence of a function that allows us to translate campaign results and requirements (e.g. Standing MVR needs, Replacements, and Penetration) into a single utility measure, we cannot tell which concept is "preferred." It may be possible to narrow the set down by testing for dominance, as illustrated in Figure 49. Each axis measures a criterion whose

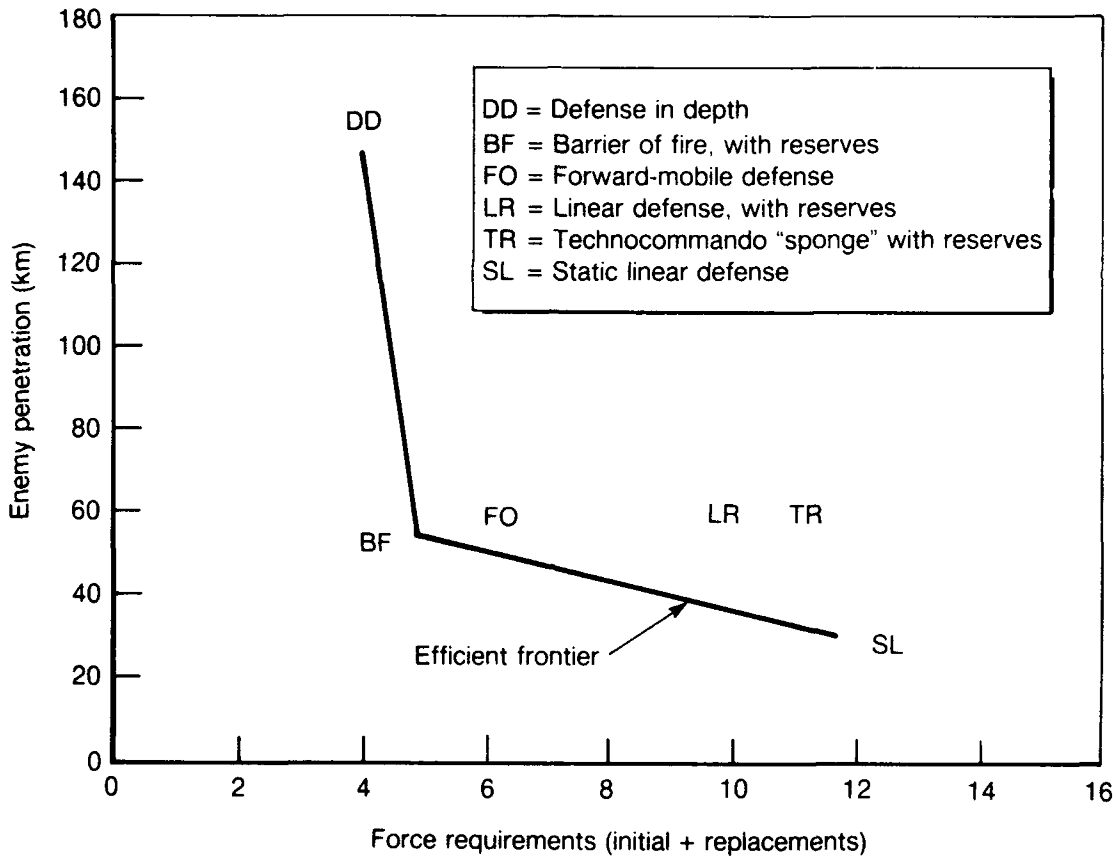

Fig. 49—Penetration/force requirements tradeoffs among six illustrative concepts

value we wish to minimize: penetration and MVRs required.[98] Because no single concept produces the lowest amount of both criteria, none of the six uniquely dominates. However, those concepts that are *dominated*—where some other concept exists that is superior in both penetration and MVR requirements—may be ruled out. In Fig. 49, the concepts *not* connected by lines are *dominated*. The lines represent an *efficient frontier*—the tradeoff surface (between penetration and MVRs required) implied by these six concepts.[99]

TWO APPROACHES TO SCREENING

Although the word "screening" was not used in the previous section, that was the function performed by the dominance test and efficient frontier: to reduce the number of concepts worthy of further exploration from six to three. What if this is still too many concepts to be practically examined in the later stages of the concept design and analysis process? There are

[98]"MVRs required" is the sum of standing and replacement MVRs required.

[99]Because only three concepts are not dominated, the tradeoff surface is simply two splines. If more concepts were examined and plotted in Fig. 49, the surface would probably take on a concave curvilinear shape.

two ways to extend the screen: by assessing each remaining concept's *sensitivity to varied assumptions* (its robustness), or by examining its sensitivity to *alternative utility weights.*

Robustness Over Scenario Variations[100]

By use of sensitivity analysis, more concepts may be screened out. Figure 50 shows the same six concepts in an excursion case (here, a 25 percent increase in assumed Red mobility), with a new efficient frontier connecting those that are not dominated. Because we are uncertain about the true values of many parameters, it is necessary to vary them and ascertain which concepts remain on or near the efficient frontier; are they *robustly* preferred under varied assumptions? In this case, one of the concepts that was preferred in Fig. 49 is not on the frontier in Fig. 50. By checking to determine which concepts remain on the frontier, we can test for robust nondominance across assumptions in the same way that we used the frontier to test for nondominance under base case assumptions.

Robustness Over Variations in Utility Weights

Even if we cannot specify *exact* weights on the importance of the several evaluation criteria (e.g., penetration vs. MVR requirements), it may be possible to get agreement that the "correct" value for weights falls within particular *ranges.* Some concepts might be screened out if they would be preferred only for utility weights outside these agreed ranges.[101]

Figure 51 illustrates the idea. If we allow the relative utility weight of MVR requirements to vary relative to that of penetration, we can plot the "disutility" of each concept.[102] Since we want to minimize this function, we choose concepts that correspond to the lowest disutility value. As the relative weights change, preferences change: At weights below 2.81, the static linear concept is preferred; at weights between 2.81 and 111.1, the barrier of fire concept; and at weights above 111.1, the defense in depth concept. Although there probably cannot be an *exact* agreement as to relative disutility weights, a *range* acceptable to all parties (e.g., greater than zero and less than 50), will be able to screen out some concepts.

Of course, with only six concepts, and even fewer that were not dominated under base case assumptions, little screening would probably be necessary. However, with a large number of concepts and versions to consider, both of these approaches will probably be necessary. Because the second approach (referred to as the *preference region* approach) does not involve any additional model runs (only simple algebra to identify concept indifference points, where disutility lines intersect), it will usually be more efficient to use it first. Once this method screens out the concepts whose preference regions fall outside of the range of plausible or agreed utility weights, excursions can be run using MOSCOW to determine the robustness of the remaining concepts' place on or near the efficient frontier.[103]

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[100]To recapitulate, "scenario" variables can be any variable not in the control of relevant Blue decisionmakers—policy variables.

[101]To my knowledge, preference regions have not formally been employed in any analyses.

[102]The Y-axis is referred to as "disutility" because we would like to minimize both components of the function. The weight per kilometer of penetration is normalized to 1.0. On the X-axis the relative weight of MVRs required is shown. This weight is denominated as [disutility per MVR required/disutility per kilometer of penetration allowed].

[103]In light of MOSCOW's crudeness—an unavoidable characteristic of any screening method—concepts should not necessarily be screened out if they are near, but not on, the efficient frontier, or if their disutility is slightly higher than the "preferred" concept in each preference region. More sophisticated analysis will retain runners-up and other close calls. Put colloquially, "When in doubt, *don't* screen it out."

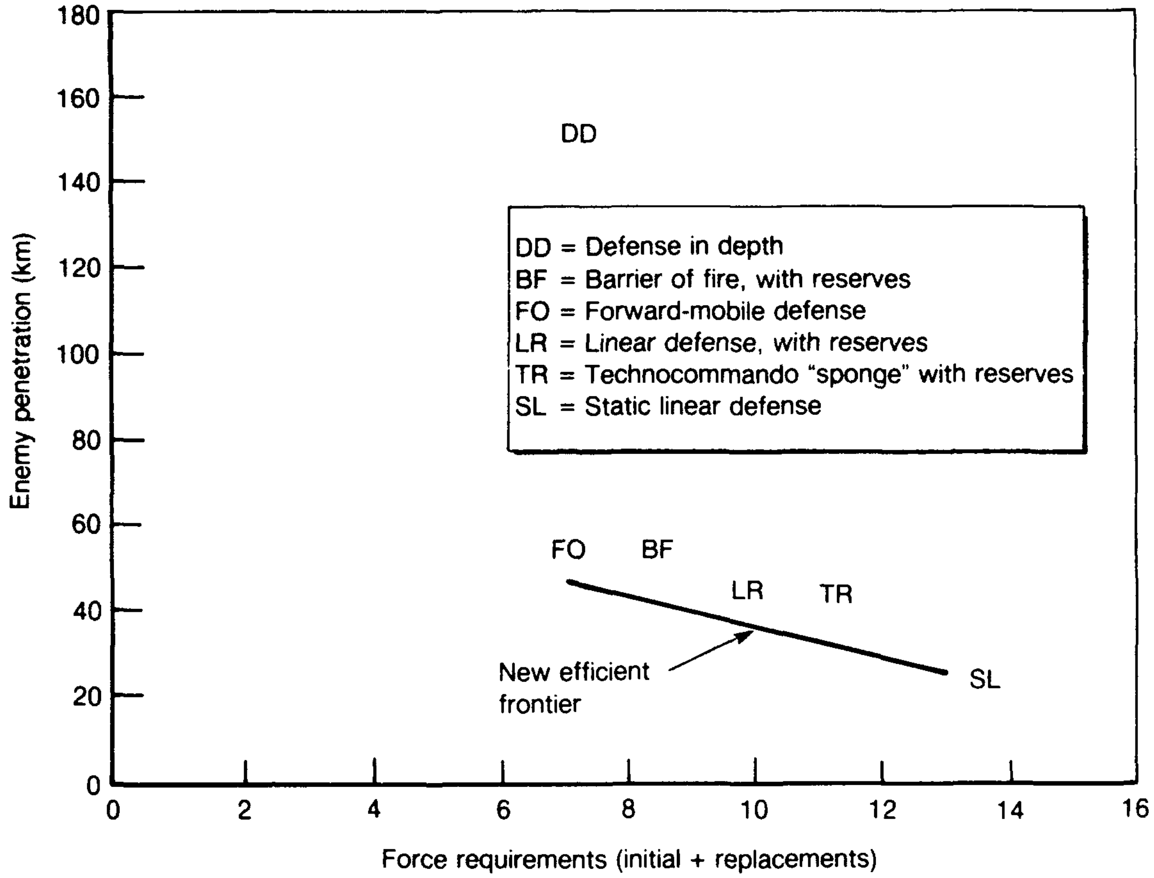

Fig. 50—Efficient frontier in higher Red mobility excursion

Figure 52 summarizes the potential steps in the screening process.[104] Beginning with the full set of candidate concepts some may be impossible to specify. Some of those that can be specified may be screened out on the basis of purely qualitative criteria or other simple measures that do not require MOSCOW. The "affordability" of each survivor is assessed in MOSCOW, screening out those whose MVR, physical resource, lift, or other requirements exceed available resources. Some can be excluded because they are dominated. Then the range of plausible utility weights can be compared with the preference regions of each concept. Finally, those that are "preferred" under plausible utility weights are assessed in MOSCOW under a range of scenario assumptions (poorer and better Blue equipment performance than base case assumptions, different values for important Red variables, etc.) to check their robustness.[105]

[104]The width of each band suggests the relative number of concepts that might be considered in each step, and the height suggests the relative amount of effort per concept that might be needed. Therefore, the area of each band gives an impression of total effort that might be required. These sizes are purely illustrative; their true values will depend on the cost, time, and analytic discrimination of the tools used in each step.

[105]Clever design of the order of these scenario variations can provide further efficiency. For instance, if all concepts are tested under favorable assumptions, those that fail to achieve a threshold level of performance will probably also fail under less favorable assumptions. This approach, often known as *a fortiori* analysis, is described in Fisher, 1970.

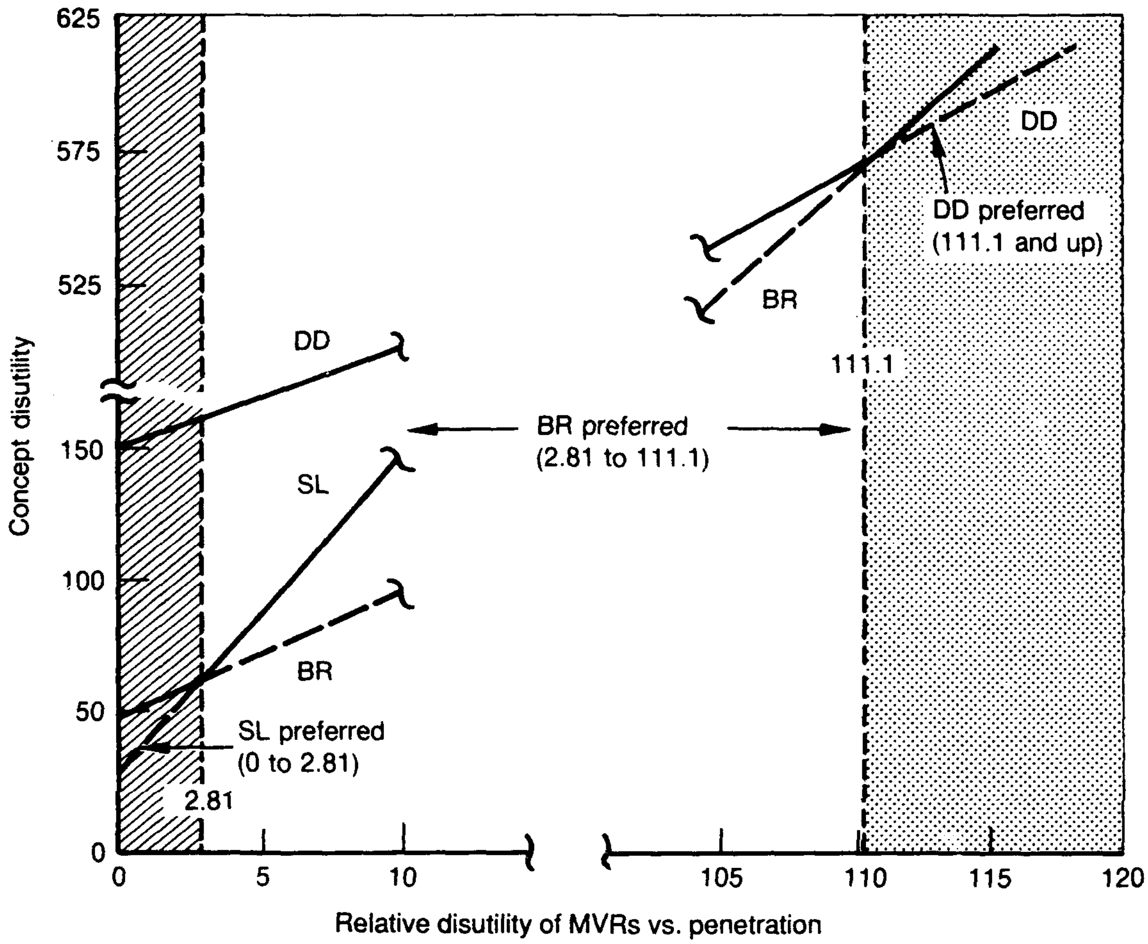

Fig. 51—Concept preference regions

Those found to be fairly robust are considered the most promising and are forwarded to the detailed evaluation stage.

AN OPERATIONAL-LEVEL EXAMPLE: SHOULD NATO'S COVERING FORCE AREA BE DEPOPULATED?

Section II briefly mentioned that function and structure of the corps covering force underwent marked changes in the 1970s and 80s Before the 1976 "Active Defense" FM 100-5, the covering force's mission emphasized the imposition of delay against attacking formations and the acquisition of intelligence.[106] The active defense doctrine emphasized that Red's main thrusts must be identified and that Red must be delayed long enough to allow Blue time to counterconcentrate. This implied a mission requiring more intensive engagements, and

[106]Expressed in terms of MOSCOW's policy variables, the attrition objectives of covering force engagements would be quite low, and the MVRs in the covering force zone would be required to destroy very few RMVRs.

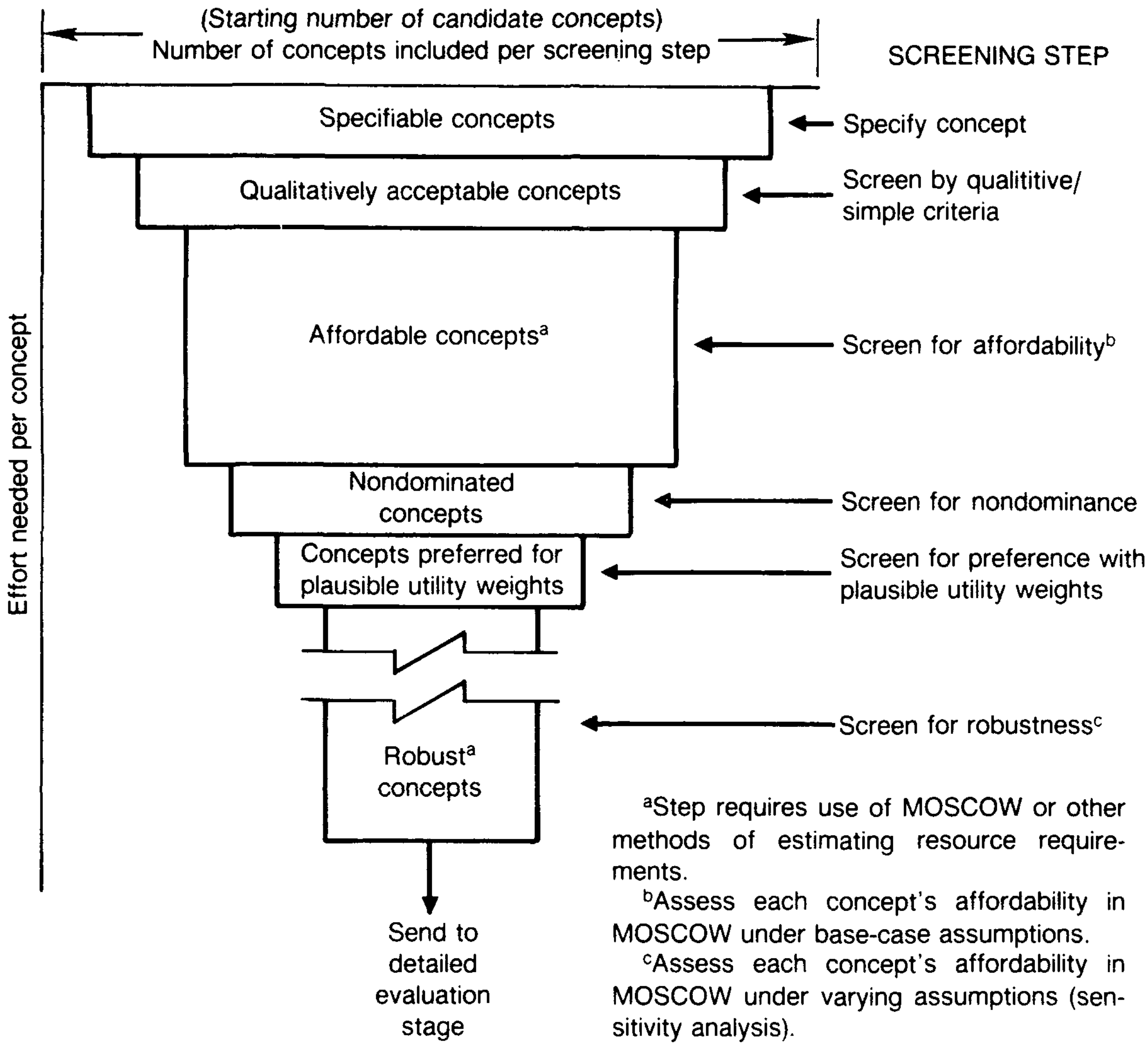

Fig. 52—Summary of steps in screening process

stronger covering forces. Consequently, the forces assigned covering force missions in NATO's U.S. corps sectors were equipped along similar lines as mechanized units rather than as light reconnaissance units, which had influenced their equipment since World War II. The size of the force allocated to the covering mission also grew, consisting nominally of one armored cavalry regiment per corps, but potentially also including one brigade from each of several divisions as well.

With the promulgation of the AirLand battle FM 100-5, the creation of reserves was given renewed priority. With so many forces assigned the covering mission (some estimates have placed it at between 25 percent and 33 percent at its peak)[107] there was little to spare.[108] Thus in the mid-1980s attention turned to reducing the size of planned covering forces to make reserves available. This was commonly referred to as "depopulating" the covering force zone.[109]

We can illustratively examine this issue in MOSCOW. Is there an ideal size for the covering force (expressed as a fraction of total friendly forces)? Or more modestly, would it be beneficial to reduce the size of the covering force from some baseline? We establish two MOSCOW zones: one for the covering force and one for the main battle. First we vary the fraction of invading RMVRs that the covering force is responsible to destroy (out of 30 in the first operational echelon), and examine the resulting size of the covering force needed to perform the mission and the length of time purchased by the force. Figure 53 shows how required covering force size and Red's transit time through the 30 km covering force zone vary by RMVR kill requirement.[110]

Plausible covering force sizes are between about 10 percent and 25 percent of total NATO forces, yielding between 2.5 and 4 RMVRs killed (or 8 percent to 13 percent of the invading RMVR force.). With the curve in Fig. 53, we can reduce the number of invading RMVRs entering the main battle area to reflect attrition from the covering force battle, then calculate MVR requirements for the main battle. Figure 54 varies the total number of RMVR kills required for the campaign, and each line shows total MVR requirements assuming a particular covering force size (either 10 percent or 17 percent of total MVRs). The line corresponding to a 10 percent covering force lies everywhere below that for a 17 percent covering force.

Consequently, in this simple example and by only one criterion, depopulating the covering force superficially appears to have a beneficial effect.[111]

USING MOSCOW FOR INSIGHTS REGARDING THE PAYOFF FROM IMPROVEMENTS IN TECHNOLOGICAL CAPABILITIES

One of the purposes of long-range CBRS studies is to identify priority technologies that complement the preferred warfighting concepts. Assessments of specific systems require high resolution, but a low resolution screening tool can aid in understanding the relationship between concepts and technologies. Although MOSCOW is not heavily technology-oriented, it describes technologically determined *capabilities* in terms of a few simple parameters. The model can be used to understand the relative value of technology improvements in crude capability terms.

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[107]For example, see Hoag, 1977.

[108]In fact, it appears that—consistent with the thrust of the active defense doctrine, which emphasized maximizing combat power at the FLOT—many corps and divisions had almost no planned reserves aside from those units that had completed their covering force missions.

[109]Another possible option, that of arming covering force units with more specialized and less expensive equipment (e.g. the type used in the 9th Motorized Division) and spending the resources saved on new forces earmarked as reserves, received little attention. This might be because the savings are perceived to be insufficient to pay for new reserves, or because the Army does not believe it can further increase the number of divisions within its present manpower limit. Even more plausibly, such specialized covering forces might be perceived as having little utility (aside from rear area protection) after being withdrawn from the covering zone, if there were any surviving to withdraw.

[110]Time delay achieved by the covering force is equal to the Red transit time shown minus Red's transit time if no covering force existed, in this case 1.5 days.

[111]Since only two covering force sizes are shown in Fig. 54, we cannot know if the marginal benefit of covering force reduction is positive all the way to zero, but such a family of lines can be indicative. Different assumptions about Red advance rates, Red losses to noncombat causes, and the efficacy of covering forces in imposing delay might yield different conclusions.

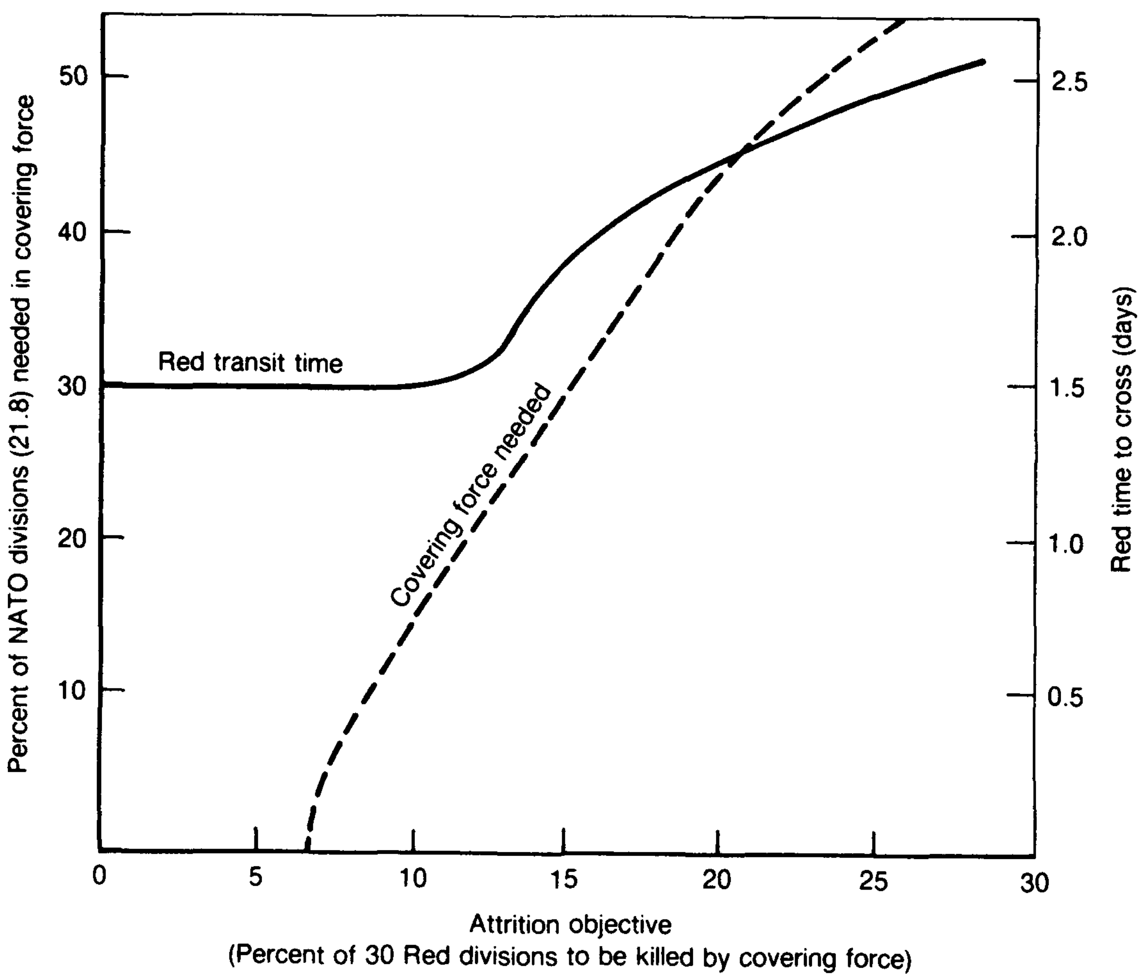


Fig. 53—Effects of mission on required covering force size

Figure 55 indicates that improvements in mobility (stemming, for example, from technical improvements) can moderate the costs of more demanding campaign requirements.[112] An eight-fold increase in mobility only reduces the force needed to kill five RMVRs within the first 30 km by about 30 percent, but if the mission is to kill 30 RMVRs, the same mobility improvement reduces MVR requirements by almost 50 percent.

Figure 56 shows combinations of lethality and mobility that yield a constant MVR (from 25 to 60) need to kill 15 RMVRs within the first 30 km under a mobile defense concept. Disproportionate increases in lethality would be needed to compensate for reductions in mobility, especially if mobility is low to begin with. Holding lethality constant, increases in mobility bring ever-greater returns (measured in terms of reduced MVR requirements).

[112]At the tactical level, this point was already made in Fig. 22. Increases in mobility may reduce the time costs of massing to higher force ratios, thus reducing engagement durations and Blue attrition.

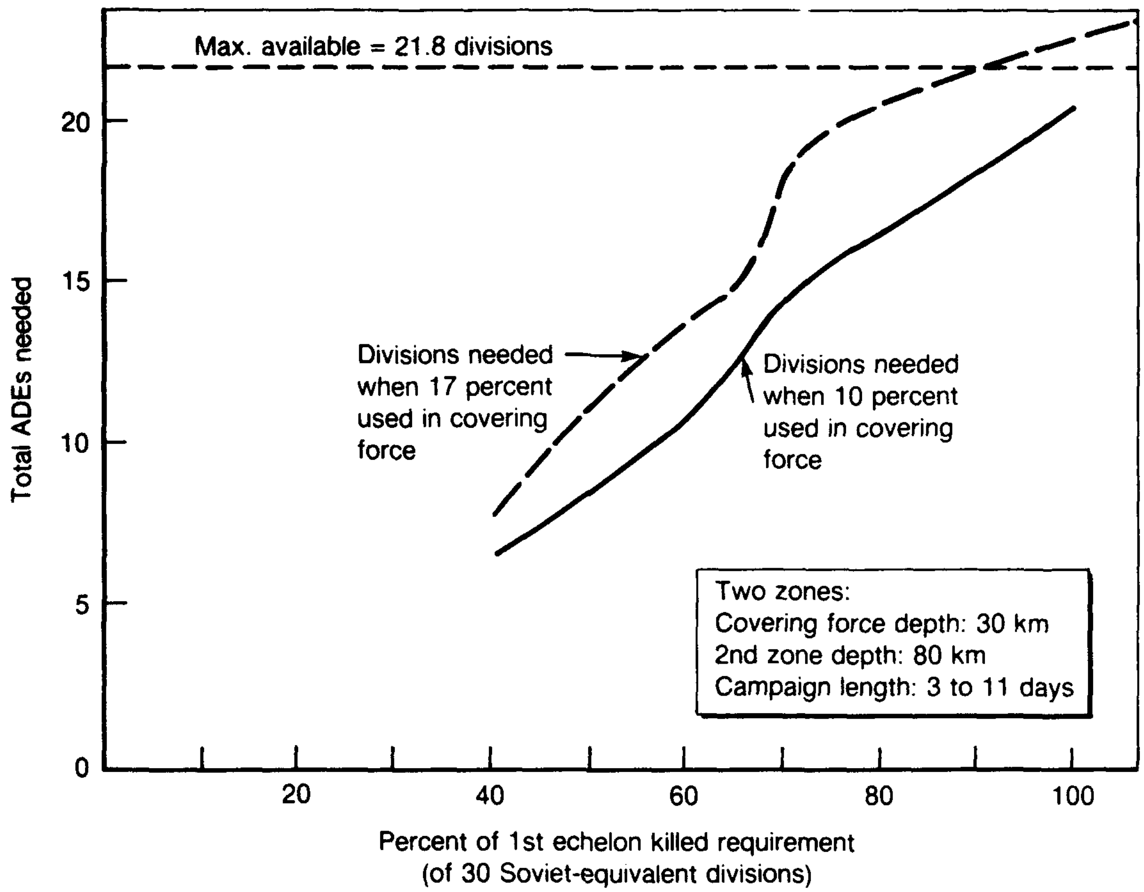


Fig. 54—NATO force needs under two alternative covering force sizes and different possible overall missions

Thus MOSCOW has a modest ability to identify, at a crude level, good matches between concepts and technological capabilities.

SUMMARY: MOSCOW'S ROLE AND UNIQUE FEATURES

MOSCOW provides both combat developers and ground forces analysts with an aggregated, first order quantitative assessment of the viability of defense concepts, with emphasis on the operational and theater-strategic levels of warfare. Users of the model can specify how Blue forces might conduct operations in a geographical area, known as a "zone," which can be as small as a corps sector or as large as an entire theater.[113] The user specifies his campaign objectives: the number of enemy combat units that must be destroyed and the maximum distance that the enemy can be allowed to advance into friendly territory. MOSCOW estimates the size of the friendly force needed to achieve the objectives, as well as the replacement

[113]Recommended size is theater or army group sector in width, and at least three to five days of Red advance in equivalent length.

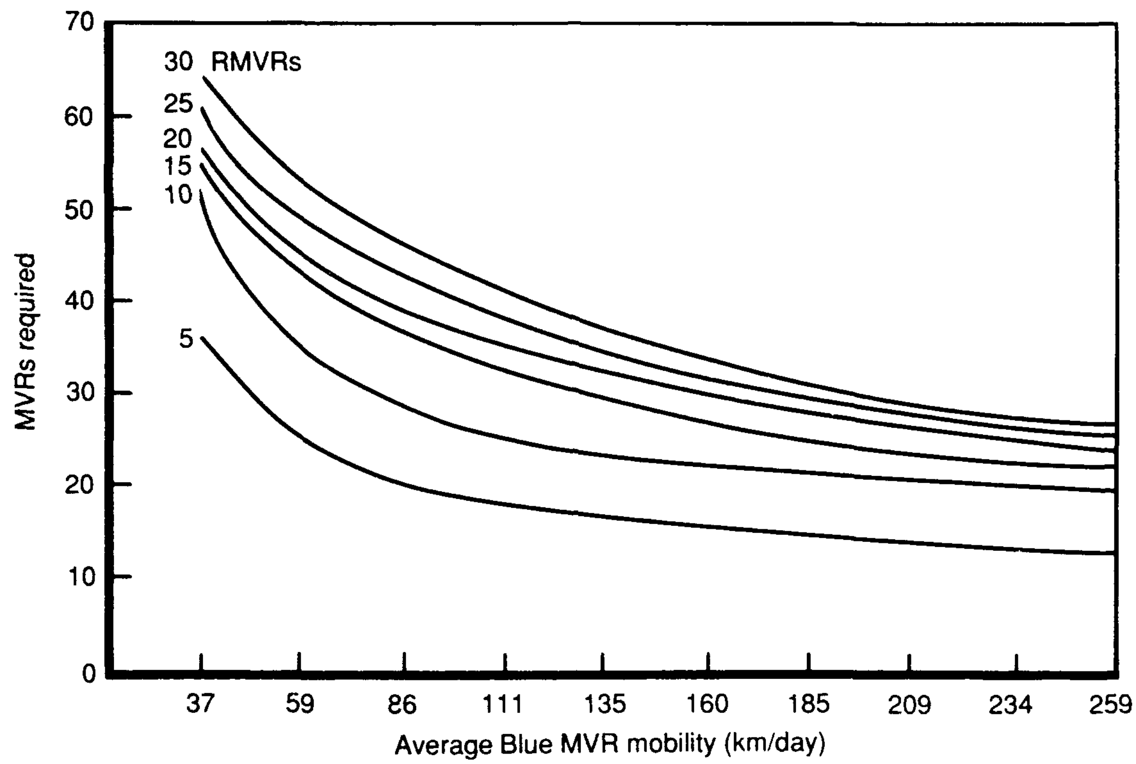


Fig. 55—Mission-dependence of the payoff of improved mobility

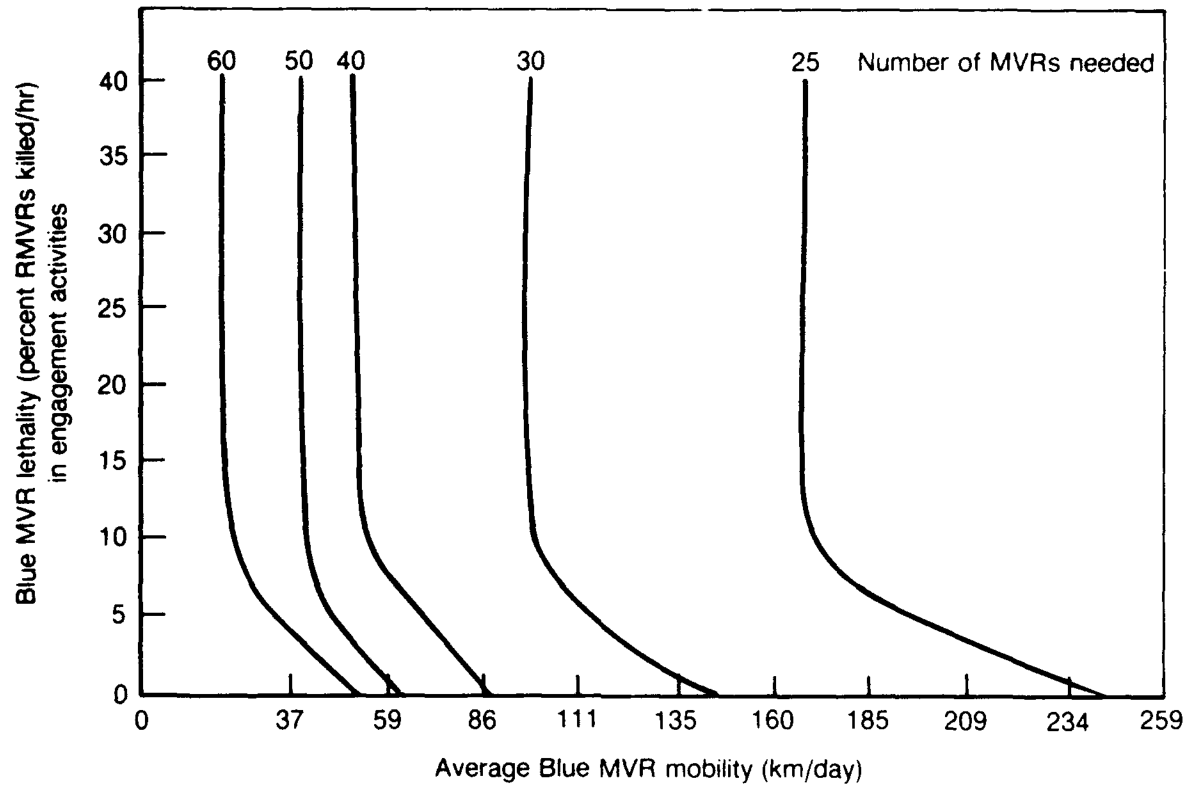
personnel, vehicles, and major consumables needed to keep it at full strength. If the amounts projected to be available to the zone can supply these needs, the concept is considered viable (or affordable) under the assumptions used. Concepts that are found to be viable over a wide range of assumed circumstances—whose viability is robust—are considered promising and eligible for further analysis using more detailed tools.

MOSCOW represents a major departure from traditional methods of both concept development and concept analysis.

MOSCOW provides a systematic and concrete framework for describing alternative concepts. Concepts can be described in a common typology, with differences represented by varying the values of key variables. Policy variables are categorized by their function and the level of warfare to which they apply.

MOSCOW differs from traditional models for the analysis of ground forces issues in the following respects:

1. It represents the effects of concepts in part through the *mix of activities* of friendly forces. This flexible format allows MOSCOW to represent a range of different concepts. Because it includes many noncombat activities, it can treat concepts more



[a]AFCENT, 30 RMVR 1st echelon; 15 Red divisions killed, 30 km penetration.

Fig. 56—Lethality/mobility tradeoffs for a mobile concept[a] (forward defense)

broadly than do traditional models that emphasize only engagements. Similarly, it describes force characteristics in a flexible format that can reflect a wide range of technologies (albeit crudely).

2. It evaluates concepts in terms of high-level grand strategy and theater strategy objectives. The model "assumes" that these objectives will be achieved and estimates the size of the force and other resources *needed* to do so.
3. It performs "what if?" analysis *quickly*, because it was constructed to run on a personal computer.
4. Its computations are readily accessible, and—especially important—*easy* for a user *to customize*, because it employs the Lotus 1-2-3™ spreadsheet program.

MOSCOW achieves this efficiency and flexibility at the expense of a certain amount of military detail. For example, all distributions (of fire, targets, aircraft sorties, etc.) are ignored: The model represents only averages. It also omits certain tactical policy variables, such as the differential allocation of indirect fire (e.g., to "counterbattery" fire). Finally, it aggregates forces that may be quite heterogeneous into average maneuver units, although users may make separate individual runs for each type of unit.

MOSCOW provides the user with an analytic "sandtable" into which he may insert his concepts and assumptions. However, because it utilizes a new and different activity-oriented approach for describing concepts, users are urged to compare the distribution of activity times calculated automatically by MOSCOW with a "reasonable" distribution and modify it as needed using MOSCOW's proportional constraints. Like any model, its estimates must be filtered by military and analytic judgment. Its virtue is that the equations and variables can easily be changed to accommodate that judgment.

V. CONCLUSIONS AND RECOMMENDATIONS

The approaches used in the past to design and analyze defense concepts are far less rigorous than those employed on narrower, better-defined defense problems. This is hardly surprising given the embryonic state of the art in this field. The Army is nevertheless attempting to expand the formal influence of concepts on its medium- and long-range planning, and it needs new approaches and new tools to help design and choose them systematically. This report has suggested three components.

1. Section II defined *defense concepts* and *warfighting concepts*. It outlined a *typology* of concepts that attempted simultaneously to be broad—encompassing *warfighting style, force allocation and deployment*, and *organizations and equipment* at each of four levels of warfare—and specific—defining several descriptive attributes in objective or quantifiable terms.

2. Section III presented a *concept design and analysis approach* geared to mid- and long-range time horizons that strives for more breadth and more rigor than past attempts without demanding impossible amounts of time or resources. The approach stresses the examination of a *wide* range of concepts and concept versions and a wide range of scenario *assumptions*, in order to identify *robust* concepts. It suggests the organization of such efforts into *stages of analysis* carefully ordered so that the number of concepts considered in each stage is commensurate with the cost per concept of the tools employed.

3. Particularly needed is a *quantitative model* that can appraise a wide variety of concepts at the operational level of war, with modest data requirements and short run times (and therefore a low level of resolution). Such a model could be used by concept designers interested in experimenting with different ideas, and by analysts in need of a tool for focusing effort by "screening out" unpromising concepts. Section IV described the Method of Screening Concepts of Operational Warfare (MOSCOW), which is a microcomputer spreadsheet-based tool that estimates the resources a concept would need to prosecute a successful campaign. MOSCOW is fast, flexible, and transportable, in order to permit users from varied military backgrounds to explore a variety of concepts under a range of theaters, time horizons, and scenario assumptions.

The conclusions that follow are of two types: those relating to general styles of thinking and intellectual approaches used to develop concepts, and specific recommended changes in the Army's present process of developing and evaluating concepts under the auspices of the CBRS.

IMPROVING THE QUALITY OF THE POLICY DEBATE ABOUT DEFENSE CONCEPTS

Concepts are too important, and they influence too many aspects of the Army and of the nation's larger security policy, to countenance the vagueness and indiscipline of past approaches. Future concept developers must bear a responsibility to *articulate their ideas explicitly within a common intellectual framework*. Although the provisional typology described in Sec. II and embellished in MOSCOW is a start,[1] it shows its humble origins in its emphasis on warfighting style and on the operational level of war. Further development is needed, but

[1]In an institution as decentralized as the U.S. Army, much less in the larger community interested in defense concepts, it would be impractical—and probably counterproductive—for any authority to *impose* a descriptive framework. However, a common *methodology* will facilitate debate and discussion about concepts as a natural byproduct of analytic effort. Thus, MOSCOW offers an opportunity to introduce coherence through the back door.

efforts must avoid falling into the temptation of adding detail in only the tangible areas (organization and equipment, or the tactical level of war), because the greatest need is for analytically tractable definitions of "soft" elements (such as doctrine).

Future concepts should indicate clearly the limits of their scope—for few concepts are likely to cover every dimension—and demonstrate at least *prima facie robustness* to uncertainty and to enemy countermeasures, incorporating promising counter-countermeasures into the concepts themselves. The breadth this implies for design efforts may have to come at the expense of depth and detail, but to the degree that this broadening elevates policy debates to more appropriate levels, it can hardly be a bad thing.

IMPROVING THE U.S. ARMY'S PLANNING PROCESS

Superficially reasonable as the CBRS may be, it cannot be denied that the results to date of the Army's attempt to give concepts a preeminent place in planning are less than impressive. The first test, the Army 21 concept, aborted after five years of development and initial evaluation. There is confusion about the proper scope of such concepts, their appropriate time horizons, and even about an accepted definition of the subject itself Unless certain fundamental intellectual prerequisites are satisfied, the prospect that intelligible, credible "concepts" can influence planning is highly questionable.

Some groundwork has been attempted in this report. Figure 57 summarizes the analytic framework—the stages of concept design, development, and analysis—that is recommended. The Army has already accepted its basic ideas. Fully implementing the framework, however, involves overcoming some cultural and organizational obstacles.

Most important, the Army must recognize that *design and analysis are effectively inseparable*. The separation of these tasks as mandated by CBRS will immensely limit the breadth and richness of any concept development effort. The membrane between designers and evaluators must be fully permeable.

Achieving such fluidity is difficult because the hybrid task of design and evaluation cuts across traditional organizational lines and, more important, across Army cultures. Combat developers and systems analysts use very different mental frameworks. The hybrid task demands that they communicate well with each other and that they both stretch beyond comfortable styles of thinking. Developers must become accustomed to thinking in quantities, or their ideas will never be widely communicable and susceptible to analysis; and analysts must be willing to grow beyond easily definable problems at high levels of resolution to entertain "squishier" issues of broader scope.

The final cultural change is probably the most difficult. A concept development and evaluation process that considers many concepts under many possible assumptions can succeed only by organizing its tasks in stages (as exemplified in Fig. 57). Implicitly, this means analyzing some things early and some things later. The Army has a natural desire to consider every criterion "at the front end" of any study, because each branch or function will have a legitimate claim as to the importance of each criterion. The fundamental compromise that must be made is to acknowledge that deferring harder analytic problems until later, when there are fewer concepts to be considered, is indicative only of the *cost* of evaluating a given issue, *not* of that issue's *importance*. If everything is accorded first priority then the role of concepts in the Army's planning will remain as before the adoption of CBRS: They will be followers rather than leaders of the Army's future.

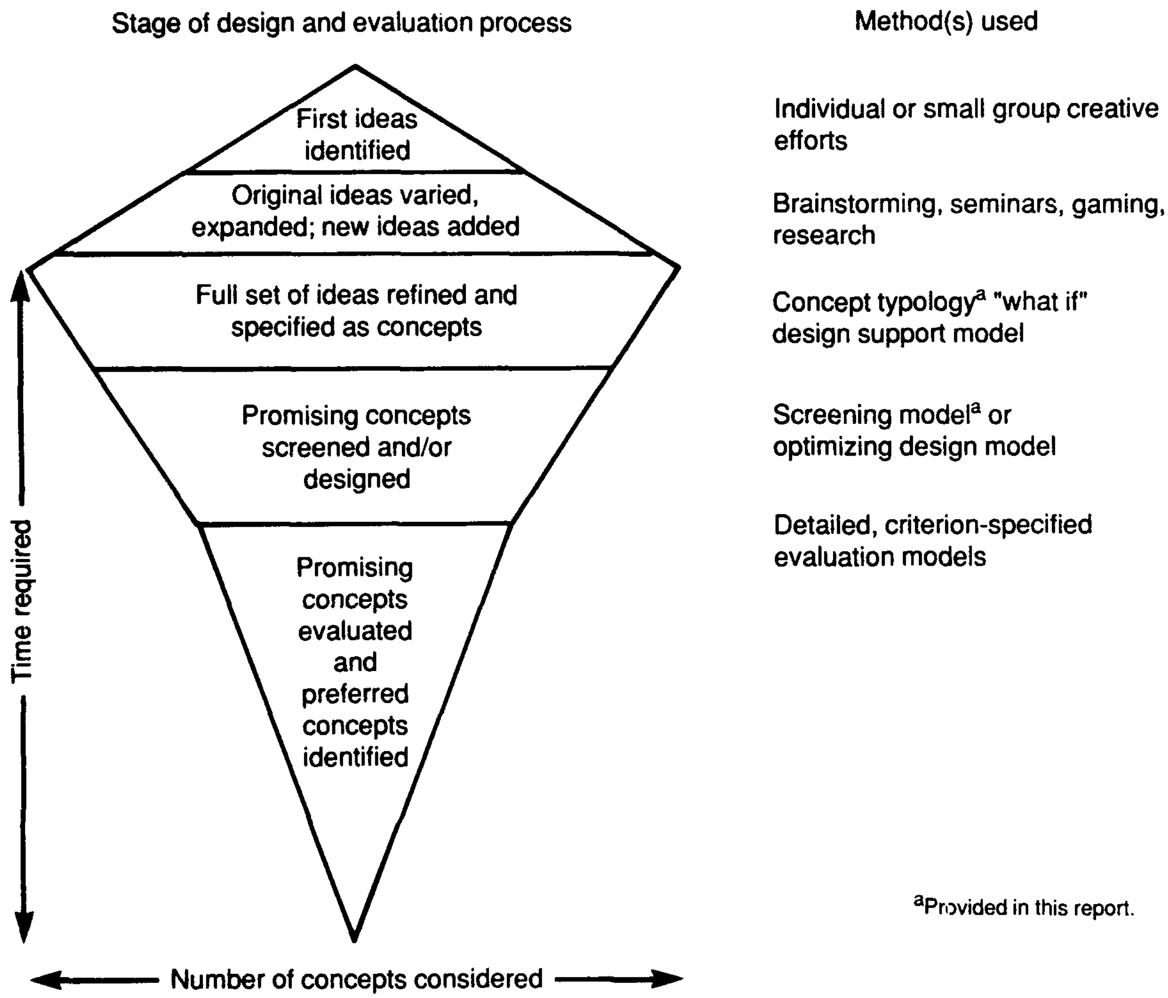


Fig. 57—Stages of analysis in proposed concept development and evaluation approach

APPENDIXES

Six appendixes provide supplementary information concerning the MOSCOW model. They are organized as follows.

Appendix A lists the principal screens in which MOSCOW's inputs, activity cycle computations, and outputs are displayed.

Appendix B describes the activity cycle, defines all 17 constituent activities, and describes how consumption is computed for all except the engagement activities.

Appendix C describes the calculation of consumption in engagement activities. (It is also referred to as the "battle calculus").

Appendix D describes how Blue mobility, Red mobility, and Red advance rate are computed. Red's rate of advance determines the time available to Blue to destroy the specified number of RMVRs.

Appendix E describes the final output computations in MOSCOW.

Appendix F illustrates how reinforcement schedules, such as echelonment, can be reflected through the use of several MOSCOW zones in sequence.

These appendixes are not complete documentation of the entire MOSCOW model. Instead, they elaborate on the brief description in Sec. IV. Further model documentation is forthcoming in a separate Note.

Appendix A

PRINCIPAL MOSCOW SCREENS

Appendix A displays the principal input, process, and output screens used in MOSCOW. It lists the screens where inputs are introduced and includes comments about the sources and methods employed to generate the input values used in the illustrations reported in Sec. IV. In view of the number of input variables, it was not possible to define every one of them in this report or cite every data source used.[1]

This appendix also lists the screens in which the *consumption* of resources in each Blue MVR's activities is displayed. It does not define the activities or explain how consumption is calculated, but merely shows the display format. Definition of activities and a derivation of their principal equations can be found in App. B (for an overview of the activity cycle and definitions of all nonengagement activities) and App. C (for engagement activities).

Also listed are the screens on which MOSCOW's output and supporting diagnostic information is displayed. Appendix E contains an explanation of how these outputs are computed.

The structure of the inputs for MOSCOW is the product of a series of compromises. One compromise is between aggregation and policy utility. It is possible, for example, to assume certain tactical behaviors on the part of Blue and Red units in combat and thus aggregate their combat power into one or a few situation-specific firepower scores (as is done in the WEI/WUV methodology and used in one form or another in many theater models).[2] However, this would prevent users from exploring the effects of many of the tactical choices that vary among different warfighting concepts, such as typical engagement distances, or the elasticity of defenses.

Another compromise is between inputs that are specific to each piece of equipment and limited model size. Making inputs too equipment-specific would mean keeping track of a large number of different types of entities, which would greatly expand (and complicate) the model. However, inputs defined in terms of physical units (speeds, firing rates, etc.) are less subject to misinterpretation or controversy than more abstract or aggregated definitions.

A third compromise is between policy richness and phenomenological detail. For a fixed model size, a designer can choose to represent campaign phenomena with great verisimilitude, but stint on the range of policy variables (in MOSCOW, concept-related variables), or the reverse.

The final, and most important, compromise is between flexibility and familiarity. Many of the inputs to MOSCOW are similar to variables used in other models or commonly calculated in analyses. They could be defined identically to these variables, but only at the price of flexibility. For example, air effectiveness against ground targets is the product of SORTIES/DAY × TONS/SORTIE × HITS/TON × KILLS/HIT. This decomposes the common formulation, KILLS/SORTIE, in order to allow the user to explicitly represent munitions effectiveness. (Present-day aircraft can carry more tons of "dumb bombs" than precision munitions, so changing munitions will change both TONS/SORTIE and HITS/TON).

[1]Readers interested in further information about MOSCOW's inputs should consult Romero, Rydell, and Stanton, 1987.

[2]See App. A in Mako, 1983, for an explanation of the WEI/WUV system for measuring firepower.

Following common practice would make it more difficult to reflect payload trades needed for different munitions. Similarly, both operational and tactical objectives are defined in terms of enemy units destroyed (or surviving), rather then percentages of a starting force, because scenario changes will change starting force size.

Sometimes a difference between an input to MOSCOW and common usage is only semantic. For example, MVRs' lethality, mobility, and vulnerability are affected by their choice of formation, called ADMIN or BATTL in MOSCOW. These are not the Army's terms for these formations, they were deliberately chosen so as to avoid becoming obsolete if official nomenclature changes. Any attempt to make MOSCOW terminologically "current" may only confuse users unable to distinguish nomological changes from real ones. Because the time horizon of concepts that may be examined by MOSCOW extends well into the 21st century, efforts were made to avoid terminology or input definitions that implied particular weapon systems or concepts.

Before illustrative cases were run, informal calibration was attempted using a base case. Calibration focused on intermediate output information, such as casualty and resource consumption rates, for which historical information is available, rather than final outputs such as Red advance rates, which would have to be taken from another model. The following categories were used, with a range considered "reasonable" indicated:

- *Red to Blue vehicle exchange ratios*: When Blue was predominantly defending (%MVRs-ATK KILS was near zero), this number ranged between 1.8 and 3.1 in engagements, and 2.6 and 6.2 in the overall campaign. These values are within ranges typically used in unclassified sources (see, for example, Posen, 1984/85, p. 113, which summarizes several other estimates).
- *Consumption per man*: U.S. Army planning factors assume that in intense combat, 124 lb will be consumed per man per day. (see Department of the Army, FM-101-10-1, 1976, Ch. 3.) This number ranged between 96 and 151 lb, and usually remained between 100 and 120. Consumption per division was also computed and compared with factors given in FM-101-10-1, Ch. 3; and Dunnigan, 1982, pp. 310–322.
- *Personnel casualties per vehicle casualty*: RAND surveys of historical studies (see Davis et al., 1986, pp. 141, 143) report that in campaigns since World War II personnel casualties per tank casualty have ranged between 13 and 22. Since MOSCOW counts all vehicles, and tanks represent about 1/4 to 1/3 of the combat vehicles in maneuver divisions in the scenarios examined, this number ranged between 4 and 6.5 (or between 12 and 26 personnel per tank).
- *Personnel casualties as a fraction of total manpower*: Although casualties in line units may sometimes be high, overall casualties are usually much smaller (because only a small part of the force is in frontline units) Davis et al., 1986, pp. 133–135, have found percentage casualties in modern combat of .2 to 3 percent of total manpower, or 2.4 +/- 1.4 percent per day in intense campaigns. Posen, 1984/85, p. 111, shows front-wide attrition estimates in a similar range. This is also broadly consistent with Dupuy, 1979. This value ranged from 1.4 to 3.9 percent.

Later calibration attempts will of course need to be concerned with a larger set of calibration variables and establish specific tolerance levels for each. For the purposes of early illustration, however, the model seemed to be reporting reasonable results.

To achieve this reasonableness, however, it was generally necessary to reduce lethalities (through the LETH MULT and %FIRERS variables, reflecting reduced intervisibility) and protract engagements (through the ENGAGEMENT TEMPO calibration coefficient). Unmodified, unit lethalities were five to ten times "too high". If this is a consequence of the data and not an idiosyncracy of the current version of MOSCOW, this suggests that weapons lethalities are greatly exaggerated and engagement tempos overestimated.

The opposite side of the same coin is to note that, with the above exception, no other changes needed to be made in the inputs to produce "reasonable" results in the base case.

INPUTS AND ESTIMATION METHODS USED

This section very briefly summarizes the principal sources used to estimate inputs for each MOSCOW block. Below are shown the inputs used for the illustrations and elaborate somewhat on sources and methods elaborated. However, not every data element is explained because of the large number.

Red Threat (Scenario)

Red MVRs (divisions), HQs are from Isby, 1981; Posen, 1984–85; Mako, 1983; International Institute for Strategic Studies, 1986–87. Red mission allocation is a guess based upon interpretation of doctrine (e.g., Department of the Army FM-100-2-3, 1984b), as is aggressiveness. Division separation is a modification of doctrine, reflecting both main effort and subsidiary axes. The description of the zone is based on Faringdon (for terrain) and Mearschiemer (for general dimensions of AFCENT, NORTHAG, and CENTAG). Blue warning is a conservative value consistent with NATO planning assumptions. Hours per day is set at 24, because weather or latitude will not typically cause halts in ground operations.

Blue Success Criteria (Objectives and Theater-level Policy)

All of these entries are policy variables (at the theater-strategic or operational level), so they will of course change as different concepts are considered. The base case, defeating the first echelon before the arrival of the second (using a forward defense concept), is my interpretation of current NATO strategy, based primarily on Karber, 1986; and Rogers, 1984. HQs and engineers are based on Isby and Kamps, 1983, and HQ SPAN is based upon traditional U.S. Army practice.

Terrain

Multipliers for mobility, target availability, and defense were based on Dupuy, 1979 (the second and third were interpolated), supplemented by Dunnigan, 1978 to 1980. Distributions of terrain types were based primarily on Faringdon, 1983, with additional material from Paxson and Weiner, 1979, and Bracken, 1975.

Air, Fire, and Engineer Support

Numbers of HQs are from IISS, 1986–87. Firing characteristics are from Weinberger, 1986, and Bellamy, 1985 and 1986. CAS and Air Interdiction aircraft totals are from Kaufmann, 1985; and Epstein, 1986 and 1987. Engineer numbers are from Isby, 1981 and Isby and Kamps, 1985, effectiveness from Epstein, 1987 (citing Scott and Leonard 1979). Air and fire effectiveness estimates are guesses, but broadly consistent with unclassified sources (e.g., Epstein, 1987; Posen, 1984–85).

MVR Characteristics and Policy

MVRs and RMVRs in the illustrations are defined as a composite U.S. or Soviet armor-mechanized division. Inputs for these composite divisions were derived as follows:

1. Using the EQUIP.WK1 preprocessing spreadsheet,[3] input sets were constructed for a U.S. mechanized, U.S. armored, Soviet motorized rifle, and Soviet armored division. Categories of equipment were Main Battle tanks, IFVs or APCs, long-range artillery (including division-organic rocket launchers) attack helicopters, and all other vehicles. Division stocks of each equipment type came from FM-100-2-3 for Soviet divisions, and FC-34-2 for U.S. divisions. Composite vehicle characteristics reflect the weighted average of each value of a particular parameter across the five vehicle types.
2. Using a distribution of armored vs. mechanized divisions derived from Sadykiewicz, 1987, for the Soviets and Mako, 1983, for the United States (converting nonsuperpower divisions into superpower equivalents using the ADE scores in Mako, 1983, and Phillips, 1987), a composite MVR and RMVR were estimated.

RMVR or MVR "budgets" input in the Red Threat and the Limits on Resources blocks were based upon the ADE score of each side's composite MVR/RMVR, using the projections of available ADEs in Mako, 1983, and Phillips, 1986.

Resource Consumption Coefficients

Coefficients assume that substantial nonorganic support is available to assist in the preparation of defenses, MVRs can be resupplied while carrying out other activities, and MVRs receive substantial intelligence support from higher echelons. Otherwise, all activities must be performed entirely by the MVR, so they are on its critical path.

Commodity consumption coefficients are guesses, checked for broad consistency with FM-101-10-1 and FC-101-5-2, further informed by Dayan, 1959; and Deitchmann, 1983, for breakdown rates and Davis et al., 1986; and Dupuy, 1979, for ratios of personnel casualties to vehicle casualty.

Limits on Available Resources

These limits do not affect model behavior, but they act as benchmarks against which resource stocks or flows needed can be compared. Total MVRs refer to the total number of ADEs available in AFCENT according to Mako, 1983. The limit on total casualties is a guess, set arbitrarily (for a war in Europe) at roughly three times fatalities in Korea or Vietnam. Stocks and flows of all commodities are guesses. Lift is based on Weinberger, 1986, and Kaufmann 1986. The tolerance level is set high so as not to rule out concepts that "almost" stay within projected resources.[4]

INPUT BLOCKS IN MOSCOW

The sections that follow display each input screen and outline the procedures used to derive input values. Every input cell cannot be described because of space limitations, but the most important or unusual are included here. See Romero, Rydell, and Stanton, 1986, for brief input definitions.

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[3]See Romero, Rydell, and Stanton, 1987, for a brief presentation of this spreadsheet, which combines the characteristics of several vehicle types into a composite vehicle whose characteristics are based on their weighted average.

[4]Alternatively, tolerance could be set low to be especially conservative.

The input data collected were based upon approximately one man-month of intensive effort using only readily available unclassified sources. TRAC is currently undertaking a more comprehensive data collection effort. The data used represent a best-effort given limited resources, but they are not "approved" by any authority. For many of the data elements pertaining to policy variables related to warfighting style, no database could be consulted because the variables are original to MOSCOW. For this reason, the cases of MOSCOW presented in Sec. IV were expressly illustrative of model capabilities, and not the basis for policy conclusions. The reader is enjoined to review these input data not to assess their accuracy—for there are undoubtedly many errors—but to establish whether they are so inaccurate (e.g., the wrong sign or the wrong order of magnitude) that illustrations using "correct" values would yield qualitatively different results.

RAND's continuing work on MOSCOW will incorporate TRAC-produced input data for later verification of the model. The data shown provide a starting point for these efforts.

RED THREAT AND ZONE GEOGRAPHY

The first portion of this block, displayed in Fig. A.1, describes the zone and any restrictions on operations it imposes because of latitude or warning time. Zone dimensions (the zone is all of AFCENT) are based on Mearschiemer, 1983, and are more or less corroborated in many other sources. Sources differ in their estimates of the width of the zone depending upon the degree to which they include the IGB's twists and turns, and as to the length of the zone, which could theoretically extend to Gibraltar, but for illustration is assumed to end in the Rhine/Ijssel area.

```
[Alt-R]   RED THREAT AND SCENARIO (ZONE GEOGRAPHY AND FORCE SIZE)
ZONE WIDTH           750          km
ZONE LENGTH          300          km

#CHOKE AREAS        0.00          # areas where traffic is confined
CHOKEAR FRONTG      0.00          Average choke area width (km)
CHOKEAR DEPTH       0.00          Average choke area depth (km)
HRS/DAY USBLE       24.0          hrs/day usable for operations
BLUE WARNING        2.00          days

# RED MVR           30.0          # Red maneuver units (rmvrs)
# FRNT LN DIVS      24.0          # rmvrs in front line
# RED HQs            7.0          # Red Headquarters (HQs)
# RED ENG UNITS      7.0          # Red engineer units

% RMVRS-ATK         0.75          % rmvrs assigned atk mission
RED DIV SEPRTN      25.0          Average distance between rmvrs (km)
RMVR AGGRSV-ATK     1.00          Dist toward enemy/total dist moved
RMVR AGGRSV-DEF    -0.05          Dist toward enemy/total dist moved
                                    (+1.0=forw; -1.0=away; 0=static)
```

Fig. A.1—Red threat input screen

The second portion of the block describes the top-level features of the invading Red force. The illustrations assume a standing-start/short-warning scenario in which the first operational echelon includes Soviet forces only, a total of 30 divisions (RMVRs); 80 percent of these are assumed to be in the first tactical echelon (front-line), and 20 percent in the second. Two Fronts of three to four armies each are assumed to control this echelon, so $2 \times (4+3)/2 = 7$ Army HQs are assumed, with one engineer unit assumed attached to each HQ. In light of the Soviets' offensive strategic objectives and operational doctrine, it is reasonable to assume that 75 percent of the invading RMVRs will have offensive missions (and the other 25 percent have defensive economy of force missions). Red is assumed to give very strong emphasis to high-speed attacks, so Red's aggressiveness on attack is 1.0. Owing to the lack of mobile defensive training by Red ground forces, defensive RMVRs are assumed to attempt to nearly stand fast, so their aggressiveness is −.05.

Finally, Red division separation is computed as follows: assume second tactical echelon divisions are distributed evenly across the width of the zone (as are first tactical echelon divisions).[5] Because there is one such division for every four front line divisions, each is assumed to be positioned at the center of a sector of $4 \times (300/24) = 50$ km wide. The center point of each front line division's sector is 12.5 km apart. The reserve division is positioned at some depth, D, behind the FLOT, at some width, W, from the average division's center to the point on the FLOT corresponding to the reserve division's horizontal position. Average distance (or DIV SEPRTN) S is, according to the Pythagorean theorem, equal to $(D^2 + W^2)^{.5}$. The W is equal to the midpoint between the two divisions to the left or two divisions to the right of the sector's midpoint, or 1/4 of the total sector width = 12.5 km. Typical Soviet doctrine might call for the second tactical echelon to be 20 to 25 km behind the FLOT, so D is about 22.5 km. Therefore $S = (22.5^2 + 12.5^2)^{.5}$, or 25.7 km, rounded to 25 km in the input.

Principal sources for these estimates are: Donnelly, 1984a and b; Savkin, 1972; Sidorenko, 1970; Simpkin, 1984; U.S. Army, 1978; Isby, 1981, pp. 20; Isby, 1983, p. 20; Steinbruner and Sigal (article by Kaufmann), 1982, p. 62; Sadykewicz, 1987, pp. 50, 54, 73, 81, 90; Dunnigan, 1979, pp. S10–S13; Mako, 1983, p. 45, 127–28; Posen, 1984/85; U.S. Army Command and General Staff College FC-101-5-2, 1987; and Erickson, Hansen, and Schneider, 1986.

SUCCESS CRITERIA AND OTHER HIGH-LEVEL POLICY VARIABLES

These variables, displayed in Fig. A.2, pertain to the criteria that concepts are required to meet and to other high-level policy variables.[6] Since many of these variables attempt to quantify behavioral characteristics that have heretofore not been quantified, seldom are specific data sources available. RED PEN LIMIT is an interpretation of NATO's "Forward Defense" doctrine, based loosely on Karber, 1984, for the first phase of a campaign against the first Red operational echelon (of 30 Soviet divisions in a standing-start/short-warning attack); and RED SURVIVORS reflects an objective of destroying half of the 30 invading 1st-echelon Red divisions. Remaining variables are interpretations of the U.S. Army's AirLand Battle doctrine, extended to cover all of AFCENT.

There are eight peacetime corps sectors in AFCENT, so eight HQs are assumed to be available. Each corps is assumed to have an attached engineer unit, with two extra reflecting additional support available to the two U.S. corps deployed in Germany in peacetime. HQ

[5]As indicated in Sec. IV, the user can distinguish main from secondary axes by constructing more than one zone.

[6]An exception is those variables pertaining to the number of headquarters and engineer units.

```
[Alt-S] BLUE SUCCESS CRITERIA AND THEATER-LEVEL POLICY (2 screens)

      SUCCESS CRITERIA
RED PEN LIMIT                30 km Red allowed to penetrate zone
RED SURVIVORS              15.0 # rmvrs allowed to survive
MAXPEN PRE-INT             10.0 km max pen before must eng Red

      TIME OBJECTIVE
DELAY                       3.0 campaign-days added by Blue opens

      DEPLOYMENT
FORW BNDRY                  0.0 km to border             --
REAR BNDRY                   50 km to border             --
%ATKOPS-LINEAR             0.50 % Blue atks using linear operations
%of ZONEW DEFD             1.00 % zone frontage covered by Blue

      MVR TACTICAL AGGRESSIVENESS
MVR AGGRSV-ATK             0.50 Dist toward enemy/total dist moved
MVR AGGRSV-DEF            -0.40 Dist toward enemy/total dist moved
                                (+1.0=forw; -1.0=away; 0=static)

      MVR MISSION ASSIGNMENTS
%MVRs-ATK KILS             0.35 % rmvrs to be killed by atk mvrs
%MVRs-DEF KILS             0.60 % rmvrs to be killed by def mvrs

      HQ CAPABILITIES
# HQs AVAIL                 8.0 # Blue HQs in zone
HQ SPAN-#MVRs               5.0 # mvrs controllable by Blue HQs
HQ RADIUS-KM               75.0 Max dist an HQ can control an mvr
# ENG UNITS AVAIL          10.0 # Blue engineer units in zone
```

Fig. A.2—Blue success criteria and theater-level policy input screens

span of control corresponds to U.S. Army planning since World War II, which has assumed that corps would be composed of between four and six divisions. Since the widest corps sector (that of the German II corps) is approximately 150 km wide, the command radius of corps HQs was set at 1/2 of 150 km.

Principal source material: Metcalf, 1960; Zierdt, 1961; Izenour, 1959; Isby and Kamps, 1985; Karber, 1984; Faringdon, 1986; Congressional Budget Office, 1980; and Cordesman, 1983. As indicated, this material was more indicative than authoritative.

TERRAIN MULTIPLIERS AND DISTRIBUTIONS

Two kinds of terrain information were collected: (1) estimates of the values of the multipliers of movement rate, defense strength, and target availability corresponding to each of several types of terrain; and (2) estimates of the percentage distribution of terrain types for portions of AFCENT and for western Iran.[7] Both sets of inputs are shown in Fig. A.3.

Multiplier Estimates

Principal sources used were: Dupuy, 1979, pp. 228–229 and passim; Dunnigan, 1978b, p. R1; and Mako, 1983, p. 94 (citing Tillson, 1979). In general, there was no lack of information available on multipliers, but it had to be used carefully because of source differences in definitions of terrain effects. All sources assume that terrain affects a defender's combat power, but few distinguish effects on lethality vs. target availability, as MOSCOW does. There were great disparities in the values assigned to the same multiplier among sources. For example, the movement multipliers in Dupuy were as much as three times those in Dunnigan.[8] In general, the multipliers used in MOSCOW correspond closely to those in Dupuy, but they were raised or lowered by 10–25% if other sources differed significantly.

TERRAIN FEATURES IN ZONE (2 screens)

							Distributions for Specific Areas (copy into GN7..GN35)			
COVER	GRADIENT	MOVEMENT RATE coeff.	DEFENSE STRENGTH coeff.	TARGET AVLBTY coeff.	FRACTION OF ZONE	L/W	Cov. F 40/750	MBA 70/650 (mvmt*.7)	Rear 200/600 (mvmt*.8)	W. Iran 1500/150
Clear	Flat	0.90	1.13	1.00	0.06		0.06	0.15	0.15	0.06
Mixed	Flat	0.83	1.24	0.90	0.05		0.05	0.08	0.08	0.04
Forest	Flat	0.64	1.30	0.65	0.06		0.06	0.04	0.04	0.01
Urban	(N/A)	0.64	1.73	0.30	0.17		0.17	0.09	0.09	0.02
Clear	Rolling	0.87	1.30	1.00	0.09		0.09	0.13	0.13	0.02
Mixed	Rolling	0.78	1.40	0.90	0.04		0.04	0.06	0.06	0.01
Forest	Rolling	0.55	1.46	0.60	0.08		0.08	0.06	0.06	0.01
Clear	Hills	0.64	1.40	0.95	0.04		0.04	0.09	0.09	0.08
Mixed	Hills	0.60	1.51	0.85	0.07		0.07	0.06	0.06	0.06
Forest	Hills	0.46	1.57	0.50	0.10		0.10	0.05	0.05	0.01
Clear	Broken	0.60	1.57	0.85	0.05		0.05	0.05	0.05	0.06
Mixed	Broken	0.46	1.62	0.75	0.06		0.06	0.04	0.04	0.05
Forest	Broken	0.37	1.73	0.55	0.08		0.08	0.05	0.05	0.01
Clr/Mixd	Marsh	0.37	1.40	0.95	0.03		0.03	0.01	0.01	0.01
Jungle	Marsh	0.18	1.40	0.90	0.00		0.00	0.00	0.00	0.00
Clear	Mountains	0.28	1.84	0.75	0.01		0.01	0.03	0.03	0.15
Mixed	Mountains	0.18	2.05	0.40	0.01		0.01	0.01	0.01	0.18
Desert	Flat/Rolli	0.83	1.27	1.00	0.00		0.00	0.00	0.00	0.13
Desert	Hills/Mtns	0.28	1.51	0.80	0.00		0.00	0.00	0.00	0.09
Arctic	Flat/Rolli	0.37	1.51	1.00	0.00		0.00	0.00	0.00	0.00
Arctic	Hills/Mtns	0.18	1.94	0.80	0.00		0.00	0.00	0.00	0.00
Tropical	Flat/Rolli	0.64	1.40	0.80	0.00		0.00	0.00	0.00	0.00
Tropical	Hills/Mtns	0.37	1.62	0.40	0.00		0.00	0.00	0.00	0.00
AVG FOR ZONE		0.66	1.47	0.72	1.00		1.00	1.00	1.00	1.00

Fig. A.3—Terrain features in zone input screens

[7] The number of terrain categories used in MOSCOW is limited only by memory. Users are free to add to, consolidate, or redefine the 22 categories in MOSCOW-M1, which attempt to span a wide range of possible environments. It is unlikely that all categories would be represented in any particular MOSCOW zone.

[8] Compare the multipliers in Dupuy, 1979, pp. 228–229; with relative "operations point costs" in Dunnigan, 1978b, p. R1.

Terrain Distribution

Distributions were estimated for four zones, three in AFCENT and a fourth in western Iran. The AFCENT zones correspond to assumed planned locations of NATO's covering force, main battle area, and rear area, with guesses as to their probable length (depth) and width informed by the research into past NATO defense lines discussed in Sec. II. These estimates rely on published information, supplemented by a cursory map study to fill in the gaps. The sources generally provided estimates of a few percentages (e.g., Bracken, 1976, p. 255 notes that covered and urban terrain in the FRG together account for about 60 percent of total territory). Other principal sources were Weiner, 1984, pp. 51–52; Isby and Kamps, 1985; p. 43; Mako, 1983, p. 34; and Faringdon, 1986, pp. 278–279 and 281.

FIRE, AIR, AND ENGINEER SUPPORT

Support to MVRs is available in the following forms in MOSCOW:

Fire support is provided by "headquarters" (higher echelon units) and represents artillery and missiles. These fires can be allocated to provide support in engagements to attacking or defending MVRs, or to suppress enemy HQ fire through counterfire. Fire effects are uniformly distributed among all entities to which the allocation pertains (attacking MVRs, defending MVRs, or enemy HQs). The vehicles killed by supporting fires are assumed to be evenly distributed among the MVRs being supported; those kills are included in the MVRs' lethality (as KILLS/MIN SUPP in the lethality calculations).

Firing rates and lethality estimates per headquarters are based loosely on the characteristics of the MLRS system, which will be deployed in several NATO corps in the late 1980s. Some MLRS information is in Isby and Kamps, 1985; "The King on His Future Battlefield," 1986; Bellamy, 1987; and Barnaby, 1986.

Air support comes in two forms:

- Close air support includes both fixed and rotary-wing aircraft, behaves analogously to fire support, against enemy MVRs. It cannot be allocated to fire upon enemy HQs.
- Air interdiction includes all air-delivered munitions against targets outside of the immediate area near the FLOT. AI can be allocated among five missions: (1) destroy enemy vehicles, (2) delay enemy formations moving forward, or (3) disrupt their command and control (which increases their C-3 ERR); (4) suppress headquarters fire, or (5) interdict resupply vehicles.

The input format is the same in each of these cases. A fixed stock of assets (aircraft or HQs) can apply munitions at a given rate. These fires/sorties are allocated on a percentage basis among the two to five alternative missions or applications. For each application, effectiveness is computed in terms of physical effect (vehicles killed, tons of fire suppressed, minutes of delay imposed, increase in C-3 error, etc.) per ton of munitions delivered. (HQ firing rates are measured in tons per day; munitions delivered by aircraft sorties are measured in tons per sortie × sorties per day.)

CAS and AI sorties may suffer attrition. Average number of sorties available per day is computed as follows:

Total sorties over the period of an "infinite" campaign are Initial aircraft/attrition rate. Average sortie per day is the minimum of (initial aircraft/attrition rate)/CAMPAIGN LENGTH; and sorties per day × initial aircraft. *Thus, MOSCOW computes average sorties and does not reflect campaign dynamics within a single run.*

HQ and CAS vehicle kills per day are uniformly distributed over all enemy MVRs, and the resulting kill rate is added into the organic lethality of friendly MVRs. AI vehicle kills are tallied separately, which reduces the number of RMVRs that Blue MVRs are required to kill in ground combat. Red AI vehicle kills are added to Blue MVRs' vehicle losses to determine vehicle replacement requirements.

Estimates of the total number of aircraft available on D-day and their assignment to AI vs. CAS missions are based on Steinbruner and Sigal (article by Kaufmann), 1982, p. 76; and Epstein 1984, 1986, and 1987b. Estimates of hit and kill probabilities are based on Deitchmann, 1979; Hersh, 1987; Posen, 1984-85, (e.g. pp. 104-105); P. Allen and Wilson, 1987a; and Epstein, 1987a. Delay estimates come from Thompson, 1987. Air attrition rates are from Deitchmann, 1979; and Posen, 1984-85, p. 105. All other parameters are guesses informed by these sources.

Engineers either impose delay (if Blue) or nullify the delay imposed by enemy engineers (if Red). Their measure of effectiveness is days of delay imposed (or reduced) per day of engineer activity. Each engineer unit is assumed to be of battalion size. Red engineers can never do better than to fully compensate for the delays imposed by Blue engineers; they cannot accelerate Red's advance rate beyond its inherent velocity.

Blue engineer effectiveness is based on Epstein, 1987a, citing Leonard and Scott, 1979. Red engineer effectiveness is a guess.

The inputs used in many models (e.g., expected kills or delay per sortie) are actually computed as input conversions in MOSCOW. Figure A.4 displays the input screens, and Fig. A.5 displays input conversion screens.

MVR AND RMVR CHARACTERISTICS AND POLICY VARIABLES

MVRs and RMVRs are described in an identical format. In a few cases variables pertain to only one side because activity consumption is computed explicitly only for Blue.[9]

The MVR and RMVR input screens represent only one type of "average" maneuver unit per side per zone, composed of one vehicle with "composite" characteristics. To translate actual mid-1980s heterogeneous divisions and armies into these terms, a preprocessing spreadsheet was used.[10] Four types of divisions were represented: U.S. Mechanized; U.S. Armored; Soviet Motorized Rifle; and Soviet Armored. Then the characteristics of an "average" MVR or RMVR were computed by combining those of the two unit types on each side, using distributions of each type from Sadykiewicz, 1987, pp. 50, 54, and 73 for Red; and Collins 1985, p. 262; and Cordesman, 1983, p. 32 for Blue. (These were supplemented by Dunnigan, 1979b, pp. S1-S13; and Suvorov, 1982, p. 152.) This averaging process is shown below. See Fig. A.6.

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[9]The equivalent of four Red activities is reflected implicitly: engagements, preparation for and recovery from engagements, movement, and other. Red's activities are treated in thi summary fashion (relative to the treatment of Blue) because of space limitations in the spreadsheet.

[10]This preprocessor (another small spreadsheet designated EQUIP. WK1), is not shown here but is described in Romero, Rydell, and Stanton, 1987, pp. 22-26. It allows the user to specify inputs for up to six vehicles and the number of each vehicle in the unit, then computes "composite" characteristics as a weighted average of the characteristics of each vehicle type.

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[Alt-F]FIRE, AIR AND ENGINEER SUPPORT ALLOCATION ([illegible] Screens)

              Red      Blue

      CLOSE AIR SUPPORT (PLANES AND HELOS)

   TECH/ORG
STARTING CAS       684      648 initial CAS aircraft
SORTIES/DAY        2.50     2.50 sorties/day
AIR ATTRITION      0.07     0.04 Attrition rate per sortie
TONS ORD/S         6.00     8.00 tons ordnance per sortie
HITS/TON           1.30     4.00 # vehicles hit per ton of ordnance
KILLS/HIT          0.90     0.25 Prob. vehicle killed given hit

   PERCENTAGE ALLOCATION
% ATTK             0.10     0.[illegible] % of aircraft supporting atk mvrs

      HEADQUARTERS ARTILLERY
   TECH/ORG
TONS/D/HQ          1E+03 1.6E+03 tons ammo fired per day per HQ
HITS/TON           0.2[illegible]    0.20 veh hits per ton ammo fired
KILLS/HIT          0.50     0.50 Prob. vehicle killed given hit
TONS SUPPD/T       0.60     0.60 tons enemy HQ fire suppressed/ton

   PERCENTAGE ALLOCATION
% ATTK             0.10     0.10 % of HQs supporting attk mvrs
%COUNTERHQ         0.10     0.50 %of HQs in counterfire against HQs

      ENGINEERS
   TECH/ORG
DEL/D/ENG          NA       0.50 Kmvr-days delay/Blue engnr-unit-day
ACCEL/ENG          0.30     NA   Kmvr-days accel Red engnr-unit-day

      AIR INTERDICTION
   TECH/ORG
INITIAL AI          162  569.00 initial AI aircraft
SORTIES/DAY        1.50     2.00 sorties/day
AIR ATTRITION      0.15     0.10 Attrition rate per sortie
TONS ORD/S         6.00     5.00 tons ordnance per sortie

      AI ATTRITION MISSION
   TECH/ORG
HITS/TON           0.40     0.75 # vehicles hit per ton of ordnance
KILLS/HIT          0.90     0.30 Prob. vehicle killed given hit

      AI DELAY MISSION
   TECH/ORG
HITS/TON           [illegible].25     [illegible].50 target hits/ton of ordnance
KILLS/HIT          [illegible].45     [illegible].50 Prob. target killed given hit

DELAY/KILL       180.00   150.00 mins. mvr delay per target killed

      AI DISRUPTION MISSION
   TECH/ORG
C3 ERR/TON         0.002    0.[illegible] Incr. in mvr C3 error/ton ordnance

      AI COUNTER HQ MISSION
   TECH/ORG
TONS SUPPD/T       0.7[illegible]     [illegible] tons enemy HQ fire suppressed/ton

      AI SUPPLY MISSION
   TECH/ORG
S VEH HITS/TON     2.[illegible]     NA   supply veh hits per ton ordnance
S VEH KILLS/H      [illegible]     NA   Prob. supply veh killed given hit
VEH REIN HITS/T    NA       4.00 Reinforcement veh hits/ton ordnance
VEH REINF K/H      NA       [illegible].80 Prob. reinf vehicle killed given hit

   POLICY AND NORMS -- PERCENTAGE ALLOCATION
% ATTRIT           [illegible]5     [illegible] % AI sorties assigned attrition mission
%DELAY             [illegible]     [illegible] % AI sorties assigned delay mission
%DISRUPT           [illegible]     [illegible] % AI sorties assigned disrpt mission
%COUNTER HQ        [illegible]     [illegible] % AI sorties assigned counterHQ mission
```

Fig. A.4—Fire, air, and engineer support input screens

FIRE, AIR AND ENGINEER SUPPORT ALLOCATION
(INPUT CONVERSIONS)

	Red	Blue	
CLOSE AIR SUPPORT (PLANES AND HELOS)			
CAS % DEFD	0.70	0.70	% supporting defd rmvrs
VEH/SORTIE	0.28	2.54	veh kills/sortie
CUM SORTIES	9771	17200	cum sorties avail
SORTIES/DAY	1272.2	1685.6	avg sorties/day
SORT/DAY--ATTK	127.2	505.7	# sorties/day supporting attk mvrs
SORT/DAY--DEFD	890.6	1179.9	# sorties/day supporting defd mvrs
HEADQUARTERS ARTILLERY			
#HQs AVAIL	7.0	8.00	Red HQs
HQ % DEFD	0.70	0.50	% supporting defd mvrs
VEH/D/HQ	6.3	116.3	vehs/day/rHQ
VEH/D-ATK (HQ)	4.4	93.0	veh kills/d suptng atk mvrs
VEH/D-DEF (HQ)	30.7	465.1	veh kills/d suptng def mvrs
TONS S/DAY (HQ)	153	2341	tons/d suppd in counterfire
CAS AND HQ			
VEH/DAY--ATTK	39.9	1375.9	#veh kills sptng atk rmvrs
VEH/DAY-DEFD	654.1	1291.0	#veh kills sptng def rmvrs
ENGINEERS			
DEL/DAY	2.10	NA	days Red accel/d
ENG DELAY	NA	5.00	days Red delayed/d
AIR INTERDICTION			
CUM SORTIES	1080	5695	cum sorties
SORTIES/DAY	206.6	1082.1	sorties/day
AI ATTRITION MISSION + HQ DEEP FIRES			
VEH/DAY--DEEP FIRE	4.4	93.0	vehs killed/day by HQs
VEH/ATTRIT S	0.52	2.21	veh kills/attr sortie
VEH/DAY	9.7	482	veh kills/day
AI & DEEP FIRES DELAY MISSION			
DEL/DAY--DEEP FIRE	0.0	0.0	mins delay/day by HQs
MINS/DELAY S	55.53	137.11	mins delay/delay sortie
MINS/DAY	1146.9	14836	mins delay/day
AI DISRUPTION MISSION			
C-3 ERR/DIS S	[illegible]	0.016	C3 error disrupt sortie
C-3 ERR/DAY	0.236	8.842	C3 error/day
AI COUNTER HQ MISSION			
HQ TONS SUPP/D	191.16	593.42	tons hq fire suppd/d
AI SUPPLY MISSION			
%SUPPLY	0.00	0.00	Percentage allocation
SUPPLY VEHS/DAY	0.00	NA	supply vehicles killed per day
VEH REINF K/D	NA	0.00	veh reinf killed/day

Fig. A.5—Fire, air, and engineer support input conversions screens (Derived from screens in Fig. A.4)

SUMMARY VEHICLE CHARACTERISTICS FOR BLUE AND RED

BLUE DIVISIONS				RED DIVISIONS		
Tank	Mech.	Avg.		Tank	Mot Rifle	Avg.
46.8%	53.2%	100.0%	Deployed	47.7%	52.3%	100.0%
36.0%	64.0%	100.0%	To M+14	53.4%	46.6%	100.[illegible]%
30.9%	69.1%	100.0%	To M+60	47.2%	52.8%	100.0%
Tank	Mech.	Avg.	Period used	Tank	Mot Rifle	Avg.
46.8%	53.2%	100.0%	Deployed	47.7%	52.3%	100.0%
17351	17312	17330	Personnel	11467	12705	12114
55.7%	58.1%	57.0%	Cbt pers/tot pers	57.9%	69.4%	63.9%
33.9%	34.4%	34.1%	Cbt vehs/tot vehs	34.9%	34.6%	34.7%
1384	1413	1399.44	VEH/MVR	1047	1037	1041.77
		17330.24	PERS/MVR			12114.38
			GENERAL			
			TECH/ORG			
0.60	0.60	0.60	DISENG %AGE-ATK			NA
0.70	0.70	0.70	DISENG %AGE-DEF			NA
0.50	0.50	0.50	% NON-MV/CBT	0.50	0.50	0.50
			POLICY & NORMS			
1.75	1.75	1.75	TAC PWR-ATK	4.00	4.00	4.00
0.15	0.15	0.15	RED ATTR-BLATK	0.05	0.05	0.05
0.10	0.10	0.10	BLUE ATTR-RATK	0.66	0.66	0.66
			MOBILITY			
			TECH/ORG			
20.00	20.00	20.00	MVMT/HR-ADMIN	15.00	15.00	15.00
5.00	5.00	5.00	MVMT/HR-BATTL	5.00	5.00	5.00
69.21	69.15	69.18	VEH DASH SPD	65.84	65.73	65.78
0.04	0.04	0.04	VEH BRKDWNS	0.06	0.06	0.06
0.79	0.73	0.76	POL CONS/KM	0.75	0.66	0.70
180	180	180.00	TIME-CHNG FORM	180	180	180.00
			POLICY & NORMS			
0.33	0.33	0.33	%MVMT-ADM FORM	0.80	0.80	0.80
0.75	0.75	0.75	TAC STA PD-ATK	0.86	0.96	0.91
1.00	1.00	1.00	TAC STA PD-DEF	1.74	1.80	1.77
50.00	50.00	50.00	DIS/TAC MV-ATK	571.63	566.83	569.12
10.00	10.00	10.00	DIS/TAC MV-DEF	234.38	242.82	238.79
0.33	0.33	0.33	IF %OPNL MOVE	0.33	0.33	0.33
			LETHALITY			
			TECH/ORG			
0.05	0.05	0.05	% FIRERS-ADMIN	0.03	0.03	0.03
0.15	0.15	0.15	% FIRERS-BATTL	0.18	0.18	0.18
5.00	5.00	5.00	MAX IF RATE-S	5.00	5.00	5.00
0.00	0.00	0.00	MAX IF RATE-M	0.00	0.00	0.00
3.42	3.37	3.40	MAX DF RATE-S	3.66	3.64	3.65
2.12	2.05	2.08	MAX DF RATE-M	2.42	2.40	2.41
20.00	20.00	20.00	IF RANGE-MAX	27.00	27.00	27.00
0.50	0.50	0.50	IF RANGE-MIN	3.00	3.00	3.00
4.17	4.17	4.17	DF RANGE-MAX	3.10	3.25	3.18
0.07	0.07	0.07	DF RANGE-MIN	0.06	0.06	0.06
0.78	0.78	0.78	HITS/RND-S/S	0.58	0.54	0.56
0.72	0.71	0.71	HITS/RND-S/M	0.49	0.46	0.47
0.66	0.66	0.66	HITS/RND-M/S	0.31	0.28	0.29
0.57	0.57	0.57	HITS/RND-M/M	0.20	0.18	0.19
1.19	1.23	1.21	HIT DEGRD-MAXR	0.60	0.64	0.62
0.47	0.47	0.47	KILLS/HIT	0.51	0.49	0.50
0.27	0.27	0.27	ANTI-PERS COEF	0.29	0.30	0.30
0.33	0.33	0.33	IF HITS/R COEF	0.33	0.33	0.33

Fig. A.6—Summary of characteristics of armored, mechanized, and average Blue and Red division used in illustrations

			POLICY & NORMS			
1.50	1.50	1.50	ACT IF RATE-S	1.50	1.50	1.50
0.00	0.00	0.00	ACT IF RATE-M	0.00	0.00	0.00
1.17	1.14	1.16	ACT DF RATE-S	1.24	1.21	1.23
0.24	0.23	0.23	ACT DF RATE-M	0.27	0.26	0.27
20.00	20.00	20.00	ACT IF RANGE-HI	25.00	25.00	25.00
0.50	0.50	0.50	ACT IF RANGE-LO	0.50	0.50	0.50
3.55	3.55	3.55	ACT DF RANGE-HI	3.64	3.70	3.67
0.07	0.07	0.07	ACT DF RANGE-LO	0.06	0.06	0.06
15.00	15.00	15.00	IF DIST-FLOT-HI	8.00	8.00	8.00
5.00	5.00	5.00	IF DIST-FLOT-LO	5.00	5.00	5.00
1.75	1.77	1.76	DF DIST-FLOT-HI	1.60	1.54	1.57
0.10	0.10	0.10	DF DIST-FLOT-LO	0.13	0.15	0.14
0.91	0.92	0.91	% FIRERS DF	0.83	0.79	0.81
0.29	0.30	0.30	% PERS DISMTD	0.12	0.13	0.13
0.10	0.10	0.10	VEH DIS%-DEF	0.10	0.10	0.10
10.00	10.00	10.00	DESIRD FRNTAGE	10.00	10.00	10.00
0.50	0.50	0.50	MISC LETH MU-ATK	0.50	0.50	0.50
0.50	0.50	0.50	MISC LETH MU-DEF	0.50	0.50	0.50
0.60	0.60	0.60	% ATKRS-1st ECH	0.67	0.67	0.67
			VULNERABILITY			
			TECH/ORG			
0.54	0.52	0.53	HARDNESS-FRONT	0.83	0.81	0.82
0.37	0.36	0.36	HARDNESS-SIDE	0.54	0.54	0.54
0.15	0.15	0.15	CONCLMT-ADMIN	0.05	0.05	0.05
0.64	0.65	0.64	CONCLMT-BATTL	0.34	0.32	0.33
0.15	0.15	0.15	MAX ATTR/DAY	0.15	0.15	0.15
0.40	0.40	0.40	BREAKPOINT	0.25	0.25	0.25
			POLICY & NORMS			
35.00	35.00	35.00	SHADOW DIS-ATK	35.00	35.00	35.00
0.00	0.00	0.00	SHADOW DIS-DEF	0.00	0.00	0.00
0.50	0.50	0.50	DEFENSE PREP%	0.50	0.50	0.50
50.0	50.0	50.00	VEH DIS-ATK	50.0	50.0	50.00
0.50	0.50	0.50	MISC VULN MU-A	0.50	0.50	0.50
0.50	0.50	0.50	MISC VULN MU-D	0.50	0.50	0.50
			C3IEW			
			TECH/ORG			
180.00	180.00	180.00	ACQ TIME-S TGT	300.00	300.00	300.00
1.50	1.50	1.50	STGT#SHOTS-ACQ	3.00	3.00	3.00
0.05	0.05	0.05	C-3 ERROR	0.05	0.05	0.05
0.02	0.02	0.02	C-3 REGEN/DAY	0.01	0.01	0.01
0.20	0.20	0.20	MAX C-3 ERR	0.40	0.40	0.40
0.03	0.03	0.03	INTEL ERROR	0.03	0.03	0.03
1.50	1.50	1.50	EW EFFNESS	1.75	1.75	1.75
3.00	3.00	3.00	ATK PREP&RECOV	3.00	3.00	3.00
0.20	0.20	0.20	DEF PREP&RECOV	0.20	0.20	0.20
			BASIC LOAD & LOGISTICS			
			TECH/ORG			
6.98	7.28	7.14	PERS/VEH	7.32	8.37	7.87
34.23	32.60	33.36	AMMO/VEH	36.64	37.09	36.87
500.00	500.00	500.00	POL/VEH	500.00	500.00	500.00
200.00	200.00	200.00	OTH/VEH	200.00	200.00	200.00
25.87	24.07	24.91	VEH WEIGHT	29.97	30.13	30.05
53.44	53.37	53.40	AMMO WEIGHT	51.76	52.83	52.32
200	200	200.00	PERS REGEN/DAY	50	50	50.00
20	20	20.00	VEH REGEN/DAY	5	5	5.00
0.33	0.33	0.33	CAS REGEN COEF	0.25	0.25	0.25
			POLICY & NORMS			
1.00	1.00	1.00	%REPL/ATK CYC	1.00	1.00	1.00
1.00	1.00	1.00	%REPL/DEF CYC	1.00	1.00	1.00
3.00	3.00	3.00	DIS-EXCHPT-DEF			NA
20.0	20.0	20.00	DIS-EXCHPT-ATK			NA
0.25	0.25	0.25	% REST			NA
0.08	0.08	0.08	%REPRBL LOSS-M			NA
0.50	0.50	0.50	%REPRBL LOSS-T			NA
0.20	0.20	0.20	% REPRD-M			NA
14000	14000	14000.00	LOAD RATE			NA
150	150	150.00	SUPP VEH MOVEF			NA
5.0	5.0	5.00	CAP/SUPP VEH			NA
0.010	0.010	0.01	CAP DEGRDN/KM			NA

Fig. A.6—continued

Sources and Methods for Estimating MVR and RMVR Inputs

There are far too many data elements to permit a comprehensive discussion of these data. This section will restrict itself to a few highlights.

(1) Unit Composition

Numbers of vehicles of each type and of personnel utilized information are from Posen, 1984–85, p. 105; Phillips, 1987, pp. 12–13, 46, 56–7; Mako, 1983, pp. 114–115; Dunnigan, 1979b, p. 7; Sadykiewicz, 1987, p. 80; U.S. Army, Command and General Staff College, FC-101-5-2, 1987, pp. 6-7 to 6-9; Cordesman, 1983, p. 47; and Erickson et al., 1986, p. 71.

(2) General Policy and Norms

Desired combat power ratios when attacking are inferred from each side's current doctrine. Desired attrition reflects a mobile, only briefly engaging concept for Blue, versus an assumed Soviet attrition orientation. Other variables are guesses.

(3) Mobility

Deitchmann, 1979a, p. 61 quotes average actual speeds in wartime, while Isby, 1981, indicates Soviet norms. Dunnigan, 1978b, provides estimates that are about '2 to 2/3 those found in Soviet norms or U.S. planning factors (e.g. those in FM-101-10-1) Dash speeds are from "Wheeled vehicles—data tables," 1987, as is POL consumption per km. Policy and norm variables are guesses, informed on the Soviet side by Isby, 1981; Bellamy, 1987; Erickson et al., 1986; and U.S. Army, 1978.

(4) Lethality

Most capability parameters are inferred or extrapolated from Isby, 1981; Isby and Kamps, 1985, and 1983, pp. 25, 26, 28, 29, 30, 42, 46, 48–53; Department of the Army (e.g. p. 3-13); Department of Defense, 1987 (e.g. p. 75); Bellamy 1986 and 1987; "King of the Battlefield," 1986 (e.g. p. 54); Dupuy, 1979 (e.g. p. 192); FC-101-5-2 1987 (e.g. p. 6-22); FM-101-10-1 1976; and Dunnigan 1982 (e.g. p. 75). Norms come in part from Isby, 1981, pp. 73–74, 163; and 176; Erickson et al., 1986, p. 165; and Bellamy, 1987, p. 204.

(5) C-3IEW

These parameters were mostly guesses.

(6) Basic Load and Logistics

Data on vehicle loads came from "Wheeled vehicles—data tables" 1987; from Isby, 1981 Isby and Kamps, 1985. Breakdown and repair rates came from Dews, 1982, pp. 6 and 8; from Dupuy, 1979, pp. 216 and 221; from Deitchmann, 1979; Dayan, 1960, p. 83; and from Cordesman, 1983, p. 51. Weights of vehicles and loads came from the above sources as well as Department of the Army, FM-101-10-1, 1976; and U.S. Army, FC-100-5-2, 1987. POL consumption came from the above plus Dunnigan, 1982, p. 48.

Figure A.7 shows the composite vehicle characteristics used in the illustrations.[11]

RESOURCE CONSUMPTION COEFFICIENTS

Explanation of the coefficients shown in Fig. A.8 is provided in App. B. Below are shown the values used for each coefficient. Most values were guesses, informed partly by the sources used for basic load and logistics information, and varied to bring base case consumption variables within acceptable ranges.

[11]Obviously, some concepts (such as the technocommandos concept) assumed the use of different types of vehicles. Under these concepts, some of the characteristics in Fig. A.7 were changed.

```
[ALT-M]  MANEUVER UNIT DESCRIPTION AND OPERATIONAL POLICY (7 screens)

                     Red      Blue

             SIZE OF MANEUVER UNIT (MVR)

     TECH/ORG
VEH/MVR              1042     1399 # vehicles per maneuver unit          [S1]

          GENERAL

     TECH/ORG
DISENG %AGE-ATK     NA        0.60 % of engagement                       [G1]
DISENG %AGE-DEF     NA        0.70 % of engagement                       [G1]
% NON-MV/CBT        0.50      NA   %time not moving or fighting          [G2]

     POLICY & NORMS
TAC PWR-ATK         2.00      1.50 Ratio: Attack to defend combat power[G3]
RED ATTR-BLATK      0.01      0.10 %desired/engagement                   [G4]
BLUE ATTR-RATK      0.05      0.70 %desired/engagement                   [G4]

          MOBILITY

     TECH/ORG
MVMT/HR-ADMIN       15.0        20 km/hr                                 [M1]
MVMT/HR-BATTL        5.0         5 km/hr                                 [M1]
VEH DASH SPD        63.8        69 km/hr                                 [M2]
VEH BRKDWNS         0.060     NA   % vehicles that breakdown per day     [M3]
POL CONS/KM         NA         0.8 gals/km                               [M4]
TIME-CHNG FORM      180.0      180 minutes to change formation type      [M5]

     POLICY & NORMS
%MVMT-ADM FORM      0.80      0.33 % of mvmt time in adm. formation      [M6]
TAC STA PD-ATK      0.91      0.75 minutes stationary when attacking     [M7]
TAC STA PD-DEF      1.77      1.00 minutes stationary when defending     [M7]
DIS/TAC MV-ATK      569.1     50.0 meters moved per dash in attack       [M8]
DIS/TAC MV-DEF      238.79    10.0 meters moved per dash on defense      [M8]
IF %OPNL MOVE       0.33      0.33 IF aggressiveness as % of DF aggrss.[M9]

          LETHALITY

     TECH/ORG
% FIRERS-ADMIN      0.10      0.20 % veh able to fire in adm. formation[L1]
% FIRERS-BATTL      0.60      0.50 % veh able to fire in btl. formation[L1]
MAX IF RATE-S       5.0       5.00 max rnds/min of IF while stationary [L2]
MAX IF RATE-M       0.0       0.00 max rnds/min of IF while moving      [L2]
MAX DF RATE-S       3.7       3.40 max rnds/min of DF while stationary [L2]
MAX DF RATE-M       2.4       2.08 max rnds/min of DF while moving      [L2]
IF RANGE-MAX        27.00    20.00 km                                   [L3]
IF RANGE-MIN        3.00      0.50 km                                   [L3]
DF RANGE-MAX        3.18      4.17 km                                   [L3]
DF RANGE-MIN        0.06      0.07 km                                   [L3]
HITS/RND-S/S        0.56      0.68 P(hit/rnd): sta DF, sta tgt @min rng[L4]
HITS/RND-S/M        0.47      0.56 P(hit/rnd): sta DF, mov tgt @min rng[L4]
HITS/RND-M/S        0.29      0.46 P(hit/rnd): mov DF, sta tgt @min rng[L4]
HITS/RND-M/M        0.19      0.37 P(hit/rnd): mov DF, mov tgt @min rng[L4]
HIT DEGRD-MAXR      0.62      1.21 Degradation of P(hit/rnd) at max rng[L5]
KILLS/HIT           0.50      0.47 Prob. of vehicle kill given hit      [L6]
ANTI-PERS COEF      0.30      0.27 Pr. dismtd infy kill given veh kill [L7]
IF HITS/R COEF      0.33      0.33 Degradation of P(hit/rnd) for IF     [L8]

     POLICY & NORMS
ACT IF RATE-S       1.50      1.50 actual IF rnds/min while stationary [L9]
ACT IF RATE-M       0.00      0.00 actual IF rnds/min while moving      [L9]
ACT DF RATE-S       1.23      1.16 actual DF rnds/min while stationary [L9]
ACT DF RATE-M       0.27      0.23 actual DF rnds/min while moving      [L9]
ACT IF RANGE-HI     25.00    20.00 km                                   [L9]
ACT IF RANGE-LO     0.50      0.50 km                                   [L9]
ACT DF RANGE-HI     3.67      3.55 km                                   [L9]
ACT DF RANGE-LO     0.06      0.07 km                                   [L9]
IF DIST-FLOT-HI     8.00     15.00 km                                   [L10]
IF DIST-FLOT-LO     [illegible]  5.00 km                                [L10]
DF DIST-FLOT-HI     .57       1.76 km                                   [L10]
DF DIST-FLOT-LO     0.14      0.10 km                                   [L10]
% FIRERS DF         0.81      0.91 % veh firing in DF mode              [L11]
% PERS DISMTD       0.13      0.30 % personnel acting as dismtd infy    [L12]
VEH DIS%-DEF        0.10      0.10 max dis betw veh as % of avg range   [L13]
DESIRD FRNTAGE      10.00    10.00 km                                   [L14]
MISC LETH MU-AT     0.90      1.20 x Friendly lethality                 [L15]
MISC LETH MU-DE     0.90      1.20 x Friendly lethality                 [L15]
% ATKRS-1st ECH     0.67      NA   % of atk veh in 1st ech              [L16]
```

Fig. A.7—Red and Blue composite MVR characteristics

```
VULNERABILITY

  TECH/ORG
HARDNESS-FRONT    0.82    0.53 x hardness assumed in enemy P(kill) [V1]
HARDNESS-SIDE     0.54    0.56 x hardness assumed in enemy P(kill) [V1]
CONCLMT-ADMIN     0.05    0.15 % veh concealed from enemy          [V2]
CONCLMT-BATTL     0.33    0.64 % veh concealed from enemy          [V2]
MAX ATTR/DAY      0.15    0.15 % pers attr/day before unit breaks  [V3]
BREAKPOINT        0.25    0.40 % pers cum attr before unit breaks  [V4]

  POLICY & NORMS
SHADOW DIS-ATK    NA     35.00 km                                  [V5]
SHADOW DIS-DEF    NA      0.00 km                                  [V5]
DEFENSE PREP%     NA      0.50 % of max preparations               [V6]
VEH DIS-ATK       50.0   50.0 min dist betw veh--m                 [V7]
MISC VULN MU-A    0.25    0.90 x Enemy lethality                   [V8]
MISC VULN MU-D    0.25    0.80 x Enemy lethality                   [V8]

   C3IEW

  TECH/ORG
ACQ TIME-S TGT   300.0  180.0 secs. reqd to acquire stationary tgt[C1]
STGT#SHOTS-ACQ    3.00   1.50 # of tgt's shots reqd to acq sta tgt[C1]
C-3 ERROR         0.05   0.05 min % errors in C-3 system          [C2]
C-3 REGEN/DAY     0.01   0.02 daily reduc. in C-3 error from regen[C3]
MAX C-3 ERR       0.40   0.20 max % errors in C-3 system          [C3]
INTEL ERROR       0.03   0.03 min % errors in Intel system        [C4]
EW EFFNESS        1.75   1.50 x Blue/red C-3 err due to EW        [C5]
ATK PREP&RECOV   10.00   NA   Prep&recov time as mult of atk time [C6]
DEF PREP&RECOV    4.00   NA   Prep&recov time as mult of def time [C6]

   BASIC LOAD & LOGISTICS

  TECH/ORG
PERS/VEH          7.87   7.14 passengers and crew per veh         [B1]
AMMO/VEH           37     33 rounds per veh                       [B1]
POL/VEH           NA     500 gals POL per veh                     [B1]
OTH/VEH           NA     200 lbs. other resources per veh         [B1]
VEH WEIGHT        NA      25 tons / veh weight                    [B1]
PERS WEIGHT       NA     200 lbs./person                          [B1]
AMMO WEIGHT       52.3    53 lbs./round
POL WEIGHT        NA     8.5 lbs./gallon
PERS REGEN/DAY    NA     200 # non cbt casualties recoverable/day[B2]
VEH REGEN/DAY        5    20 # veh losses recoverable/day         [B2]
CAS REGEN COEF    NA    0.33 Cbt cas recov per non cbt cas recov  [B2]

  POLICY & NORMS
%REPL/ATK CYC     1.00   1.00 % veh losses repl. by next atk engmt[B3]
%REPL/DEF CYC     1.00   1.00 % veh losses repl. by next def engmt[B3]
DIS-EXCHPT-DEF    NA     3.00 km from def engmt to supply exch. pt[B4]
DIS-EXCHPT-ATK    NA     20.0 km from atk engmt to supply exch. pt[B4]
% REST            NA     0.25 % of time spent resting             [B5]
%REPRBL LOSS-M    NA     0.08 % of losses repairable by mvr       [B6]
%REPRBL LOSS-T    NA     0.50 % of losses repairable by theater   [B6]
% REPRD-M         NA     0.20 % of reprbl losses reprd by mvr     [B7]
LOAD RATE         NA    14000 tons supplies loaded/hr             [B8]
SUPP VEH MOVEF    NA      150 km/day that a supply veh can move   [B9]
CAP/SUPP VEH      NA      5.0 tons capacity per supply veh        [B10]
CAP DEGRDN/KM     NA    0.001 tons cap degrdn per km total dist   [B11]
```

Fig. A.7—continued

LIMITS ON AVAILABLE BLUE FORCES AND RESOURCES

In this block shown in Fig. A.9 are included all "budgets" of Blue resources against which are compared the needs estimated by MOSCOW. Some of these are unambiguous, such as the total tons of ammunition or number of personnel that can be available for the campaign. Others are subjective and somewhat arbitrary, such as the maximum number and maximum average daily rate of acceptable personnel casualties. Flow limits (expressed as daily rates) depend primarily on the assumed throughput of transportation or logistics infrastructure, while force limits are based on mobilization assumptions.

{cons. coeffs.}COEFFICIENTS OF RESOURCE CONSUMPTION (BLUE ACTIVITIES)

ACTIVITIES	
Prepare defenses	[PRE]
Survey and reconnoiter	[S&R]
Delay for higher echelon orders	[DEL]
Move to wpn range (1st contact)	[MWR]
Attack--1st phase (1 Red unit)	[ATK1]
Attack--2nd phase (reinf. Red)	[ATK2]
Defend	[DEF]
Disengage (to shadow dist)	[DIS]
Re-close (from shadow dist)	[RCL]
Reconstitute (unit cohesion)	[RCST]
Move to exchange point	[MTX]
Load supplies	[LOD]
Repair (vehicles and pers)	[RPR]
Rest	[RES]
Move to standby position	[MTS]
Move cross-country (non-mvr)	[MXC]
Unload supplies	[UNL]
Total--all activities in cycle	[TOT]

Units/wt. conversion factors:

	Lbs.	Tons
Vehicle	49820	24.9
Personnel	200	0.10
Ammo	53	0.03
POL	8.5	0.004
Other	1.0	0.001

RESOURCE CONSUMPTION COEFFICIENTS

ACTVTY	%Crit path	%Unit-tm	Veh	Pers	Ammo	POL	Other
PRE	1.00	1.00	0.020	0.30	0.33	0.50	25.0
S&R	1.00	1.00	0.040	0.40	0.75	0.75	25.0
DEL	1.00	1.00	0.010	0.20	0.33	0.50	25.0
MWR	1.00	1.00	0.060	0.30	1.00	1.00	25.0
ATK1	1.00	1.00	0.080	0.60	1.00	1.00	25.0
ATK2	1.00	1.00	0.080	0.60	1.00	1.00	25.0
DEF	1.00	1.00	0.080	0.60	1.00	1.00	25.0
DIS	1.00	1.00	0.040	0.40	1.00	1.00	25.0
RCL	1.00	1.00	0.040	0.40	1.00	1.00	25.0
RCST	1.00	1.00	0.030	0.10	1.00	0.50	25.0
MTX	1.00	1.00	0.020	0.15	0.75	0.85	25.0
LOD	0.00	1.00	0.005	0.07	0.33	0.50	25.0
RPR	0.33	1.00	0.005	0.07	0.33	0.50	25.0
RES	1.00	1.00	0.005	0.07	0.33	0.50	25.0
MTS	1.00	1.00	0.040	0.15	0.75	0.85	25.0
MXC	1.00	1.00	0.040	0.15	0.75	0.85	25.0
UNL	1.00	1.00	0.005	0.07	0.33	0.50	25.0
Units	%of actvy time	%mvr	%vehs/d	%pers/v	%ammo/v	%act(mv)	lbs

Fig. A.8—Resource consumption coefficients

MVRs available were based on the number of ADEs available at or just after M-day given in Posen, 1984, p. 95 (interpolating based on Posen's figure), and supplemented by Mako, 1983, p. 134. Casualty limits are guesses, presuming that total acceptable casualties in a short European war are approximately double those in Korea or Vietnam (and about five times the number of fatalities in each war). Weekly casualties are a guess. Stocks of replacement personnel and vehicles are guesses but are probably within a factor of two of the stocks and reinforcements that could be available in Europe in the first 30 days after mobilization. Amounts of other resources are pure guesses.[12]

Daily limits, except lift, are either arbitrary or divide available stocks by an assumed campaign duration planning factor (usually 30 days) that might be used to plan lift requirements. Lift per day available assumes that *all* of DoD's *66 million ton-miles per day strategic lift* objective (see, for example, Epstein, 1986, p. 72; or Weinberger, 1987, p. 36) is made available to transport reinforcements and supplies to Europe. 6.6×10^7 divided by an approximately 6.0

[Alt-L] LIMITS OF BLUE FORCES AND RESOURCES FOR ZONE (2 screens)

CATEGORY	RESOURCE	AVAIL.	
TOTAL MVR AVAILABLE	INITIAL	21.80	mvrs
MAXIMUM CASUALTIES	TOT CASLTY	250000	pers
	AVG CASLTY/DAY	5000.0	pers/day
REPLACEMENT STOCKS AVAILABLE	PERSONNEL	200000	pers
	VEHICLES	12000	veh
	AMMO (TONS)	7.0E+05	tons
	POL (TONS)	5.0E+06	tons
	OTHER (TONS)	1.0E+05	tons
	LIFT (TONS)	1.5E+06	tons
DAILY REPLACEMENTS AVAILABLE	PERSONNEL	4000.0	pers/day
	VEHICLES	400.0	veh/day
	AMMO (TONS)	2.0E+04	tons/day
	POL (TONS)	4.0E+05	tons/day
	OTHER (TONS)	4.0E+03	tons/day
	LIFT (TONS)	1.1E+04	tons/day
SUPPLY & HQs AVAILABLE	SUPP. VEHS	100000	# vehs
	TOLERANCE LEVEL:	110%	Reqd/avail

Fig. A.9—Limits of Blue forces and resources available

[12]*Stock* of lift available probably is meaningless because it is the capacity of lift *per day* that matters.

$\times\ 10^3$ mile round trip yields the average number of tons per day that available lift could transport to Europe. (This estimate of 11,000 tons per day falls between Kaufmann's estimates of 7,200 for a scenario in which Europe and Southwest Asia require resupply simultaneously and 14,700 if it is needed in Europe alone. See Kaufmann, 1986, p. 34.) The estimated number of supply trucks is arbitrary. HQs available is a derived variable that repeats the input provided in the success criteria block. Obviously, all of these estimates are very crude.

CONSTRAINTS ON BLUE AND RED UNIT ACTIVITIES

The user can constrain the time taken by any activity to be a fixed fraction of total cycle time, for both the attack and defend cycles. Figures A.9 and A.10 show, for each activity, the "unconstrained" time and cycle fraction absorbed by each activity. If the user inputs a nonzero value in the "Constraint % of Total" cell, a nonzero value will appear in the corresponding "Constrained time" cell and be reported to the corresponding cell in the activity cycle block. In the illustrations, no proportional constraints were employed.

ACTIVITY CYCLES DISPLAY SCREENS

The activity cycles of attack and defend MVRs each occupy two horizontally adjacent screens. (Computation of inputs to their equations occupies several others, of which the most important are described in Apps. B and C.) The first screen is a table in which each row corresponds to an activity and each column to a resource. (The cycle is elaborated in App. B.) The second screen provides summary statistics on total and daily consumption of each resource across the entire cycle, and a calculation of the MVR's Campaign Kill Rate. Figures A.11 and A.12 show the attack and the defend cycle respectively.

MOSCOW OUTPUT DISPLAY SCREENS

Figure A.13 lists the two screens used to display MOSCOW's output and supporting output calculations, and diagnostic and supplementary information. Appendix E describes these output calculations. This section discusses the diagnostic and miscellaneous outputs, shown below in Fig. A.14.

MOSCOW's principal outputs are the resources needed to achieve the success criteria designated by the user while campaigning according to the specified concept. In the supporting calculations section, additional information is provided for two purposes. First, ground forces analysts are often accustomed to measures of effectiveness that relate more to *relative* force *performance* than to *absolute* force *requirements*; a typical example is the "force exchange ratio." Some of this information can be provided for the benefit of users who wish to emphasize it. Second, some output variables can be checked to see if they fall within broad historical norms. This screen displays these computations.[13]

[13]The diagnostic and miscellaneous outputs screen can be found on the spreadsheet immediately below the two main output and supporting calculations screens.

ACTIVITY	TOT	MVR/ATK CONSTRAINTS
Unconstrained Time (days)	2.289	
- Constrained Time	0.000	

ACTIVITY	PRE	S&R	DEL	MWR	ATK1	
Unconstrained % of Total	0.0%	2.3%	1.1%	1.2%	1.4%	
Unconstrained Time (days)	0.000	0.052	0.025	0.028	0.032	
- Constraint %of Total	0.0%	0.0%	0.0%	0.0%	0.0%	
Constrained Time (days)	0.000	0.000	0.000	0.000	0.000	
ACTIVITY	ATK2	DEF	DIS	RCL	RCST	MTX
Unconstrained % of Total	0.0%	0.0%	19.3%	18.1%	2.4%	11.1%
Unconstrained Time (days)	0.000	0.000	0.443	0.414	0.056	0.254
- Constraint %of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Constrained Time (days)	0.000	0.000	0.000	0.000	0.000	0.000
ACTIVITY	LOD	RPR	RES	MTS	MXC	UNL
Unconstrained % of Total	0.5%	3.7%	25.0%	13.7%	0.0%	0.0%
Unconstrained Time (days)	0.011	0.086	0.572	0.314	0.000	0.000
- Constraint %of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Constrained Time (days)	0.000	0.000	0.000	0.000	0.000	0.000

ACTIVITY	TOT	MVR/DEF CONSTRAINTS
Unconstrained Time (days)	2.187	
- Constrained Time	0.000	

ACTIVITY	PRE	S&R	DEL	MWR	ATK1	
Unconstrained % of Total	22.9%	2.4%	1.1%	0.0%	0.0%	
Unconstrained Time (days)	0.500	0.052	0.025	0.000	0.000	
- Constraint %of Total	0.0%	0.0%	0.0%	0.0%	0.0%	
Constrained Time (days)	0.000	0.000	0.000	0.000	0.000	
ACTIVITY	ATK2	DEF	DIS	RCL	RCST	MTX
Unconstrained % of Total	0.0%	13.8%	0.0%	0.0%	3.3%	1.7%
Unconstrained Time (days)	0.000	0.301	0.000	0.000	0.072	0.038
- Constraint %of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Constrained Time (days)	0.000	0.000	0.000	0.000	0.000	0.000
ACTIVITY	LOD	RPR	RES	MTS	MXC	UNL
Unconstrained % of Total	3.5%	30.2%	26.3%	0.0%	0.0%	0.0%
Unconstrained Time (days)	0.076	0.660	0.575	0.000	0.000	0.000
- Constraint %of Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Constrained Time (days)	0.000	0.000	0.000	0.000	0.000	0.000

Fig. A.10—Proportional constraints on MVR activities
(Can be constrained to be a fixed fraction of total cycle time)

TIME CONSUMED BY MVR/ATK IN ITS CYCLE OF ACTIVITIES

ACTIVITY	TIME-CONSTRAINED	TIME-ACTUAL	Time-unconstraind	
PRE	0.000	0.000	0	days
S&R	0.000	0.052	0.052	days
DEL	0.000	0.007	0.007	days
MWR	0.000	0.009	0.009	days
ATK1	0.000	0.036	0.036	days
ATK2	0.000	0.000	0.000	days
DEF	0.000	0.000	0	days
DIS	0.000	0.489	0.489	days
RCL	0.000	0.457	0.457	days
RCST	0.000	0.055	0.055	days
MTX	0.000	0.269	0.269	days
LOD	0.000	0.000	0.012	days
RPR	0.000	0.029	0.088	days
RES	0.000	0.590	0.590	days
MTS	0.000	0.295	0.295	days
MXC	0.000	0.000	0	days
UNL	0.000	0.000	0	days
TOTAL	0.00	2.288	2.361	days

COMMODITIES CONSUMED BY MVR/ATK IN ACTIVITY CYCLE

ACTIVITY	Veh	Pers	Ammo	POL	Other	Cargo
PRE	0	0	0	0	0	0E+00
S&R	2.9	8.3	72.9	5E+03	1E+04	1E+02
DEL	0.1	0.1	1.1	3E+02	2E+03	5E+00
MWR	0.5	1.1	17.2	7E+02	2E+03	2E+01
ATK1	43.0	233.7	10914	2E+04	2E+04	1E+03
ATK2	0.1	0.9	133	5E+01	1E+02	5E+00
DEF	0	0	0	0	0	0E+00
DIS	27.4	78.2	913.0	5E+04	1E+05	1E+03
RCL	25.6	73.0	852.9	5E+04	1E+05	9E+02
RCST	2.3	1.7	77.5	3E 03	1E+04	8E+01
MTX	7.5	8.1	188.3	2E+04	7E+04	3E+02
LOD	0.1	0.0	0.9	5E+02	3E+03	6E+00
RPR	-1.1	-10.7	-12.5	3E+03	2E+04	-7E+00
RES	4.1	2.1	45.4	3E+04	1E+05	3E+02
MTS	16.5	17.7	413.6	3E+04	8E+04	6E+02
MXC	0	0	0	0	0	0E+00
UNL	0	0	0	0	0	0E+00
TOTAL	129.0	414	13617	2E+05	6E+05	5E+03

```
        SUMMARY OF MVR/ATK  CHARACTERISTICS IN ACTIVITY CYCLE
RESOURCE TYPE          CONSUMPTION BY AN MVR/ATK
                          Units               Tons         % Time in
         Veh            1.3E+02            3.21E+03      non-mv/cbt:
Per      Pers           4.1E+02            4.14E+01             0.44
Cycle    Ammo           1.4E+04            3.64E+02
         POL            2.1E+05            8.94E+02        % Time in
         Other          6.1E+05            3.04E+02          mv/cbt:
         Cargo          4.8E+03            4.82E+03             0.56

Peak/day          Pers  1847.78 *EXCESS*   18.49% No. MVRs/engmt:
                                                            1.00
         Veh            5.6E+01            1.40E+03
Per      Pers           1.8E+02            1.81E+01  # cyc rqd/kill:
Day      Ammo           6.0E+03            1.59E+02             4.00
(Avg.)   POL            9.2E+04            3.91E+02
         Other          2.7E+05            1.33E+02      No. cyc/mvr:
         Cargo          2.1E+03            2.10E+03            34.00

     CAMPAIGN KILL RATE FOR ATTACK MVR:   0.109 kills/day/mvr
```

Fig. A.11—Attack MVR's activity cycle

Traditional MOEs

These computations show the Red to Blue rate of exchange of vehicles in ground engagements and over the entire campaign. Similarly, the starting and ending ratios of raw RMVRs to MVRs and of Red to Blue combat power are shown.

TIME CONSUMED BY MVR DEF IN ITS CYCLE OF ACTIVITIES

ACTIVITY	TIME-CONSTRAINED	TIME-ACTUAL	Time-unconstraind	
PRE	0.000	0.500	0.500	days
S&R	0.000	0.032	0.052	days
DEL	0.000	0.007	0.007	days
MWR	0.000	0.000	0	days
ATK1	0.000	0.000	0	days
ATK2	0.000	0.000	0	days
DEF	0.000	0.258	0.268	days
DIS	0.000	0.000	0.000	days
RCL	0.000	[illegible]	0	days
RCST	0.000	0.069	0.069	days
MTX	0.000	0.040	0.040	days
LOD	0.000	0.000	0.071	days
RPR	0.000	0.201	0.608	days
RES	0.000	0.545	0.545	days
MTS	0.000	0.000	0.000	days
MXC	0.000	0.000	0	days
UNL	0.000	0.000	0	days
TOTAL	0.00	1.703	2.181	days

COMMODITIES CONSUMED BY MVR/DEF IN ACTIVITY CYCLE

ACTIVITY	Veh	Pers	Ammo	POL	Other	Cargo
PRE	14.0	30.0	154.1	5E+04	1E+05	5E+02
S&R	2.9	8.3	72.9	5E+03	1E+04	1E+02
DEL	0.1	0.1	1.1	3E+02	2E+03	5E+00
MWR	0	0	0	0	0	0E+00
ATK1	0	0	0	0	0	0E+00
ATK2	0	0	0	0	0	0E+00
DEF	739.0	3560.1	92101	4E+05	2E+05	2E+04
DIS	0.0	0.0	0.0	0E+00	0E+00	0E+00
RCL	0	0	0	0	0	0E+00
RCST	2.9	2.1	96.5	4E+03	2E+04	1E+02
MTX	1.1	1.2	28.2	3E+03	1E+04	5E+01
LOD	0.5	0.2	5.4	3E+03	2E+04	3E+01
RPR	-7.9	-121.7	-87.1	2E+04	1E+05	-5E+01
RES	3.8	1.9	42.0	2E+04	1E+05	3E+02
MTS	0.0	0.0	0.0	0E+00	0E+00	0E+00
MXC	0	0	0	0	0	0.0
UNL	0	0	0	0	0	0.0
TOTAL	756	3482	92414	5E+05	7E+05	2E+04

SUMMARY OF MVR DEF CHARACTERISTICS IN ACTIVITY CYCLE

RESOURCE	TYPE	CONSUMPTION BY AN MVR/DEF Units	Tons	% Time in
	Veh	7.6E+02	1.88E+04	mv [illegible]
Per	Pers	3.5E+03	[illegible]+02	0.8[illegible]
	Ammo	9.2E+04	2.47E+03	
Cycle	POL	4.6E+05	1.96E+03	% Time in
	Other	6.0E+05	3.47E+02	mv [illegible]
	Cargo	2.4E+04	2.40E+[illegible]	[illegible]

[illegible]/day Pers [illegible] [illegible] No. MVRs [illegible]

		Units	Tons	
	Veh	4.4E+02	[illegible]	
Per	Pers	[illegible]	2.[illegible]E+02	[illegible]
Day	Ammo	[illegible]	[illegible]	[illegible]
Avg.	POL	[illegible]	[illegible]	
	Other	[illegible]	[illegible]	No. [illegible]
	Cargo	[illegible]	[illegible]	[illegible]

CAMPAIGN FILL RATE FOR DEFEND MVR [illegible]

Fig. A.12—Defend MVR's activity cycle

Consumption Calibration Information

The average fraction of Blue personnel who become casualties per day is shown, as well as the ratio of personnel to vehicle casualties. Also, consumption per man per day of consumable resources are computed, as are consumption per MVR per day. For each of these variables a great deal of historical information is available, and planning factors have been established by the Army.

Additional Information of Interest

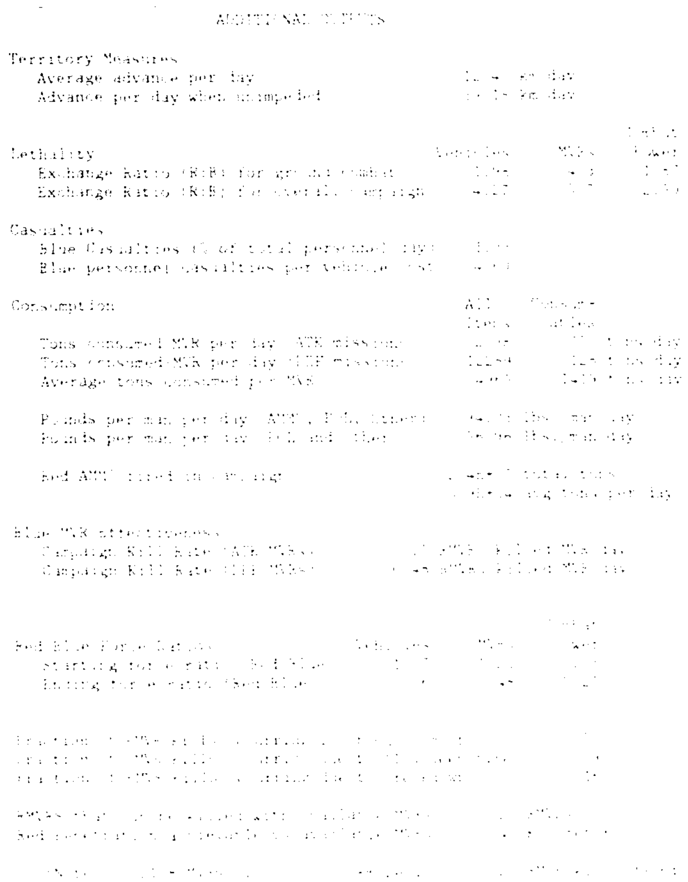
This section shows or repeats the computed campaign kill rates of Blue attack and defend MVRs, Red's average advance rate per day, and the starting and ending force ratio for the campaign, measured in raw RMVRs/MVRs, and in combat power.

MOSCOW was constructed under the assumption that a user would have a firm definition of success criteria (kills required within allowable penetration) and would screen on the basis of the force and other resources needed to meet them. However, there may be instances where the user is less certain of the success criteria than of his limit on forces. He may wish to know "How many RMVRs can be killed (within the specified penetration limit) by the number of MVRs available?" This screen includes a crude estimate of that quantity based on an extrapolation of the results in the output screen. It is unlikely to be exactly correct, but it

BLUE REQUIREMENTS FOR SUCCESS

Resource	Required	Available	Reqd/ Avail	Affordable?
MANEUVER UNITS				
Initial stock	20.9	21.8	96%	YES
Maximum replacement equivalents	3.5	8.6	41%	YES
Initial + Repl Equivs. (grand total)	24.4	30.4	80%	YES
Replacement equivalents per day	0.86	0.29	302%	*NO*
INITIAL STOCKS				
Personnel	209250	217620	96%	YES
Vehicles	29307	30518	96%	YES
AMMO (tons)	9.8E+05	1.0E+06	96%	YES
POL (tons)	1.5E+07	1.5E+07	96%	YES
Other commodities (tons)	5.9E+06	6.1E+06	96%	YES
REPLACEMENTS				
Personnel	[illegible]	[illegible]	[illegible]	YES
Vehicles	[illegible]	[illegible]	41%	YES
AMMO (tons)	[illegible]	[illegible]	[illegible]	YES
POL (tons)	[illegible]	[illegible]	[illegible]	YES
Other commodities (tons)	[illegible]	[illegible]	[illegible]	YES
REPLACEMENTS PER DAY				
Personnel	[illegible]	[illegible]	[illegible]	[illegible]
Vehicles	[illegible]	[illegible]	[illegible]	[illegible]
AMMO (tons)	[illegible]	[illegible]	[illegible]	[illegible]
POL (tons)	[illegible]	[illegible]	[illegible]	YES
Other commodities (tons)	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig. A.13—Principal MOSCOW output screens gives the user a first approximation for the valve of the RED SURVIVORS input in the success criteria block, thus reducing the number of additional model iterations needed to answer the question.



[illegible]

Territory Measures
Average advance per day [illegible]
Advance per day when unimpeded [illegible]

Lethality
Exchange Ratio (R:B) for ground combat [illegible]
Exchange Ratio (R:B) for overall campaign [illegible]

Casualties
Blue Casualties (% of total personnel /day) [illegible]
Blue personnel casualties per vehicle lost [illegible]

Consumption
Tons consumed MLR per day [illegible]
Tons consumed MLR per day [illegible]
Average tons consumed per [illegible]

Pounds per man per day [illegible]
Pounds per man per day [illegible]

Red [illegible]

Blue [illegible]
Campaign Kill Rate [illegible]
Campaign Kill Rate [illegible]

[illegible]

Fig. A.14—Diagnostic and miscellaneous outputs

Appendix B

DEFINITION OF BLUE UNIT ACTIVITIES IN MOSCOW

MOSCOW calculates Blue units' average effectiveness at the operational level of war (the *Campaign Kill Rate*) by accounting for the amounts of time an average attacking or defending Blue unit spends performing each of 15 activities.[1] The activities are a simplified categorization of tasks that must be carried out by an MVR engaged in mobile offensive or defensive operations whose ultimate purpose is the destruction of some number of enemy units.

The centerpiece activity is the combat *engagement* (ATK1 and ATK2 activities for attacking maneuver units, DEF activity for defending units; referred to as "engagement activities"). This is when enemy units are actually attributed. The remainder of the activities represent preparations for or recovery from engagements, or other activities necessary to maintain the personnel, equipment, and organizational cohesion of Blue MVRs. Together, they constitute the *activity cycle* for attacking or defending MVRs representing the total length of time a given maneuver unit is occupied with a given mission (and thus unavailable for other missions). Since MOSCOW does not represent specific MVRs, the cycle represents *average* times spent in each activity among all attacking or all defending MVRs.

Each activity is, of course, an abstraction of a series of more complex individual steps. Although the activities listed below are in an order that implies a sequence through time, for the most part order does not matter, although a few activities are exceptions and are so indicated in the discussion below. In reality, of course, activities do not separate as neatly as implied here, and such "cycles" are not uniform. MOSCOW's activity times are *averages* across all attacking or defending units within a particular zone for the campaign length calculated.[2] For the analyst, what is most important is, first, that the *total* resources consumed in the activity cycle be accurate (within the limits of data accuracy and MOSCOW's low resolution) and, second, that the *distribution* of time spent in each activity be a reasonable reflection of the concept being screened.

The reader might also infer at this point that MVR activities are mutually exclusive—that is, while performing one, such as resting (RES), it would not be possible to also perform some others, such as load supplies (LOD). In fact, MOSCOW provides a mechanism for reflecting some simultaneity of activity, as described below.

MOSCOW-M1[3] distinguishes among six categories of Blue ground units assigned to the following missions: attack; defend; hold in reserve; and provide rear area security, headquarters units

[1]There is nothing magic about the number 15. Originally MOSCOW contained seven activities to reflect the Army 21 concept (Scan, Swarm, Strike, Scatter, Rest, Resupply, and Move to Standby Position). As I became persuaded that the activity framework was flexible enough to treat some other concepts as well, I added activities that seemed to distinguish among them. For instance, in early versions of MOSCOW there was no specific "Rest" activity, but frequent references to intense operations in some concepts suggested the addition of a policy variable (and activity) representing the fraction of time Blue MVRs are permitted to rest. (Changing this variable has mixed effects, trading off operational efficiency for tactical performance.) MOSCOW's spreadsheet framework allows users to add or delete activities.

[2]In effect, MOSCOW uses a "steady-state" approximation of average conditions in the course of a campaign that includes a fairly large number of engagements—at least several dozen. This abstraction is a key argument against using MOSCOW to represent small zones (in width or depth) or short campaign lengths (less than a few days).

[3]M1 is the version of the model produced in September 1987 and described here. It translates as "Mobile, strategically defensive concepts, model version 1."

and associated fire and missile support; and vehicles carrying supplies. The number of attacking and defending MVRs needed is based on a comparison of their campaign kill rates, which are calculated based upon their activity cycles, with the required kill rate determined by Blue's campaign objectives. Needs for each of the other MVR types (reserve and security MVRs, Headquarters, and supply vehicles) are based on other factors (detailed in App. E) that in MOSCOW-M1 do not rely on activity cycles.[4] Several activities are used only in specific cycles, as indicated in Fig. B.1.

OVERVIEW OF ATTACK AND DEFEND ACTIVITY CYCLES

Attacking MVR Cycle

Attacking MVRs are evenly distributed throughout the two-dimensional area of Blue's deployment (set by the Blue FORW BNDRY and REAR BNDRY). They intercept penetrating RMVRs, drawing MVRs from the distance required in order to achieve Blue's desired combat power ratio on attack (TAC PWR-ATK). After any attack of less duration than that needed to kill the target RMVR, the MVRs disengage, "shadow" the target, recuperate, then close again. This continues until the target is fully destroyed, at which point the MVR moves to reestablish the assumed uniform distribution and wait for its next assignment.

ACTIVITY		
Prepare defenses	[PRE]	*D*
Survey and reconnoiter	[S&R]	
Delay for higher echelon orders	[DEL]	
Move to wpn range (1st contact)	[MWR]	*A*
Attack--1st phase (1 Red unit)	[ATK1]	*A*
Attack--2nd phase (reinf. Red)	[ATK2]	*A*
Defend	[DEF]	*D*
Disengage (to shadow dist)	[DIS]	
Re-close (from shadow dist)	[RCL]	*A*
Reconstitute (unit cohesion)	[RCST]	
Move to exchange point	[MTX]	
Load supplies	[LOD]	
Repair (vehicles and pers)	[RPR]	
Rest	[RES]	
Move to standby position	[MTS]	
Move cross-country (non-mvr)	[MXC]	*0*
Unload supplies	[UNL]	*0*
Total--all activities in cycle	[TOT]	

A -- Used only by Attacking MVRs
D -- Used only by Defending MVRs
0 -- Set to zero in MOSCOW-M1

Fig. B.1—Activities in MOSCOW

[4]Activity cycles have been outlined for these units, and later versions of MOSCOW may include them.

The MVR carries out surveillance and reconnaissance of its assigned area *[S&R]*, and waits to receive any orders or intelligence from higher echelons *[DEL]*. It moves into position ("Swarm" in the early Army 21 parlance) to attack *[MWR]* and is assumed to attack a lone Red MVR (RMVR) *[ATK1]*. If the MVR cannot impose the level of attrition specified by the concept before a second RMVR can arrive to reinforce the defenders, the attack is continued against two defending RMVRs *[ATK2]*.

After breaking off the engagement, the MVR disengages *[DIS]*. If the target RMVR has not been destroyed in the first engagement, the MVR moves to a distance from which the RMVR can be "shadowed," later reclosing to renew the fight *[RCL]*. The MVR reconstitutes its organization *[RCST]*, then moves to an "exchange point" *[MTX]* to rendezvous with supply vehicles. It loads supplies *[LOD]*, repairs vehicle and personnel damage *[RPR]*, rests *[RES]*, then moves to a new position where it stands by to be assigned a new target RMVR *[MTS]*.[5]

Defending MVR Cycle

Defending MVRs are assumed to begin the campaign positioned in locations that deny attacking RMVRs access to some territory behind them—key blocking terrain or avenues of approacn.[6] After engaging and breaking off, the defender must recuperate, then move to a new blocking position in the rear. (The distance that must be retreated will depend upon the availability of other friendly MVRs to continue to block the attacking RMVRs.)

The defending MVR cycle is very similar to that of attacking MVRs, with the following modifications: (a) Since MVRs are generally assumed to take up blocking positions astride the enemy's advance, they have no Move to Weapons Range *[MWR]* activity. (b) Blue defenders may prepare defenses *[PRE]*, taking advantage of terrain to reduce the attacker's combat power. (c) The engagement activity is Defend *[DEF]* instead of Attack. Blue defending MVRs cannot be reinforced (although they may be relieved by other MVRs), so there is only one DEF activity. (d) After breaking off an engagement *[DIS]*, defending units retire to recuperate before moving to new blocking positions *[MTS]*. They do not "shadow" attacking RMVRs, so they do not Reclose *[RCL]* as do attacking MVRs.

Figures B.2 and B.3 illustrate the attacking and defending MVRs' activity cycles. The order of activities might vary from that shown here, or more than one activity might be undertaken simultaneously. The chief difference between attacking and defending MVRs' cycles is that attacking MVRs are assumed to start from, and return to, a uniform two-dimensional distribution throughout the zone, while defending MVRs start each cycle evenly distributed across blocking positions or avenues of approach.

---

[5]The attacking cycle occurs once for each engagement. An MVR may have to attack a target RMVR more than once to kill it. Assume, for example, that each engagement will impose 25 percent attrition on an RMVR, requiring four engagements to kill it. The MVR will perform all activities four times with the following exceptions: (a) It will Move to Weapons Range and Move to Standby Position only once; to reflect this, the equations for these activities will allocate 25 percent of their resource costs to each cycle. (b) It will not need to Reclose after the final engagement; thus (4 − 1)/4, or 75 percent of its resource cost, will be allocated to each cycle.

[6]By increasing the "Move to Standby" activity by a coefficient equal to [(Distance to defensive positions/ MVR movement rate) / Number of defending engagements per defending MVR], and adjusting FORW BNDRY appropriately, the user can reflect scenarios (such as a surprise attack) where defending units must move forward into position before their first engagement.

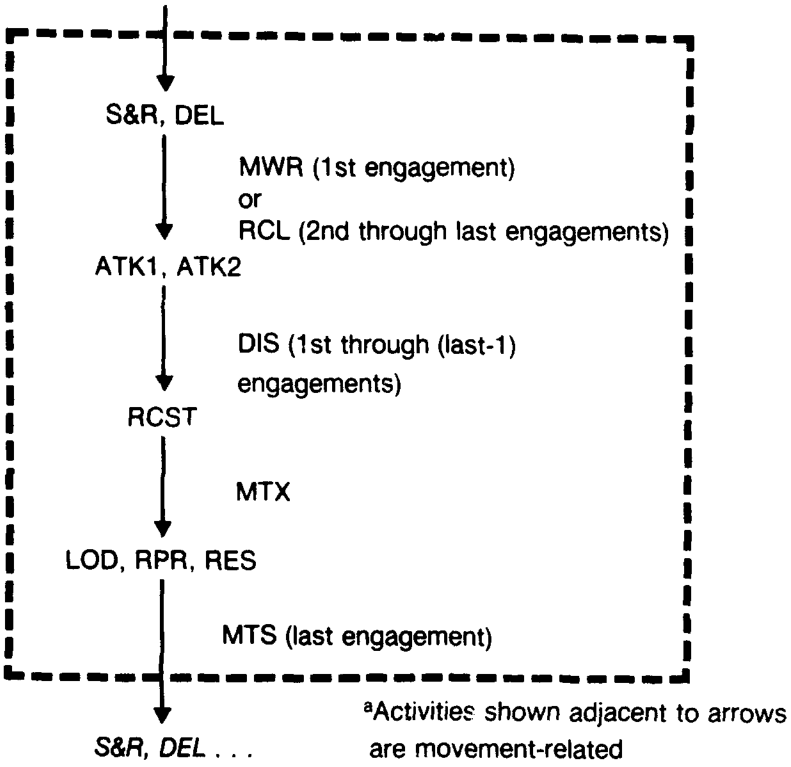


Fig. B.2—Attacking MVR activity cycle

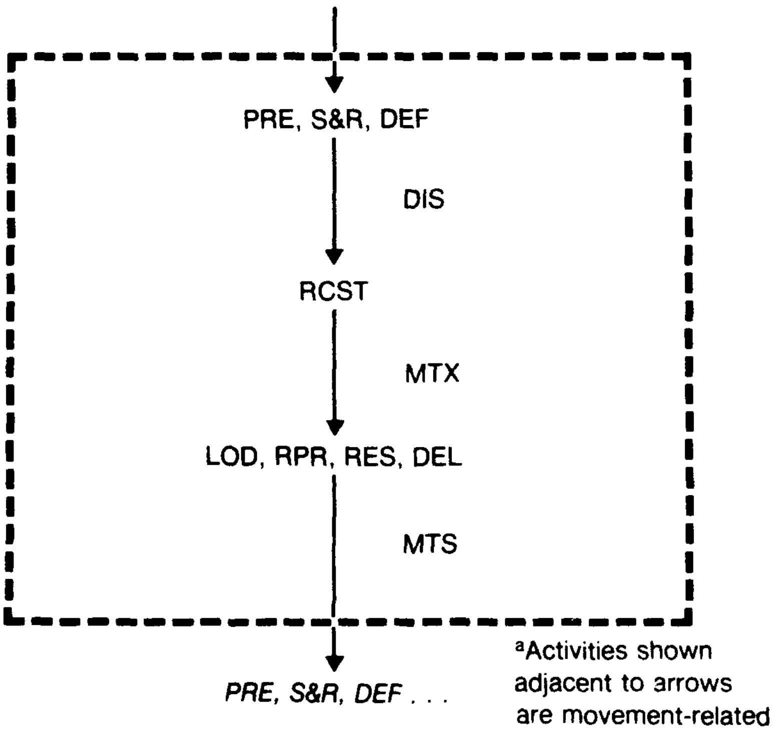


Fig. B.3—Defending MVR activity cycle

GENERAL FLOW OF INFORMATION IN ACTIVITY CYCLE EQUATIONS

Using the MVR activity as an example, Fig. B.4 illustrates the flow of information within a typical noncombat activity and its aggregation in the activity cycle. A time equation estimates the time required to perform the activity based on the policy and scenario variables. Using the first of the resource consumption coefficients defined in the next section, expected vehicle breakdowns (Class VII) are calculated. Coefficients representing the expected fraction of a vehicle's basic load of personnel, ammunition (Class V), POL (Class III), and other commodities (Classes I, II, IV, VI, VIII, and IX) lost with broken vehicles are used to calculate losses of these items. Two commodities, POL and other, will be consumed by surviving vehicles as well; other coefficients are used to compute the MVR's consumption of these commodities.

In engagement activities (ATK1, ATK2, and DEF) three additional computations are made: Vehicle combat attrition is calculated using the Lanchester equations, as described in App. C, and is added to vehicle breakdowns, resulting in personnel attrition in the form of crew and passenger combat casualties; dismounted infantry casualties are calculated on the basis of the length of the engagement; and ammunition fired by the MVR's weapons is computed.

Figure B.5 shows part of MOSCOW's screen display of resource consumption in the

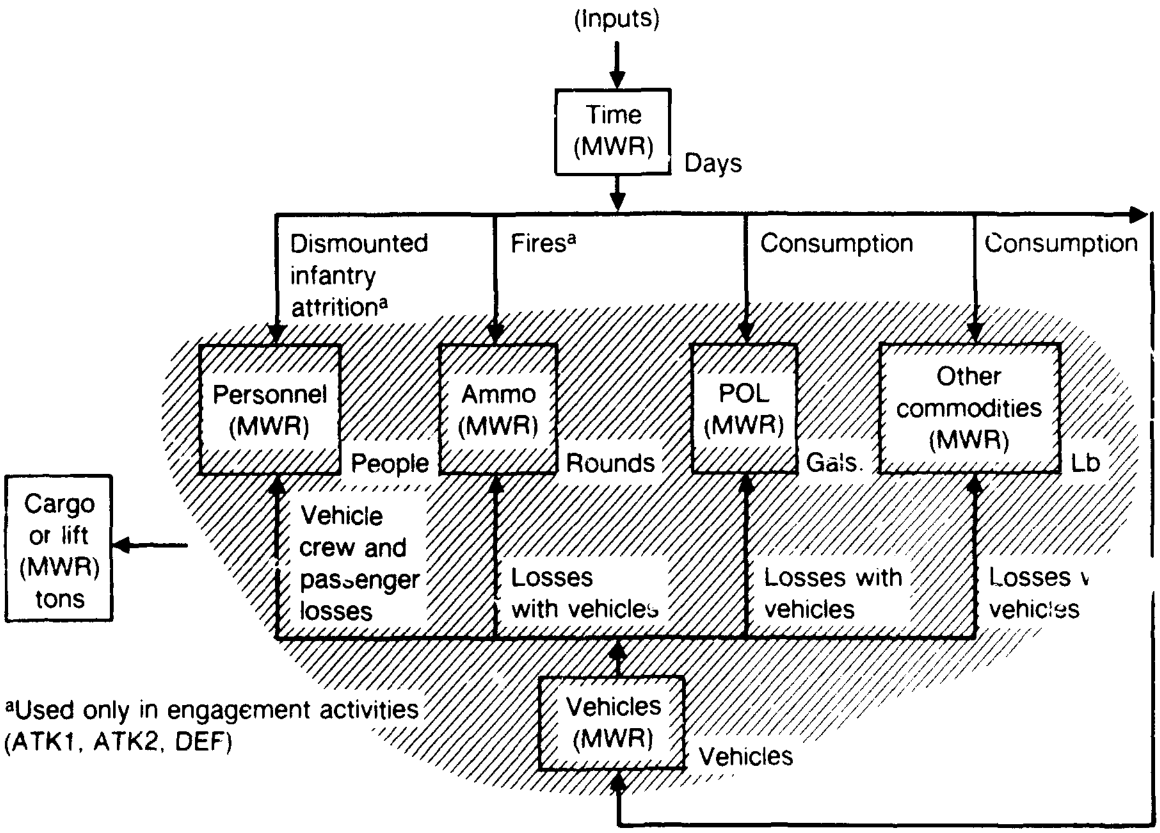


Fig. B.4—Information flow to compute resource consumption in an example activity

MVR/ATTK activity cycle.[7] Each activity occupies a row and each resource consumed occupies a column. Units of measurement are shown in the last row. Computations of three types are of interest:

1. *Total time of cycle*—the time required for an average MVR assigned an attack mission to perform the attack and all supporting activities—is the sum of individual activity times, at the foot of the TIME column.
2. *Total consumption per cycle* of Vehicles, Personnel, Ammo, POL, and Other commodities are at the foot of their respective columns. Therefore, average consumption per day of each commodity (e.g., POL) is:

   Total consumption of POL per cycle / Total time (in days) of cycle
3. Using weight conversion coefficients (e.g., gallons of fuel to tons of fuel), *consumption* of each commodity except time is converted into the weight *in tons* of materiel needed to bring the MVR back to full strength. (Recall that returning to full strength is an assumption of the activity cycle.)

   Tons of materiel required per cycle / Total time of cycle = Average cargo (or average lift capacity) required per day.[8]

RESOURCES CONSUMED BY MVR/ATTK IN ITS CYCLE OF ACTIVITIES (extract)

TIME[11]	Veh	Pers	Ammo	POL	Other	Cargo	ACTVTY
0	0	0	0	0	0	0E+00	PRE
0.546	30.6	54.6	765.3	1E+05	2E+05	1E+03	S&R
0.228	12.8	13.7	140.6	3E+04	7E+04	5E+02	DEL
0.113	6.7	12.0	224.7	2E+04	5E+04	3E+02	MWR
0.044	61.5	232.9	3289	3E+04	5E+04	2E+03	ATK1
0.000	0.1	0.8	16	7E+01	4E+02	2E+00	ATK2
0	0	0	0	0	0	0E+00	DEF
0.199	16.7	29.8	557.5	6E+04	2E+05	7E+02	DIS
0.199	16.7	29.8	557.5	6E+04	1E+05	7E+02	RCL
0.041	2.3	1.2	77.0	6E+03	2E+04	1E+02	RCST
0.171	14.3	10.2	358.4	4E+04	9E+04	6E+02	MTX
0.018	1.0	0.2	11.2	3E+03	6E+03	4E+01	LOD
0.130	-4.7	-15.5	-51.6	2E+04	4E+04	2E+02	RPR
0.423	23.7	3.4	260.4	6E+04	1E+05	9E+02	RES
0.103	8.6	6.2	216.3	3E+04	4E+04	3E+02	MTS
0	0	0	0	0	0	0E+00	MXC
0	0	0	0	0	0	0E+00	UNL
2.220	199.7	379	6526	5E+05	1E+06	8E+03	TOTAL
Days	Vehicles	People	Rnds	Gals	Lbs.	Tons	(Units)

Fig. B.5—Extract of MOSCOW's display of resources consumed in activity cycle

[7] Two columns of intermediate time computations have been omitted; they will be discussed below.

[8] The terms "Cargo" and "Lift" are interchangeable, because both represent a demand in tons per day that must be satisfied by the strategic and local logistics systems.

This cargo demand is used to calculate loading time (time [LOD]). Note that the cargo requirements of each individual activity are also computed; therefore, the lower right corner of the matrix (cargo consumed per cycle, 8,000 tons in Fig. B.5) can be computed by either adding the entries in the column above it or by converting the commodity requirements (other than time) to the left of it into tons and adding them.[9]

Figure B.5 also highlights the most important consequence of MOSCOW's activity-oriented approach: Because it attempts to consider activities besides combat, *the resource demands it estimates will be greater than if combat alone were considered.* The increase resulting from this more comprehensive approach will not necessarily have equal effect on each resource, however. Figure B.6[10] shows the resources consumed in the engagement activity, ATK1, as a proportion of the total resources consumed in the cycle.

In this example the MVR was on average engaged only 2 percent of the time; ATK1's draw on the commodities that are consumed throughout the cycle (primarily POL and Other) would therefore be a similar small fraction of total consumption. Conversely, ATK1 would be a major consumer of commodities (Vehicles, People, and Ammo) that are heavily consumed in engagements.

More important, this example suggests the folly of overemphasis on engagement-related components of a warfighting concept to the exclusion of other activities:

1. Since Blue MVRs' Campaign Kill Rates are calculated by dividing attrition imposed per cycle per MVR by the Total Time of Cycle, even a substantial improvement in MVR lethality (e.g., one that reduces the time to kill a specified fraction of an RMVR in the ATK activity by 50 percent) would, other things equal, only reduce total cycle time by only 1 percent in this example. The required number of MVRs would only be reduced by about the same percentage.
2. Improvements in Blue's lethality or vulnerability might nevertheless be very important if reducing combat losses were a high priority. However, overemphasis on the engagement activity will ignore noncombat losses of vehicles or personnel, which in this example are quite substantial (between 39 and 69 percent of total losses).

Resource	*Consumption (ATK1) / Consumption (Total Cycle)*
Time	2%
Vehicles	31%
People	61%
Ammo	50%
POL	6%
Other	5%
Cargo	25%

Fig. B.6—Proportion of total cycle consumption occurring in attack engagement (example)

[9]Several commodities show *negative* consumption in the RPR activity, because repairs return vehicles and people consumed in other activities back into service, along with the portion of those vehicles' load that would otherwise have been lost.

[10]In the spreadsheet this table includes three TIME columns; see "Time Coefficients" for explanation.

RESOURCE CONSUMPTION COEFFICIENTS

Figure B.7 shows MOSCOW's table of resource consumption coefficients, which the user inputs. There are four types of coefficients: (1) time, (2) probability of vehicle loss, (3) probability of vehicle load loss, (4) consumable commodities consumption.

Time Coefficients

The activity framework implicitly assumes that: Blue MVRs operate independently and must rely on organic resources to perform each activity; and activities are mutually exclusive—the MVR cannot perform more than one activity at a time. These coefficients allow the user to relax each of these assumptions. Both will take on values between zero and 1.

(a) *%Unit-tm* is the fraction of the total time spent in performance of an activity that is consumed by the MVR itself (as distinct from any other organization). For instance, if logistics support assets were available from a higher headquarters to assist in loading the MVR's supplies, and these assets performed 75 percent of the loading, the MVR would need spend only 25% of the required time itself, and %Unit-tm would be set to 25 percent. (The user must be careful to distinguish false from real time savings. Adding nonorganic resources will not necessarily accelerate an activity, as suggested by the proverbial example of nine women trying to bear a child in one month.)

RESOURCE CONSUMPTION COEFFICIENTS

ACTVTY	%Crit path	%Unit-tm	Veh	Pers	Ammo	POL	Other	
PRE	1.00	1.00	0.040	0.20	0.33	0.50	30.0	PRE
S&R	1.00	1.00	0.040	0.25	0.75	0.75	40.0	S&R
DEL	1.00	1.00	0.040	0.15	0.33	0.50	30.0	DEL
MWR	1.00	1.00	0.060	0.25	1.00	1.00	60.0	MWR
ATK1	1.00	1.00	0.080	0.40	1.00	1.00	80.0	ATK1
ATK2	1.00	1.00	0.080	0.40	1.00	1.00	80.0	ATK2
DEF	1.00	1.00	0.080	0.40	1.00	1.00	80.0	DEF
DIS	1.00	1.00	0.060	0.25	1.00	1.00	80.0	DIS
RCL	1.00	1.00	0.060	0.25	1.00	1.00	60.0	RCL
RCST	1.00	1.00	0.040	0.07	1.00	0.50	50.0	RCST
MTX	1.00	1.00	0.060	0.10	0.75	0.85	50.0	MTX
LOD	0.00	1.00	0.040	0.03	0.33	0.50	30.0	LOD
RPR	1.00	1.00	0.040	0.03	0.33	0.50	30.0	RPR
RES	1.00	1.00	0.040	0.02	0.33	0.50	30.0	RES
MTS	1.00	1.00	0.060	0.10	0.75	0.85	40.0	MTS
MXC	1.00	1.00	0.060	0.10	0.75	0.85	40.0	MXC
UNL	1.00	1.00	0.040	0.03	0.33	0.50	30.0	UNL
Units	%of actvy time	%mvr	%vehs/d	%pers/v	%ammo/v	%act(mv)	lbs oth/pers/d	

Fig. B.7—MOSCOW resource consumption coefficients

There will always be a limit to the fungibility of organic vs. nonorganic assets; thus, for some activities, there may be some nonzero lower limit on %Unit-tm. In the example above, it is assumed that all MVR movement and combat activities must be performed by the MVR itself; hence, %Unit-tm is set to 1.0.

Activities for which %Unit-tm might be less than 1.0 are: PRE, S&R, RPR, and LOD, reflecting assistance from engineers, intelligence, maintenance, and supply assets, respectively.

(b) *%Crit path.* The organization of MVRs and the support architecture developed under some concepts may imply assumptions about the ability of MVRs to perform certain activities simultaneously. For example, it may be expected that MVRs can be continually supported (the LOD activity) during combat and throughout the cycle. Therefore LOD would not be on the activity cycle's "critical path." This coefficient, which the user sets at values between zero and one, denotes the degree to which the applicable activity is on the MVR's critical path—the fraction of the activity's time that cannot be performed simultaneously with other activities.

In the summary table of consumption during a cycle, three columns include "Time" in their titles: Time-Unconstrained; Time-Constrained; and Time-Actual. The Unconstrained calculation includes the %Unit-tm coefficient, but not the %Crit-path coefficient. The Constrained calculation shows the time of the activity if it has been constrained to be a certain proportion of the overall cycle, as can be done utilizing the Proportional Constraints section [Alt-P]. The Actual computation utilizes the %Crit path coefficient to multiply the Constrained time (if nonzero), otherwise using the unconstrained time.

Probability of Vehicle Breakdown/Loss Coefficients. These represent the probability per day that an MVR vehicle will go out of commission, which can vary by activity. In Fig. B.7, activities are classified as putting high, medium, or low stress on vehicles, each with its own probability of breakdown (4 to 8 percent). These coefficients will usually be low numbers, always between zero and 1. Units are probability of serious vehicle breakdown per day.

Probability of Vehicle Load Loss Coefficients. These coefficients, which pertain to the loss of Personnel and Ammunition, refer to the expected loss of the basic vehicle load of personnel or ammunition when the carrying vehicle breaks down (see above). Units are in expected fraction of basic load lost per lost vehicle. In the example, the probability of an individual becoming a casualty when his vehicle breaks down varies from 3 percent in nonstressful activities (such as RPR or LOD) to 40 percent in activities where the enemy is nearby. The fraction of a basic load of ammunition that is lost is higher than that of personnel, reflecting the lower priority and presumably greater difficulty of removing ammunition from broken vehicles than removing people. By analogous reasoning, the entire load of POL and Other in a vehicle is assumed to be lost (left behind) when the vehicle breaks down near the enemy.

Consumable Commodities Consumption Coefficients. Two resources, POL and Other, are consumed by the MVR throughout all activities.

(a) *POL:* Based on POL consumption (in gallons per km) provided as an input by the user, the "Miscellaneous" section of MOSCOW computes average consumption of fuel per vehicle for two types of reference days: a day of movement and a day of combat. The POL consumption coefficient reflects the amount of vehicle movement and idling per day expected for each activity relative to one of the two reference days. The ATK1, ATK2, and DEF activities use the combat-day as their reference case. All other activities use the movement-day. In the example, a movement-related activity such as MWR has a coefficient of 1.0, indicating that vehicles run their engines as much per day of MWR as in the reference day—in this instance a tautology, since the activity assumed in the movement reference day is movement. Even in "stationary" activities vehicles may run their engines some fraction of the time, so the value of this coefficient in the RES activity is .5. These values will generally be between zero and 1.0.

(b) *Other*: Other is assumed to primarily be food, water, etc. Its coefficient is therefore denominated in pounds consumed per person per day of each activity. In the example, some activities are assumed to stimulate higher needs for sustainment than others—in this case, the engagement-related activities have the highest coefficients. The values of these coefficients will depend upon sustainment and support assumptions used, but typically would be expected to fall in the range of 20 to 80.[11]

TIME OF ACTIVITY EQUATIONS

This section provides further details on the equations that compute the time required for each activity, except for ATK1, ATK2, and DEF, which are covered in App. C.

The purpose of an activity-oriented approach is to reflect the effects of Blue policy (concept) choices on operations, including those that had no direct effect on engagements themselves (I believe noncombat activities were underemphasized in most models). However, an ancillary constraint was to minimize the number of complex (which, for present purposes, is synonymous with nonlinear) equations. Thus the time equations for individual activities were intended to reflect the effects of Blue policies or capabilities as simply as possible.

In several instances, this entailed positing relationships to represent effects typically overlooked in other models. I make no claim that the formulation shown is the "best" one. I merely assert that it includes elements that appear relevant in a relatively simple function. Because MOSCOW attempts to represent activities new to combat modeling, there were few guideposts. Consequently, the definitions of many calibration coefficients are unorthodox—"Percentage increase in disengagement time per percentage increase in Red survivors of engagement." In each case, the approach was to posit as simple a relationship as possible, include a calibration coefficient that allows the user to choose—within broad limits—its general functional form, and include a counterpart "null coefficient" that permits the user to neutralize the calibration coefficient's effect.

Activity-times are affected by Blue policy, by Blue capabilities, by the Red counterparts of these, and by interactions with other activities. They can be summarized as falling into the following categories:

- Determined by Blue policy and capability: PRE, MWR, MTX, RES, MXC, UNL (MXC and UNL are not used in MOSCOW-M1);
- Determined by Blue policy, capability, and results of other activities: DIS, RCL, RCST, LOD, RPR;
- Determined by Blue capabilities and scenario factors (e.g., geography or unit density): S&R, DEL;
- Determined by interaction of Blue and Red policy and capabilities: ATK1, ATK2, DEF, MTS.

Further, several activities are affected directly or indirectly by outputs (primarily by MVRs Needed or CAMPAIGN LENGTH), as summarized in Fig. B.8.

[11]FC 101-5-2 (U.S. Army Command and General Staff College, 1987) uses 23.1 lb/man/day as an average for a campaign (p. 7-6), while FM-101-10-1 (Department of the Army, 1976) uses 23.53 (p. 3-4). Neither document distinguishes among activities.

Activity	*Affected by:*	*Explanation*
MWR	MVRs (Attack) Needed	Density of MVRs determines distance farthest must travel
ATK1, ATK2, DEF	CAMPAIGN LENGTH	Lethality affected by average supporting tons fired/flown per day
MWR, DEL, RCST	CAMPAIGN LENGTH	Operational C-3 Error determined by (Disruption/day - Recovery/day) * CAMPAIGN LENGTH
ATK1, ATK2, DEF	TATK1+TATK2 or TDEF	Length of Attack or Defend engagement affects average distances between firers and targets; this affects lethality and target availability, which in turn affects length of engagement.

Fig. B.8—Activities affected by model outputs, causing simultaneity

The following entries display each activity time equation and provide its rationale. Activities used in only one cycle, or in neither cycle in MOSCOW-M1, are indicated by the same footnotes as used in Fig. B.1.

Prepare Defenses [PRE] *D*. DEFENSE PREP% is the fraction of maximum defense preparations that defending MVRs make per cycle. Using an input in the calibration coefficients section, HRS/DEFENSE PREP %, TPRE becomes:

$$\text{TPRE} = \text{DEFENSE PREP\%} \times \text{HRS/DEFENSE PEP \%} / \text{HRS/DAY USABLE} \times \\ \text{\%Unit-tm (PRE)} \times \text{\%Crit path (PRE)}$$

Thus time increases as a linear function of desired preparation. Defense preparations reduce the attacker's lethality. 100 percent defense preparation would cause the TERRAIN ATTACK MULT to take on the value corresponding to the most defensible terrain in the zone. Values between 0 and 100 percent increase the attack multiplier from its base corresponding to the average terrain for the zone to the most defensible terrain.

Survey and Reconnoiter [S&R]. Surveillance time is presumed to be affected by Intel error rate (a capability variable—policy variables do not affect TS&R). A coefficient, IERRCOEFSURVTM, attempts to capture the relationship. Recalling that intell error will take on small values between 0 and 1 (e.g., 10 percent), TS&R is:

$$\text{TS\&R} = ((1 + \text{INTEL ERROR})^{\text{IERRCOEFSURVTM}}) \times (\text{Null}) \times \\ \text{\%Unit-tm(S\&R)} \times \text{\%Crit path(S\&R)}$$

(Null) refers to the companion parameter to IERRCOEFSURVTM[12] that allows the user to override this assumed relationship. In this case, the relationship between intel error and the time required to conduct a given amount of surveillance/reconnaissance is assumed to be nonlinear; that is, as an MVR's intelligence system gets worse, it will need to spend a greater than proportional amount of time performing S&R to compensate for these weaknesses.

Delay for higher echelon orders [DEL]. Delay is one of MOSCOW's two ways of reflecting the effects of imperfect high-level C^3I on MVR requirements. Under both methods imperfections result in "wastage" of MVRs. At the most aggregate level, extra MVRs are needed to compensate for wastage. At the MVR activity cycle level, *time* is wasted—useful activities are delayed while the MVR waits for higher echelons to decide and to transmit their decisions.

This equation assumes that delay will be nonlinear along each of two related dimensions:

1. The number of MVRs per headquarters, relative to headquarters' "rated" span of control. The assumption here is that errors and delays multiply exponentially as headquarters are required to take on more MVRs than they were designed to handle.
2. The "rated" span of control of headquarters. The assumption here is that even within its design limits, extra MVRs impose burdens on HQs that cause delays.

As in S&R, there are no policy variables in this equation.

$$\text{TDEL} = \left[\text{HQ SPAN} - \#\text{MVRs}) \times {}^{(\text{HQLOADDELCOEF} \times (\text{Null}))}\right] \times \left[\text{HQBURDEN/HQ SPAN} - \#\text{MVRs} \times {}^{(\text{HQBURDDELCOEF} \times (\text{Null}))}\right] \times \%\textit{Unit-tm}\ (\textit{DEL}) \times \%\textit{Crit path}\ (\textit{DEL})$$

HQ SPAN is an input from the Success Criteria section. HQ BURDEN is calculated based upon the number of MVRs required, reflecting the burden on available headquarters relative to their design span of control:

$$(\text{MVRs Needed}/\#\ \text{HQs AVAIL})/\text{HQ SPAN} - \#\text{MVRs}$$

MVRs Needed is displayed in the output block, while the other terms are inputs in the Success Criteria block.

Move to wpn Range (1st Contact) [MWR] *A*. Blue MVRs, which are uniformly distributed over the area (FORW BNDRY − REAR BNDRY) × ZONE WIDTH, move to mass a the number of vehicles needed to achieve TAC PWR ATK, the desired tactical combat power ratio. We define a parameter, BLUE GEOM, representing the fraction of a circle from which Blue can gather forces. If the campaign is purely linear, then they can come from only 50 percent of a circle; if completely fluid (nonlinear), then from 100 percent. If forces must travel long distances forward relative to their starting horizontal separation, BLUE GEOM may be between 0.0 and 0.5.

Time (MWR) is defined as the time until the most distant MVR needed to achieve the desired power ratio arrives. The number needed occupies the area, A, that is large enough to include the required number of vehicles, B, assuming some density of Blue vehicles per km^2.

[12]IERRCOEFSURVTM is one of a small number of "optional" calibration coefficients in MOSCOW. These treat plausible phenomena for which there is no established theory or empirical evidence. Consequently, they produce behavior that is intuitively plausible in direction, but of unknown plausibility in magnitude. Users can suppress any optional coefficient by setting its (Null) to zero.

Note that A = BLUE GEOM × PI × $RADIUS^2$. The distance traveled by the most distant MVR is RADIUS. So the problem is to solve for RADIUS.

Note that A, the area needed, equals B divided by Blue MVR density. So:

$$\text{BLUE GEOM} \times \Pi \times \text{RADIUS} = \text{B}/(\text{MVRs needed}/([\text{REAR BNDRY} - \text{FORW BNDRY}] \times \text{ZONE WIDTH}))$$

Where MVRs needed is an output, B is computed in the combat power section, and all other variables are input in the Threat or Success Criteria sections.

$$\text{Therefore, RADIUS}^2 = (\text{B} \times [\text{REAR BNDRY} - \text{FORW BNDRY}] \times \text{ZONE WIDTH})/(\text{MVRs needed} \times \text{BLUEGEOM} \times \Pi)$$

$$\therefore \text{RADIUS} = \{(\text{B} \times [\text{REAR BNDRY} - \text{FORW BNDRY}] \times \text{ZONE WIDTH})/(\text{MVRs needed} \times \text{BLUE GEOM} \times \Pi)\}^{.5}$$

Because MVRs may engage at some standoff distance from enemy vehicles—input as IF DIST-FLOT-LO for indirect fire and DF DIST-FLOT-LO for direct fire—RADIUS will actually be reduced by the minimum of these amounts, if both are applicable. Knowing the distance that the farthest MVR must travel, time is simply distance divided by MVR velocity, in this case BLUE MOVEF (from the mobility section, see App. D). Further, because an MVR moves to within weapon range only once per target RMVR (further "closings" being included in the Reclose activity, RCL), this is divided by CYCLES/MVR-ATK, the number of cycles per Red kill.

Therefore, the entire TMWR equation is:

$$\text{TMWR} = \left[(\{(\text{B} \times [\text{REAR BNDRY} - \text{FORW BNDRY}] \times \text{ZONE WIDTH})/(\text{MVRs needed} \times \text{BLUE GEOM} \times \Pi)\}^{.5}\right]/(\text{BLUEMOVEF} \times \text{CYC/MVR-ATK}) \times \%\text{Unit-tm (MWR)} \times \%\text{ Crit path (MWR)}$$

Attack—1st phase (1 Red unit) [ATK1] *A*; Attack—2nd phase (reinf. Red) [ATK2] *A*; Defend [DEF] *D*. These three activities are detailed in the "Battle Calculus" appendix (App. C).

Disengage (to shadow dist) [DIS]. After terminating an engagement, Blue units disengage and move some distance (SHADOW DIS-ATK or SHADOW DIS-DEF) away from the enemy unit. The time required for the movement itself is simply SHADOW DIS / BLUE MOVEF. However, the designer posited that a further term should be included to reflect the ability of the surviving Red force to delay Blue's withdrawal. The two terms that are included are the fraction of Red's starting force that survives the engagement (shown here as %RED SURV) and Blue's ability to determine the point of disengagement, %DISENG-ATK or %DISENG-DEF. The first term increases delay while the second mitigates the increase. Coupled with a calibration coefficient, the equation for Time (DIS) becomes:

$$\text{TDIS} = \text{SHADOW DIS-ATK (or -DEF)/BLUE MOVEF} + (\text{Null}) \times \%\text{RED SURV}^{(\text{REDSURVCOEFDIS}/\%\text{DISENG-ATK (or -DEF)})} \times \%\text{Unit tm (DIS)} \times \%\text{Crit path (DIS)}$$

Finally, because MVRs in attack cycles are not required to disengage after the final attack against a particular target RMVR (the final attack will have destroyed it), the above equation must be deflated multiplying by the term (CYC/MVR-ATK – 1) / CYC/MVR-ATK, yielding:

$$\text{TDIS} = \Big[\text{SHADOW DIS-ATK (or -DEF) / BLUE MOVEF} + (\text{Null}) \times \%\text{RED SURV}^{(\text{REDSURVCOEFDIS}/\%\text{DISENG-ATK (or -DEF)})}\Big] \times \%\text{Unit tm (DIS)} \times \%\text{Crit path (DIS)} \times (\text{CYC/MVR-ATK-1})/\text{CYC/MVR-ATK})$$

Reclose (from Shadow Dist) [RCL] *A*. Time to reclose is simply the time to traverse SHADOW DIS, adjusted for the fact that the first closing was captured in the MWR activity:

$$\text{TRCL} = \text{SHADOW DIS-ATK (or-DEF)/BLUE MOVEF} \times (\text{CYC/MVR-ATK} - 1)/\text{CYC/MVR-ATK}) \times \%\text{Unit tm (RCL)} \times \%\text{Crit path (RCL)}$$

If the null coefficient of REDSURVCOEFDIS (see above) is set to zero or the second term of the sum (in brackets) in the TDIS equation is negligible, then TRCL will be equal, or very close, to TDIS.

Reconstitute Unit Cohesion [RCST]. Time to reconstitute is the time needed to regain organizational cohesion, reestablish command links, and change or tighten up the unit's formation after an engagement. It is posited to be affected by Blue C-3 ERROR, Blue's attrition in the engagement, and TIME-CHNG FORMN. The equation is as follows:

$$\text{TRCST} = \{\ [\text{RECONSTMCOEFF}/(1 - \text{C-3 ERROR}) \times (\%\ \text{Losses-ATK1} + \%\ \text{Losses-ATK2, or } \%\ \text{Losses-DEF}) \times (\text{Null})\ ] + \%\text{MVMT-ADMIN} \times \text{TIME-FORMN CHNG}\ \} \times \%\text{Unit tm (RCST)} \times \%\text{Crit path (RCST)}$$

In the model, (%MVMT-ADMIN × TIME-FORMN CHANG), the expected time to change formation, includes a branch that omits this time if the engagement was very short (and the MVR never left ADMIN formation) and includes a term converting from the time needed to change formation (TIME-FORMN CHANG) from minutes to days.

Move to Exchange Point [MTX]. Time to move to the "exchange point," at which the MVR receives supplies, is simply:

$$\text{TMXC} = \text{DIS-EXCHPT-DEF (or -ATK) /BLUEMOVEF} \times \%\text{Unit tm (MXC)} \times \%\ \text{Crit path (MXC)}$$

Load Supplies [LOD]. Time to load is a function of consumption (aggregated into tons of supplies) during the cycle divided by the MVR's loading rate.

$$\text{TLOD} = (\text{Tons consumed in cycle}) / \text{LOAD RATE} / \text{HRS USBLE/DAY} \times \%\text{Unit tm (LOD)} \times \%\text{Crit path (LOD)}$$

Repair (Vehicles and Personnel) [RPR]. Repair time is a function of vehicles and personnel lost during the cycle, the fraction repairable by the MVR's organic assets, the fraction of repairables that Blue chooses to repair, and the rate at which the MVR can repair them. Thus:

TRPR = (Sum vehicles consumed in cycle) × %REPRBL LOSS-M × % REPRD-M/

VEH REGEN/DAY × %Unit tm (RPR) × %Crit path (RPR)

Vehicles repaired per day thus is VEH REGEN/DAY × TRPR

Personnel repaired per day is PERS REGEN/DAY × TRPR

Rest [RES]. Blue chooses a %REST policy, representing the average portion of a cycle (or other time period) that Blue MVRs may rest. In the calibration coefficients section, the user sets a BASELINE %RES, representing the fraction of MVR time spent resting that is assumed in all input values. Mobility and lethality are affected by a REST MULT, which is bounded above at 1.0. The equation for the REST MULT (of mobility and lethality) is:

$$\text{REST MULT} = \text{Min}[\ 1, (\%\text{REST} / \text{BASELINE } \%\text{RES})^{(\text{LOWRESTCOEF} \times \text{Null})}]$$

If LOWRESTCOEF is set at 2 and Null at 1, then the consequences of less than baseline rest will be magnified (squared) in its effects on mobility and lethality.

Time to rest is simply %REST × Time of the entire cycle (TTOT). If Time of Cycle consists of two components, TRES and T(OTH) (for time of all other activities), then this equation becomes:

TRES + T(OTH) = TTOT

%RES × TTOT + T(OTH) = TTOT

T(OTH) = (1 − %RES) TTOT

T(OTH) / (1 − %RES) = TTOT

Since TRES = %RES × TTOT,

Then TRES = %RES × T(OTH) / (1 − %RES); or TRES = %RES / (1 -%RES) × T(OTH); where T(OTH) is the sum of [TPRE + TS&R + TDEL . . . TMTS].

Move to Standby Position [MTS]. In this activity MVRs return to the same position relative to other MVRs as they were in their starting place. The absolute position will of course have moved if the FLOT has advanced during the MVR's cycle. The general form of the equation is therefore

TMTS = [Distance moved in other parts of cycle − FLOT movement/day ×

length of cycle in days] / BLUE MOVEF × %Unit tm (MTS) × %Crit path (MTS)

For ATK cycles, (Distance moved) = RADIUS, and FLOT Movement/day

refers to ATK engagements

For DEF cycles, (Distance moved) = DIS-EXCHPT-DEF, and FLOT Movement/day

refers to DEF engagements

Move cross-country (non-MVR) [MXC] *0* and unload supplies [UNL] *0* are reserved for HQ or supply units, whose consumption is not computed in MOSCOW-M1 but may be calculated in later versions. They are not used in MOSCOW-M1, so no equations have been written.

Appendix C

COMPUTING LOSSES AND DURATIONS IN ENGAGEMENT-RELATED ACTIVITIES "BATTLE CALCULUS"

The single most complex portion of MOSCOW translates maneuver unit capabilities and warfighting concept policy variables at the operational and tactical levels into battle losses and durations. Unlike most campaign models, however, activities in which combat occurs constitute no more than two of the 17 in the cycle.[1] Although these may consume a large fraction of some *resources*, such as vehicles and personnel, they may involve a fairly small proportion of overall cycle *time*. Thus, improvements in combat performance that substantially reduced attrition may nevertheless have only a marginal effect on the campaign kill rate of Blue MVRs and consequently on their required numbers.

The Battle Calculus is composed of seven elements:

1. Engagement initiation criteria (tactical attacker: defender combat power ratio) and starting strengths
2. Hardness of vehicles (which act as firers of weapons and as targets of enemy weapons)
3. Availability of vehicles (as targets of enemy weapons)
4. Lethality of vehicles (incorporating enemy hardness and availability)
5. Engagement termination criteria (attrition imposed on or suffered by the defender)
6. Engagement duration and vehicle attrition
7. Blue's consumption of additional commodities during the engagement (POL, ammo, etc.)

Item 1 is determined by the combat power ratio desired by each side in engagements where it is the attacker (TAC PWR-ATK, an input), with the vehicle strengths of each side's MVRs reflecting the effects of unrepaired breakdowns (for Red) and unreplaced attrition from previous engagements (for both). Items 2 through 4 are computed for engagements in which Blue and Red are each attacking or defending (four calculations). Using the fraction of engagements in which Blue is presumed to be able to dictate the duration in the inputs (DISENG %AGE-ATK and DISENG %AGE-DEF), and each side's preferences regarding the attrition Red suffers in Blue attacks (RED ATTR-BLATK) and that Blue suffers in Red attacks (BLUE ATTR-RATK), item 5 determines the amount of attrition to be imposed on the defending side in engagements where Blue attacks and where Red attacks. Using the starting strengths from Item 1, the lethalities from item 4, and the attrition objective from item 5, item 6 uses an inverted Lanchester equation to compute the duration of the engagement.[2] Once this duration is established, item 6 goes on to use this duration in the normal form of Lanchester to compute vehicle attrition. Using item 6's duration as the time of the engagement (and therefore of activities ATK1, ATK2, or DEF), item 7 computes the quantities of other commodities (POL, Ammunition, and Other) consumed.

[1]The engagement activities for MVRs assigned attack missions are ATK1 and ATK2; for defend missions, DEF.

[2]In MOSCOW-M1, this equation is set for the square version of Lanchester, but it includes calibration parameters permitting adjustment to other values of the exponent of vehicle numbers.

ENGAGEMENT INITIATION CRITERIA

Engagements begin when the attacker amasses the combat power ratio he desires (input as TAC PWR ATK). Combat power is equal to an MVR's strength in vehicles × (Lethality)$^{.5}$.

Both Red and Blue assign portions of their force to Attack and Defend missions (Red in the *Red Threat* block and Blue in the *Success Criteria* block). Thus, four types of engagements are possible: Blue attacking vs. Red attacking; Blue defending vs. Red attacking; Blue attacking vs. Red defending; and Blue defending vs. Red defending. MOSCOW assumes that the last type of engagement does not occur. It combines the first and third into a single type in which Blue, using its attacking lethality, faces a Red whose lethality is a weighted mixture of attacking and defending lethalities (as illustrated in Fig. C.1).

The unit combat power calculations shown in Fig. C.2 are used to compute the number of vehicles (and therefore of MVRs or RMVRs) that must be amassed to achieve the desired combat power ratio for two types of engagements: Red attacking against a Blue defender, and Blue attacking against a weighted average of Red defenders and attackers.

```
ATK/ATKR KILL    5.995 rmvrs
ATK/DFDR KILL    1.998 rmvrs

            %ATKS/ATTKR:        75.0%
            %ATKS/DEFDR:        25.0%
```

Fig. C.1—Distribution of Blue attacks in which RMVRs are attackers vs. defenders

```
                     UNIT COMBAT POWER CALCULATIONS

                                                  KILL RATES/HR:
MVR STRENGTH-ATK:        1200 vehicles                 Blue     Red
MVR STRENGTH-DEF:        1200 vehicles     Attack     0.103    0.015
                                           Defense    0.156    0.053
RMVR STRENGTH:            736 vehicles     Average    0.123    0.024

   MVR Combat Power                        RMVR Combat Power
   Attack            385.48                Attack     90.22
   Defend            473.47                Defend    169.36
   Average           419.32                Average   115.22

 Blue:Red Combat Power Ratios for a One unit-on-One-unit engagement
                                           Red Posture
                                   Attack    Avg.   Defend

   Blue           Attack             4.27    3.35     2.28
   Posture
                  Defend             5.25    N/A      N/A

   Number of Blue MVRs required to achieve combat power ratios.

                                           Red Posture
                                   Attack    Avg.   Defend

              Blu Attack       [illegible].41    0.52     0.77
          Power Ratio (B:R):
Blue                   1.75
Posture
              Blu Defend       [illegible].19    N/A      N/A
          Power Ratio (B:R):
                       0.99
```

Fig. C.2—MOSCOW screens displaying MVR and RMVR combat power and effective combat power ratios

VULNERABILITY (AVAILABILITY AND HARDNESS) COMPUTATIONS

As with mobility, the hardness and availability of targets is formation-dependent, using as inputs HARDNESS-ADMIN or HARDNESS-BATTL, and CONCLMT-ADMIN and CONCLMT-BATTL, respectively.

HARDNESS is calculated based upon the fraction of attack and defense engagements an MVR is expected to spend in each formation. Since this requires knowledge of the engagement length (TATK1+TATK2 for attacks, and TDEF for defending engagements), which is affected by target hardness, simultaneity is introduced. Hardness, then, depends on the following variables:

Functional Form	Capability	Policy	Scenario	Activity Time
Linear	HARDNESS-ADMIN HARDNESS-BATTL TIME-CHNG FORMN	%MVMT-ADMIN %MVMT-BATTL		TATK1+TATK2 TDEF

All hardness calculations are linear, leading to HARDNESS-ATK and HARDNESS-DEF.

Availability is a measure of the fraction of vehicles in an MVR that are targets for enemy weapons. Like hardness, it is computed for both attack and defense engagements. Perfect availability is degraded by terrain, by concealment measures, by intelligence errors on the firing side, and by range limitations. It is increased by concentration of MVRs (to achieve a high combat power ratio).

Availability is also affected by engagement times in the following way: vehicle DF and IF distances from an "INITIAL FLOT," an imaginary line between the engaged units, are provided as inputs. Each vehicle conducts the battle alternating a series of periods when stationary (TAC STA PD), then dashing in a "tactical move" at VEH DASH SPD to the next location (the distance equal to DIS/TAC MV). The MVR AGGRSVNESS inputs indicate the fraction of each DIS/TAC MV that each vehicle advances toward the enemy, ranging from +1.0 if directly forward to −1.0 if directly backward.[3] Thus distances between firers and targets may change during the course of an engagement. MOSCOW uses the distance at the midpoint of the engagement as the average distance—at (TATK1+TATK2)/2 for attack engagements and TDEF/2 for defense engagements—to compute the fraction of friendly direct and indirect fire targets in range of the enemy's direct and indirect fire weapons. Overall availability is the product of each effect weighted by the fraction of friendly vehicles assigned to fire in direct vs. indirect fire mode.

The variables that affect availability are as shown in the following text table.

Figure C.3 shows the discursive form of the model's availability calculations.

[3]The relative displacement with relation to the enemy is referred to on the spreadsheet as an OPNL MOVE.

Functional Form	Capability	Policy	Scenario/Threat	Activity Time
	CONCLMT-ADMIN			TATK1+TATK2
	CONCLMT-BATTL			TDEF
			TERR AVLBTY MULT-A	
			TERR AVLBTY MULT-D	
Linear	VEH DASH SPD	TAC STA PD	RED INTEL ERROR	
		DIS/TAC MV	IF DIST-FLOT-HI (Red)	
		IF %OPNL MOVE	IF DIST-FLOT-LO (Red)	
		IF DIST-FLOT-HI (Blue)	DF DIST-FLOT-HI (Red)	
		IF DIST-FLOT-LO (Blue)	DF DIST-FLOT-LO (Red)	
		DF DIST-FLOT-HI (Blue)		
		DF DIST-FLOT-LO (Blue)		
Nonlinear		TAC PWR RA-ATK		

CALCULATIONS OF LETHALITY

Lethality is measured in the number of enemy vehicles, or fraction of an enemy unit's starting strength in vehicles, that can be destroyed per unit time. Computations proceed as follows.

(a) Firing rates (ACT IF RATE-S, and its analogs) and hit probabilities per shot (HITS/RND-X/X)[4] are provided in the inputs for firer/target pairs in each of four states: stationary/moving, stationary/stationary, moving/stationary, and moving/moving. Utilizing the TAC STA PD, DIS/TAC MOVE, and VEH DASH SPD inputs for each side, joint distributions of these four states are calculated (separately for engagements in which Blue is defending and in which Blue is attacking).

(b) Based on this distribution, the average firing rate per vehicle is computed. Incorporating the inputs reflecting the fraction of an MVR able to fire at any given moment as affected by formation (%FIRERS-ADMIN and %FIRERS-BATTL), and the fraction of the engagement in which the MVR is in ADMIN formation[5] the average number of vehicles able to fire (#FIRERS-ATK and #FIRERS-DEF) is computed. Using the input distribution of each side's vehicles between direct and indirect fire (%FIRERS DF), hit, kill, and personnel hits (using ANTI-PERS COEF to modify the basic hit probabilities) per minute per MVR in attack and defense and in both direct and indirect fire are computed at HITS/MIN IF1D . . . PHITS/MIN DF1D.[6] The lethality computations are given in Figs. C.4 to C.8.

(c) Next, the degradation of attack lethalities due to terrain (TERRAIN ATK MULT), C-3 ERROR, target hardness, and lack of rest (REST MULT) are applied, yielding HITS/MIN IF2D . . . PHITS/MIN DF2D.

(d) Using (TATK1+TATK2)/2 as the midpoint of the attack engagement and TDEF/2 for the defense, as was done for availability, the average distance between firers and targets

[4]HITS/RND and KILLS/HIT are input for Direct Fire (DF) at minimum range. the IF HITS/R COEF modifies this hit probability to reflect indirect fire, and the HIT DEGRD-MAXR reflects degradation of this hit probability at maximum range, with an assumed negative exponential function between them.

[5]This variable introduces simultaneity as noted in Sec. IV.

[6]The notation is interpreted: type of fire, stage in computation, type of engagement.

```
                 VULNERABILITY CALCULATIONS

                 AVAILABILITY (as a target)
                    ENGAGEMENT: RA BD

                   Red      Blue

  ENGAGEMENT: RA BD

CONCLMT-ADMIN     0.05    0.15 % of vehicles concealed--admin formation
CONCLMT-BATTL     0.33    0.64 % of vehicles concealed--battle formation

       AVAIL1     0.67    0.36 % of RMVR or MVR available as a target

TERR AVLBTY MUL   0.69    0.69 terrain availability multiplier

       AVAIL2     0.46    0.25 % of RMVR or MVR available as a target

INTEL ERR         0.03    0.03 intelligence error rate

       AVAIL3     0.45    0.24 % of RMVR or MVR available as a target

TAC PWR RA       2.000   0.500 tactical power ratio (own side : enemy)

       AVAIL4     0.45    0.24 % of RMVR or MVR available as a target

EFFECTS OF WEAPON RANGE & TACTICAL DEPLOYMENT ON AVAILABILITY:
       Engagement: RD BA

              **(calculations deleted from this figure)**

RANGE-BASED AVAILABILITY SUMMARIZED:

IF RANGE AVAIL.   0.09    0.19 % of IF vehs available (based on range)
DF RANGE AVAIL.   1.00    1.00 % of DF vehs available (based on range)

MVR RANGE AVAIL   0.83    0.93 % of MVR vehs available (based on range)

ENGAGEMENT: RA BD
  AVAILABILITYF   0.37    0.22 % of MVR available (final)
```

Fig. C.3—Principal availability calculations

LETHALITY CALCULATIONS
ENGAGEMENT: RD BA

ENGAGEMENT: RD BA

	Red	Blue	
%ENGMT STATNRY	0.27	0.43	[N.B. There are two identical
%ENGMT MOVING	0.73	0.57	sets of "%Engmt.." cells.
%ENGMT STATNRY	0.27	0.43	Both are referenced later.]
%ENGMT MOVING	0.73	0.57	
% OF ENGMT-ADM	0.116	0.048	
AVG FIRING RATE	0.30	0.63	rnds/min
# OF VEH FIRING	617.5	679.7	# veh
% FIRERS IF	0.19	0.09	% of vehs firing in IF mode
% FIRERS DF	0.81	0.91	% of vehs firing in DF mode
% FIRERS DF	0.81	0.91	% of vehs firing in DF mode
ADMIN % FIRERS	0.10	0.20	% of vehs able to fire
BATTL % FIRERS	0.60	0.50	% of vehs able to fire
TAC STATRY PER.	0.91	0.75	mins
ACQ TIME-S TGT	300.00	180.00	sec.
STGT#SHOTS-ACQ	3.00	1.50	#shots
ACT IF RATE-STA	1.50	1.50	rnds/min
ACT DF RATE-STA	1.23	1.16	rnds/min
FIRE RATE-STA	1.28	1.19	rnds/min
HITS/RND-S/S	0.00	0.00	avg DF hits/rnd: sta firer/sta target
HITS/RND-S/M	0.47	0.56	avg DF hits/rnd: sta firer/mov target
HITS/RND-M/S	0.00	0.00	avg DF hits/rnd: mov firer/sta target
HITS/RND-M/M	0.19	0.37	avg DF hits/rnd: mov firer/mov target
IF HITS/R COEF	0.33	0.33	multiplier of avg. DF hits/round for IF
KILLS/HIT	0.50	0.47	prob (kill given hit)
ANTI-PERS COEF	0.30	0.27	multiplier of P(k|h) for personnel tgts
% PERS DISMTD	0.13	0.30	% of pers dismounted
			Firer/tgt movement status distribution:
% STA/STA	0.12	0.12	% of engmt stationary/stationary
% STA/MOV	0.16	0.31	% of engmt stationary/moving
% MOV/STA	0.31	0.16	% of engmt moving/stationary
% MOV/MOV	0.41	0.41	% of engmt moving/moving
(Totals check)	1.00	1.00	
HITS/MIN BY IF1	2.73	4.21	hits per minute by IF vehicles-1
HITS/MIN BY DF1	35.30	128.89	hits per minute by DF vehicles-1
KILLS/MIN IF1	1.37	1.98	kills per minute by IF vehicles-1
KILLS/MIN DF1	17.65	60.58	kills per minute by DF vehicles-1
P HITS/MIN IF1	0.82	1.14	personnel hits per minute by IF vehicles1
P HITS/MIN DF1	10.59	34.80	personnel hits per minute by DF vehicles1

Fig. C.4—Lethality computations: 1st stage

(d) Using (TATK1+TATK2)/2 as the midpoint of the attack engagement and TDEF/2 for the defense, as was done for availability, the average distance between firers and targets (each of DF and IF) is computed, in order to represent the effects of distance on lethality. A coefficient is calculated that can take on a value between 1.0 and HIT DEGRD-MAX between minimum and maximum ranges, interpolated as a negative exponential function in between. These coefficients are applied to the above lethalities to produce HITS/MIN IF3D . . . PHITS/MIN DF3D.

(e) The calibration coefficients include DISMTDLETHCOEF, a coefficient to reflect increased direct fire lethality through dismounted combat. This coefficient utilizes %PERS DISMTD to affect each of the ". . . DF . . ." lethalities. Here, also, the miscellaneous friendly lethality and enemy vulnerability multipliers (MISC VULN-A, MISC LETH-D, etc.) are applied.

HARDNESS	0.79	0.52	x nominal hardness
C-3 ERROR	0.40	0.09	prob. of C-3 error
TERRAIN ATK MULT	NA	0.66	multiplier of attacker hit prob.
REST MULTIPLIER	NA	0.57	mult of hit prob. due to insuff. rest
HITS/MIN BY IF2	3.10	1.79	hits per minute by IF vehicles-2
HITS/MIN BY DF2	40.04	54.95	hits per minute by DF vehicles-2
KILLS/MIN IF2	1.55	0.84	kills per minute by IF vehicles-2
KILLS/MIN DF2	20.02	25.83	kills per minute by DF vehicles-2
P HITS/MIN IF2	0.49	0.40	personnel hits per minute by IF vehicles2
P HITS/MIN DF2	6.35	12.11	personnel hits per minute by DF vehicles2

Fig. C.5—Lethality computations: 2nd stage

AVERAGE FIRING DISTANCE COMPUTATIONS:

ENGAGEMENT: RD BA

(calculations omitted from this figure)

IF RANGE COEF	0.717	1.210	multiplier of p(hit)--IF firer
DF RANGE COEF	0.986	1.210	multiplier of p(hit)--DF firer
HITS/MIN IF3A	2.22	2.17	hits per minute by IF vehicles-3
HITS/MIN DF3A	39.46	66.49	hits per minute by DF vehicles-3
KILLS/MIN IF3A	1.11	1.02	kills per minute by IF vehicles-3
KILLS/MIN DF3A	19.73	31.25	kills per minute by DF vehicles-3
P HITS/MIN IF3A	0.35	0.48	personnel hits per minute by IF vehicles3
P HITS/MIN DF3A	6.26	14.65	personnel hits per minute by DF vehicles3

Fig. C.6—Lethality computations: 3rd stage

	Red Firer	Blue Firer	
% PERS DISMTD	0.13	0.30	% dismounted
HITS/MIN IF4	1.80	0.16	hits per minute by IF vehicles-4
HITS/MIN DF4	31.96	4.99	hits per minute by DF vehicles-4
KILLS/MIN IF4	0.90	0.08	kills per minute by IF vehicles-4
KILLS/MIN DF4	15.98	2.34	kills per minute by DF vehicles-4
P HITS/MIN IF4	0.29	0.04	personnel hits per minute by IF vehicles4
P HITS/MIN DF4	5.07	1.10	personnel hits per minute by DF vehicles4
LETHALITY MULT	0.90	0.30	multiplier of lethality
VULN. MULT	0.25	0.90	multiplier of vulnerability

Fig. C.7—Lethality computations: 4th stage

(f) Final lethality parameters add together kills per minute from indirect and direct fire, plus kills per minute from supporting fires (Headquarters and CAS), for Attack and Defend engagements. These lethalities are then multiplied by Red's availability to produce kills and personnel hits per unit time, calculated in absolute units (vehicles and people) and as a percentage of a full-strength enemy MVR. The %KILLS/HR-DEF and %KILLS/HR-ATK are the versions of lethality actually used to compute combat power and in the Lanchester equations that calculate engagement durations and attrition.

Figure C.9 summarizes lethality-related information flow in a simplified example.

ENGAGEMENT TERMINATION CRITERIA

Engagements last as long as necessary to achieve a designated amount of attrition. (See Fig. C.10.) That amount is bounded by Red and Blue's preferences (RED ATTR-BL ATK and BL ATTR-RATK), with the value determined by the fraction of engagements in which Blue is assumed to be able to dictate termination (DISENG %AGE). The calculations below compute the fraction of the weaker side (Red in a Blue attack, Blue in a Red attack) that will survive each engagement of that type. This variable is s, the surviving fraction, used in the next subsection.

LETHALITY SUMMARY--ENGAGEMENT: RD BA

	Red Leth.	Blue Leth.	
KILLS/MIN IFF	0.90	0.08	kills per minute by IF vehicles-final
KILLS/MIN DFF	15.99	2.34	kills per minute by DF vehicles-final
KILLS/MIN SUPT	0.06056	0.11240	kills per minute by support (CAS and HQs)
P HITS/MIN IFF	0.28569	0.04	personnel hits per minute by IF vehiclesF
P HITS/MIN DFF	5.07260	1.10	personnel hits per minute by DF vehiclesF
P HITS/MIN SUP	0.01922	0.05268	personnel hits per minute by support
ENEMY AVAILBTY	0.24	0.17	enemy target availability (from above)
KILLS/HR	231.20	53.27	enemy vehicles killed per hour per MVR
KILLS/DAY	5548.82	1278.39	enemy vehicles killed per day per MVR
P HITS/DAY	1760.23	599.23	personnel hits per day per MVR
% KILLS/DAY	396.50%	122.71%	% of enemy MVR killed/day of engagement
% KILLS/HR	16.52%	5.11%	% of enemy MVR killed/hr of engagement

Fig. C.8—Lethality computations: final values

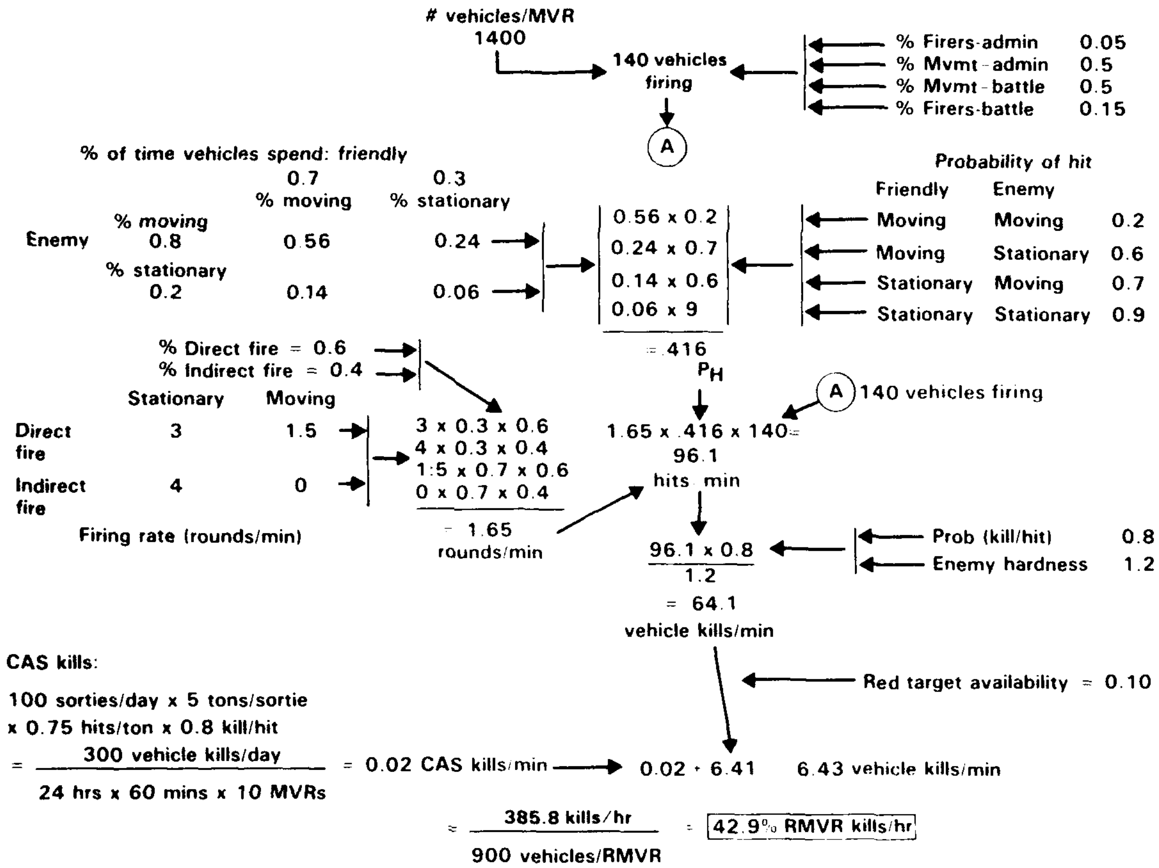


Fig. C.9—Simplified calculation of lethality parameter (example)

ENGAGEMENT DURATION AND VEHICLE ATTRITION

Utilizing the starting engagement strengths in vehicles, lethalities of Blue and Red in Attack or Defense engagements, and the attrition to be imposed on the defender, as computed in the earlier sections, these equations compute the duration of the engagement (and therefore of the ATK1, ATK2, or DEF activity, as applicable) with an inverted form of the Lanchester square attrition equation, then using this duration, compute vehicle attrition to each side.

(a) The notation used in this section is as follows:

- B and R are the starting strengths (in vehicles) of Blue and Red
- b and r are the lethalities of Blue and Red (in portions of a starting enemy MVR killed per hour)
- R(t) and B(t) are Red and Blue's strength (in vehicles) at time t of an engagement
- a is the percentage attrition that will be imposed on the weaker side in the engagement; therefore $s = (1 - a)$ is the percentage to survive. Note that $s = R(t)/R$ for the duration that imposes a attrition on the weaker side.

MISCELLANEOUS CALCULATIONS

(1) ACTUAL ATTRITION IN ENGAGEMENTS:

Blue:	DISENG %AGE-ATK	0.60 % of eng.
	DISENG %AGE-DEF	0.70 % of eng.
Red:	DISENG %AGE-ATK	0.40 % of eng.
	DISENG %AGE-DEF	0.30 % of eng.

	Red Attrition--Defense		Blue Attrition--Defense	
Preferred	Blue Pref.	15.0%desrd/eng	Blue Pr	10.0%desrd/eng
Attrition	Red Pref.	5.0%desrd/eng	Red Pre	66.0%desrd/eng
Actual	R ATR-BLU ATK	11%	BL ATR-BL ATK	3%
attrition	R ATR-BLU DEF	26%	BL ATR-BL DEF	27%
Actual	R SURV-BLU ATK	89%	B SURV-BL ATK	97%
survivors	R SURV-BLU DEF	74%	B SURV-BL DEF	73%
Avg.	S/RMVR: BLU ATK	82%	S/MVR: BLU DEF	100% at engmt
str/mvr in engmt	S/RMVR: BLU DEF	82%	S/MVR: BLU ATK	100% at engmt

Fig. C.10—Attrition in engagements (input to Lanchester computations)

The problem is to find t such that $R(t)/R = s = (1 - a)$.

Traditional Lanchester Square Formula

Throughout the remainder of this example we will assume that Blue is the stronger side in a tactical engagement and is attacking. The traditional version of Lanchester computes $R\ (t)$, the surviving Red strength, as a function of the assumed duration of their engagement:[7]

$$R(t) = [((R - (b^{.5}/r^{.5}) \times B) \times e^{(((r \times b)^{.5}) \times t)} + (R + (b^{.5}/r^{.5}) \times B) \times e^{(-((r \times b)^{.5}) \times t)}]/2 \qquad (1)$$

Derivation of Engagement Duration Equation[8]

First, express survivors in percentage terms, or $R(t)/R$:

[7]As an example, see Steinbrunner and Sigal, 1982 (Appendix by Kaufmann), p. 245.

[8]I am indebted to James Bigelow and James Hewitt for assistance with this derivation.

$$R(t)/R = [((R - (b^{.5}/r^{.5}) \times B) \times e^{(((r \times b)^{.5}) \times t)} +$$
$$(R + (b^{.5}/r.5) \times B) \times e^{(-((r \times b)^{.5}) \times t)}]/2 \times R$$

Next, change notation, since $R(t)/R = s$, and multiply both sides by $2 \times R$:

$$s \times 2 \times R = ((R - (b^{.5}/r^{.5}) \times B) \times e^{(((r \times b)^{.5}) \times t)} +$$
$$(R + (b^{.5}/r^{.5}) \times B) \times e^{(-((r \times b)^{.5}) \times t)}$$

Now, we define some notation to simplify exposition:

$A = ((R - (b^{.5}/r^{.5}) \times B)$

$B = s \times 2 \times R$

$C = ((R + (b^{.5}/r^{.5}) \times B)$

$X = e^{(((r \times b)^{.5}) \times t)}$

So the previous equation can be expressed as:

$$s \times 2 \times R = A \times X + C \times X^{-1}$$

Multiply through both sides by X:

$$s \times 2 \times R \times X = A \times X^2 + C$$

Using the notation that $B = s \times 2 \times R$:

$$B \times X^2 = A \times X^2 + C$$

Forming the quadratic:

$$A \times X^2 - B \times X + C = 0$$

Using the quadratic solution, $X = [-B +/-(B^2 - 4 \times A \times C)^{.5}]/(2 \times A)$, and converting back to original notation, possible roots are:

$$e^{(((r \times b)^{.5}) \times t)} = [s \times 2 \times R + (s^2 \times 4 \times R^2 -$$
$$(((R - (b^{.5}/r^{.5}) \times B) \times ((R + (b^{.5}/r^{.5}) \times B)))^{.5}]/$$
$$[2 \times ((R - (b^{.5}/r^{.5}) \times B)]$$

and

$$e^{(((r \times b)^{.5}) \times t)} = [s \times 2 \times R - (s^2 \times 4 \times R_2 -$$
$$(((R - (b^{.5}/r^{.5}) \times B) \times ((R + (b^{.5}/r^{.5}) \times B)))^{.5}]/$$
$$[2 \times ((R - (b^{.5}/r^{.5}) \times B)]$$

The term under the radical in the numerator can be factored:

$$(R - (b^{.5}/r^{.5} \times B) \times (R + (b^{.5}/r^{.5}) \times B) = R^2 - b/r \times B^2$$

So the root equations become:

$$e^{(((r \times b)^{.5}) \times t)} = [s \times 2 \times R + (s^2 \times 4 \times R^2 - (R^2 - b/r \times B^2))^{.5}]/ [2 \times ((R - (b^{.5}/r^{.5}) \times B)]$$

and

$$e^{(((r \times b)^{.5}) \times t)} = [s \times 2 \times R - (s^2 \times 4 \times R^2 - (R^2 - b/r \times B^2))^{.5}]/ [2 \times ((R - (b^{.5}/r^{.5}) \times B)]$$

Factor out 2s in the numerator and denominator and multiply both numerator and denominator by $r^{.5}/r^{.5}$:

$$e^{(((r \times b)^{.5}) \times t)} = [s \times r^{.5} \times R + (r \times s^2 \times R^2 - (r \times R^2 - b \times B^2))^{.5}] / [((R \times r^{.5} - b \times {}^{.5} \times B)]$$

and

$$e^{(((r \times b)^{.5}) \times t)} = [s \times r^{.5} \times R - (r \times s^2 \times R^2 - (r \times R^2 - b \times B^2))^{.5}] /[((R \times r^{.5} - b^{.5} \times B)]$$

Factor out $r \times R^2$ to yield:

$$e^{(((r \times b)^{.5}) \times t)} = [s \times r^{.5} \times R + (r \times R^2 \times (s^2 - 1) + b \times B^2)^{.5}] /[((R \times r^{.5} - b^{.5} \times B)]$$

and

$$e^{(((r \times b)^{.5}) \times t)} = [s \times r^{.5} \times R - (r \times R^2 \times (s^2 - 1) + b \times B^{2)^{.5}}] /[((R \times r^{.5} - b^{.5} \times B)]$$

Rearrange terms under the radical in the numerator, and taking the natural logarithm of both sides, yields:

$$((r \times b)^{.5}) \times t = \ln \{ [s \times r^{.5} \times R + (b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}] /[((R \times r^{.5} - b^{.5} \times B)]\}$$

and

$$((r \times b)^{.5}) \times t = \ell n \{ [s \times r^{.5} \times R - (b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}] /[((R \times r^{.5} - b^{.5} \times B)]\}$$

Dividing both sides by $(r \times b)^{.5}$ yields the duration equation:

$$t = \ell n \{ [s \times r^{.5} \times R + (b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}] /[((R \times r^{.5} - b^{.5} \times B)]\}/((r \times b)^{.5})$$

and

$$t = \ell n \{ [s \times r^{.5} \times R - (b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}] / [((R \times r^{.5} - b^{.5} \times B)] \} / ((r \times b)^{.5})$$

Determining the Unique Root Equation

Recall that:

(i) $B, b, R, r,$ and s are all positive numbers.
(ii) Since Blue is the attacker and attacks can occur only at combat power ratios greater than one ($B \times b^{.5}/R \times r^{.5} > 1$), $B \times b^{.5}$ must be greater than $R \times r^{.5}$.
(iii) Since s is the fraction of starting Red strength that survives the engagement, $0 \leq s \leq 1$, and also $s^2 \leq s$.

For the equation to have a real root, the term inside the logarithmic brackets must be positive. Note, however, that the denominator of this logarithm is $(R \times r^{.5} - B \times b^{.5})$, which we know from (ii) must be negative. Therefore the numerator of the logarithm must also be negative.

We know from (i) that the first expression, $(s \times r^{.5} \times R)$, is positive.

Therefore, for the first root equation to be true, the expression under the radical, $(b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}$, would have to be negative and of absolute value greater than $(s \times r^{.5} \times R)$.

For the second root equation to be true, the expression under the radical, $(b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}$, would have to be positive and greater than $(s \times r^{.5} \times R)$.

There are two reasons why the radical cannot be negative:

(iv) There are no real negative even-numbered roots.
(v) Since from (iii), s^2 is a positive number less than 1, $0 \leq (1 - s^2) \leq 1$. This is a coefficient of $(r \times R^2)$. Since from (ii), $B \times b^{.5} > R \times r^{.5}$, it must also be true that $B^2 \times b > R^2 \times r$. The radical, then, is the difference between $B^2 \times b$ and $R^2 \times r \times c$.[9] If $B^2 \times b > R^2 \times r$, then it is also greater than $(R^2 \times r \times 0 \leq c \leq 1)$, and therefore the value under the radical must be positive.

Therefore, the duration equation used to compute the length of the ATK1 and ATK2 activities is:

$$t = \ell n \{ [s \times r^{.5} \times R - (b \times B^2 - ((1 - s^2) \times r \times R^2))^{.5}] / [((R \times r^{.5} - b^{.5} \times B)] \} / ((r \times b)^{.5}) \quad (2a)$$

When Red is the attacker, the equation used for the DEF activity becomes:

$$t = \ell n \{ [s \times b^{.5} \times B - (r \times R^2 - ((1 - s^2) \times b \times B^2))^{.5}] / [((B \times b^{.5} - r^{.5} \times R)] \} / ((b \times r)^{.5}) \quad (2b)$$

[9] c represents any coefficient with a value between 0 and 1.

Implementation in MOSCOW Activities

The section below shows, in turn, the ranges of MOSCOW where engagement duration and attrition are computed. These can be found in the model at the "Miscellaneous calculations" section, part (11), Attrition in Attack and Defense Engagements.

ATK1 Activity. The distinction between the ATK1 and ATK2 activities relates to the assumed number of defenders present. For both Blue and Red, attacks begin against a lone defending unit. However, reserve or nearby units may reinforce the defender after a delay period that reflects warning and travel time. In MOSCOW, the average distance between a Red frontline RMVR and its potential reinforcement (e.g. a second tactical or operational echelon) is input as RED DIV SEPRTN, and an effective reinforcement movement rate is calculated as RED REINF MOVE, thus producing the delay period after the initiation of a Blue attack before the arrival of the reinforcing RMVR.

ATK1 is the part of the engagement in which the attacking Blue MVRs are faced with a lone defending RMVR. Its length is the lesser of the desired engagement duration (TATK1DES), computed per the above equation, and the delay prior to the arrival of the defenders' reinforcements. If the delay exceeds TATK1DES, then there is no ATK2 activity, and TATK2 is zero.

Several of the parameters are displayed in Fig. C.11 more than once, so as to provide their values in terms of natural units as well as percentages. Using the values shown below as an illustration, the computation is performed in the following way: Based on the average starting strength of an RMVR (846 vehicles), and Red and Blue respective lethality (7 and 11 percent per hour, which is also displayed as 94.9 and 95.7 vehicles per hour), and the combat power ratio ($B^2 \times b/R^2 \times r$) Blue desires before attacking, the number of Blue vehicles (818)

ATK1 ACTIVITY				Hours	Days
RED DIV SEPRTN	25.0 km	TATK1DES:		0.87	
RED REINF MOVE	2.68 km/hr	TATK1ACT:		0.87	0.036
TATK1DES elements 0.2	0.11	0.0	0.22	0.33	0.05
Blue veh surv. elements		0.49	2.45	1.04	0.96
Red veh surv. elements		-0.50	2.50	1.04	0.96
FR-ATK (BLUE : RED):	1.50	Normalized			
RED STRENGTH:	952	1.00	# RED UNITS:		1.00
BLUE STRENGTH:	1398	1.47	# BLUE UNITS:		1.00
RED LETHALITY:	46.55 Veh		0.05 MVR		
BLUE LETHALITY:	71.56 Veh		0.05 RMVR		
			Vehicle%	of start	Losses/hr
	Blue Strength Surviving:		1359	0.97	45.05
	Red Strength Surviving:		891	0.94	70.46
			R:B Exchnge Ratio		1.56

Fig. C.11—ATK1 activity time and vehicle attrition is computed, and expressed in terms of the number of MVRs (.58). Blue and Red vehicle strengths are reexpressed, normalized on the smaller value (to 1.03 and 1.00). The duration equation is subdivided into six terms, which are hidden where indicated, then combined to compute TATK1DES. Parameter values are: B = 1.00; b = .11; R = 1.03; r = .07; s = .89 (so desired attrition = 11 percent). Furthermore, the exponents of the terms in the duration equation are variables that can be changed from their customary values of 2 and .5.

In this instance, the reinforcing RMVR will require 15 km/ .98 km/hr, or a bit more than 15 hours to reinforce the defending RMVR. However, Blue can achieve the desired amount of attrition in 1.04 hours. Therefore, there need be no ATK2 activity.

Once TATK1 has been calculated, it is used in the traditional form of the Lanchester equation (Eq. 1), which is subdivided into four hidden terms each for Blue and Red as shown. Red's fraction surviving is of course s, .89, while Blue's is .93. These two values are reexpressed in terms of vehicles using the starting strengths (818 and 846), to yield 762 Blue and 752 Red vehicles surviving when the engagement breaks off. The difference between starting and surviving Blue vehicles represents Blue's combat attrition. TATK1 and vehicle attrition are reported to the ATK1 part of Blue's attack activity cycle.

ATK2 Activity. Computations in Fig. C.12 are identical to ATK1, with the following exceptions. First, no further Red reinforcements beyond the second RMVR are assumed to be available within conceivable engagement durations, so there is no constraint on TATK2. Second, Blue's starting strength is the ending strength of ATK1, and Red's is ATK1 ending strength plus the strength of reinforcing unit (762 and 1598 vehicles, respectively). In the example below, if Blue continued to attack (TATK2 was greater than zero), Blue would face unfavorable exchange rates. MOSCOW will continue engagements until the objective amount of attrition is imposed, even if it ceases to be advantageous to do so. *Users therefore should check to see if TATK2 exceeds zero and if the implied behavior really is consistent with a concept under examination.*

Finally, combined attrition (in MVRs or RMVRs) for the two activities is shown.

```
        ATK2 ACTIVITY:
                                                  TATK2:      0.00     0.000
****Time computations hidden in these cells****            Hours      Days

FR-ATK (BLUE : RED):         0.62  Normalized
RED STRENGTH:                1598          2.10 # RED UNITS:           1.89
BLUE STRENGTH:                762          1.00 # BLUE UNITS:          0.54

RED LETHALITY:              94.90 Veh            0.07 MVR
BLUE LETHALITY:             95.71 Veh            0.11 RMVR
                                                      Vehicles % of start
                        Blue Strength Surviving:           762       1.00
****Blue attrition computations hidden in these cells****
                        Red Strength Surviving:           1598       1.00
****Red attrition computations hidden in these cells****
```

Fig. C.12—ATK2 activity time and vehicle attrition

DEF Activity. The computations in Fig. C.13 parallel those above, except that roles are reversed: Blue is the weaker party and his attrition determines the engagement's duration; and as the attacker, Red chooses the combat power ratio (in this case 2:1). By way of comparison, note the change in relative lethalities as attacker and defender reverse. In the ATK1 and ATK2 activities, Blue's lethality as the attacker was .11 to Red's .07, implying that technical superiority more than compensated for a defender's advantage. In the DEF activity, Blue as a defender has a lethality of .15, or approximately a 45 percent increase over the attacking lethality, to Red's .04, about a 40 percent decrease over his defending lethality. Naturally, the user is free to represent the relative advantages of attack vs. defense as he deems appropriate.

Again, an attrition summary appears at the bottom of the range. Although Red lost only 4 percent of his starting strength, since he employed 6.61 RMVRs in the attack, that translates to the loss of 29 percent of one RMVR.

Figure C.14 summarizes MOSCOW's use of the Lanchester equation to compute engagement duration and attrition.

```
         DEF ACTIVITY:
                                                         Hours        Days
                                                TDEF:     6.92        0.288

TDEF elements         0.2      0.59         0.1   0.38     0.77        0.04
Blue veh surv. elements                   -1.00   3.00     1.31        0.77
Red veh surv. elements                     3.83  11.48     1.31        0.77

FR-DEF (RED : BLUE):           2.00  Normalized
RED STRENGTH:                 10706         7.65 # RED UNITS:          11.24
BLUE STRENGTH:                 1399         1.00 # BLUE UNITS:          1.00

RED LETHALITY:                46.55 Veh            0.01 MVR
BLUE LETHALITY:               71.56 Veh            0.15 RMVR
                                                 Vehicle% of start Losses/hr
                    Blue Strength Surviving:      693      0.50      102.16

                    Red Strength Surviving:      9643      0.90      153.67

                                                 R:B Exchnge Ratio      1.50

                                Total Blue mvr attr/def eng:         0.50
                                Total Red rmvr attr/atk eng:         1.12
```

Fig. C.13—DEF activity time and vehicle attrition computations

(A) Notation: B,R = Number of Blue or Red vehicles in engagement
b,r = Blue or Red lethality (in vehicles or MVRs per hour)

Combat power = $B \times \sqrt{b}$ or $R \times \sqrt{r}$

Combat power ratio = $\frac{B\sqrt{b}}{R\sqrt{r}}$ when Blue attacks; $\frac{R\sqrt{r}}{B\sqrt{b}}$ when Red attacks

Da_B = Desired defender's attrition (Blue's preference)

Da_R = Desired defenders attrition (Red's preference)

$a = Da_{(actual)}\ Da_R + (\text{DISENG\%} \times [Da_B - Da_R])$

Defending survivors (actual = $s = 1 - Da_{(actual)} = 1 - a$

(Abbreviated as $s = 1 - a$. Note that $s = \frac{R_{surviving}}{R_{initial}}$

(B) Traditional use of Lanchester fixes time to find attrition.

$$S = \frac{R_t}{R_i} = \frac{(R - \sqrt{b}/\sqrt{r}B)e^{\sqrt{rb}\,t} + (R + \sqrt{b}/\sqrt{r}B)e^{\sqrt{rb}\,t}}{2}$$

(Time = t)

(This equation assumes Red is the defender. When R[illegible] attacker and you wish to calculate B_t, reverse positions of B and R, and b and r.

(See Steinbrunner and Sigal, 1982, p. 211 for traditional form.)

(C) In MOSCOW's ATK or DEF activities, attrition is fixed, and the Lanchester equation is used to calculate engagement time.

$$\text{Time (ATK1)} = \left\{ \ln \left[\frac{\sqrt{r}\, sR - \sqrt{bB^2 - (1-s)^2 r R^2}}{\sqrt{r}R - \sqrt{b}B} \right] \right\} \Big/ \sqrt{br}$$

at which $\frac{R_t}{R_i} = s$

Blue and Red attrition are then calculated using the traditional Lanchester equation, with + determined by the above

(D) Finally, tuning parameters can be used to vary the function

(i) In the traditional Lanchester state equation, $B^2 b = R^2 r$; thus the "exponent of strength" (in vehicles) is 2. In MOSCOW, this exponent may be changed to another value (which will modify the exponents in (B) and (C) above to values other than 2 or ½).

(ii) An "engagement tempo coefficient" will increase or decrease the engagement time reported to the activity section of MOSCOW, but not to the attrition (Lanchester) equation

Fig. C.14—MOSCOW's employment of Lanchester equation

Appendix D

BLUE AND RED MOBILITY CALCULATIONS

BLUE MOVEMENT RATE

Blue's input mobility (MVMT/HR ADMIN and MVMT/HR-BATTL) is affected by the following variables. All effects are linear, calculated as coefficients of basic mobility of value less than one, or that add a fixed amount of delay per day (thus reducing the number of hours in which MVRs can move).

Capability	Policy	Scenario	Threat
	%MVMT-ADMIN %REST	TERRAIN MVMT MULT HRS/DAY USBLE	INITIAL AI SORTIES %DELAY
C-3 ERROR			%DISRUPT

The format of the mobility calculations is shown in Fig. D.1. Intermediate values of movement rate are shown, leading to a final value of MOVEF. MOVEF is denominated in km per day of movement-related activity, and is used in the MWR, DIS, RCL, and MTS activities.

```
                    BLUE MOBILITY CALCULATIONS

MVMT/DAY-ADMIN          360.00 km/day
MVMT/DAY-BATTL          120.00 km/day

%MVMT-ADM FORM            0.33 % of mvmt
%MVMT-BAT FORM            0.67 % of mvmt

                               BLUE MOVE1          199.20 km/day
REST MULT                 1.00
TERRAIN MVMT MULT         0.76
C-3 ERROR                 0.11
                               BLUE MOVE2          135.01 km/day

AI DELAY-THEATR        1467.19 mins/day (theater)

DELAY/MVR               127.42 mins/day/mvr          2.12 (hrs/day)
                                                     0.09 (days)
                               BLUE MOVEF          123.07 km/day
```

Fig. D.1—Blue mobility calculations

RED ADVANCE RATE

Red's movement rate is the basis for RED ADVANCEF, Red's average advance rate through the zone. RED ADVANCEF has two components: RED ADVANCE4, Red's advance rate unopposed by ground combat (but reflecting the delays caused by engineers and air interdiction, in a manner identical to BLUE MOVEF); and additional advance during engagements as the engagement FLOT position changes (which may be negative). Furthermore, because MOSCOW does not explicitly compute Red activity times, the input %NON-MV/ENG, or fraction of an average day that Red units spend neither moving nor in engagements, also slows Red's advance rate.

Red's advance rate equations are analogous to Blue's through the computation of RED ADVANCE3, which is analogous to BLUE MOVEF. The only difference is the inclusion of any additional delay caused by the net effects of Blue and Red engineers; this is added to the delay caused by AI. Thereafter, additional computations are:

Red unopposed advance rate = RED ADVANCE4 = RED ADVANCE3
× (1 − %NON MV/ENG)

Delay caused by engagements = [Number of attack engagements × (ATK1 +TATK2)
× (1 + ATK PREP&RECOV)] + [analogous for
defend engagements] / (# RMVRs)

This computes the average delay imposed on an RMVR by engagements, including the delay caused by time required to prepare for or recover from them.[1]

Red's final advance rate is computed as follows:

RED ADVANCEF = REDADVANCE4 + FLOT ADV/DAY −
(DELAY / CAMPAIGN LENGTH)

Calculation of CAMPAIGN LENGTH is described in the App. E.

FLOT ADV/DAY = [FLOT ADV (DEF) × Number of Defend engagements +
(Analogous for attack engagements)] /
(#RMVRs × CAMPAIGN LENGTH).

Figure D.2 displays the MOSCOW screens in which Red's mobility and advance rate are computed. Figure D.3 illustrates the computation of Red advance rate.

---

[1]A user who wished to reflect preparation and recovery time as absolute amounts rather than as a multiple of engagement time could change the first term in brackets above to:

[Number of attack engagements × (TATK1+TATK2+Time (atk prep)+Time(atk recov))]

RED MOBILITY CALCULATIONS				
MVMT/DAY-ADMIN	288.00	km/day		
MVMT/DAY-BATTL	96.00	km/day		
%MVMT-ADM FORM	0.20	% of mvmt		
%MVMT-BAT FORM	0.80	% of mvmt		
		RED MOVE1	134.40	km/day
TERRAIN MVMT MU	0.76			
C-3 ERROR	0.08			
		RED MOVE2	94.48	km/day
ENG DELAY-THEAT	11520.00	mins/day (theater)		
AI DELAY-THEATR	2605.47	mins/day (theater)		
DELAY/RMVR	588.56	mins/day/rmvr	9.81	(hrs/day
			0.41	(days/da
		RED MOVE3	55.87	km/day
%NON MOVE/ENG	0.40	% of time not moving or in cbt		
AVG DELAY-CBT	0.79	RED ADVANCE4	33.64	km/day
		RED ADVANCEF	29.61	km/day

Fig. D.2—Red mobility and advance rate computations

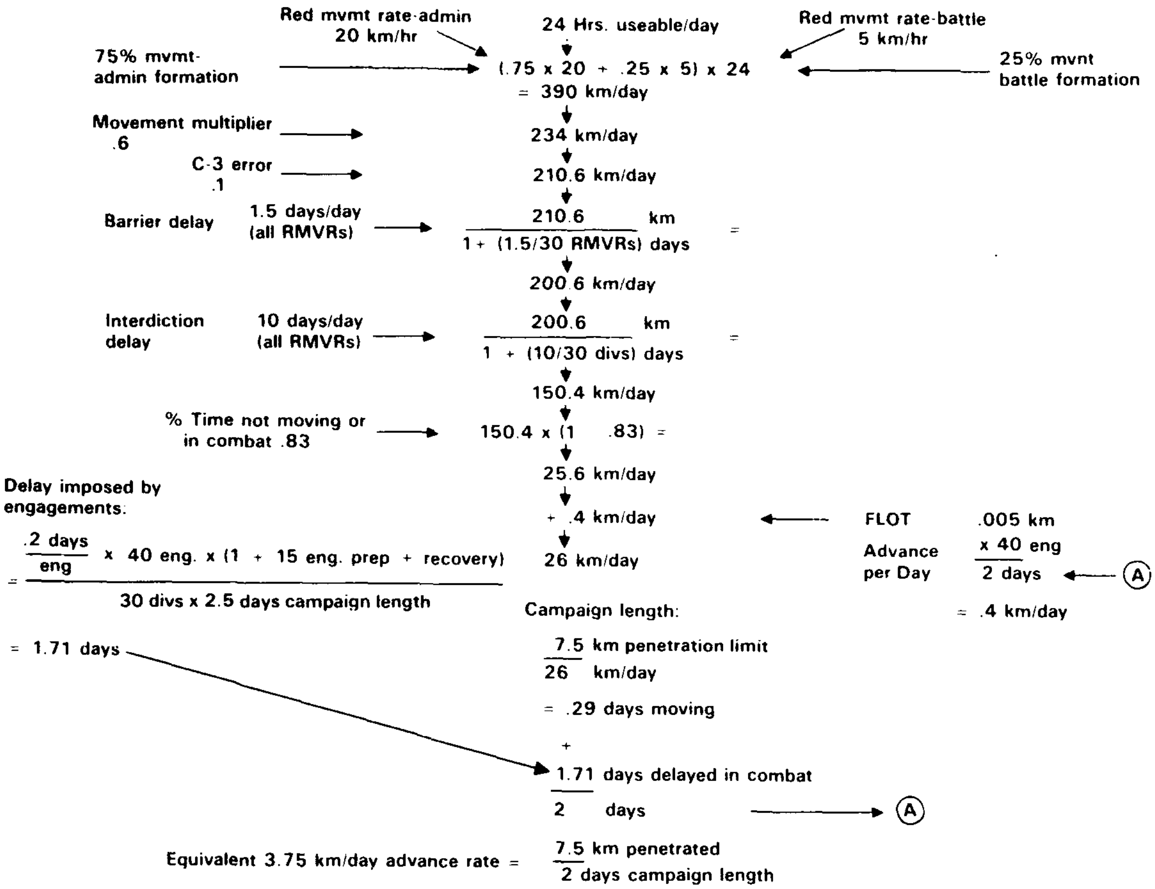


Fig. D.3—Example calculation of Red advance rate

Appendix E

CALCULATION OF REQUIREMENTS (FINAL OUTPUT OF MOSCOW)

Final outputs in MOSCOW are estimates of the required amounts of maneuver units, headquarters, supply units, and major physical resources (Vehicles, Personnel, Ammunition, POL, Other commodities, and by extension, the lift to transport them) needed to achieve the attrition and territory goals specified (in the BLUE SUCCESS CRITERIA input block) for the model run. MOSCOW computes the following parameters in order to produce them:

(1) Campaign Length (in days)
(2) RMVRs that must be killed by Blue ground forces, after deducting Red RMVRs not available to participate in Red's advance because of
  - permanent equipment breakdowns,
  - rear-area security requirements,
  - air interdiction.
(3) Allocation of Blue's required ground combat kills to Attack vs. Defend MVRs
(4) Number of Attack and Defend engagements required
(5) Blue Attack and Defend MVRs' campaign kill rates
(6) Blue Attack MVR and Defend MVR requirements
(7) Blue Reserve MVR requirements
(8) Blue Rear-Area Security MVR requirements
(9) Total amounts of physical commodities required
(10) Average amounts of physical commodities required per day
(11) Number of Blue headquarters required
(12) Number of Blue supply vehicles required
(13) Amount of delay imposed on Red
(14) Assessment of the concept's "affordability" in terms of each output
(15) Miscellaneous supporting information.

Figure E.1 shows a sample output screen. For each resource, the leftmost column that contains a number presents MOSCOW's estimate of the amount needed. The number to the right of it shows the amount projected to be available (which is a user input, or calculated directly from one). The rightmost number in each row computes the ratio of amount needed / amount available; its use will be explained below.

CAMPAIGN LENGTH (IN DAYS)

After RED ADVANCEF (Red's average advance rate, composed of unopposed movement, delay while in combat, and FLOT advance during combat) is calculated, as was described in App. D on Mobility, CAMPAIGN LENGTH is simply the expected time required for Red to advance to RED PEN LIMIT (the distance by which # RED MVR − RED SURVIVORS must be destroyed). Therefore CAMPAIGN LENGTH = RED PEN LIMIT / RED ADVANCEF.

[Alt-B]

Run # copied to table: 1

BLUE REQUIREMENTS FOR SUCCESS

Resource	Required	Available	Reqd/ Avail	Afford- able?
MANEUVER UNITS				
Initial stock	20.9	21.8	96%	YES
Maximum replacement equivalents	3.5	8.6	41%	YES
Initial + Repl Equivs. (grand total)	24.4	30.4	80%	YES
Replacement equivalents per day	0.86	0.29	302%	*NO*
INITIAL STOCKS				
Personnel	209250	217826	96%	YES
Vehicles	29307	30508	96%	YES
AMMO (tons)	9.8E+05	1.0E+06	96%	YES
POL (tons)	1.5E+07	1.5E+07	96%	YES
Other commodities (tons)	5.9E+06	6.1E+06	96%	YES

Resource	Required	Available	Reqd/ Avail	Afford- able?
REPLACEMENTS				
Personnel	22724	200000	11%	YES
Vehicles	4880	12000	41%	YES
AMMO (tons)	1.5E+05	7.0E+05	21%	YES
POL (tons)	3.8E+04	5.0E+06	1%	YES
Other commodities (tons)	1.0E+04	1.0E+05	10%	YES
REPLACEMENTS PER DAY				
Personnel	5634	4000	141%	*NO*
Vehicles	1210	400	302%	*NO*
AMMO (tons)	3.7E+04	2.0E+04	183%	*NO*
POL (tons)	9.5E+03	4.0E+05	2%	YES
Other commodities (tons)	2.6E+03	4.0E+03	65%	YES
LIFT (tons of personnel, vehicles and commodities)				
Total during campaign	3.5E+05	1.5E+06	23%	YES
Average per day of campaign	8.7E+04	1.1E+04	791%	*NO*
CASUALTIES				
Total during campaign	46199	250000	18%	YES
Average per day during campaign	11455	5000	229%	*NO*
Max daily rate (%) to an MVR	39.4%	15.0%	262%	*NO*
SUPPORT FOR MANEUVER UNITS				
Supply vehicles	1.2E+05	1.0E+05	115%	*NO*
Headquarters	3.7	8.0	47%	YES

CAMPAIGN LENGTH

	Achieved	Desired	Desired/ Achieved	Afford- able?
Days Red delayed	3.25	3.00	92%	YES
Days Red advance unimpeded	0.78	0.78	100%	NA
Total Campaign Length	4.03	3.78	94%	YES

ADDITIONAL OUTPUTS

Territory Measures

Average advance per day	12.40 km/day
Advance per day when unimpeded	39.18 km/day

Lethality	Vehicles	MVRs	Combat Power
Exchange Ratio (R:B) for ground combat	1.98	4.3	1.87
Exchange Ratio (R:B) for overall campaign	4.27	5.7	2.50

Casualties

Blue Casualties (% of total personnel/day)	1.33%
Blue personnel casualties per vehicle lost	4.69

Consumption	All Items	Consum- ables	
Tons consumed/MVR per day (ATK missions)	2098	750	tons/day
Tons consumed/MVR per day (DEF missions)	12289	3128	tons/day
Average tons consumed per MVR	4965	1419	tons/day

Pounds per man per day (AMMO, POL, Other)	94.03 lbs /man/day
Pounds per man per day (POL and Other)	56.96 lbs /man/day
Red AMMO fired in campaign:	2.4E+05 total tons
	5.9E+04 avg tons per day

Fig. E.1—MOSCOW output screens

```
Blue MVR Effectiveness
   Campaign Kill Rate (ATK MVRs)        0.11 RMVRs killed/MVR/day
   Campaign Kill Rate (DEF MVRs)        0.46 RMVRs killed/MVR/day

                                                             Combat
Red/Blue Force Ratios                   Vehicles     MVRs    Power
   Starting force ratio (Red:Blue)         1.07      1.23     0.53
   Ending force ratio (Red:Blue)           0.36      0.46     0.21

Fraction of RMVR Kills occuring in ground combat              0.75
Fraction of RMVR Kills occuring due to AI & deep fires        0.09
Fraction of RMVR Kills occuring due to breakdowns             0.16

RMVRS that can be killed with available MVRs      20 RMVRs
Red Penetration achievable vs available MVRs      47 Kilometers

   (Note:   21.8 MVRs avl,     50 km pen,      20 RMVR kills desrd.)
```

Fig. E.1—continued

RMVRS THAT MUST BE KILLED BY BLUE GROUND FORCES

Based upon VEH BRKDWNS and VEH REGEN/DAY (the rate at which RMVR vehicles breakdown per day, and the absolute number that can be repaired per day) a NET VEH BREAKDOWN rate is computed. Survival rates are computed for two points in time: the time at which Red reaches CAMPAIGN MIDPT (which is RED PEN LIMIT / 2), where all combat is assumed to occur, and at CAMPAIGN LENGTH. Losses that occur prior to CAMPAIGN MIDPT are reflected by decreasing the engagement starting vehicle count of RMVRs (shown as R in App. C on the Battle Calculus). Red vehicle losses that occur between CAMPAIGN MIDPT and CAMPAIGN LENGTH reduce the required number of RMVR kills, once converted into RMVR-equivalents.

MOSCOW computes the area occupied by Red when RED PEN LIMIT is reached. Using a rear-area security planning factor for each side (which is input in the Calibration Coefficients, defined as number of personnel required per km^2 of occupied territory), the number of RMVRs needed for occupation duty is computed. "Losses" due to breakdowns and to occupation/rear are security responsibilities and shown as BREAKDOWNS/SEC.

The Fire, Air, and Engineer Support section (discussed in App. A) computed vehicles killed per day by Blue air interdiction. (Kills by CAS and Headquarters are treated as direct support of MVRs and included in MVR lethality, as described under the Battle Calculus.) Total RMVRs killed by air is: AI VEH KILLS/DAY × CAMPAIGN LENGTH / (VEHs/RMVR).

Kills required of ground and CAS forces are thus RMVR KILLS REQD − BREAKDOWNS/SEC − AIR INTERDICTION.

ALLOCATION OF BLUE'S REQUIRED GROUND COMBAT KILLS TO ATTACK VS. DEFEND MVRS

A key Blue policy variable is %MVRs-ATK KILS and %MVRs-DEF KILS, which allocates kills among Attack and Defend Missions. It also determines the fraction of MVRs that will be held in reserve in the zone, where they do not participate in combat or consume commodities but do add to total MVR requirements. (%MVRs-RSV = 1 − %MVRs-ATK KILS − %MVRs-DEF KILS). The fraction of kills to come from the Attack mission is %MVRS-ATK

KILS / (%MVRS-ATK KILS + %MVRS-DEF KILS).[1] There is a further distinction between attacks against attacking vs. defending RMVRs, using the Red input %RMVRS-ATK to compute average lethalities (based on the mix of Red attack and Red defend lethalities) in Blue attack engagements.

NUMBER OF ATTACK AND DEFEND ENGAGEMENTS NEEDED

Once total RMVR ground + CAS kills, attrition per engagement, and the allocation of kills to Attack and Defend engagements have been established, the number of each type of engagement is computed as follows:

Number of attack engagements required = Ground + CAS RMVR kills required
× (Fraction from Attack engagements) /
(Attrition in Attack engagements /
RED BKPOINT)

Ground + CAS RMVR kills required is calculated as indicated above.

An analogous equation determines the required number of Defend engagements. Because each activity cycle (of either an Attack or a Defend MVR) includes one engagement, this is also the number of cycles required.

BLUE ATTACK AND DEFEND MVRS' CAMPAIGN KILL RATES

Appendix C explained how attrition in the ATK1, ATK2, and DEF activities is computed. Having also computed the duration of these activities as well as of each other activity in the Attack and the Defend cycle (see App. B on the Activity Cycle), total time of cycle is computed. An attack or Defend MVR's campaign kill rate is ((Red attrition in engagement activity) / RED BRKPOINT) / (Total time of cycle × Number of MVRs per engagement).[2]

BLUE MVRS NEEDED

The required rate at which RMVRs must be killed by ground action is subdivided into a required Attack and Defense kill rate (using Ground plus CAS kills required / CAMPAIGN LENGTH) × the kill allocation above.

Required Attack Kill Rate / Attack MVR Campaign Kill Rate = Required Attack MVRs .
(RMVR kills/day) *(RMVR kills/day/Attack MVR)* *(MVRs)*

An analogous equation computes Required Defend MVRs.

Since Operational C-3 ERROR and INTEL ERROR are considered to cause "wastage" of Blue MVRs (by misallocating them), this wastage is reflected in computing the number of combatant MVRs:

Required Combatant MVRs = (Reqd Attack MVRs + Reqd Defend MVRs) /
[(1 − OPNL C-3 ERROR) × (1− OPNL INTEL ERROR)]

---

[1]For the Defend mission, %MVRS-DEF KILS is in the numerator.

[2]RED BREAKPT is an input; Red attrition and Number of MVRs per engagement are discussed in App. C; Total time of Cycle is discussed in App. B. The *Campaign Kill Rate* is the rate at which, on average of the entire campaign, each Blue Attack or Defend MVR is able to kill RMVRs. Its units are RMVRs killed per Blue MVR per day.

BLUE RESERVE MVRS NEEDED

Blue Reserve MVR requirements are:

[(1 - %MVRs-ATK KILS - %MVRs-DEF KILs) /
(%MVRs-ATK KILS + %MVRs-DEF KILS)]
× Required Combatant MVRs.

BLUE REAR-AREA SECURITY MVRS NEEDED

SEC MVRs is calculated in a like manner to the Red calculation, using (ZONE LENGTH – CAMPAIGN MIDPT) × ZONE WIDTH as the average area Blue must occupy during the campaign.

Figure E.2 summarizes how MVR requirements are computed for a hypothetical example. It illustrates schematically how kills are allocated between Attack and Defend missions and how total MVR requirements are calculated. In the example, %MVRKILs-ATK is set at 0.5, %MVRKILs-DEF at 0.3, and by implication %MVRs-RSV is 0.2. Assume that 20 RMVRs must be killed in total, so after deducting 1.5 RMVRs that break down or are needed for rear area security and 3.5 lost to Blue air interdiction, 15 RMVRs must be killed in ground engagements. Therefore (0.5 /(0.3 + 0.5)) × 15 RMVRs must be killed in Attack engagements, and (0.3 /(0.3 + 0.5)) × 15 RMVRs, or 15 minus the above number, must be killed in Defend engagements. Attack engagements can occur against either Attack or Defend RMVRs, in proportions equal to those assigned by Red (in this case, 75 and 25 percent respectively). Defend engagements can occur only against Attack RMVRs, because it is assumed that units of each side assigned to Defend will not engage each other.

Engagement computations for Defend MVRs utilize inputs (such as lethalities) for a defending Blue and an attacking Red. Computations for Attack MVRs use inputs based on an attacking Blue and a mix of attacking and defending RMVRs equal to the proportions Red established. Ultimately, the engagement activities and other activities yield Blue Attack and Defend Campaign Kill rates, shown here as 0.47 and 0.62 respectively. Assuming a campaign length of 1.0 days for simplicity, then 9.37 / 0.47 = 19.93 attack MVRs and 5.62 / 0.62 = 9.06 Defend MVRs are needed. Including "wastage" factors due to C^3 and intelligence errors in the same manner as the Agincourt example, increases the combat requirement to 33.90. Reserve MVRs are 0.2 × 33.90 = 6.78 MVRs. Finally, MVRs needed for rear-area security, which is computed based upon a desired density of security troops per km^2 of territory occupied, is 1.5 MVRs. The grand total number of standing MVRs required is 42.2.

TOTAL AMOUNTS OF PHYSICAL COMMODITIES NEEDED FOR CAMPAIGN

The activity equations compute an MVR's total consumption per cycle (after repairs) of Personnel, Vehicles, Ammo, POL, and Other, and converts their sum into tons of Cargo (or Lift to provide them). For each commodity, total consumption is:

(Consumption per Attack Cycle × Number of Attack Cycles × Number of MVRs per
Attack engagement) + (Analogous values for Defend cycles)

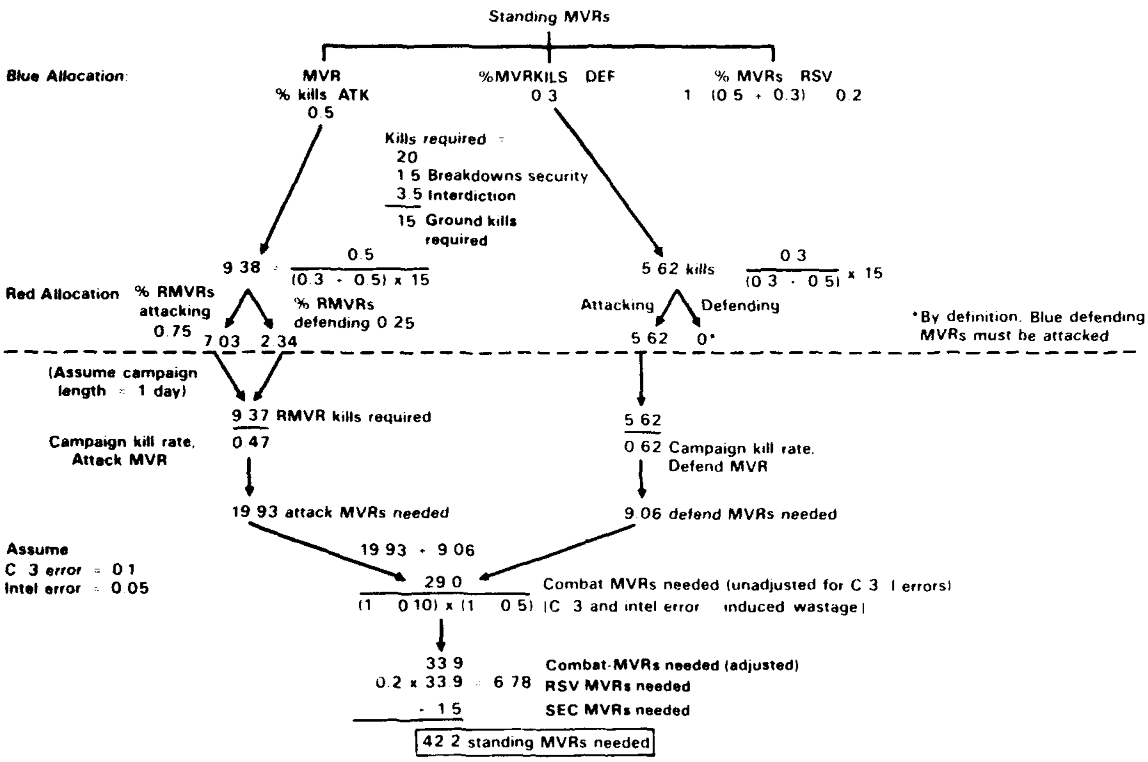


Fig. E.2—Illustrative computation of standing MVR requirements

Vehicle consumption is augmented by kills from Red interdiction, adding (Red AI VEH KILLS/DAY × CAMPAIGN LENGTH) / (VEH/MVR).

Ammo consumption is augmented by tons fired by headquarters, adding # HQs AVAIL × TONS/D/HQ × CAMPAIGN LENGTH.

Vehicles and Personnel are partly recoverable (presumed repaired) by %REPRBL LOSS-T.[3] Therefore, consumption of these is multiplied by the coefficient (1 − %REPRBL LOSS-T). Since %REPRBL LOSS-T is a total, not a daily, repair rate, it implicitly assumes a campaign of some general length, and should be adjusted if CAMPAIGN LENGTH differs markedly from that assumption. Adjusting %REPRBL-T will change required amounts of each commodity, but will not change any other parameters. So only one additional model iteration is necessary. Personnel CASUALTIES include wounded personnel later returned to action through %REPRBL-M, the MVRs organic casualty treatment capability, and %REPRBL-T, which is the theater's. CASUALTIES will consequently be larger than Personnel replacement requirements unless %REPBRLBL-M and %REPRBL-T are set to zero.

[3]T stands for "Theater" and refers to all repairs performed at echelons above the MVR.

AVERAGE AMOUNTS OF PHYSICAL COMMODITIES NEEDED PER DAY

Average requirements of a commodity per day are simply the amount computed above divided by CAMPAIGN LENGTH. If a campaign is much shorter than expected, a concept may exceed available average *daily* amounts of resources, even if it does not exhaust *total* amounts available.

NUMBER OF BLUE HEADQUARTERS NEEDED

The capacity of Blue HQs is input in two forms: their span of control (HQ SPAN) and their radius of command (HQ RADIUS). Therefore, two alternative HQ requirements are computed:

HQ (MVRs) = MVRs Required / HQ SPAN; and

HQ (Area) = [(REAR BNDRY − FORW BNDRY) × ZONE WIDTH] / (pi × HQ RADIUS^2).

MOSCOW uses the larger of these as the required number of HQs. This number is compared with the input #HQs AVAIL, which is the number of HQs providing supporting fire.

NUMBER OF BLUE SUPPLY VEHICLES NEEDED

Blue's total demand for Cargo (or the Lift to carry it) per day is computed as outlined above. Each Blue supply vehicle has a starting capacity (CAP/SUPP VEH), a degradation of that capacity per kilometer traveled (CAP DEGRDN/KM), and a movement rate, (SUPP VEH MOVEF). Treating the average distance it must travel as the distance from a base at the rear of the zone to the campaign midpoint, minus the distance that MVRs pull back from the fighting in order to resupply (ZONE LENGTH − CAMPAIGN MIDPT − DIS-EXCHPT) (termed "Dist" here for simplicity), the average capacity of a supply vehicle (in tons supplied per day) is:

[CAP/SUPP VEH − (CAP DEGRDN/KM × "Dist")] /
[(2 × "Dist" / (SUPP VEH MOVEF × TERRAIN MVMT MULT))
+ TLOD]

TLOD is the average time an MVR spends loading supplies (using the Attack and Defense weights outlined above under number of Attack and Defend Engagements Needed).

AMOUNT OF DELAY IMPOSED ON RED

Delay is a comparison between CAMPAIGN LENGTH and the time Red would have needed if he had not met with any ground opposition. The equation is CAMPAIGN LENGTH − RED PEN LIMIT / RED ADVANCE4, where RED ADVANCE4 is the Red advance rate that reflects interdiction and engineer delays, but not delays (and FLOT displacement) caused by combat.

ASSESSMENT OF THE CONCEPT'S "AFFORDABILITY" IN TERMS OF EACH RESOURCE NEEDED

Finally, required amounts of each resource are compared with input amounts projected to be available, and the ratio of Required / available is computed. Each ratio is tested to determine if it falls below a YES/NO "affordability" threshold,[4] which can be set by the user. (The threshold is input as TOLERANCE LEVEL.) A conservative setting for TOLERANCE LEVEL might be 85 percent, and a generous one might be 110 percent. This YES/NO statement helps direct the eye to those resources that are most stressed by the concept being evaluated.

MISCELLANEOUS SUPPORTING INFORMATION

Below the "Supporting Calculations" (which are used in portions of the computations outlined in the above sections) several quantities (such as exchange rates and force ratios) are computed because they are of traditional interest or because they are useful for calibration.

[4]The one exception is DELAY. Blue wants the DELAY achieved to *exceed* his DELAY objective (which is set as an input in the Success Criteria inputs block). The "affordability" test reflects this.

Appendix F

USING MULTIPLE MOSCOW ZONES TO REPRESENT REINFORCEMENT SCHEDULES

To represent follow-on forces at the operational or strategic levels, zone boundaries must be set to distinguish the battle against the first echelon from the battle against the second.[1] The theater (or smaller sector) is divided into three areas: NATO vs. Pact territory, and within NATO territory into the enclave it wishes to preserve vs. the area where the campaign will occur. On D-day, the Red first echelon attacks across the Inner German Border and simultaneously the Red second echelon begins advancing from some starting point in its own rear (e.g. assembly areas on the Polish/Soviet border). To separate the first and second echelon battles, the user must run MOSCOW once for each battle. First he sets a RED PEN LIMIT for the first echelon that will continue the battle for the maximum time until the second echelon arrives to join, then he sets RED PEN LIMIT for the second battle to correspond to the penetration that preserves NATO's enclave.

Variable definitions used in this section are as follows:

Variable	Definition
RED PEN LIMIT (1)	Penetration limit for 1st echelon
RED PEN LIMIT (2+1)	Penetration limit for 2nd echelon (and survivors from 1st echelon)
MAX TOT RED PEN	Maximum Red penetration that preserves NATO enclave
RED ADVANCEF(1)	Estimated Red advance rate for 1st echelon
RED ADVANCEF(2)	Estimated Red advance rate for 2nd echelon
# RMVRs(1)	Starting number of RMVRs in 1st echelon
# RMVRs(2)	Starting number of RMVRs in 2nd echelon
RMVRs KILLED(1)	Number of RMVRs killed in 1st echelon battle
RMVRs KILLED(2)	Number of RMVRs killed (by breakdowns and air interdiction) in 2nd echelon transit
TRANSIT DIST	Distance from 2nd echelon starting point to Inner German Border
MVRS REQD (1)	MVRs required to achieve objectives against 1st echelon
MVRS REQD (2+1)	MVRs required to achieve objectives against 1st and 2nd echelons
MVR REPL REQD (1)	Replacements (in MVR-equivalents) required in battle against 1st echelon
MVR REPL REQD (2+1)	Replacements (in MVR-equivalents) required in battle against 1st and 2nd echelons

[1]This appendix will use terminology reflecting a NATO/Warsaw Pact example, but the procedures outlined here will apply to any situation in which Red invades in multiple echelons, or Blue reinforcements arrive after a campaign has commenced.

PRE-ANALYSIS VARIABLE ESTIMATION

(1) Run MOSCOW to determine the "advance rate" (movement or closure rate) of the second echelon as it moves through Pact territory (from its starting point to the IGB). Set the required kills equal to zero, but include some AI sorties if appropriate to the concept. The sole output of this run used in the estimated movement rate (RED ADVANCEF(2)) for the second echelon.

(2) Pick an arbitrary RED PEN LIMIT for the first echelon battle, to compute the first echelon's RED ADVANCEF(1). (Ignore all other output.)

ANALYSIS

(3) Set up MOSCOW for the first echelon battle. Set RED PEN LIMIT(1) =

TRANSIT DIST / ([RED ADVANCEF(2) / RED ADVANCEF(1)] - 1).

This equation will be derived with the help of a numerical example to check the algebra. Set TRANSIT DIST = 200km, RED ADVANCEF(1) = 10 km/day, and RED ADVANCEF(2) = 50 km/day. What is the RED PEN LIMIT (how far will the first echelon have penetrated) when the two echelons rendezvous?

Assume that the 2d echelon departs its starting point simultaneously with the opening of the 1st echelon's campaign (when the lst echelon crosses the Inner German Border). The length of time the 1st echelon campaigns equals the time before the 2d echelon arrives.

(TRANSIT DIST + RED PEN LIMIT) / (REDADVANCEF(2))
= RED PEN LIMIT / RED ADVANCEF(1).

or

(TRANSIT DIST / (REDADVANCEF(2)) + (RED PEN LIMIT / REDADVANCEF(2))
= RED PEN LIMIT / RED ADVANCEF(1).

Subtracting (RED PEN LIMIT / REDADVANCEF(2)) yields:

(TRANSIT DIST / (REDADVANCEF(2)) = (RED PEN LIMIT / RED ADVANCEF (1)) -
(RED PEN LIMIT / REDADVANCEF(2)).

Factoring RED PEN LIMIT yields:

(TRANSIT DIST / (REDADVANCEF(2)) = RED PEN LIMIT × (1 /
RED ADVANCEF(1) - 1 / REDADVANCEF(2)).

Dividing by (1 / REDADVANCEF(1) - 1 / RED ADVANCEF(2)) yields:

RED PEN LIMIT = (TRANSIT DIST / (REDADVANCEF(2)) /
(1 / RED ADVANCEF(1) - 1 / REDADVANCEF(2)).

Multiplying numerator and denominator by REDADVANCEF(2) yields:

RED PEN LIMIT = TRANSIT DIST / [REDADVANCEF(2) ×
(1 / RED ADVANCEF(1) - 1 / REDADVANCEF(2))].

Which can be factored to yield the final equation:

RED PEN LIMIT = TRANSIT DIST / [(REDADVANCEF(2) / RED ADVANCEF(1)) – 1].

By inspection, it can be seen that the time of rendezvous will be five days. At a RED-ADVANCEF(1) of 10 km/day, RED PEN LIMIT will be 50 km. The total distance the 2d echelon will travel before arriving at the FLOT is TRANSIT DIST + RED PEN LIMIT, or 200 + 50 km = 250 km. At a RED ADVANCEF(2) of 50 km/day, this will take five days also (as expected).

Using the above formula, RED PEN LIMIT = 200 / [(50 / 10) – 1] = 200 / (5 – 1) = 200 / 4 = 50 km.

This is the distance that the first echelon will penetrate at the moment the 2d echelon arrives. Set the required number of 1st echelon RMVRs killed (RMVRs KILLED(1)) to conform with the concept or to stay within estimated available forces. For example, "winning the first echelon battle" might be defined as killing 2/3 of the first echelon RMVRs, or as leaving the ratio of Blue to surviving 1st echelon Red forces above some threshold value (e.g., 1.5). Alternatively, the user might experiment to determine the maximum number of 1st echelon RMVRs that can be destroyed within Blue's MVR budget.

(4) Calculate 2d echelon attrition before arrival at the FLOT. Using RED PEN LIMIT(2) = TRANSIT DIST + RED PEN LIMIT(1), and required number of RMVR kills equal to zero, run MOSCOW to calculate attrition to the 2nd echelon caused by interdiction and breakdowns. This is RMVRS KILLED(2).[2]

(5) Estimate requirements for the battle of the second echelon (with any survivors of the first echelon). RED PEN LIMIT (2+1) is set to MAX TOT RED PEN – RED PEN LIMIT(1). Starting RMVRS are (#RMVRs(1) + #RMVRs(2)) – (RMVRS KILLED(1) + RMVRS KILLED(2)).

OUTPUT PROCESSING

(6) MVR requirements were calculated separately (in steps 3 and 4) for each echelon. The campaign MVR requirement is the maximum of MVRS REQD (1), and MVRS REQD (2+1).

(7) All other resource campaign requirements are the sum of those required for each echelon. For example, campaign replacement requirements are MVR REPL REQD (1) + MVR REPL REQD (2+1).

This procedure can be extended to represent arrival schedules of large groups of Blue and Red forces. However, this higher resolution of reinforcement schedules requires additional model runs. MOSCOW makes no distinction between Blue reinforcing units and Blue individual replacements; "Replacement MVR-Equivalents" are treated as if they are used to maintain the "Standing" force of MVRs at their initial strength.

[2]If the user wishes to reflect differing interdiction effectiveness and platform attrition at different depths behind the FLOT, the distance TRANSIT DIST + RED PEN LIMIT (1) can be subdivided into smaller zones, with different numbers of aircraft, different effects, and different air attrition. The sum of 2d echelon attrition in each zone would be RMVRS KILLED(2).

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