(4)

A RAND NOTE

Variables Affecting Central-Region Stability: The "Operational Minimum" and Other Issues at Low Force Levels

Paul K. Davis, Robert D. Howe,
Richard L. Kugler, William G. Wild, Jr.

September 1989

RAND

The research described in this report was sponsored by the Office of the Under Secretary of Defense for Policy under a federally funded research and development center relationship with the Office of the Secretary of Defense, Contract No. MDA903-85-C-0030.

Published by The RAND Corporation
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90406-2138

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: N-2976-USDP
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): Variables Affecting Central-Region Stability: The "Operational Minimum" and other Issues at Low Force Levels
5. TYPE OF REPORT & PERIOD COVERED: interim
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): Paul K. Davis, Robert D. Howe, Richard L. Kugler, William G. Wild, Jr.
8. CONTRACT OR GRANT NUMBER(s): MDA903-85-C-0030
9. PERFORMING ORGANIZATION NAME AND ADDRESS: The RAND Corporation, 1700 Main Street, Santa Monica, CA 90406
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS:
11. CONTROLLING OFFICE NAME AND ADDRESS: Assistant Secretary of Defense, Office, Under Secretary of Defense for Policy, Washington, DC 20301
12. REPORT DATE: September 1989
13. NUMBER OF PAGES: 69
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): unclassified
15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:
16. DISTRIBUTION STATEMENT (of this Report): Approved for Public Release; Distribution Unlimited
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report): No Restrictions
18. SUPPLEMENTARY NOTES:
19. KEY WORDS (Continue on reverse side if necessary and identify by block number):

NATO
Military Force Levels
Balance of Power
Arms Control
Reduction
Central Europe
Operations Research
Stability
Conventional Warfare
Parity
Forward Areas

20. ABSTRACT (Continue on reverse side if necessary and identify by block number): see reverse side

DD FORM 1 JAN 73 1473

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The negotiations on conventional forces in Europe (CFE) include the principle of mutual reductions to parity at force levels below NATO's current levels. The participants' proposals set limits on equipment such as main battle tanks and artillery in the Atlantic-to-the-Urals region and various subregions. This Note provides an analysis of the following issues: (1) defining and estimating the "operational minimum," which is the operational-level strength of forces below which the feasibility of narrowly defined forward defense would be questionable (although by no means impossible) even under conditions of parity; (2) the significance for Central Region stability of the D-Day theater force ratio; (3) the potential stability at low force levels (i.e., below the "operational minimum"); and (4) possible CFE "stabilizing measures."

A RAND NOTE

N-2976-USDP

Variables Affecting Central-Region Stability: The "Operational Minimum" and Other Issues at Low Force Levels

Paul K. Davis, Robert D. Howe,
Richard L. Kugler, William G. Wild, Jr.

September 1989

Prepared for
The Under Secretary of Defense for Policy

RAND

PREFACE

This Note, adapted from an annotated briefing on interim research and analysis, was developed as part of a project on conventional arms control sponsored by the Under Secretary of Defense for Policy. Some pains have been taken to disseminate the interim results early and to keep the work unclassified and technically straightforward. The work was conducted in the RAND Strategy Assessment Center (RSAC), which is part of RAND's National Defense Research Institute (NDRI), a federally funded research and development center sponsored by the Office of the Secretary of Defense. Comments are welcome and should be addressed to Dr. Paul K. Davis, who directs the RSAC, at RAND headquarters in Santa Monica, California.

SUMMARY

Objectives and Scope

The negotiations on Conventional Forces in Europe (CFE) include the principle of mutual reductions to parity at force levels below NATO's current levels. The sides' proposals set limits on equipment such as main battle tanks and artillery in the Atlantic-to-the-Urals region (ATTU) and various subregions. *This Note provides an interim analysis of the following relevant issues*:

- *Defining and estimating the "operational minimum,"* which is the operational-level density of forces below which the feasibility of narrowly defined forward defense would be questionable (although by no means impossible) even under conditions of parity.
- *The significance for Central Region stability of the D-Day theater force ratio*, recognizing that this could be quite different from the overall ATTU force ratio in peacetime.
- *The potential for stability at low force levels* (below the "operational minimum") as a function of strategy, doctrine, forces, and arms control measures.
- Possible *CFE "stabilizing measures"* (sometimes called "operational arms control").

The Minimum Force for Narrowly Defined Forward Defense

The "operational minimum" turns out to be a highly ambiguous concept on which there are many opinions and flatly contradictory rules of thumb. The study reviews the underlying technical issues, defines terms, proposes improved procedures for discussing the matter, and gives an illustrative, strawman, estimate what might be considered to be NATO's operational minimum in the Central Region. The estimate is somewhat complicated, because no single measure of capability is adequate, there really exists no clear-cut minimum, and there are large uncertainties as discussed below. Nonetheless, based on conservative analysis of force-to-space issues *our illustrative estimate of the force constituting the operational minimum for the Central Region is that*:

- The force should consist of about 27 "equivalent divisions" (EDs) measuring equipment "score" relative to a U.S. armored division, or about 34 "division equivalents in firepower" (DEFs) measuring the same score relative to a

composite NATO heavy division. This corresponds in either case to roughly 8000 main battle tanks.[1]

- The force with 27 EDs might consist of a significantly larger number of divisions and an even larger number of "division equivalents in manpower" (DEMs) (e.g., 30–35 divisional flags and 32–38 DEMs). The smaller the number of divisions, the larger those divisions would need to be in terms of combat manpower.

- The force would have to be *tailored* to make judicious use of light but mobile infantry in covering defense-favorable terrain efficiently. The support slice for such a force should be smaller than for a comparable heavier force, which makes such tailoring attractive in reducing overall costs and manpower end strength, a fact that has been noted by several of the national armies independent of arms control considerations.

The basic idea underlying this estimate of the operational minimum is that the forces required to maintain a cohesive forward defense for a reasonable length of time (and indefinitely in the case of overall force parity) could be much "lighter" than today's forces (i.e., they could have many fewer tanks and artillery), but the need to maintain a high density of combat manpower would remain. Thus, one might end up with divisions large in combat manpower but small in terms of attack firepower. The manpower needed would depend significantly on the defending commanders' latitude in allowing temporary tactical penetrations, the mobility of the combat infantry (suggesting the need to avoid excessive limitations on armored personnel carriers and infantry fighting vehicles), the degree to which modern command and control and maneuvering of fire can substitute for manpower, and other factors such as the attacker's ability—based on equipment, doctrine, and training—to exploit rough terrain rather than the classic avenues of approach. Our strawman estimate is somewhat conservative because, in time periods short compared to those NATO would need to produce additional force structure, the Pact armies could probably reorganize and retrain to make better use of rough terrain than would be likely if war occurred tomorrow.

The analysis in this Note focuses primarily on the firepower-sensitive measure of EDs and, as shown in the text, reasonable people can estimate requirements higher or

---

[1]As points of comparison, NATO might today expect to be able to employ *roughly* 40 EDs (perhaps 10,000–12,000 tanks) or about 50 DEFs, divisions, or DEMs in the first month following D-Day of a Central Region campaign. The relationship between these numbers and the "bean counts" being negotiated in Vienna is complex because the negotiations involve both active and nonactive equipment, a variety of regions, and an approach that counts equipment where it is stationed rather than where it would probably be used in wartime (OSD, 1989).

lower than ours—from the low 20s to the mid 30s depending on terrain-related facts, assumptions, and military judgments. Ultimately, the estimates decided upon should reflect judgments of NATO's field commanders, but the framework here should be useful for defining terms, posing issues, and communicating concepts—especially since it is evident that there is no single "correct" answer. We provide a nomogram to facilitate alternative estimates.

Defense at Force Levels Below the Operational Minimum

By definition, at force levels below the operational minimum force-posture stability would be questionable if NATO were committed to a narrowly defined forward defense seeking everywhere across the front to prevent even temporary operational-level losses of territory. As demonstrated with preliminary simulations reported here at force levels as low as 18 equivalent divisions, *however, stability could in theory be achieved at equal force levels below the operational minimum —with forward defense in "good scenarios" and in other scenarios with other strategies and/or defensive criteria.* For example, the defensive concept might allow, in some contingencies, for temporarily giving ground at the operational level to buy time for counterconcentration and counterattack. Despite impressions to the contrary, such concepts would not require changes in NATO's flexible-response strategy as embodied in MC 14/3; they would, however, require fundamental changes in NATO's political and military thinking, doctrine, and forces. There would be a premium on unity and simplicity of command, maneuver and counterattack-capable forces, fungibility of forces, countermaneuver operations by tactical air forces, highly responsive surveillance and assessment, responsive command and control systems more generally, and operational flexibility that would include options for trading space for time to avoid having decisive battles under adverse circumstances. These are not the characteristics favored by most proponents of "defensive defense," although there are a range of views among proponents.

The prospects at low force levels for successful defense generally and for forward defense in particular would be substantially enhanced by a variety of stabilizing measures sometimes referred to as "operational arms control." In general, such measures would seek (Davis, 1988) to (a) avoid strategic and operational surprise; (b) raise risks for the attacker (including risks of preemptive air strikes interdicting attack forces and logistics units en route to the front), and (c) improve the defender's tactical odds. *Among the most important stabilizing measures would be*:

- Cutting back attack-specific infrastructure such as *excess* forward-deployed tonnage of artillery ammunition, bridging equipment, and perhaps mobile air defense units.

- Preferentially reducing *Soviet* forces deployed in Eastern Europe.

- Clearly prohibiting a broad range of actions necessary in preparation for attack (e.g., increasing beyond a threshold the number of in-place and likely reinforcing units at high readiness, redeploying attack infrastructure, conducting certain types of large-scale *comprehensive* exercises, and, of course, redeploying forces previously pulled out of the region).

Such measures would be especially effective at low force levels and approximate parity, because—assuming comparable skill levels and current concepts of operations—the attacker's prospects for success would depend heavily on achieving and exploiting temporary force-ratio advantages on one or two main sectors. Appropriate stabilizing measures could make it more likely that the defending alliance would recognize *and react cohesively* to strategic warning, diagnose and react to attacker strategy quickly enough to avoid operational surprise and early breakthroughs, and mount interdiction operations early enough to disrupt the attacker's operations. As our simulations illustrate at low force levels and parity, even modest counterconcentration before D-Day could be extremely important—primarily in preventing early breakthroughs while further counterconcentration could take place and, in many cases, making a forward defense possible. Although we have not analyzed them as yet in detail, it seems likely that attacks based on alternative concepts of operations deemphasizing dependence on large-scale concentrations of force (Glantz, 1989; Donnelly, 1989; Hines, 1988; and Karber, 1984) would depend sensitively on tactical-level prowess that would also be difficult to achieve without a considerable degree of surprise.

On the Importance of Dynamic Parity at Low Force Levels

All of this assumes the parity sought under the CFE proposals, but even if the sides had parity in the ATTU aggregate, NATO could have a significantly adverse D-Day force ratio in the Central Region because of faster Pact force generation or the use by the Pact of out-of-region forces such as those drawn from elsewhere in the ATTU or even from areas such as Central Asia and the Far East. *The significance of an adverse D-Day theater force ratio (e.g., 1.5:1) would be substantially greater at force levels below the operational minimum than it would be today* (except in the limit of force levels so low as to preclude a permanent strategic victory by the attacker even if the attacker were

successful in battle). As an example, if the sides both had 18 EDs slated for the Central Region, but the Pact could generate them faster and attack while the theater force ratio were 1.5:1, it would be able to concentrate and achieve high force ratios (e.g., 3 or 4 to !) on three or four corps-sized sectors, rather than the one or two possible from a theater force ratio of parity. This could have a dramatic effect on the attacker's ability to achieve a strategically decisive victory. This is not necessarily evident in "best-estimate" war games and simulations that assume good NATO response to warning, efficient command-control, and nominal combat equations, but it is evident in excursions that would be especially plausible in the absence of stabilizing measures such as those mentioned above. It follows also that NATO should seek to achieve *dynamic parity* as the outcome of the CFE negotiations. This will require paying careful attention to the sides' relative ability to use out-of-region forces in the Central Region, which will depend in part on the outcome of negotiations on subzones within the ATTU. For example, it matters whether the Baltic Military District is or is not included in the same subzone as the others expected to provide Soviet reinforcements for the Central Region. It also suggests that NATO should seek limitations on the sum of active and ready reserve forces that could be employed quickly in the Central Region. Alternatively, NATO could unilaterally maintain an active/reserve mix denying the Pact force-generation advantages. For the United States, this could mean leaving more forces in Europe than some might prefer, additional POMCUS efforts, or expensive mobility programs.

There is a great deal of analysis yet to be done on these issues, especially since even the analytic methodology currently available is not well suited to studying some of the maneuver issues that arise at low force levels, much less to examining the consequences of new concepts of operation and attempts to change and integrate national doctrines to provide greater coherence in a NATO defense effort at low force levels. The study concludes by listing some of the more important items remaining on the analysis agenda.

ACKNOWLEDGMENTS

In the course of this work we had discussions with serving and retired military officers from several nations. We appreciate their time and contributions, although they may not always agree with the analysis presented here. We would also like to acknowledge useful review comments (on the briefing or the draft Note) by RAND colleagues Edison M. Cesar, Glenn A. Kent, James A. Thomson, and Edward L. Warner.

CONTENTS

I. INTRODUCTION

Both NATO and the Warsaw Treaty Organization (WTO) have proposed ambitious measures in the negotiations on conventional forces in Europe (the CFE talks) being held in Vienna. Both sides propose reductions to parity at force levels significantly lower than NATO's current levels. It is therefore appropriate to ask how low those force levels might be made if the CFE talks prove successful. It may seem natural to assume "the lower the better," but there is reason for conservatism, since many military and civilian figures in the West have argued that reductions below a threshold sometimes called the "operational minimum" might actually *decrease* "stability." We address this issue here and, while offering no definitive conclusions, seek to clarify the problems and variables, and to define the framework within which discussion can better take place. On the whole, the briefing ends up being more optimistic than is currently customary about the *theoretical* potential for stability at low but equal force levels. At the same time, we post important caveats about apparent required adaptations in NATO's force structure, the need for CFE stabilizing measures, and the risks that would exist at low force levels if the attacker gained an advantage in theater force ratio in any of several ways.

The Note proceeds as follows. First we discuss the *concept* of stability briefly. Then we discuss the "operational minimum." Next, we consider the significance of theater force ratio to warfighting strategy, which leads into an analysis of stability at low force levels. Finally, we offer some recommendations for the CFE negotiations and sum up.

II. DEFINING STABILITY

Let us begin by discussing what we mean by "stability." As Fig. 1 indicates, the word "stability" has many different meanings. A given arms control measure could be stabilizing in some respects and destabilizing in others. When quantitative analysts discuss stability, they usually have in mind what we call force-posture stability. *A military balance is force-posture stable if the defender would be quite likely to prevail if invaded and that fact is correctly perceived by both sides.* We use "force *posture*" here because what matters to the warfighting outcome is not only the force structure, but also where the forces are deployed, how well they are trained, their state of readiness, and other aspects of overall "posture." Some other authors use the term "conventional stability" for the same thing (e.g., Warner and Ochmanek, 1989). Conventional force-posture stability is approximately analogous to the force-posture component of first-strike stability in strategic nuclear analysis.[1] As Fig. 1 indicates, how much force is needed to

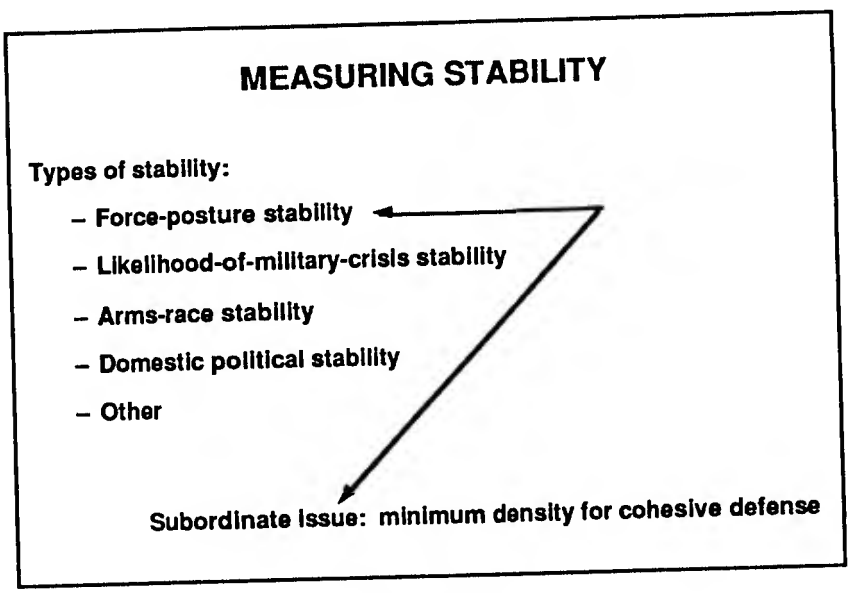

Fig. 1

[1]See Davis (1989a), Kent, DeValk, and Thaler (1988), and Wilkening and Watman (1986). The latter two discuss strategic force-posture stability; the first gives a broader view based on a theory of crisis decisionmaking with both force-posture sensitivities and behavioral factors. RAND colleague Kenneth Watman has also done considerable recent work on conventional force-posture stability, which has been briefed widely but not yet published. He has correctly emphasized that (force-posture) stability requires that the defender's warfighting prospects be

maintain a cohesive defense line is a subordinate issue, one keyed to the strategy of forward defense.

The other types of stability mentioned in Fig. 1 are less commonly discussed by quantitative analysts, but are often on the minds of policymakers or ordinary citizens even if they use different terminology. For example, the United States and Canada enjoy a highly stable relationship in the sense that no military crisis—or military coercion—between us is at all likely, even though there is an overwhelming difference in military capabilities. Indeed, the two sides' military force structures appear to be irrelevant to the bilateral stability. Many Europeans believe that the Soviet Union has no interest in invading Western Europe and could be easily deterred from doing so if it flirted with such interests. They believe that increasing stability is best achieved by political measures reducing international tensions and the likelihood of military crises. Another dimension of stability involves the arms race, which hardly needs definition here. Arms-race stability is related to another issue, which we call domestic political stability, because to the extent that there are or appear to be large and worrisome asymmetries in force structure or in military efforts such as research and development, the domestic political agenda may be heavily influenced by debates on the topic—some of them important and valid such as Churchill's unsuccessful warnings during the rise of Hitler, and some of them spurious and disruptive such as discussions of the missile gap in 1960 and the window of vulnerability in 1979–1980.

The reason for raising these matters is that we should be cautious in discussing "stability" to avoid the common practice of equating it strictly with the quantitative assessments so dear to the hearts of analysts. Even though this Note focuses on force-posture stability, the other types are at least equally important to the current policy debates.

Figure 2 illustrates how different aspects of stability can interact. It postulates that the likelihood of war (one of the ultimate measures of overall stability) is a monotonic

---

favorable in worse than expected scenarios, not merely someone's notion of a best-estimate or convenient planning scenario. Rohn (1989) discusses force-posture stability separately from the viewpoints of the would-be attacker and defender. Huber (1989) also provides an elegant theory of structural changes that might be necessary to achieve stability, and discusses the transitional problems that might arise as a function of the unknown efficiency of alternative force elements.

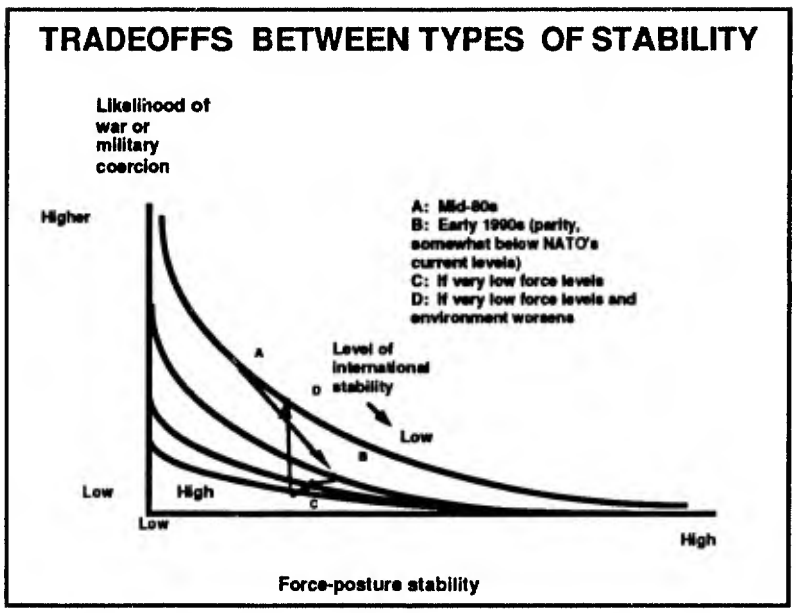

Fig. 2

function of force-posture instability and what is here called "international stability," which one can think of as measuring the level of political tension between East and West, and of the likelihood of military crisis. Thus, war is relatively more likely if tensions are high and force-posture stability is low (Point A). In this picture the likelihood of war was relatively higher in the early to mid 1980s, because tensions were high and there was a significant force-posture instability, especially when one took into account NATO's maldeployed forces and politically constrained command-control. Point B speculates about the early 1990s after Gorbachev's unilateral reductions have taken place and, perhaps, the first CFE measures have been implemented. International stability improves and force-posture stability improves. Point C imagines a next phase with very low force levels; here the hypothesis is that force-posture stability decreases (for reasons that will become more evident later), but international stability improves. The net result, temporarily at least, is a reduced likelihood of war. This is the case when NATO takes a military risk to improve an aspect of stability not treated in technical work. Point D, however, illustrates the other side of the coin. If for some reason the international environment worsened and tensions rose again, then the significance of the reduced force-posture stability would come into play. That is, Point D is less stable than Point C, and also less stable than Point B.

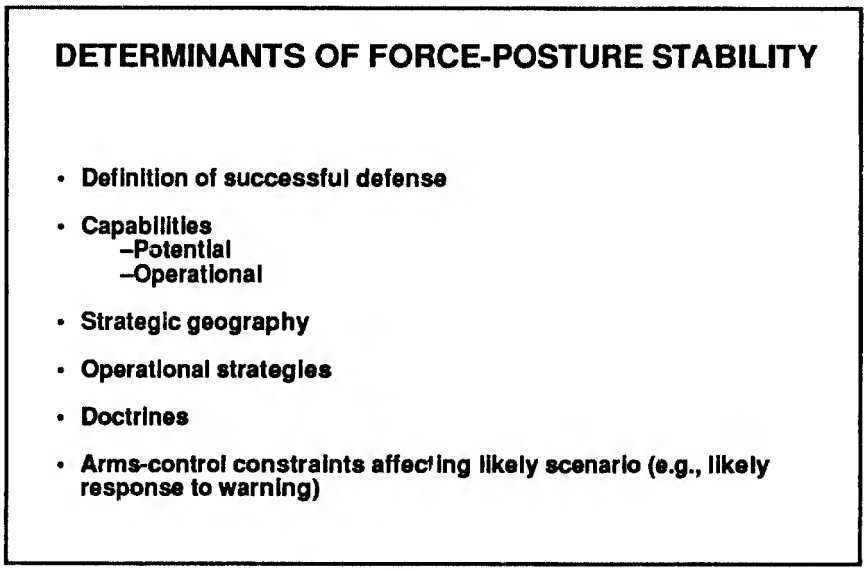

Fig. 3

With this general background on stability, let us focus now on force-posture stability and its determinants (Fig. 3). A modest amount of thought reveals that assessing the effects of a particular arms control measure on this type of stability depends on at least the factors shown here. We shall discuss all of these, but for now consider especially the first one—the very definition of defense. If a measure is stabilizing to the degree that it increases the likelihood a defender would be successful if attacked, we need to understand what we mean by "successful."

In thinking about what constitutes successful defense from NATO's perspective (Fig. 4), we see several dimensions of choice:

- **Objectives**: Is the military objective one of deterrence by denying the attacker a strategic victory; is it to restore the status quo ante; or is it, in addition, to defeat the attacker decisively—by pursuit and a change of boundaries if necessary? Would the first, less ambitious, objective be more acceptable if the likelihood of war could be reduced? What if, in addition, the maximum victory an attacker could achieve would be modest and short-lived?

- **Strategies**: Is the strategy one of merely buying time for nuclear coercion, or should the strategy seek conventional success? Is there a conflict between these? Does the strategy countenance some initial loss of territory to buy time and flexibility, or does it require holding ground forward everywhere?

- Does the strategy permit counterattacks at the operational level? At the strategic level? (No, it does not.)[2] How deep can the war be carried, from the air and on the ground to defeat the attacker's army and reduce future risks? Should the attacker be treated as a monolith or does the strategy allow for exploiting divisions within the attacker's alliance?

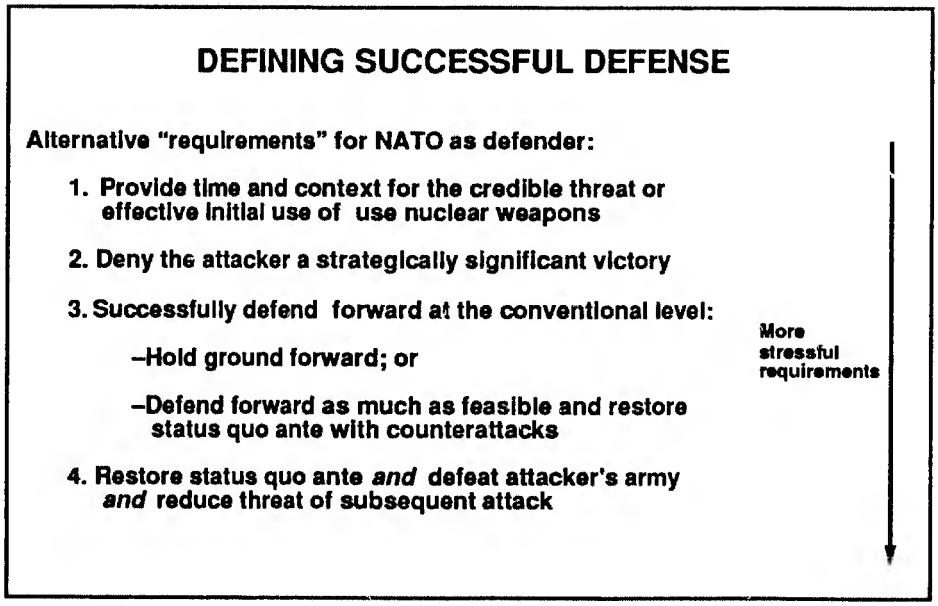

Fig. 4

NATO's strategy as described in MC-14/3 is studiously ambiguous on most of these matters, but the impression is widespread that NATO's strategy requires a mindless forward defense because the German populace insists that every inch of German soil is precious and there can thus be no talk of trading space for time anywhere in the theater. However, what response would be obtained if these citizens were asked "Which strategy would you prefer in the event that the Warsaw Pact attacked tomorrow and caught NATO by surprise: a strategy in which NATO forces rushed to the front for certain annihilation, or a strategy involving some initial fallback and a counterattack with some reasonable

[2]The Soviets have been doing considerable soul searching on these issues. They have discussed alternative defense strategies in various forums (e.g., Kokoshin and Larianov, 1988), and have argued that while older Soviet strategy clearly required the decisive defeat of the enemy's army, the new strategy is somewhat closer to the one of being able to counterattack and restore the status quo ante. The issue is not resolved, however, and senior Soviet military spokesmen have continued to refer to the need to be able to launch a "decisive" counteroffensive. See, for example, comments by Defense Minister Yazov and V. G. Kulikov as quoted in Hines (1988).

prospects for success?" We reject the notion that there is a political imperative for NATO to plan exclusively on a rigid forward defense in any and all circumstances.

In fact, when NATO's flexible response strategy was first announced in the 1960s, the operational military strategy was by no means a rigid forward defense; to the contrary, it contemplated defense at rearward river lines such as the Weser-Lech line, or even the Rhine.[3] Only as capabilities improved in the 1970s and 1980s did the strategy evolve into what we know today, a strategy that plans on defending forward wherever possible. Thus, "flexible response" and "forward defense" can and have been interpreted differently in different periods. There is no reason to saddle the military planners with foolishly rigid concepts, and many reasons for not doing so. Similarly, we should not assess potential agreements on the sole criterion of narrowly defined forward defense. Most reasonable people would consider the force structure stable if NATO could: (a) defend forward with confidence in most plausible scenarios and (b) confidently restore the status quo ante in even the more unlikely worst-case scenarios.

As final background on the force-posture stability issue, consider briefly some problems that tend to be swept under the proverbial rug by analysts. The preceding discussion implicitly assumed stereotyped wars with an all-out invasion of one alliance by the other, but suppose we had a regime in which such stereotyped attacks were doomed to failure but in which *limited* attacks might be successful in that the defender could not restore the status quo ante? The Soviets might worry here about a Federal Republic of Germany or FRG-American effort to "grab off" the German Democratic Republic under circumstances where some elements in the GDR were cooperating. (See Fig. 5.)

This dimension of force-posture stability is clearly important and will be considered in future work, but here we merely indicate its existence and argue that analysts should not implicitly protect Soviet imperial interests through a technical concept of stability. Nor should NATO consider the line dividing the Germanys to be the natural middle, since from a strategic perspective: (a) Western Europe and the Soviet Union are both superpowers needing a protective buffer zone, and (b) East European nations, although currently members of the Warsaw Pact, would probably prefer being neutral buffers over having continued Soviet occupation. Thus, NATO should not be shy in persisting in its CFE proposal that the Soviet proportion of Pact forces in Eastern Europe be greatly reduced. NATO should also reject arguments claiming that a "fair"

---

[3]See, for example, Brezinski (1986), pp. 177–179.

concept of stability would require pulling all non-FRG forces out of the FRG to balance Soviet forces being pulled from Eastern Europe.

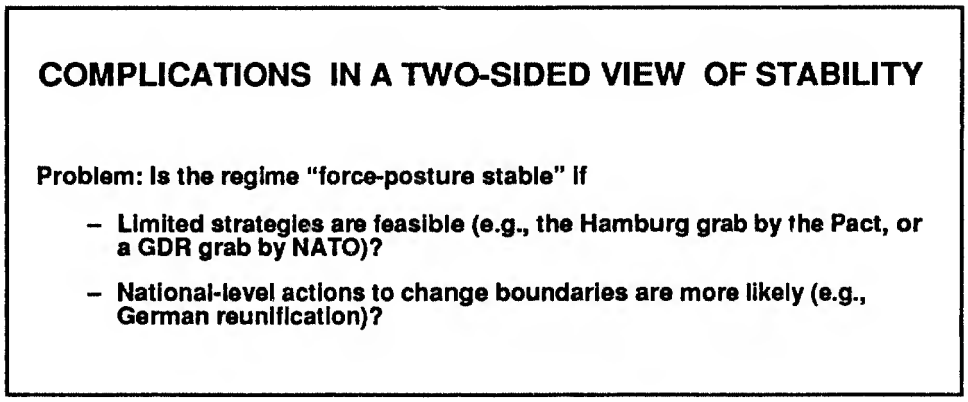

Fig. 5

III. THE OPERATIONAL MINIMUM FOR FORWARD DEFENSE

Having discussed stability generally and then discussed alternative concepts for force-posture stability in particular, we shall in this section focus on the concept of force-posture stability that requires forward defense and discuss how to determine the so-called operational minimum force level below which forward defense would be questionable (although by no means impossible). We offer no definitive conclusions, since authoritative conclusions should reflect the careful and potentially private and classified judgments of NATO's military commanders, who are thoroughly acquainted with details of the actual terrain and strategy. Instead, our purpose is to clarify the questions being asked and to suggest an improved analytic framework for discussion. We also provide some estimates, but more as an illustrative strawman then as final conclusions.

Figure 6 indicates the questions we will address, starting with the basic question of why one would even expect an instability below some level of forces. As we shall see, the "standard" methods for estimating the operational minimum vary drastically because there have been many ambiguities and implicit assumptions in most discussions. We shall try to do better.

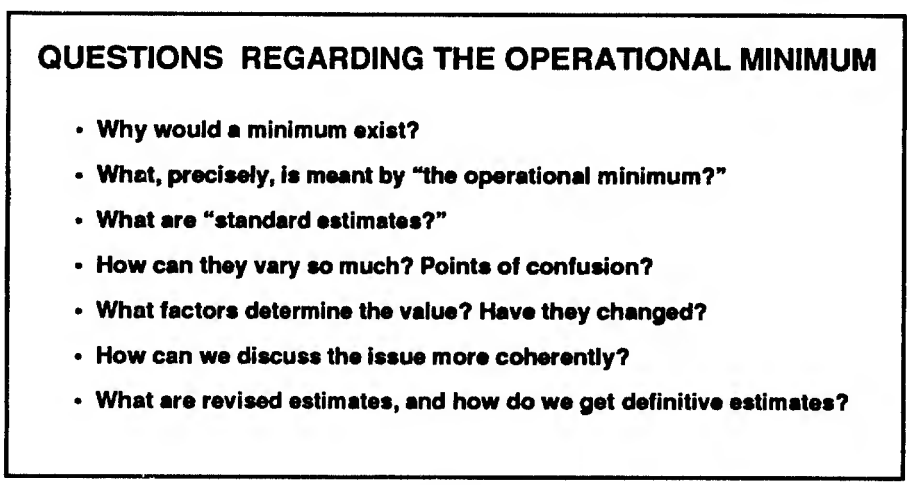

Fig. 6

The key to understanding the concept of an operational minimum is thinking about what it takes to prevent the attacker from successfully penetrating the defense. A football analogy is apt here: in 6-man rather than 11-man football, the rules say that it takes 15 yards to get a first down rather than 10. Why? Because it's so easy for the offense to get some penetration. The point here is that the ability to prevent penetrations depends on defensive density, because the attacker always has some initial advantage in choosing where to concentrate his attack (Fig. 7). Unless the defender's combination of density, intelligence, command-control, and mobility are good enough, there will be some penetration before the attack can be contained—even if the sides have equal forces overall.

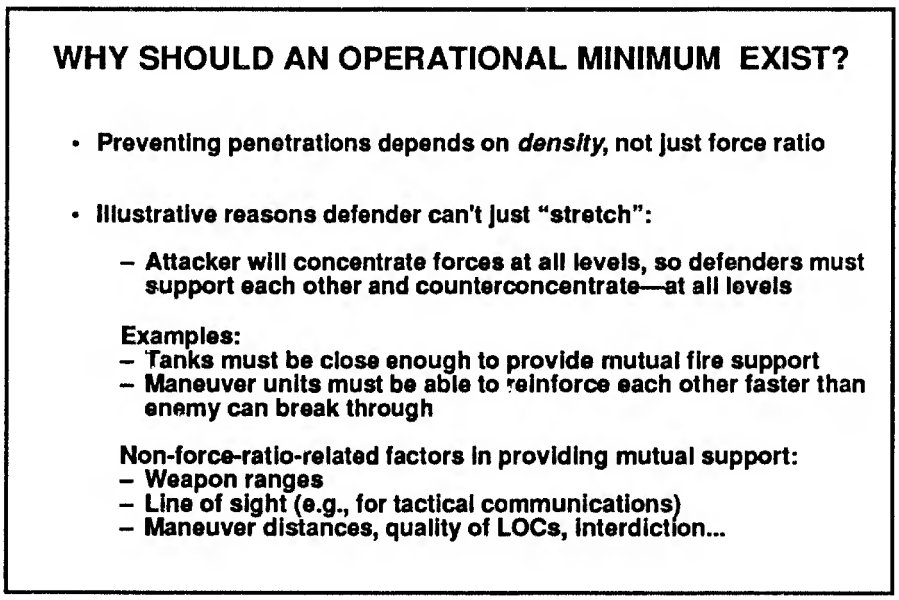

Fig. 7

This process of the attacker concentrating and the defender counterconcentrating applies at all levels of warfare. At the lowest levels, defenders may counterconcentrate by merely shifting their fire rather than maneuvering. For example, adjacent tanks or machine guns will have overlapping fields of fire. At higher levels, entire units must maneuver in response to the attacker's concentration. How long this takes depends on how quickly the attacker's plan is correctly discerned in the presence of feints and other deceptions, how quickly the appropriate commander orders the maneuver, and how quickly the maneuver units can respond given the terrain and the attacker's efforts to interdict or otherwise obstruct the maneuver. Army officers with field experience

emphasize that it is difficult for others to appreciate how important it is under battlefield circumstances to "see" the battle and to communicate quickly and reliably. Doing these things often depends on absolute distances being relatively short. Note, for example, that current tactical communications are typically line-of-sight limited and that electronic countermeasures only make things worse for the defender trying to diagnose and respond to what is happening.

While an overall force level of 1:1 is much better than an adverse force ratio for the defender, it does not in itself allow him to prevent penetrations. Whether such penetrations would be decisive is another matter that we shall discuss later.

If it is reasonable, then, to think about an operational minimum, we need a definition. The definition in Fig. 7 involves operational density, which is best explained in Fig. 8. Consider, however, that this definition contemplates defense for a reasonable period of time such as a week—without a specified threat—and indefinitely at parity. It is natural to ask how this minimum force level could possibly be independent of threat. In fact, the concept depends implicitly on threat, as follows. Current types of forces cannot be massed arbitrarily tight while attacking, because the result is a combination of friction (mutual interference in this case) and extreme vulnerability. Soviet forces might be expected to have divisional frontages as small as 4–8 km on occasion (at the focal

DEFINING THE "OPERATIONAL MINIMUM"

***Definition*: The minimum operational density of forces to maintain cohesion and hold ground for perhaps a week or so (indefinitely, at parity) with reasonable confidence.**

***Synonyms*: defensive minimum, breakpoint, minimum defender density, or (inverse of) maximum defender frontage per division**

***Operational density*: forces per km of geographic frontage viewed from army-group perspective**

***Tactical density*: forces assigned to the front per km of geographic frontage, viewed from corps or army-group perspective**

Operational minimum = Minimum operational density

= (Minimum Tactical density) (1 + Reserve factor)

Fig. 8

point of an army's attack), but average frontages across a main-thrust army's front (and, hence, across the front of a NATO corps sector) would more likely be something like 12–20 km per division.[4] Thus, regardless of overall force levels, the *maximum* on-line attack force might be, in open terrain, about six divisions over, say, a 25 km defensive sector. Thus, it is in theory straightforward to estimate what defensive force would be required to hold that sector until it could be reinforced tactically. If there were one defensive division and the two sides' divisions were equal in capability, the force ratio would be about 6:1. Complications include the fact that the Pact would mass artillery, airpower, and perhaps surface-to-surface missiles on the intended breakthrough area and, working in the other direction, that the *effective* force ratio would be reduced by the defender's preparations. Also, the defender would counterconcentrate artillery fire and airpower, and would give ground tactically as necessary. The point, however, is that the concept of a threat-independent operational minimum makes sense only because there is (at least currently) an effective upper limit on the local threat density. If 6:1 would be intolerable, then the defender would need to have a higher density than one division per 25 km in open terrain.

Figure 9 makes it easier to distinguish between tactical and operational-level densities. It depicts an illustrative corps that is part of an army group and assumes three brigades per division. The tactical density on the FLOT is one division (two x's) or three brigades (one x) per 25 km of frontage. This counts the on-FLOT divisions' reserve brigades as on the FLOT also. (From the division commander's viewpoint, only two of his three brigades may be "up," but from a higher-level viewpoint, there are two divisions covering a FLOT of 50 km.)

The operational density is more complex. The defending corps has two divisions and two reserve brigades, but for the purpose of assessing the defender's situation we must assume the corps would also get its fair share of army-group reserves if needed. If there were four equal corps, then the fair share to each would be one brigade and the

---

[4]General information on Soviet massing concepts can be found in Hines (1988) and Donnelly (1989). Mearsheimer (1989) discusses the attacker-frontage issue, responding to earlier criticisms by Cohen (see Cohen, 1989 and earlier references). None of these discusses the role of terrain clearly, however, and it should be noted that it is in open terrain that the Pact might achieve the most extreme concentrations with mechanized units (e.g., divisional fronts of 4–8 km). In mixed terrain, that would not generally be practical. With straight-leg infantry forces, of course, smaller attack frontages would be possible (e.g., 1–2 km, as in World War II), but the firepower and momentum of those forces would be lower and their vulnerability higher.

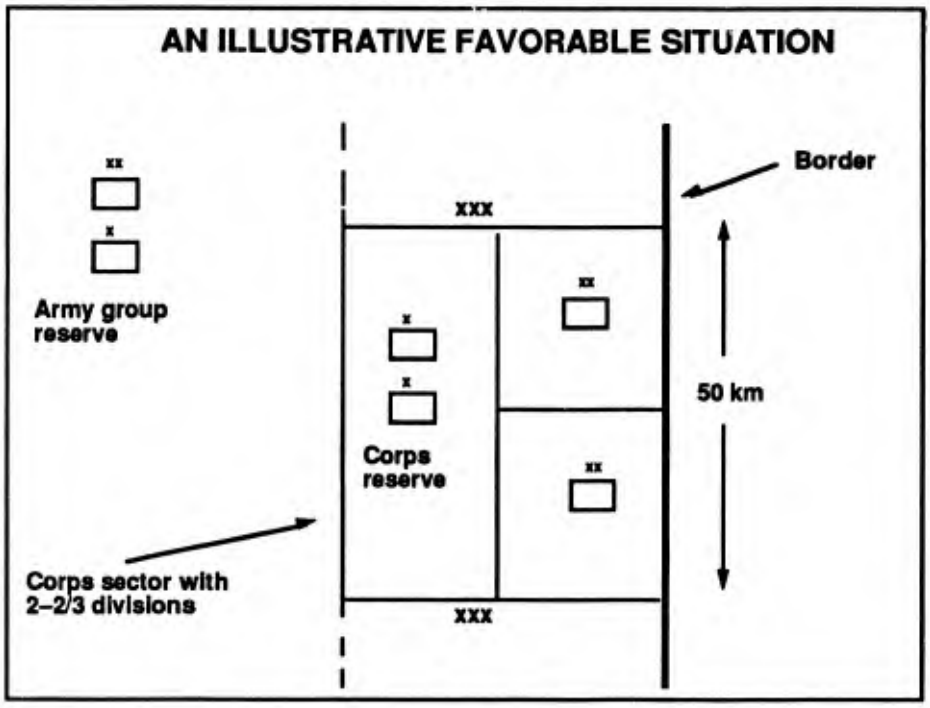

Fig. 9

corps shown would have a total of three brigades as available reserves in support of its two on-FLOT divisions (or six on-FLOT brigades). This would mean a reserve factor of 0.50 (or 50%) and an operational density of 16.7 km per division.

Now, an individual army-group commander might choose to strip away more of his corps' units so as to build a larger army-group reserve for operational-level counterattacks. And, if he did so, the corps commanders might reduce their tactical densities on the FLOT to maintain corps reserves. However, none of this would affect the operational density as defined here. Indeed, it is because such choices exist that defense planning needs to focus on aggregations such as the operational density, which measures the resources *available* to the defending commanders. Precisely how they use the resources is up to them.

How large, then, is the operational minimum given our definition? (See Fig. 10.) Current estimates vary by about a factor of three, depending on what rules of thumb and assumptions about terrain are applied. We have seen both of the above estimates presented seriously in discussions and papers; they are not strawmen to be knocked down

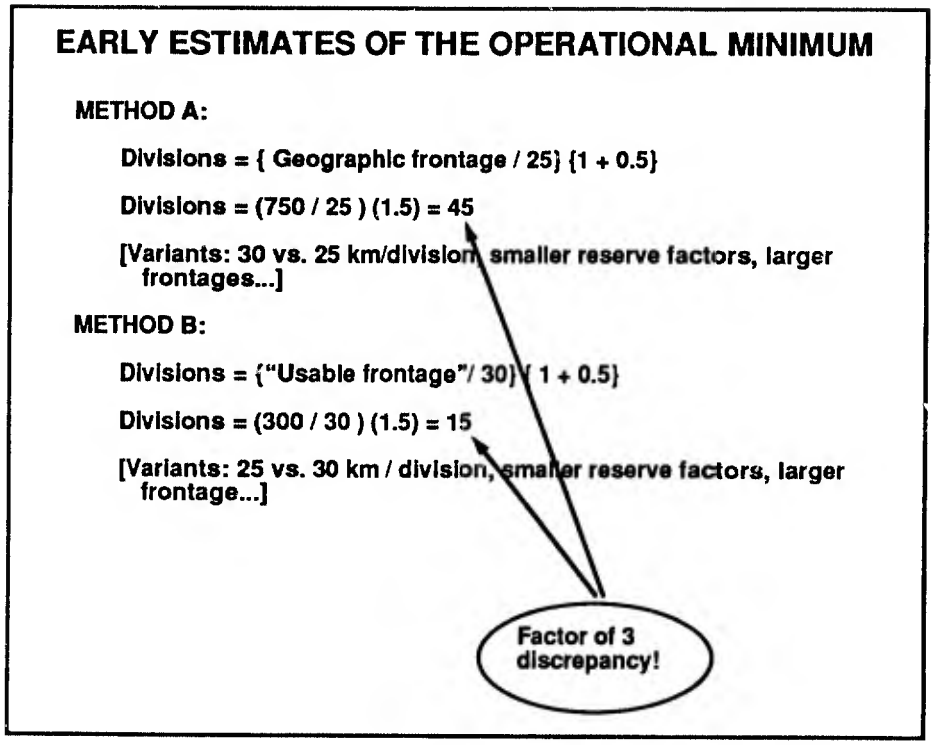

Fig. 10

trivially. The lower figure uses a concept of "usable frontage," which we shall discuss in more detail in what follows.

Figure 11 summarizes the factors confusing the discussion, notably the following.

Frontage. The Central Region's frontage is variously estimated as between about 680 and 1000 km. This can be understood with the following illustrative table.

Straightlining of Border?	Austrian Border?	Danish Sector?	Frontage (km)
Some	No	No	675
More	No	Yes	695
Some	No	Yes	750
Some	Yes	Yes	900
Less	Yes	Yes	1000

By and large it is common for Germans and representatives of NATO to use the larger numbers, especially in public discussion. However, Central Region analysis in the

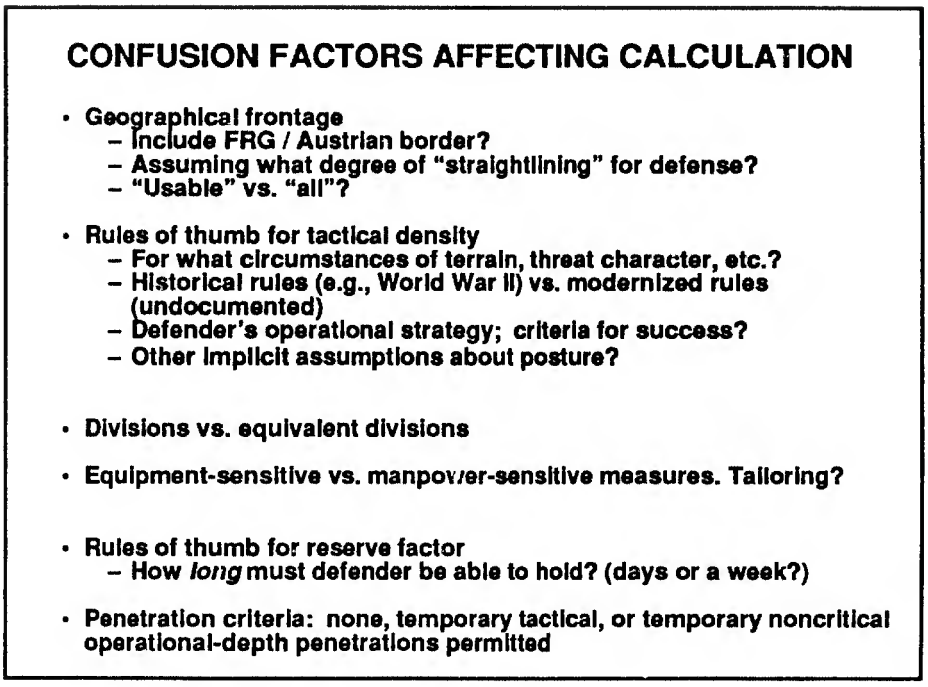

Fig. 11

United States and much of Europe more often focuses on the 750 km frontage, in part because if the border with Austria is included, military assessments should consider the use of Austrian, Italian, and more French forces than are usually treated.

Next, there is the important issue of "usable" vs. geographic frontage. We will discuss this in more detail later, but planning usually assumes that attackers will be channelized into major attack corridors, effectively reducing the terrain to be heavily covered. There are major discrepancies among analyst groups on how much of the geographic frontage should be counted.

The Rules of Thumb. The rules of thumb have only a tenuous basis in national doctrines, and one can search in vain without finding authoritative doctrinal statements (except in the Soviet literature, which attempts with varied success to be more scientific). The various rules of thumb used in the West are poorly defined, inconsistent, and even downright contradictory—however fervently accepted. The sources cited for them are usually a combination of informal discussions and dubious inferences from doctrinal manuals. There is also a degree of cynicism involved. For example, if an organization believes that the approved "requirement" is and always has been 30 on-FLOT divisions (always with some threat in mind, however), then one person may "derive it" as 900/30, while another may "derive it" as 750/25. A proper approach must instead start with

basics, including questions about the circumstances (terrain, mission, threat, and so on), and also about implicit assumptions such as to whether the type of combat envisioned will revolve around armor or infantry.

Divisions vs. equivalent divisions. It is not even clear what the rules *mean* in most cases. Typically, the tactical rules (e.g., 25 km/div) are said to apply to "typical" FRG, NATO, or U.S. divisions. But which, and does this mean the most common type of division or some hypothetical division constructed with an average number of tanks and so on? Another ambiguity is that disagreements exist about whether the rules should really be based on firepower, firepower and mobility, manpower, or perhaps a number of vehicles. Thus, different people may cite what appears to be the same rule (e.g., 25 km per . . .), but the ellipses may be divisions, "division equivalents" (DEs), "armored division equivalents" (ADEs), "division equivalents in firepower" (DEFs), "equivalent divisions" (EDs), "division equivalents in manpower" (DEMs), or a variety of others.[5] To make things worse, the common "firepower" measures (EDs, ADEs and DEFs) are defined differently by different organizations,[6] and are redefined from time to time so that the standard division with a score of 1.0 can be a current division. The result is that a force of 50 ADEs according to late 1970s definitions would have a score of about 40 ADEs with revised definitions.[7] And, finally, there are often implicit assumptions about whether divisions are or are not tailored to the terrain. Bluntly stated, the subject is a morass.

---

[5]ADEs, EDs, and DEFs are all variants of normalized WEI-WUV scores (see Mako, 1983, for an explanation and references; see CBO, 1982, and other publications for some more recent scores) that attempt to account in the aggregate for lethality (firepower), vulnerability, and mobility of division-sized forces. ADEs and EDs are measured relative to a U.S. armored division, considered to have a score of 1. DEFs are measured relative to a composite NATO division. DEMs are computed as divisional manpower divided by 16,500, the manpower of an average U.S. or FRG division. DEs ("division equivalents," rather than "equivalent divisions") are just the number of divisional and independent brigades divided by 3. Current ED scores as used at RAND by the authors are about 20 percent smaller than DEF scores, because typical NATO heavy divisions have about 10 percent fewer tanks and IFVs than U.S. heavy divisions (see, e.g., Donnelly, 1989, p. 230, or the somewhat dated Appendix A in Mako, 1983).

[6]Common differences include whether and how nondivisional weapons are counted (e.g., whether they are distributed among the divisions or ignored); whether offensive, defensive, or average WEI-WUV scores are used; whether the WEI-WUV II or III scores are used; whether some categories of equipment are excluded, to be treated separately (e.g., helicopters); and whether and how many hand-held anti-tank weapons are counted. As one of us (Davis) and RAND colleague Patrick Allen have shown in unpublished work, these differences can have a substantial effect on even aggregated assessments such as trends in theater force ratio.

[7]This can be inferred from OSD/PA&E (1979, p. I-17).

Reserve requirements. Opinions differ on the number of corps, army-group, and theater-level reserves needed, although a reserve factor of 50 percent is usually considered reasonable and will be assumed in most of this Note. A more subtle issue is that in discussing rules of thumb for tactical densities individuals may have different implicit assumptions about higher-level reserves. Someone assuming few reserves will be much more reluctant to consider low tactical densities as safe than will someone reasoning that some parts of the front can be covered lightly until and unless an attack develops, in which case reserves can be committed.

Penetration criteria. The rules of thumb, when most stringently applied, assume that the defender is to allow virtually no penetrations. By contrast, many officers accept that temporary tactical penetrations of no great operational-level significance can be tolerated (and in some cases even encouraged). This is especially so for areas such as southern Germany, where attacks are *possible* through some of the difficult terrain, but are neither very likely nor very worrisome because the attacker would have slow movement, long and vulnerable lines, and long distances to move before achieving operationally or strategically decisive goals. To put it differently, "requirements" are often quietly relaxed for sound military reasons (and lack of resources). The U.S. VII and German II Corps cover considerably more frontage than rules of thumb would suggest (roughly 335 km with 6.7 divisions or 50 km/division) according to OSD/PA&E (1979, p. I-10), although this is somewhat complicated by the possible participation of French forces.

General. It is remarkably difficult to discuss the issue of operational minimum because there exist so many points of ambiguity and disagreement. Having touched on many of the most serious ones, let us first take an interlude to consider some historical episodes and trends over time on the matter of acceptable tactical densities. After that we will return to the issue of "usable" terrain.

Before giving some historical examples, let us observe that the tactical density required for defense has changed over time, although the rules of thumb often appear not to have been adjusted in the last twenty-five years and some of those using historical examples fail to make needed adjustments in numbers when applying the lessons. Based on discussions with retired officers whose experience goes back to World War II and Korea, as well as on material on Soviet military doctrine in World War II (Dupuy and Martell, 1982), it appears that U.S., German, and Soviet armies all believed that divisions

could defend frontages of *about* 10–15 km in World War II (a function of terrain, quality, and leadership, with Rommel's forces doing particularly well in North Africa).[8]

The U.S. doctrinal requirement for defense shifted from about one division per 10 km (more in some circumstances) to about one division per 25 km in the 1960s, after a review stimulated in the 1950s by concerns about dispersal for nuclear war fighting. The conclusion was that larger frontages were possible even in conventional war because of increases in firepower (more tanks), mobility (e.g., APCs vs. foot infantry), better reconnaissance (e.g., helicopters), and longer ranges (e.g., TOW vs. bazookas). It was also recognized that divisions could cover even larger frontages given good defensive terrain—e.g., 40 km or even significantly more.[9]

Although historical data are seldom definitive for our purposes today, it is nonetheless interesting to observe that for the Eastern Front in World War II, Hitler's orders required the German army frequently to attempt holding ground on larger divisional frontages than 10 km/division (i.e., more than 25 km/division if we assume 0.4 EDs per division as a probable upper bound for German forces). The result was a long string of breakthrough-and-exploitation campaigns for the Soviets, despite German tactical superiority (Fig. 12). The Soviets have long been proud of these campaigns and believe that they demonstrated a level of offensive military competence at the strategic and operational levels that has not been matched in the West (see, for example, discussion of this by Donnelly, 1989). At Kursk, the Soviets were initially on the defense—with extensive preparations and densities better than their doctrinal requirement for no more than a division per 10 km of frontage (i.e., less than 25 km per ED). The Soviet army held against a fierce German attack, and then began the counteroffensive that represented a major turning point of the war.

---

[8]Liddell Hart (1960, pp. 97 ff) devotes an entire chapter to the force-to-space issue over time. He concludes with observations very much valid today: "It is, of course, obvious that any numerical calculation. . . is subject to a variety of other important factors. . . The obvious difficulty presented by such 'variables' was always brought up by the General Staff as an insuperable objection whenever the idea of operational research. . . was urged in the years before World War II . Yet once it was accepted. . . the practical benefit. . . became very clear. It is worth bearing in mind. . . that everyone who has to make plans in war or exercises, from the Supreme Command down to the platoon leader, actually works on a 'force-to- space' calculation—but it is a rough rule-of-thumb calculation, in which *norm* is apt to be a product of custom and habit. It is desirable to replace that hazy proceeding by a norm derived from scientifically analyzed data. . . If such a basis had been worked out before the last war, it would [have avoided the fatal miscalculations leading to the fall of the Western Front in 1940, which Liddell Hart discusses in some detail]."

[9]This is based primarily on discussions with RAND colleague Richard Wise, who taught doctrine and was personally involved in the studies mentioned.

FRONTAGES ON EASTERN FRONT, WW II

Battle	Tac Frontage (defender)	Result
East Prussia	20 km/div	Germans broke
Byelorussian	26	Germans broke
Kursk	5–10	Russians held
Kursk counter. attack	15–21	Germans broke

If assume WW II divisions were ≤ 0.4 ED,

Battle	Tac Frontage (defender)	Result
East Prussia	≥50 km/ED	Germans broke
Byelorussian	≥65 km/ED	Germans broke
Kursk	≥12.5-25 k/ED	Russians held
Kursk counter. attack	≥38–50 km/ED	Germans broke

Fig. 12

These campaigns illustrate the importance of force-to-space ratio—i.e., the importance of the defender's *density*. While the numbers have changed as forces have changed, the principle, presumably, remains: a defender attempting to hold ground on an excessive frontage is doomed not only to failure, but to catastrophic breakthroughs.[10]

If divisional frontages increased between World War II and the 1960s, we should ask whether they have (or should have) grown since then. Certainly, weapon-system ranges, divisional firepower, and mobility have continued to increase. However, it is less clear how much defendable frontage has increased, primarily because of terrain issues. On balance it seems prudent to be conservative about postulated increases in divisional frontage since the big jump in the 1950s and 1960s, because many of the new improvements could be obviated by line-of-sight limitations, electronic countermeasures, deception practices, and other factors making a high density of men on the ground essential. Thus, while many officers believe that frontages for average terrain are

[10]It was on the basis of such historical data that the senior author designed into the combat models of the RAND Strategy Assessment System (RSAS) a strong dependence on defender density and a concept of breakthrough about which we shall have more to say later (see Davis, 1989b, and for details Bennett, Jones, Bullock, and Davis, 1988).

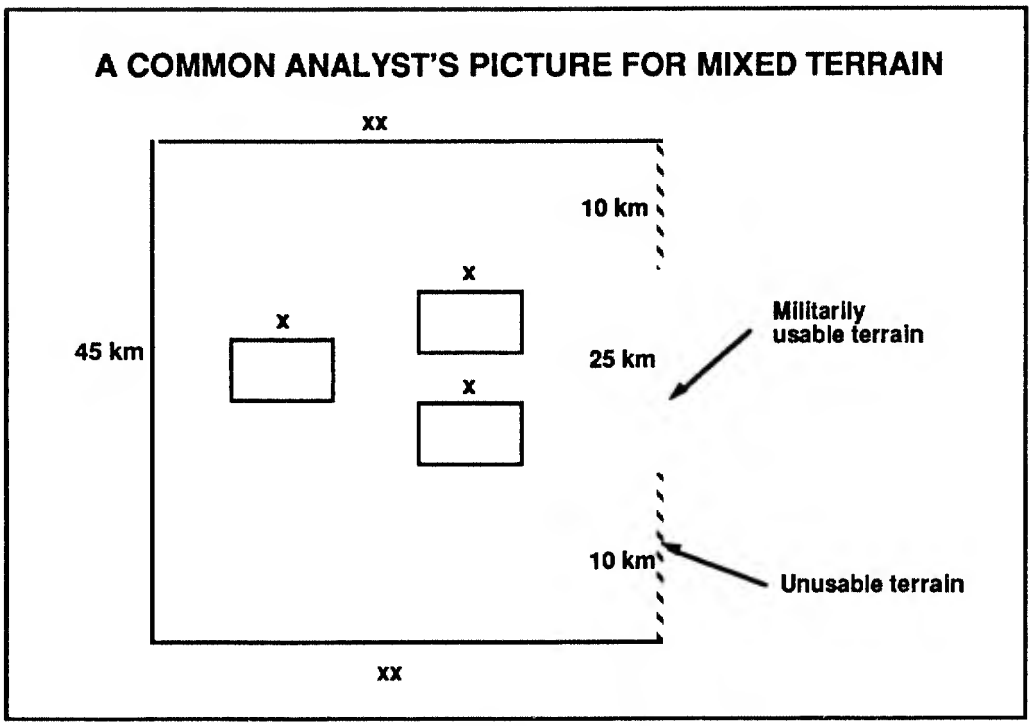

Fig. 13

somewhat higher today than ten or twenty years ago (e.g., 30 instead of 25 km), they are skeptical about anything much larger.

Figure 13 is the first of a series dealing with terrain and its relationship to density requirements. It is a strawman designed to bring out another point of common confusion—the notion of "usable" terrain. It suggests that some terrain is so bad as to be unusable to the attacker. Thus, the division can ignore it completely and focus strictly on the "usable" terrain. By this logic, defender requirements would then be based on usable frontage divided by, say, 25 or 30 km per division. This is the image projected by many analysts using computer models in which usable terrain is assumed (and often buried) as "data."

This presents a troublesome image to non-modeler military officers, because history makes it abundantly clear that virtually all frontage is "usable" given a determined and resourceful attacker. The German attack through the Ardennes in 1940 is but one of many examples in this respect (see Liddell Hart, 1960). Further, the Central Region does not have much extremely rugged or virtually impassable terrain of the sort that might be found in the Rocky or Zagros Mountains. Even the thickest forests along

much of its border have numerous logging roads usable by mechanized forces, and the Hartz mountains are relatively modest. Also, what constitutes good and bad terrain depends to some extent on one's life experience. [11]

Part of the confusion here is due to appearances only, and the concept of "usable frontage," when properly applied with appropriate "data," is merely a convenient but unfortunately named shortcut device that is in no way inconsistent with the requirement to cover all frontage. We shall see this in more detail later.

This somewhat more realistic figure (Fig. 14) suggests that the "good" and "bad" terrain for the attacker comes in many small chunks and the defender must cover all of it to some extent. He may get by with a somewhat smaller divisional reserve (one fewer battalion, indicated as x(-) and by assigning battalions (|| 's) to cover certain areas where he might assign brigades (x's) if he had more forces. At a lower level (higher detail) he would probably cover the few roads with regular ground forces (e.g., a tank unit) and

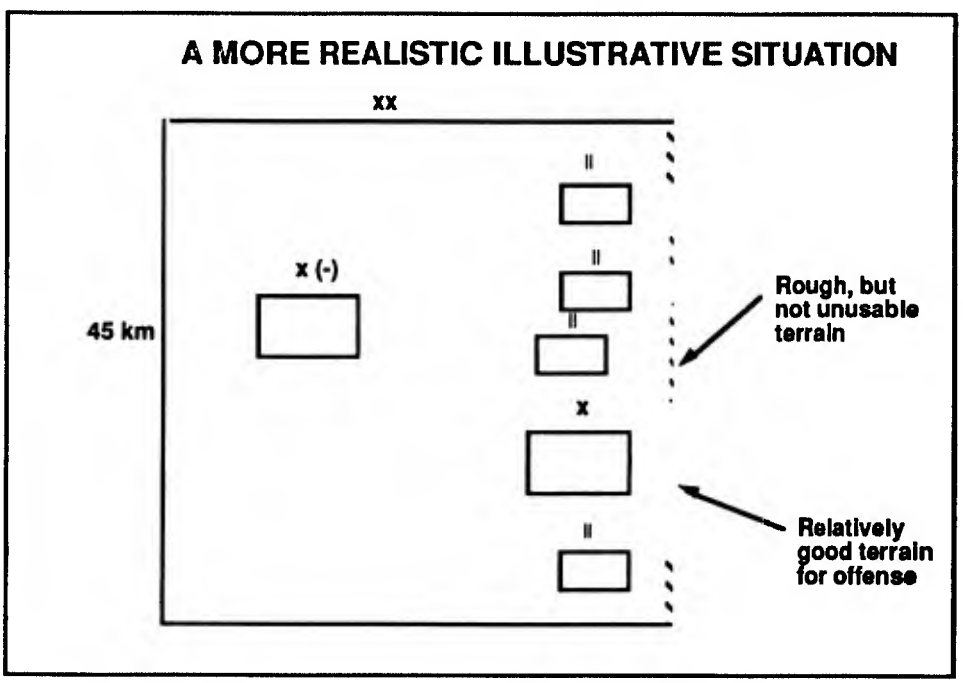

Fig. 14

[11]Donnelly (1988, p. 28) observes, "What to a NATO officer is a dirt track, a forest ride, a narrow path through a forest is, to a Russian, almost as much a 'road' as an *autobahn*, and therefore just as much a candidate for a regimental main axis or rear supply route. If a NATO officer, in planning his defence, considers that an advancing Soviet division will be channelled along valleys because the flanking or dissecting wooded hill features constitute an obstacle 'on account of their lack of roads,' then he may be in for an unpleasant surprise."

by laying mines and other obstacles, while covering the intervening forests with infantry and heliborne reconnaissance forces. The more important it was to stop penetrations early, the more mobile infantry units would be needed—perhaps more than indicated here. *If tactical penetrations could be accepted temporarily because any attacker movements would be slow and noncritical, then the coverage would be more reconnaissance oriented and defense would depend on moving reserves up quickly as needed.*

Whether terrain that is difficult for the attacker to move through can be covered and held with smaller forces than more passable terrain depends on many details of the situation such as:

- The availability of *roads, paths, and tracks* (high in Germany)
- The *depth* of the poor terain
- The defense line itself (e.g., in or in front of the poor terrain)
- The defender's mission (e.g., hold ground vs. delay)
- *Defender force tailoring* (e.g., by having unusually large numbers of infantry battalions and fewer heavy battalions; by having specialized tactical communication mechanisms such as relays to compensate for line-of-sight-limited radios; and by C^3I capabilities generally)
- Availability of active and passive *obstacles* (mines and abatis), and remotely monitored sensor systems to detect and assess intrusions
- *Attacker force tailoring* (e.g., specialized assault infantry)

There are also some very confusing and apparently contradictory aspects of terrain. For example, one officer may look at a heavily forested or urbanized area and consider it to be excellent defensive terrain; another may regard it to be very difficult terrain! At a quantitative level, the first officer might think in terms of covering the area with fewer forces than the major advance corridors—perhaps at half the normal density. The other officer might note that line of sight is so short that it will require *more* weapons per km to cover it all. Further, while the attacker's movement will be difficult, so also will his own. It may prove very difficult for one unit to reinforce another when it gets in trouble. Again, then, this would argue for higher rather than lower defender densities in "defender favorable" terrain.

Rather remarkably, this schism in viewpoint seems never to have been resolved cleanly over the years in the analytic and operational military communities. As a result, there are some significant discrepancies among analytic models being used in the community, and significant discrepancies between lessons taught by different publications.[12]

The resolution of these apparent contradictions depends on distinguishing between firepower measures and manpower measures of divisional strength. It also depends on being more explicit about what the mission of the defending force is rather than assuming it is to hold ground everywhere, regardless of its military importance or cost. The key points here are probably these:

- Areas such as forests, urban sprawl, and mountains can be defended with a much lower density of firepower than more open areas.

- However, completely covering the front in such an area may require an unusually large number of soldiers, preferably light and highly mobile infantry.[13]

- Also, attempting to defend such areas with heavy forces may be very inefficient. Lighter forces tailored to the terrain are much more appropriate.

- Typically, defenders should not be required to hold ground rigorously in the areas in question. Instead, such areas are usually prime candidates for operations that give space gradually but exact a very high exchange ratio if properly handled. [14]

What is not clear, even with these distinctions, is how to measure the "size" of units when examining terrain. EDs, ADEs, and DEFs all attempt to measure *mobility* as well as lethality and vulnerability, and in practice the mobility of NATO's divisions has

---

[12]As merely one example of this, Mako (1983, p. 37) states that a standard divisional frontage may be 25 km for a U.S. heavy division in central Europe, but (footnote 19) "The norm would be wider in mountainous regions, narrower in forested or urban areas, and narrower for traditional infantry divisions." By contrast, nearly all war games and simulations with which we are acquainted ordinarily assume that the norm would be greater for mountainous *and* forested and urban areas.

[13]Karber (1984) comments on the density requirements as follows: "The plethora of small ingress routes that make a defense so successful virtually insures multiple deep penetrations if there are insufficient defenders forward to cover every one."

[14]British historical data indicates that the exchange ratio is *adverse* for defenders attempting to hold urban areas rather than counterattacking along the attacker's flanks or fighting delay operations. Similarly, in mountain operations, the defender trying stubbornly to hold on to a narrow pass may be encircled and annihilated if he doesn't know when to fall back.

been increasing as its ED-like scores have been increasing (more and better attack and transportation helicopters, faster cross-country movement for tanks, greater infantry survivability while moving due to IFVs rather than APCs). At the same time, the basic organizational structure of divisions has not changed greatly, and the physical distances over which such basic units as battalions can operate effectively are limited by such factors as line-of-sight communications and the time needed to "drive over in a jeep if necessary." Many officers argue that this is especially true of defense in forests and urban areas. These officers insist that what matters most is the density of combat soldiers. Thus, they tend to prefer a rule of thumb that amounts to, for example, 20–40 km per division or 20–40 km per DEM, where a DEM is a division equivalent in manpower—i.e., 16,500 men.

Figure 15 presents a relatively simple formula, including serious strawman rules of thumb, for estimating divisional requirements as a function of the terrain mix—either in a given sector, or for the theater as a whole. It seeks to reflect both firepower and manpower aspects of the problem. "Closed" terrain typically means densely urbanized areas or very rough mountainous areas. In other theaters, it might include in some seasons of the year impassable marshes (and in other theaters the coverage requirements might be less because the closed areas would be *more* closed). "Rough" terrain might

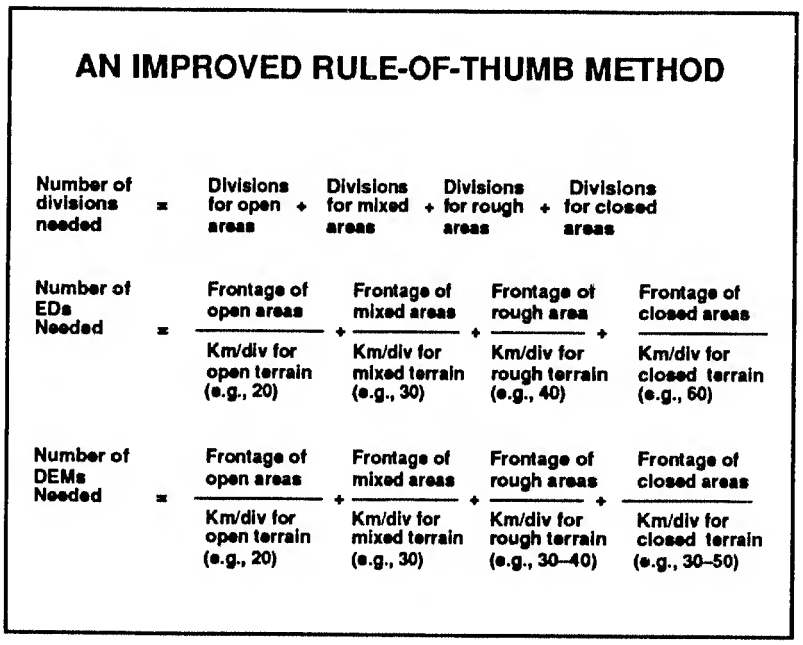

Fig. 15

include thickly and deeply forested areas with only narrow logging roads; or, as another example, moderately mountainous or very hilly areas with only a very few roads, but many appropriate places for the defender to operate from. "Mixed" terrain means, approximately, a mix of relatively open and relatively rough terrain. Trafficability is good, but there are many places for the defender to use effectively. "Open" terrain usually implies relatively flat and highly trafficable terrain with relatively little opportunity for channelization of the attacker.

We have no rigorous basis for the figures shown here,[15] but they are based on a variety of published documents, numerous conversations with active and retired American, German, and British officers, and reasoning. The basic ideas appear highly cross national. The density requirements shown for poor terrain are believed to be conservative, especially if tactical penetrations can be permitted. We give a range of values for the estimates on DEM requirements because they appear to be more controversial. Indeed, we do not even agree among ourselves on what baseline values should be. In particular, it can be argued that manpower density is really not the issue, despite our tentative use of DEMs, and that with a suitable reorganization of basic divisional structures (i.e., the nature and size of companies and battalions) of divisional structure it *might* be possible to cover the ground more efficiently than the rules of thumb suggest with modern equipment. However, that is entirely speculative.

---

[15]None of the sources could be regarded as authoritative, because there were many ambiguities and many of the sources were themselves drawing upon little more than anecdote or accepted wisdom. In any case, Thomson (1988, p. 21) notes the widely used 25 km/ED rule, although he does not make clear that in war games and simulations (including those at RAND) this rule is applied to typical (open-to-mixed) "militarily usable" frontage. Flanagan and Hamilton (1988, p. 463, footnote 20), use a 1977 U.S. Army field manual on battalion frontages to infer a maximum frontage of 30 km/division. However, these doctrinal numbers apply essentially to those portions of the front that are being fully defended because they are reasonable attack axes. Other, more nearly closed, areas can be covered more lightly until and unless attacks are detected—so long as the tactical reserves can arrive quickly enough to contain or reverse any tactical penetrations. Mearsheimer (1982) also refers to defender frontages of 15 km per brigade (30 km per division), again basing his work on Army doctrine and discussion. Mako (1983) settles on 25 km/ADE as an average, which has been used for many years by OSD (PA&E), but mentions Army officers expressing the view that a division could perhaps defend frontages of 30 to 60 km. Posen (1985) quotes David Isby in stating that Soviet military doctrine calls for a motorized rifle division (then about 0.7 ADEs and perhaps 20 percent smaller in manpower than a U.S. division) to defend 25 km of front—i.e., about 36 km/ADE). In developing our rules of thumb for rough and closed terrain we have depended on expert opinion, logic, and our observation of how NATO has planned to deploy its forces operationally (see, for example, OSD/PA&E (1979, p. 1–10), which can be understood readily in terms of this figure's rules).

The breakdown of an area's terrain into open, mixed, rough, and closed is an *output* of terrain analysis rather than the starting point. Military officers studying a given sector must examine the purely geographic topography, the presence of cities and urban sprawl, the number and nature of roads, the density, width, and depth of forests (and the density and character of logging roads), special features such as natural choke points, and so on. This assessment must be made for the *area* to be defended, not just the perimeter, since, for example, a dense but shallow forest will not prove much of an obstacle in the long run. Then, as a way to communicate the results simply, the officers may characterize their sector in terms such as percent open, mixed, rough, and closed. Or, they may simplify further and report the effective "military frontage," by which they may mean the sum of open and mixed, the sum of open and mixed plus a fraction of the rough and closed, or the sum of open, mixed, and rough. Different officers (and different civilian analysts) will have different things in mind. If frontage is simplified to the level of "militarily usable frontage" and "other," the effect will be that in calculating the number of divisions needed, only the usable frontage will be counted. Thus, it is important to characterize the average nature of the "militarily usable" terrain in the sector in question and even to provide the km/ED rule of thumb to be used against it.

Figure 16 suggests schematically how a terrain analysis for a sector to be defended must take into account more than the circumstances along the front. The apparent usable frontage along the border may be about 10 percent here, but the area "opens up" farther back, and there are some good roads through even the rough or closed areas (actually, there would almost always be many more minor roads than shown here). An analyst might, for example, characterize the area shown as having 60 percent militarily usable frontage, depending on details not evident here.

Figure 17 summarizes pictorially the rules of thumb as a function of type terrain, and highlights the point that manpower density rather than firepower density may become the limiting factor. For example, in rough terrain, the figure would say that the defender could have up to 40 km/ED, but up to only 35 km/DEM. In closed terrain the discrepancy would be even larger— up to 60 km/ED but up to only 40 km/DEM. Once again we emphasize that the basic rules are intended to be conservative. Larger frontages would be possible, as shown, if temporary tactical penetrations could be permitted or if, for example, it proves possible to maneuver fire effectively and reliably (e.g., through the use of both attack helicopters and artillery with advanced munitions).

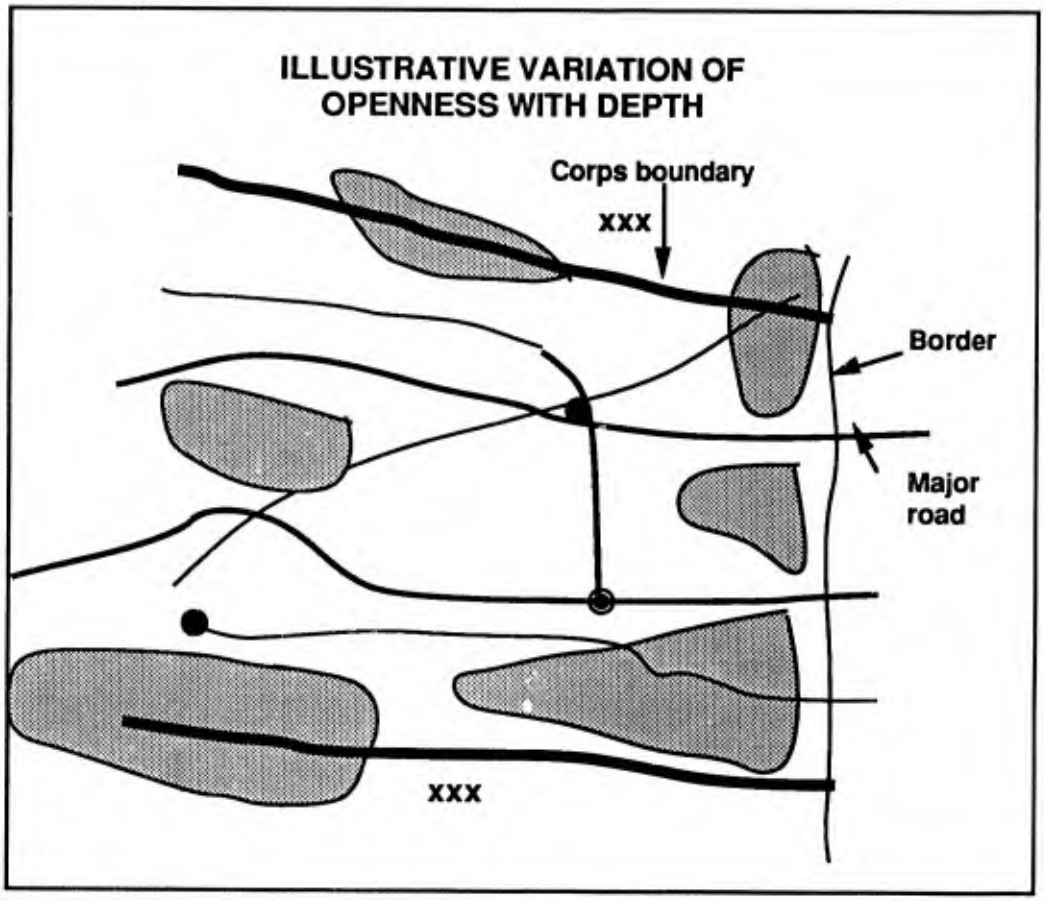

Fig. 16

We have mentioned tailoring at several points, especially when arguing that coverage requirements go down substantially (in terms of ED scores) where the terrain is defender favorable. Figure 18 suggests the type of changes needed for this and emphasizes additional mobile infantry, which means the need for personnel carriers, transport helicopters, and attack helicopters. Also, in covering rough or closed terrain, the fraction of the division's resources devoted to C^3I generally (or Reconnaissance, Intelligence, Surveillance, and Target Acquisition—i.e., RISTA, to use the current acronym) should be larger than normal. MLRS, coupled with both advanced munitions and appropriately tailored command and control arrangements, could prove highly valuable.

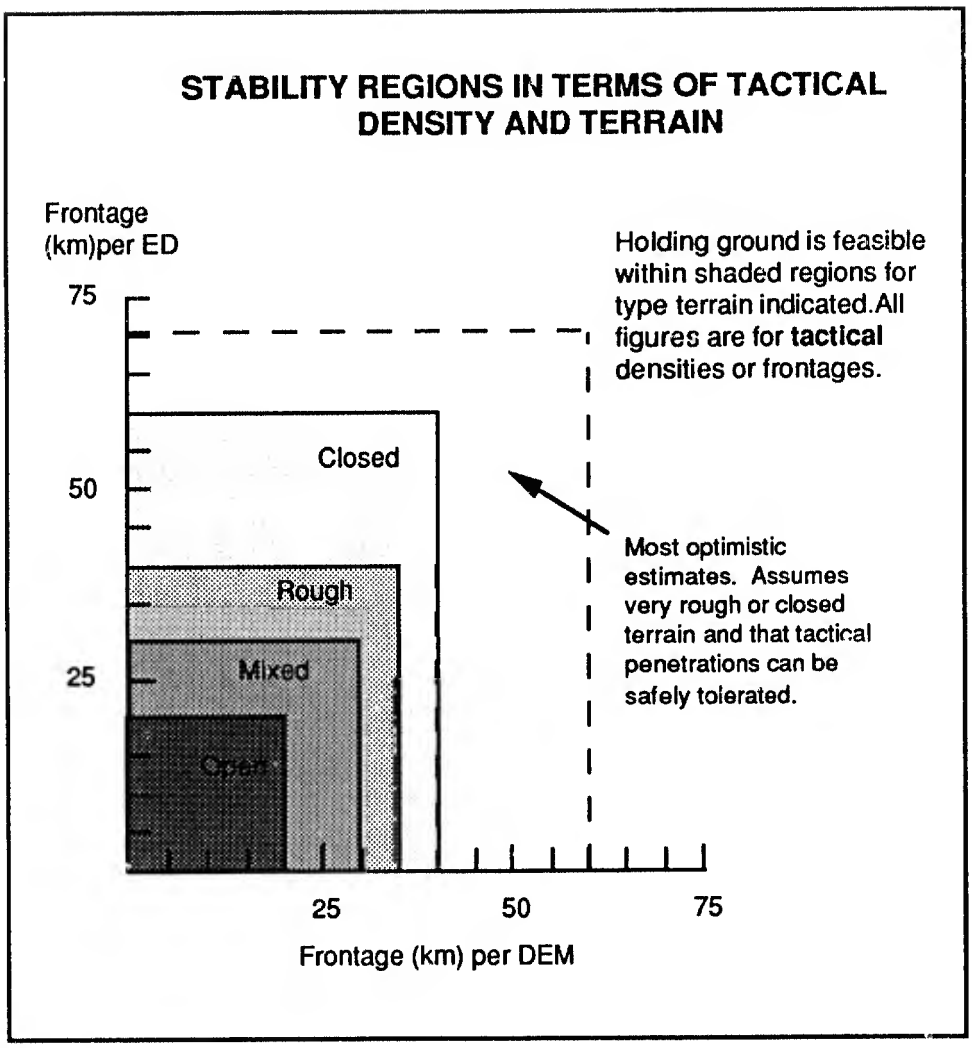

Fig. 17

The preferred tailored units are by no means simple and static . Nonetheless, because they involve many fewer tanks and artillery, such units could probably get along with substantially less nondivisional support. The overall end strength and cost of an ED's worth of tailored light divisions/brigades and their support slice should be significantly (but not dramatically) smaller than that of an armored division and its support slice. It is for the purpose of reducing end strength and costs that the German army already plans to do such tailoring unilaterally over the years ahead. German and American officers familiar with force tailoring concepts tend to argue that the

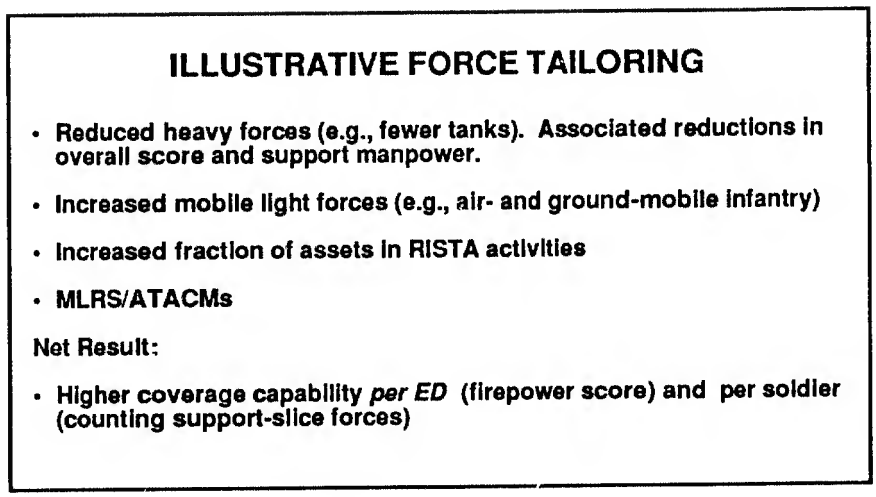

Fig. 18

resulting hybrid divisions (hybrids between current types of heavy and light divisions) could be quite effective for forward defense and subsequent defense along well defined lines with appropriate terrain, although they would not have the flexibility and capability for more open forms of battle if forward defense failed, and extracting them from forward areas could be quite costly. Colonel Karl Lowe of National Defense University proposed such hybrid divisions several years ago as a way to improve NATO's force structure unilaterally at low expense, essentially by making better use of existing home-defense brigades and their equivalent in other NATO nations. Colonel Wass de Czege of the U.S. Army and now in SHAPE has also written about and argued for tailored light-infantry divisions as elements of an effective NATO defense.

Figure 19 illustrates the calculations, focusing on the number of EDs needed. Consider a corps sector 80 km in width. Upon studying it, one might conclude that the sector can be characterized as having no open, 40 km of mixed, 24 km of rough, and 16 km of closed terrain. Or one might simplify even further and say that nearly all the sector has to be significantly defended (a militarily usable frontage of 80 percent), but that the usable part of the sector can be characterized on average as "mixed." Yet another simplified characterization might consider all frontage usable, but say that the sector

ILLUSTRATIVE CALCULATIONS OF EDs NEEDED

Example: 80 km corps sector

Characterization 1: has 0, 40, 24, and 16 km of open, mixed, rough, and closed terrain respectively.

Characterization 2: has 64 km of militarily usable frontage (80% of geographic), which is mixed.

Number of EDs needed:

Method 1:
Number EDs = 0.0 + 1.33 + 0.6 + 0.27 = 2.2

Method 2:
Number EDs = 80 (0.8) / 30 = 2.1

Fig. 19

should be regarded as "mixed-to-rough." That would result in 80/35 = 2.3 EDs as the requirement. Given the inherent crudeness of such methods, all three estimates (2.1, 2.2, or 2.3 EDs) could be considered equivalent.

Clearly, similar calculations and similarly equivalent characterizations can be made for the purposes of manpower requirements.

If we apply the cruder concept with an *illustrative* set of terrain data such as we typically use in our combat models, we obtain the strawman estimate shown in Fig. 20. If approximately 60 percent of the Central Region's frontage is militarily usable and characterized approximately as open-to-mixed, then the minimum operational density for NATO's Central Region is on the order of 27 Equivalent Divisions (EDs). [16] These forces would need to be available at D-Day or, for some of them, very shortly thereafter.

[16]The estimate would vary up and down substantially depending on which model's or agency's standard database for terrain was being used. The lowest number we have seen is that given in Karber (1984), who gives 240 km as the effective frontage along the border and 360 km as the effective frontage 120 km to the rear. Karber, in turn, is quoting from Charles T. Kamps, *Hof Gap: The Nurnberg Pincer*, SPI, New York, 1978. Many workers, by contrast, equate geographic and militarily usable frontage. The longstanding nature of this discrepancy should be embarrassing to governments, but it seems to have gone largely unnoticed until now.

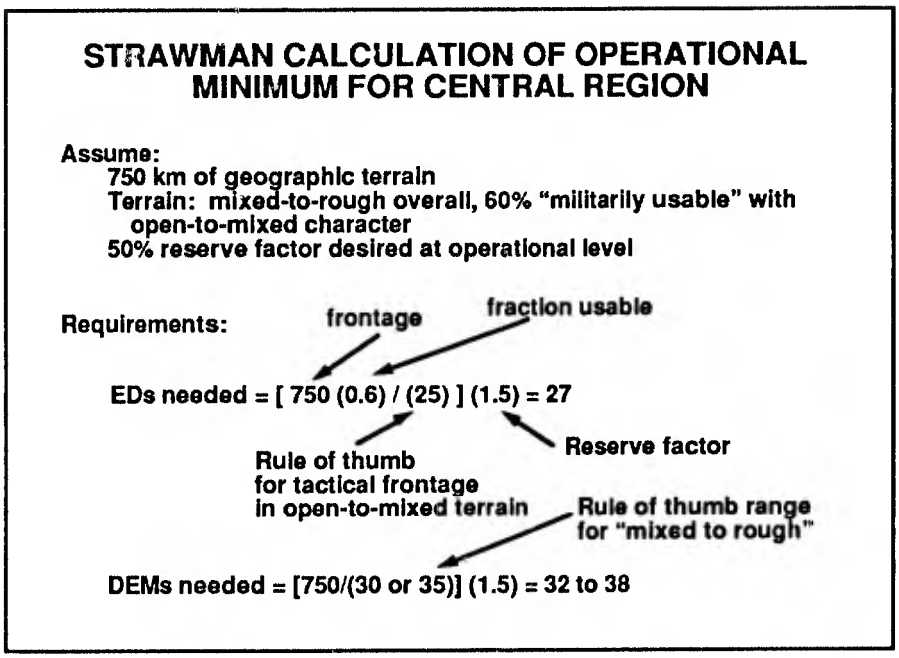

Fig. 20

Just as a rough point of comparison, if we assume 300 tanks per ED, then the operational minimum would correspond to 8100 tanks in the Central Region.[17] These include not only the active forces there in peacetime, but such forces as would be mobilized and deployed there from elsewhere, notably the Western Military Districts of the USSR, and the U.S. POMCUS units. At the same time, it does *not* include war reserve equipment in the Central Region. Nor does it include French tanks in France that would not be employed early in the Central Region. Thus, the relationship between the requirement we derive and the "bean count" limitations being negotiated in the CFE talks is highly ambiguous. We shall report on such issues elsewhere.

---

[17]As a point of comparison, NATO might today expect to employ approximately 10,000–12,000 tanks in the first thirty days of conflict in the Central Region. Approximately 10,000 tanks (CBO, 1980, p. 21) are part of the nominal deployment to the Central Region, with more than 6000 additional tanks potentially available (including war reserves), not counting those committed to other areas.

We also show here an estimate of the requirement in terms of manpower, using the measure of DEMs. Here our illustration assumes that the overall characterization of the Central Region's terrain, especially in the Eastern part of the FRG, is mixed-to-rough. We also use relatively conservative figures for the frontage per DEM. The result is an estimate in the range of 32 to 38 DEMs.[18]

There is no "right" answer for the operational minimum based on current knowledge, although some opinions are better than others. The nomogram in Fig. 21 makes it easy to demonstrate how much effect individual assumptions can have. To use it, one enters from the left with one's estimate of geographic frontage. One then moves horizontally to the diagonal line corresponding to the fraction of geographic frontage that one considers usable. Next, one goes vertically to the line in the upper chart with the correct rule of thumb for tactical frontage per division (or equivalent division). Then, one moves horizontally to the left to the vertical line with the correct reserve factor. The operational minimum is measured in the same units used in the rule of thumb for tactical density (although the label indicates it must be in km per ED). Thus, one can use the nomogram, which merely does simple arithmetic, for EDs, DEFs, ADEs, DEMs, or DEs. For example, if one used 750 km for frontage, 1 for the militarily usable fraction, 35 km/DEM for the required tactical density, and a reserve factor of 1.5, one would then get 32 DEMs as the operational minimum.

---

[18]Karber (1984) provides information amounting to an estimate of the tactical minimum. On page 34 he states that 75 percent of NATO's 71 in-place brigades would have to be on line for a sufficiently dense defense. From this and assumptions of a 750 km front and an average of 0.8 EDs per brigade we can infer that to have "two up and one back" tactically, as well as operationally, the operational minimum would be 32 EDs. Flanagan and Hamilton (1988) estimate the need for 30 EDs on line, which would mean 45 EDs for the operational minimum given our definition. However, we infer from their figures on NATO force levels vs time that their EDs are smaller than our EDs (probably because they used scores based on late-1970s sources) by roughly 25 percent. Thus, a revised version of their estimate in our terms might be 33 EDs.

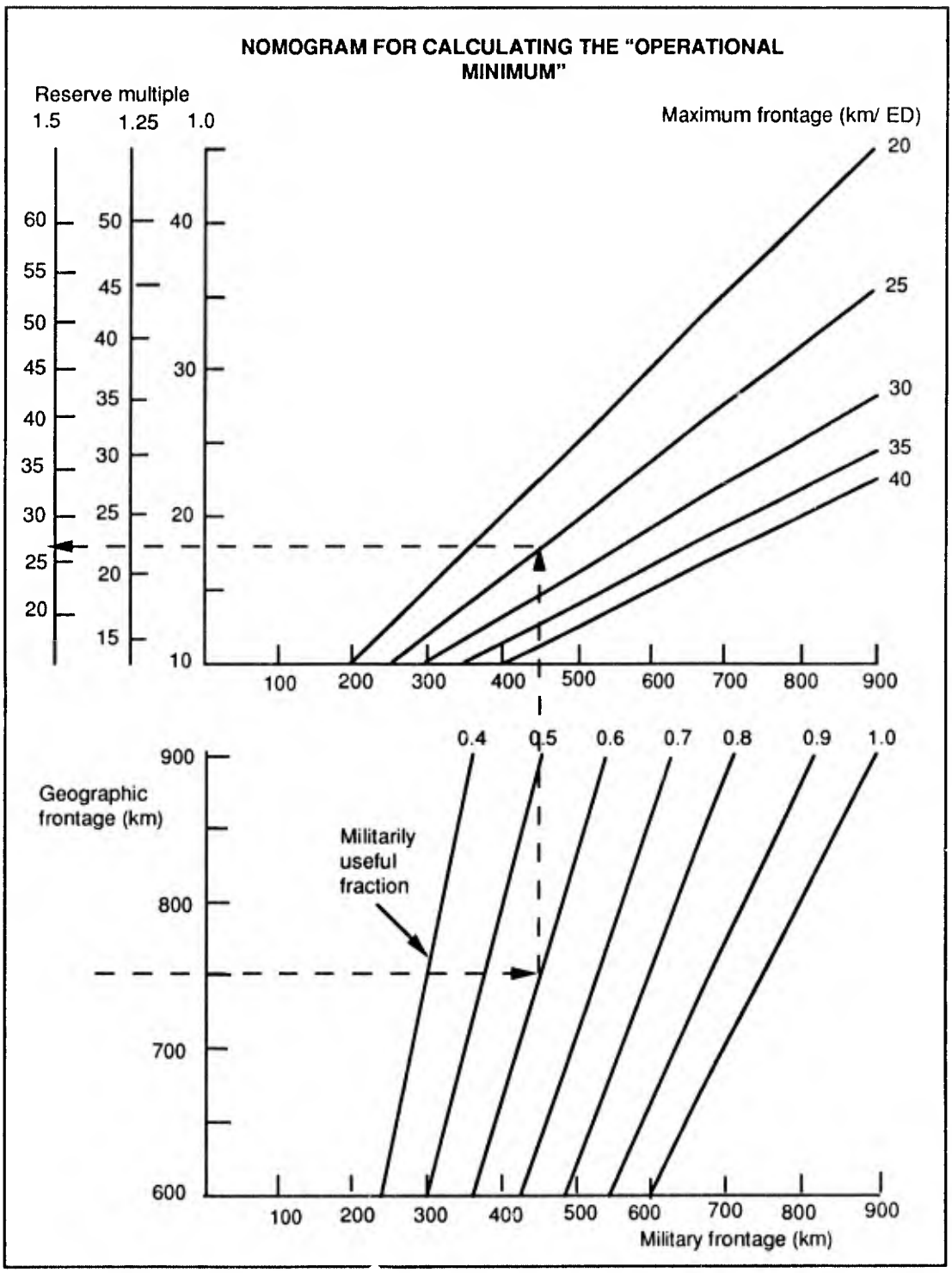
NOMOGRAM FOR CALCULATING THE "OPERATIONAL MINIMUM"
Reserve multiple
1.5
1.25
1.0
Maximum frontage (km/ ED)
20
25
30
35
40
60
55
50
45
40
35
30
25
20
50
45
40
35
30
25
20
15
40
30
20
10
100
200
300
400
500
600
700
800
900
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Geographic frontage (km)
Militarily useful fraction
900
800
700
600
Military frontage (km)

Fig. 21

Figure 22 notes that some of the apparently gross discrepancies among simulation models may not have any effect on results of simulated combat because of cancellation of discrepancies. Someone using a model that considers all frontage equally usable may, *for example*, assume that Soviet shoulder space limits are about 15 km per division. On the other hand, another model may count only 50 percent of the frontage as usable, but may assume that Soviet shoulder space limits are about 7.5 km per division. There are significant discrepancies among models, but some of the apparent discrepancies merely reflect differences in definition and differences in where analysts have chosen to reflect the same effects.

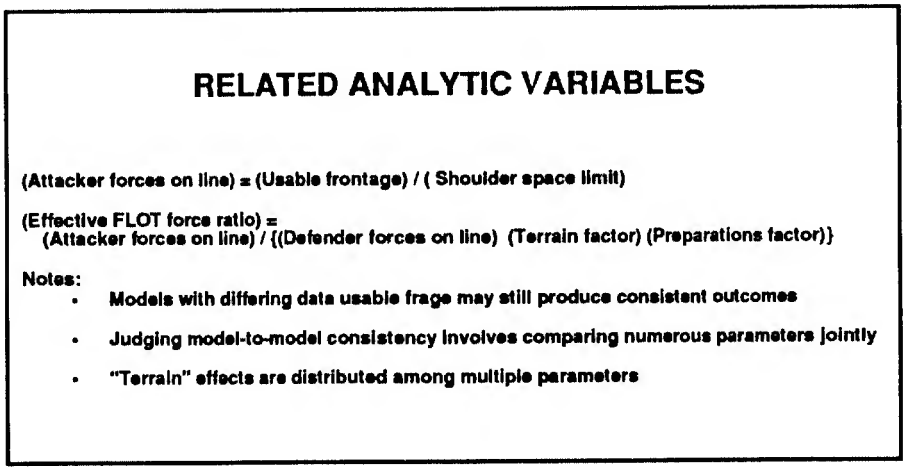

Fig. 22

Figure 23 indicates schematically how terrain analysis fits into analytic modeling and how different approaches can be used to estimate the number of attacker and defender forces actually in contact. Solid arrows indicate the usual path taken by model-oriented groups. The dashed arrows on the right show the somewhat more detailed breakdown of terrain suggested here as a way to clarify discussion, but the results can be the same. It is possible for all three (A, B, and C) to agree. Indeed, one important way we test the reasonableness of our models is to compare our analytic methods (A and B) with the way operational commanders apparently plan to employ their forces today (C).

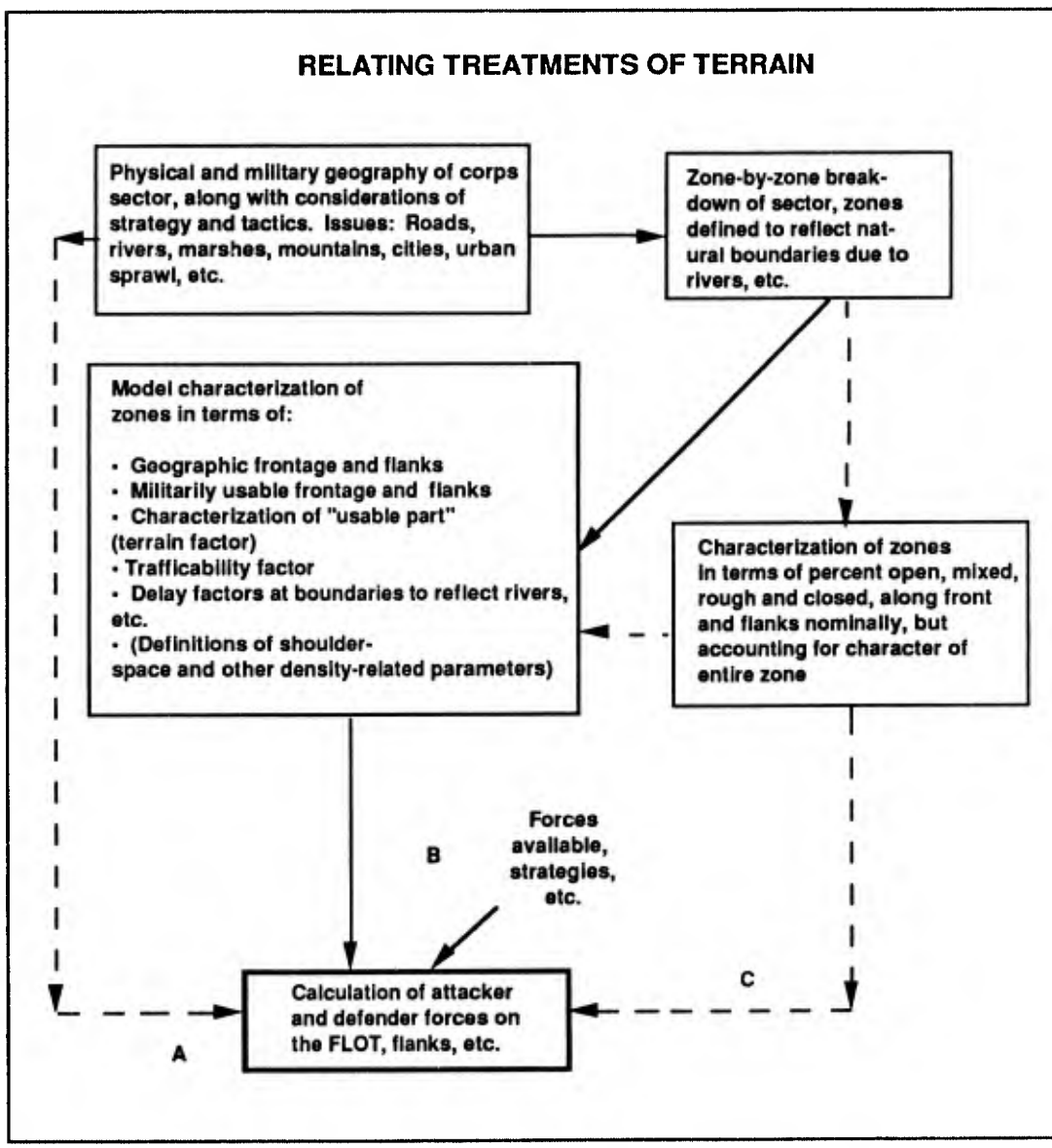
RELATING TREATMENTS OF TERRAIN
Physical and military geography of corps sector, along with considerations of strategy and tactics. Issues: Roads, rivers, marshes, mountains, cities, urban sprawl, etc.
Zone-by-zone break-down of sector, zones defined to reflect natural boundaries due to rivers, etc.
Model characterization of zones in terms of:
• Geographic frontage and flanks
• Militarily usable frontage and flanks
• Characterization of "usable part" (terrain factor)
• Trafficability factor
• Delay factors at boundaries to reflect rivers, etc.
• (Definitions of shoulder-space and other density-related parameters)
Characterization of zones in terms of percent open, mixed, rough and closed, along front and flanks nominally, but accounting for character of entire zone
B
Forces available, strategies, etc.
C
Calculation of attacker and defender forces on the FLOT, flanks, etc.
A

Fig. 23

Since much of the discussion has been abstract, we include Fig. 24 to show at least one illustrative defense structure intendedly consistent with forward defense. It involves only 30 EDs and 8100 main battle tanks, but it is near the conservative end of our range of estimates with regard to manpower on the ground, having the manpower equivalent of about 37 standard divisions. Note also that it has a large number of APCs and IFVs.[19]

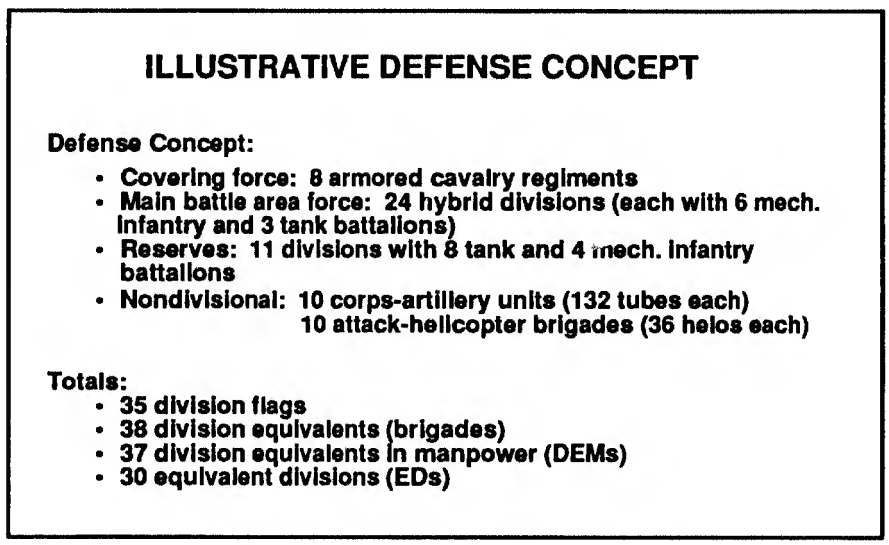

Fig. 24

[19]This illustrative force structure was developed by one of us (Kugler) in connection with an Army sponsored project at RAND that is examining both future army force structures and conventional arms control options.

IV. SIGNIFICANCE OF D-DAY THEATER FORCE RATIO AND FORCE LEVELS BELOW THE OPERATIONAL MINIMUM: INSIGHTS FROM MODELING AND SIMULATION

In the first half of this Note we focused on the operational minimum, because that is a topic of major current interest. In the second half, we discuss two subjects that should be of great interest, but that have so far received less attention. First, we examine the sensitivity of the balance to theater force ratio on D-Day, because, despite progress in the CFE negotiations, it is not clear that parity will be achieved:

- Equality of tanks, artillery, etc., does not guarantee equally effective forces (equal "effective equivalent division scores"), because of differences in weapon quality, troop quality, support forces, etc.
- It is obviously important to know how sensitive the balance is to potential cheating (i.e., to actual force ratios different from the agreed parity).
- Even if the sides' force holdings were identical in the ATTU aggregate, there could be major disparities in force-generation rate, resulting in asymmetries at D-Day, because of force-generation asymmetries and the use of out-of-region forces.

We shall discuss the issue of D-Day force ratios using a simple model that does not worry about absolute force levels or the operational minimum. As we shall see, this will also give us certain insights that apply to the regime of low force levels—levels below the operational minimum.

Here (Fig. 25) we indicate the model's objectives in more detail and lists the simplifying assumptions, which we will relax later.[20]

In Fig. 26 we list and define the variables constituting the model. The factor (1+f) is the theater force ratio, while C and C' refer to force ratios on particular operational-level sectors. These must be defined to be appropriately large. If they are too small, it would be unreasonable to treat them as independent; if they were too large, it

[20]Apparently, several workers have independently used somewhat similar models over the years (e.g., Reiner Huber in Germany, and Wilbur Payne and Andrew Hamilton in the United States (see Hamilton, 1985)), although apparently never for the purposes of interest here. Similar models must be a part of the underlying basis for some of the correlation-of-forces-and-means calculations taught to Soviet officers. See Hines, 1988.

FORCE RATIO METHOD FOR ASSESSING STRATEGY: A SIMPLIFIED MATH MODEL AT THEATER LEVEL

Specific Objectives:

- Develop formulas for main-sector force ratios resulting from choices
- Focus on simplicity; avoid assumptions about attrition and movement processes
- Observe sensitivities and implications
- Set stage for more detailed simulation

Assumptions:

- Attacker concentrates on main-thrust sectors
- Defender responds but does not counterattack
- Defender does not pull forces from one sector for use in another
- All main-thrust sectors are treated the same; likewise all non-main-thrust sectors
- All reserves are eventually committed evenly to main-thrust sectors
- No *explicit* effects of airpower
- All forces fungible and infinitely divisible
- Attacker is not limited by shoulder-space constraints
- Force ratio is the key variable determining outcome

Fig. 25

VARIABLES

A	Attacker forces
D	Defender forces
1+f	Theater Force Ratio: $A = (1 + f) D$
R	Defender's fraction in reserve *
R'	Attacker's fraction in reserve*
s	Number of sectors (*)
t	Number of main-thrust sectors*
h	Force ratio to be tolerated on non main-thrust sectors*
C	Force ratio on main-thrust sectors before reserves are committed
C'	Force ratio on main-thrust sectors after reserves are committed

* Decision variables defining attacker strategy (attacker must assume defender's reserve fraction)

Fig. 26

would have the effect of underestimating the attacker's ability to gain advantage through concentration. The sectors we have in mind here are comparable in size to today's NATO corps sectors, within which it is not unreasonable to assume that the defender can counterconcentrate tactically so that the overall battle within a sector is governed largely by the sector force ratio.

Figures 27 and 28 demonstrate that one can solve the model analytically, obtaining a closed-form solution that is easy to interpret and experiment with. Figure 27 shows the force ratios that may be achieved initially on the main-thrust sectors—i.e., after the attacker concentrates, but before the defender can counterconcentrate. Actually, this is an upper bound, since the defender may react quickly, and even anticipate the main thrusts. This will be important to remember later in the discussion.

Here we solve for C', the sector force ratio after the defender responds by committing his reserves to the main-thrust sectors and the attacker does likewise. The formula would be a bit different if we assumed, for example, that the defender also pulled forces out of non-main-thrust sectors to reinforce main sectors. Indeed, if the defender did so in such a way as to leave a 1:1 force ratio in the non-main-thrust sectors, then

DERIVATION OF FORMULAS:
Initial Main-Sector Force Ratios

$$(1+f)\,D = h\,(s-t)\,(1-R)\,D/s + t\,C\,(1-R)\,D/s + R'\,(1+f)\,D$$

attacker forces = those on "other" sectors + those on main-thrust sectors + reserves

To solve for C: multiply by s/D, rearrange, factor, and divide by t (1-R).

$$C = \frac{s\,(1+f)\,(1-R')}{t\,(1-R)} - \frac{h\,(s-t)\,(1-R)}{t\,(1-R)}$$

$$= \frac{s\,(1+f)\,(1-R')}{t\,(1-R)} - \frac{h\,(s-t)}{t}$$

$$\boxed{C = \frac{s\,(1+f)\,(1-R') - h\,(s-t)\,(1-R)}{t\,(1-R)}}$$

Fig. 27

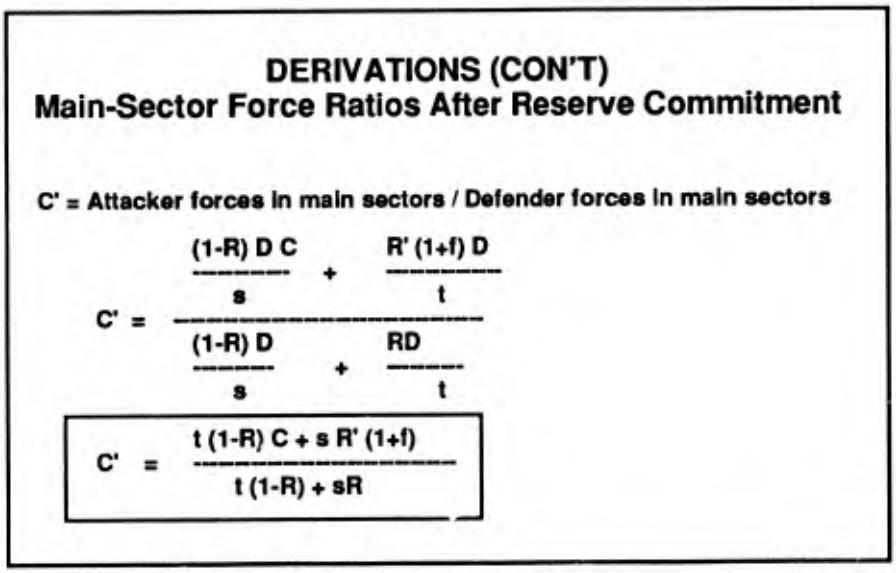

Fig. 28

C'=1 if parity obtained overall (i.e., if f=0). When we turn to simulation, we can make more realistic estimates about precisely how the defender and attacker would employ forces.

Figure 29 illustrates the formulas for two particular cases. Here and in what follows we use nine sectors in our examples. In relating this to the actual Central Region, consider the nine sectors to be the standard eight plus the Danish sector (Jutland).

In Fig. 30 we assume two main thrusts and view main-thrust force ratio as a function of theater force ratio. The attacker accepts a 2:3 ratio against him in other sectors. The principal point to make here is that if one applies the rules of thumb indicated by the horizontal lines, then there is a significant difference between theater force ratios of, say, 1.25 vs. 1.5, and the difference between 1.0 (parity) and 1.5 is dramatic. This figure also provides a graphic justification for the rule of thumb (usually said to be of unknown origin) that a theater force ratio worse than 1.25, or certainly 1.5:1, is dangerously adverse for the defender, even though the more commonly known rule of thumb is 3:1. The 3:1 rule applies to battles at the operational level (assuming good defender command-control) and the tactical level.

The other major point to be made here is that the would-be attacker must look at both the top line and the bottom line, because the sector force ratio C (the top line) will

FORMULAS FOR A GIVEN THEATER FORCE RATIO

For case of parity, nine sectors, early commitment of attacker reserves, nominal defense strategy, and one or two main thrusts:

s = 9 R = 1/3 R' = 1/6 f ≈ 0 t = 1 ←	s = 9 R = 1/3 R' = 1/6 f = 0 t = 2 ←
C = 11 - 8 h C' = 0.18 C + 0.40	C = 5.6 - 3.5 h C' = 0.31 C + 0.41

Fig. 29

ILLUSTRATIVE MAIN-SECTOR FORCE RATIOS

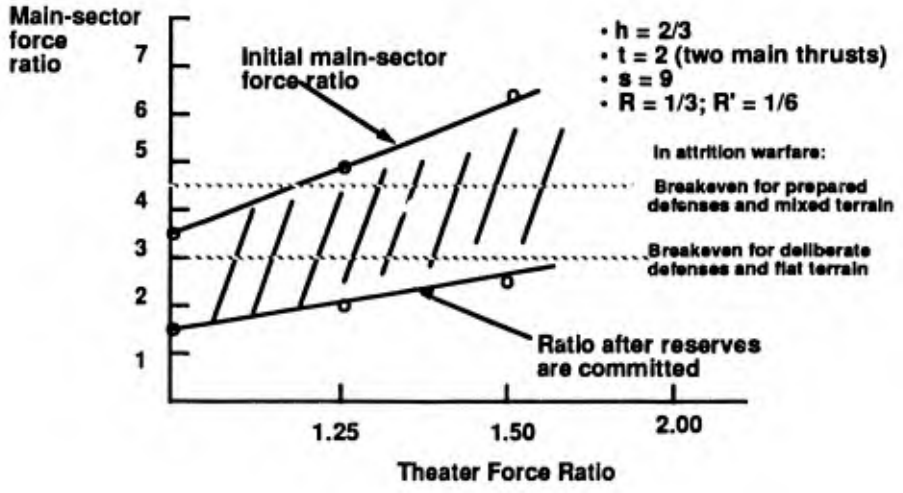

Fig. 30

obtain only for some period of time if at all, after which the defender will assuredly counterconcentrate. Thus, the average main-thrust force ratio over the critical portion of an army-level operation will lie somewhere in the shaded area. If the attacker can exploit his initial force-ratio advantage and break through the defender's lines quickly, destroying the defender's cohesion, then the momentum of his attack may preclude the defender from recontaining it, even after reserves are committed.

The attacker does not need 3:1 force ratios in fast-moving maneuver warfare. However, if the breakthrough is not achieved quickly, then the force ratio will worsen and the attack as a whole may fail.

Here (Fig. 31) we assume that the attacker is so concerned about improving his main-thrust force ratio that he is willing to tolerate force ratios of 1:3 against him in "other sectors." In practice, he might leave some sectors entirely uncovered because of a conviction that the defender could accomplish nothing significant by starting offensives in those sectors. We see that the results for the attacker are somewhat better. However, if the attacker can convince himself, from military geography and other factors, that some sectors should be attacked preferentially and others can be left almost bare, then the defender may use the same reasoning to preferentially defend the important sectors in the first place. While this may not make sense in the simplified math model, it surely makes sense in the Central Region, where the potential avenues of attack vary drastically in their potential strategic significance: a main thrust through Bavaria would simply not bring about a strategic victory unless accompanied by other thrusts elsewhere.

Figure 32 shows results as a function of the risk taken on non-main-thrust sectors, assuming parity. Once again, it is evident that a conservative would-be attacker would not like the results of such an assessment. Indeed, one would expect him to be deterred unless there were special factors at work such as the defender having gaping holes in his defense or the attacker being able to achieve a better theater force ratio than parity because of superior force-generation rates coupled with deception. History gives us numerous examples of where a numerically inferior attacker has indeed succeeded, although the usual examples involve attackers whose forces were qualitatively superior to the defender forces, thus requiring an adjustment of effective theater force ratio. Sometimes the qualitative superiority was due to generalship, sometimes to training, sometimes to both.

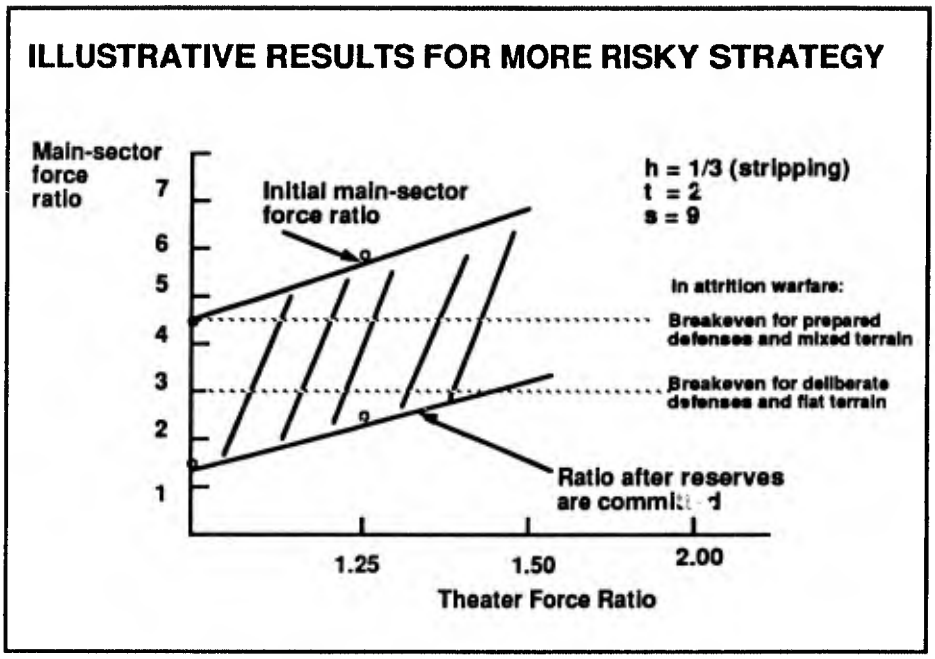
ILLUSTRATIVE RESULTS FOR MORE RISKY STRATEGY
Main-sector force ratio
7
6
5
4
3
2
1
Initial main-sector force ratio
h = 1/3 (stripping)
t = 2
s = 9
In attrition warfare:
Breakeven for prepared defenses and mixed terrain
Breakeven for deliberate defenses and flat terrain
Ratio after reserves are committed
1.25
1.50
2.00
Theater Force Ratio

Fig. 31

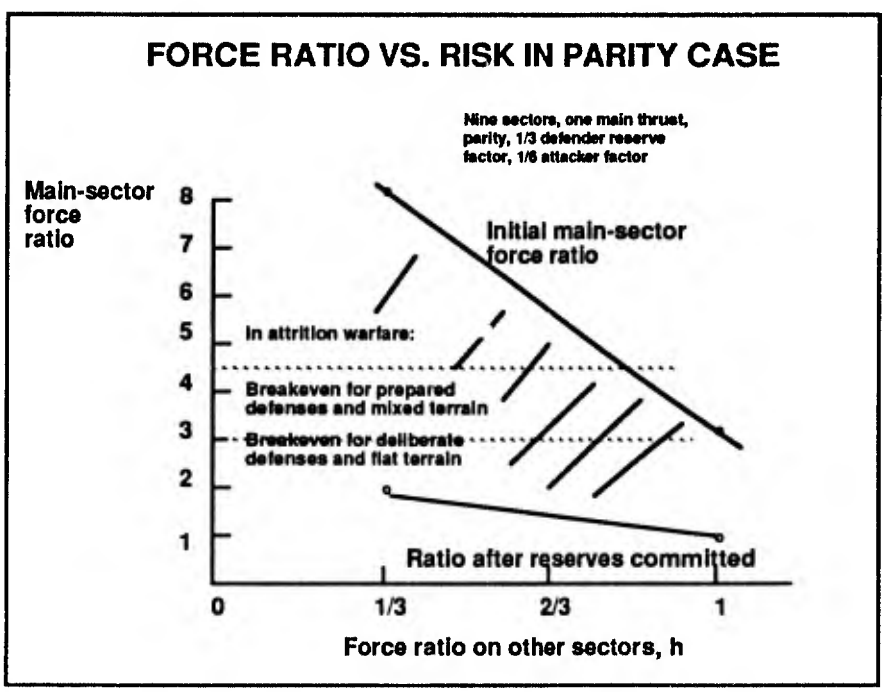
FORCE RATIO VS. RISK IN PARITY CASE
Nine sectors, one main thrust, parity, 1/3 defender reserve factor, 1/6 attacker factor
Main-sector force ratio
8
7
6
5
4
3
2
1
Initial main-sector force ratio
In attrition warfare:
Breakeven for prepared defenses and mixed terrain
Breakeven for deliberate defenses and flat terrain
Ratio after reserves committed
0
1/3
2/3
1
Force ratio on other sectors, h

Fig. 32

Importantly, observe here that the attacker's risk in going to low force ratios on "other sectors" depends strongly on the defender's capabilities, doctrine, and operational strategy for counterattacks. If the defender had adopted a static defensive defense on each sector, the attacker could have high confidence in being able to strip away forces from "other" sectors in order to concentrate on the most important ones.

In Figs. 33 and 34 we invert the logic and solve for the number of main thrusts feasible, given a particular desired force ratio on main-thrust sectors and other decisions.

For particular assumptions about reserve ratios and the acceptable force ratio on non-main-thrust sectors, an attacker enjoying a 2:1 theater force ratio can have about 4 main thrusts with initial force ratios of 4.5—assuming that he can concentrate before the defender begins to counterconcentrate.[21] By contrast, at parity, the attacker can achieve such force ratios on only one sector.

This calculation depends, of course, on the force-ratio "requirement" selected. If the attacker believed he could succeed with half as large a main-sector force ratio (2.25:1), perhaps counting on surprise or other special factors, then he could have three

INVERTING THE PROBLEM

Alternative approach: set desired force ratio and solve for number of main-thrust sectors:

t = integer part of T

$$T = \frac{s\,(1+f)\,(1-R') - h\,s\,(1-R)}{(1-R)\,(C-h)}$$

Note: T grows in proportion to (1+f), the theater force ratio.

Fig. 33

[21]Soviet officers are taught in military academies to seek sector force ratios of 3:1–4:1 in tanks, and even higher ratios in artillery. They would probably want even higher ratios if they faced prepared defenses in depth as contemplated by NATO in the event it has several weeks of warning time.

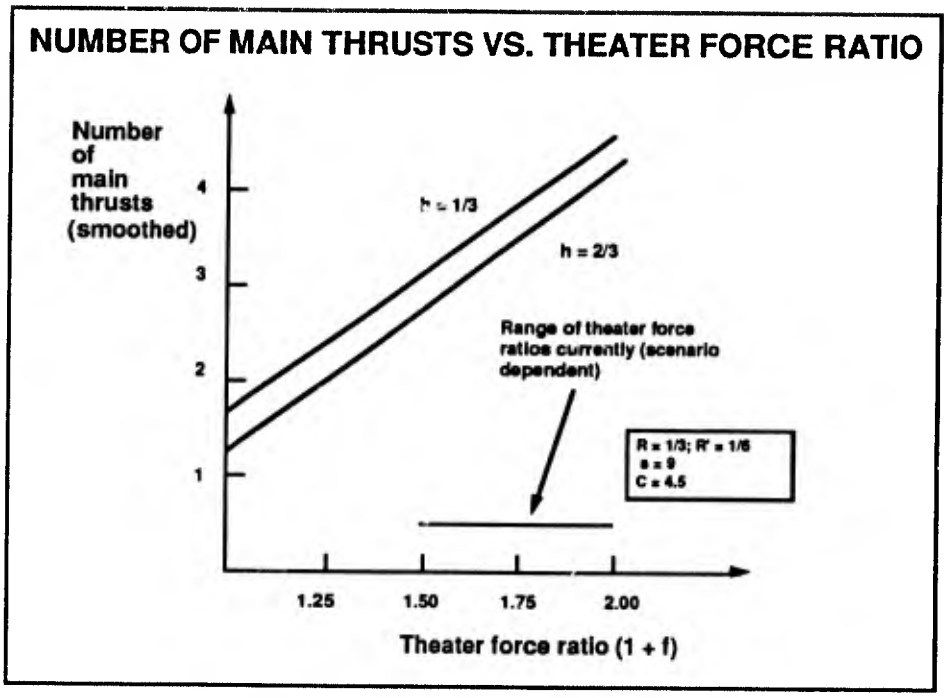

Fig. 34

main sectors. On the other hand, all of this analysis assumes that the defender has not preferentially defended the attack sector based on a priori knowledge about strategic geography and does no counterconcentration before war begins—a highly conservative assumption if, for example, the arms control regime included a variety of "operational arms control measures" making such concentration both more visible and more unambiguously aggressive (Davis, 1988).

Figure 35 summarizes some of the conclusions that can be drawn from even this simple analysis—at least tentatively. In subsequent figures we shall discuss where the model breaks down, but these insights are still useful. Note in particular that:

- If parity can be achieved, it will have major effects on the balance (assuming that force-generation rates are not adverse). In particular, it will make it impossible to achieve high force ratios in more than one or two sectors.

A side benefit of the simple math model work has been recognition that the analytic methods we have been working with for some time do not all become irrelevant

CONCLUSIONS FROM MATH-MODEL ANALYSIS

For attrition warfare, where force ratio matters greatly:

- **Attacker's prospects improve quickly with increasing D-Day theater force ratio**
- **Attacker's prospects at parity are *not* good with "standard" assumptions and models—unless defender has Achilles Heels**
- **Attacker's prospects improve if defender will not counterattack and/or if attacker can ignore some sectors while defender is politically bound to defend all of them.**
- **Defender's prospects improve by holding more reserves, covering sectors in proportion to strategic significance, and being able and willing to counterattack**
- **Defender's prospects improve if main thrusts can be identified early (are feints really possible at low force levels and parity?).**

Fig. 35

at lower force levels (Fig. 36). To be sure, if the defender's forward forces in the main-thrust sectors were thin, the first phase of warfare would be very different from that envisioned in current models. However, after counterconcentration, battles would revert to attrition warfare.

CONCLUSIONS (CONT'D)
WARFARE AT LOW FORCE LEVELS

***Current Myth*: At low force levels, models of attrition warfare would necessarily be irrelevant because maneuver would dominate.**

***Reality*: If Soviet doctrine continues to emphasize large-scale concentration and breakthrough, then at low force levels:**

- **Rapid initial penetrations on main sectors are very likely and could not be described well by "attrition models."**
- **However, if defender can counterconcentrate before war is "over," resulting battles will be attrition battles of high-density forces**

Fig. 36

It is perhaps easiest to see the point by looking at some schematic diagrams consistent with the simple math model. Figure 37 illustrates the force levels that might obtain today in a Central Region war as described by the simple model. Both attacker and defender force densities are above the operational minimum per sector (shown on the figures as "operational minimum").

In Figure 38 we show schematically the situation that might obtain if the overall force ratio were approximately equal and force levels were low. In "other" sectors, both sides would have very few forces, well below the operational minimum. In main-thrust sectors, however, of which there could be only one or two, the situation would be more complex. Initially, the defender's forces would be very thin, below the operational minimum. That first-phase battle would by no means be characterized as a battle of attrition. However, after the defender committed his reserves, and if he were able to reestablish a defense line somewhere, then force levels in the main thrust sectors would be rather high—even higher than currently envisioned for main-thrust sectors!

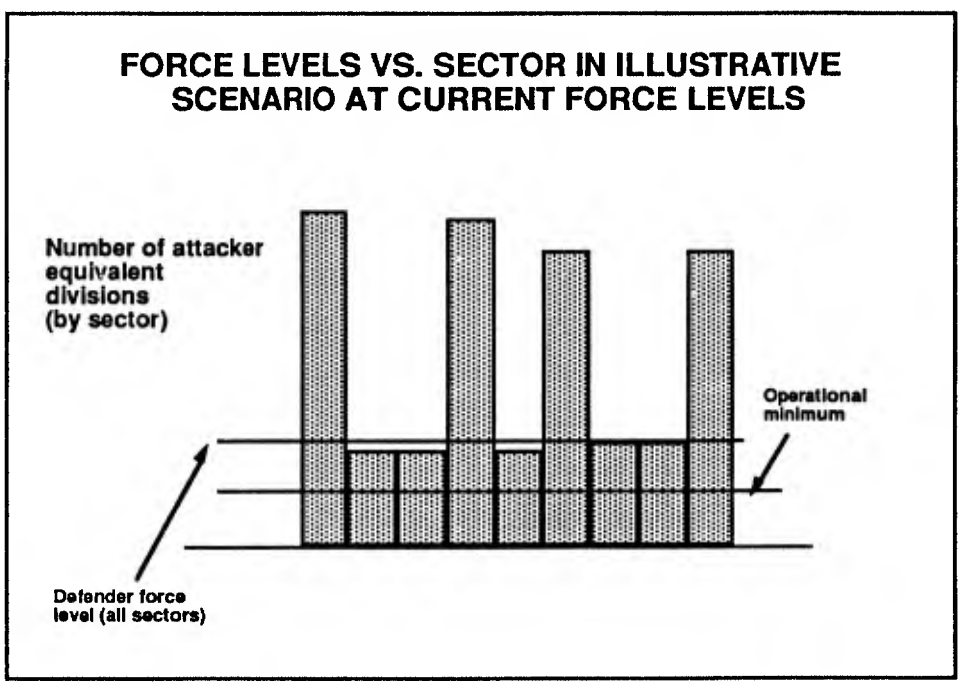

Fig. 37

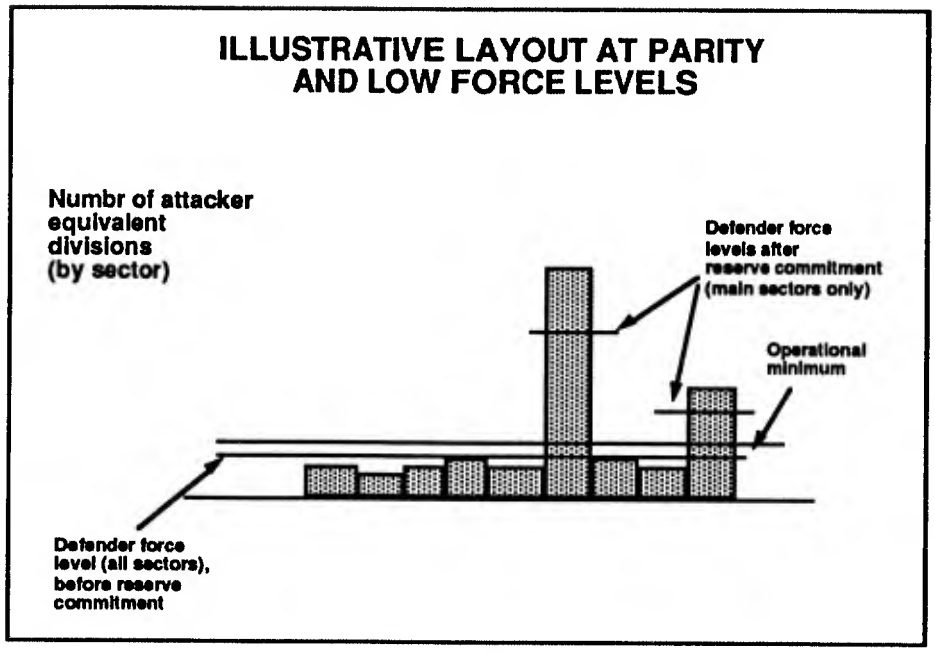

Fig. 38

The point here is that there is a strong interaction between the theater force ratio and the implications of low force levels. Low force levels and even moderately adverse theater force ratios could be disastrous for defense. Low force levels at parity, however, are another matter.

V. DEFENSE AT LOW FORCE LEVELS

The last part of our interim analysis involved simulations using the RSAS and highly simplified and unclassified assumptions about forces, strategies, command-control, and other factors. Our general approach was to eliminate all the complicating details that we believed were not at the essence of the issue when examining the effects of low force levels, and some additional complications as well that will be reintroduced in our next round of work. Our starting point was a simulation-model version of the simple math model we have just discussed. We temporarily turned all air-war models off. However, the simulation included logic for attrition, movement, constraints on the speed of reserve maneuvers, terrain, prepared defenses, flank expansion, and breakthrough phenomena having major consequences for both attrition and movement.

Before showing simulation results, let us discuss briefly some modeling issues (Fig. 39). The first observation here is that most current theater-level models (and, indeed, most detailed models) were not designed for the regime of low force densities. Instead, they are "attrition models" that see combat as a sequence of large battles governed by something like Lanchester equations, although details vary significantly

TREATMENT OF MANEUVER IN RSAS

- **Usual image of theater models: head-on-head attrition in "pistons"**
- **Maneuver features included in current Central-Region model:**
  - **Explosive "breakthroughs and pursuits"**
  - **Flank combat and flank expansion**
  - **Rear-area battles (airborne, air-assault, OMGs)**
  - **Effects of rear-area battle on FLOT battle**
  - **Countermaneuver effects of CAS, BAI, helicopters, and AI**
  - **Terrain effects on maneuver: shoulder space limits, military vs. geographic frontage (for FLOT and flanks), trafficability factors**
  - **Operational/strategic encirclements and counterattacks (best done interactively)**
  - **Various delay parameters for all types of rear movement**
  - **Command-control dictated by rule-based decision models reacting to perceived situation and higher-level strategy, and accounting for military geography (e.g., river lines)**
- **New network-oriented model in development**

Fig. 39

among models. Most models also constrain forces to move in "pistons." At low force levels, however, the nature of war would probably be quite different. Penetrations would occur by the attacker avoiding large scale battle. Further, many of the battles that would occur would be relatively small. And, importantly, one would expect to see the "defender" counterattacking into the rear of the "attacker," so that, after a time, there would be battles in the rear areas of both sides.

It might seem, then, that it would be impossible to use current theater level models for the regime of low force levels. Indeed, we are experimenting currently with the adaptation of a network-oriented model (Allen and Wilson, 1987) that should be more suitable for studying maneuver warfare. However, upon reflection we have concluded that the current Central Region model of the RSAS can be used to gain valid insights about the low-force-level regime—so long as it is used carefully. There are two reasons for this: (1) As Fig. 39 indicates, the RSAS includes a large number of important maneuver phenomena, including flank battles and encirclement operations, but most importantly, perhaps, a unique description of the breakthrough process (Bennett, Jones, Bullock, and Davis, 1988); and (2), as illustrated in the preceding work with the simple math model, we would expect the force densities in main-thrust sectors to be about the same in low force-level regimes as in high force-level regimes, the difference being more in the number of such sectors than in the nature of battle within them, except for the initial period. All of this means we can do some finessing. To understand this, we need to discuss how the RSAS treats breakthroughs.

Figure 40 illustrates the type of FLOT movement one sees in the RSAS for a sector in which the attacker succeeds in achieving a breakthrough. Note that movement is only slight initially, but as attrition occurs and the FLOT expands, the defender's density declines (more km of frontage per ED). If the defender continues to try to hold ground rather than falling back, a "breakthrough" occurs when the defender's density drops too much. The model then characterizes battle as "pursuit"; the defender is heavily penalized in terms of attrition and, more importantly, the attacker is assumed to move at a potentially high speed limited by terrain and defender air power (rather than force ratio). The maximum movement rate is a parameter; the actual movement rate during pursuit is this maximum rate multiplied by slowing factors that depend on terrain and the defender's level of air-to-ground activity. In the example, the attacker moves about 60 km/day during the exploitation (or pursuit) phase. The movement slows when objectives are reached or when the attacker reaches the next defense line that has enough forces to

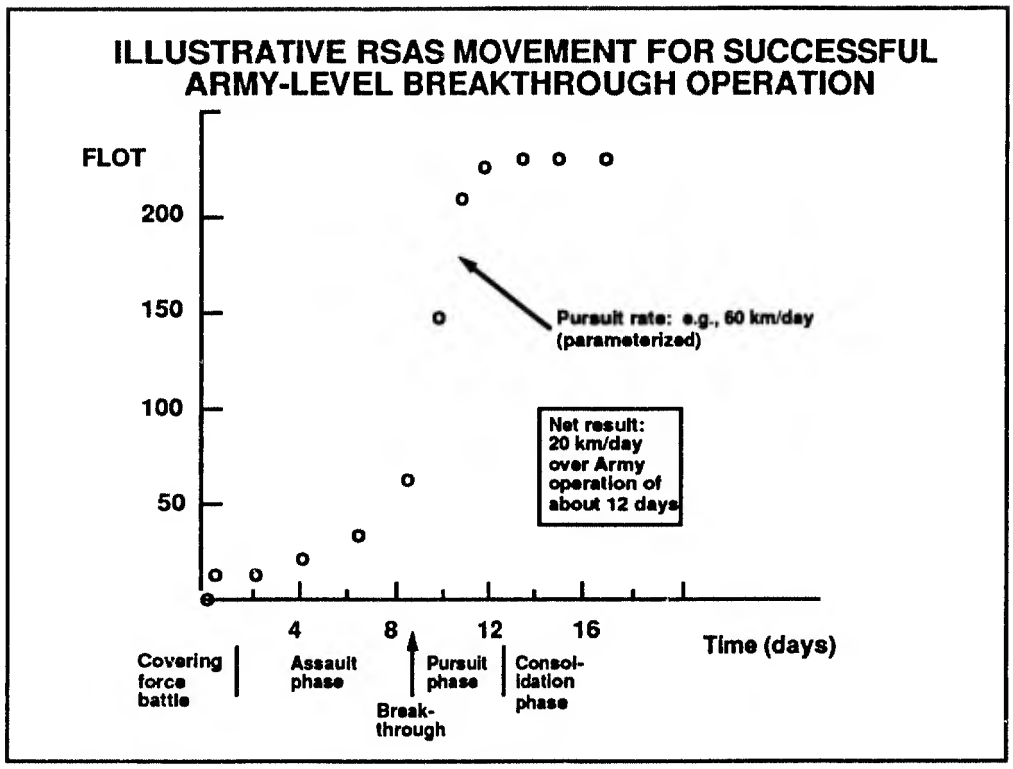

Fig. 40

require assault operations (shown here as at about 240 km depth). The defender may or may not be able to establish such a line.

The important points here are these:

- The model recognizes the transition point between attrition warfare and maneuver warfare, and estimates where that point occurs (a parameterized function of defender density, using historical evidence as a rough calibration).

- Although not shown in this example, the model predicts early breakthroughs when the defender's initial density (force-to-space ratio) is low.

- The consequences of the breakthrough are estimated, but these are determined largely by variable parameters.

- Thus, the analyst can examine the implications of low force levels parametrically by varying his assumptions about how quickly the attacker can move during the pursuit phase and how effective tactical air can be in slowing it.

As a result, we have a model that allows us to explore theater-level conflict that begins with low-density battles and breakthroughs and that later evolves into a more standard attrition-style battle.

With this background, then, let us now view some of the interim results of our work with the RSAS. Figure 41 shows the principal assumptions. Note that although the basic RSAS is rather detailed, we have simplified its input data so as to work with generic forces and simplified strategies. In ongoing work we are, of course, relaxing some of the assumptions—adding in the air war, introducing more complex strategies, and so on. Our intention here, however, is to show that the model demonstrates the expected instability below the operational minimum, and to then go on and indicate what the defender might do to avoid disaster in the low-force-level regime.

Figures 42 and 43 locate and summarize the results of baseline cases using the assumptions above. As expected at parity, even with conservative assumptions, such as no prepared defenses or counterconcentration as of D-Day, the defense holds at or east of the Weser River for force levels and defender densities above (and at) the operational minimum. With less conservative assumptions, the defense would hold near the border. At the level of 18 EDs each, however, the defense collapses under the baseline conservative assumptions: there are immediate breakthroughs and the Pact forces sweep through what is now the Dutch corps sector, cross the Rhine in about a week, and move into the Low Countries within about three weeks (the 300 km line). Movement rates are very high, but no faster and perhaps even less fast than Pact doctrine calls for in all seriousness under such circumstances, and no faster than some of the advances observed historically 45–50 years ago in World War II. Although, after D-Day, NATO reinforces the sector under attack, there are enough constraints of space, roads, and logistics so that the reinforcements do not arrive quickly enough to contain the breakthrough.

Having demonstrated the instability of forward defense capability below the operational minimum, we next began to examine alternative defense strategies. In Fig. 44 we show the simulated results of (a) a strategy calling for an immediate fallback to the Weser River, albeit with major attempts to accomplish delay, and (b) earlier counterconcentration (arrival in the main-attack sector by D-Day of one additional

RESULTS OF PRELIMINARY SIMULATIONS AT LOW FORCE LEVELS AND PARITY

Assumptions:

- Generic forces
- Defender defends all sectors equally
- Force levels of 45, 36, 27, 18 EDs each
- RSAS models. Air models turned off
- Main thrusts in Dutch and (in two-thrust cases) Ge I corps (results shown for more successful of one- and two-thrust attacks)
- Relatively sluggish defender command-control
- Risky attacker strategy (force ratio of 1:2 on "other" sectors)
- Defender has no prepared defenses on D-Day
- All forces ready by D-Day

Fig. 41

SIMULATION RESULTS: FORWARD DEFENSE AT 18 EDS

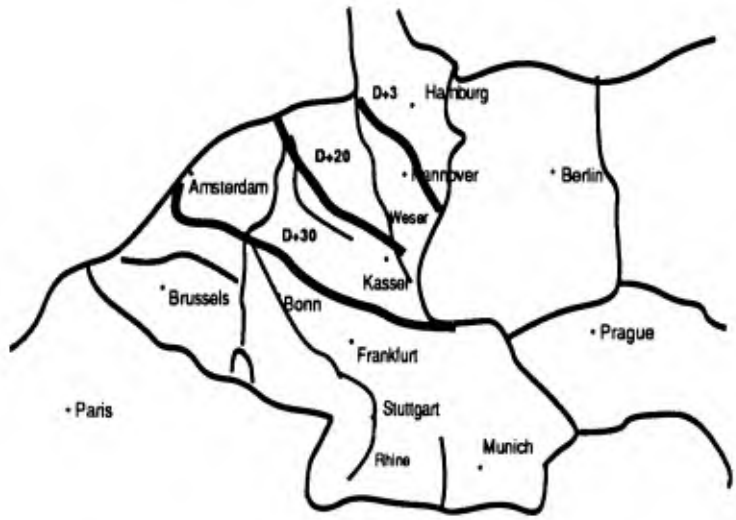

Fig. 42

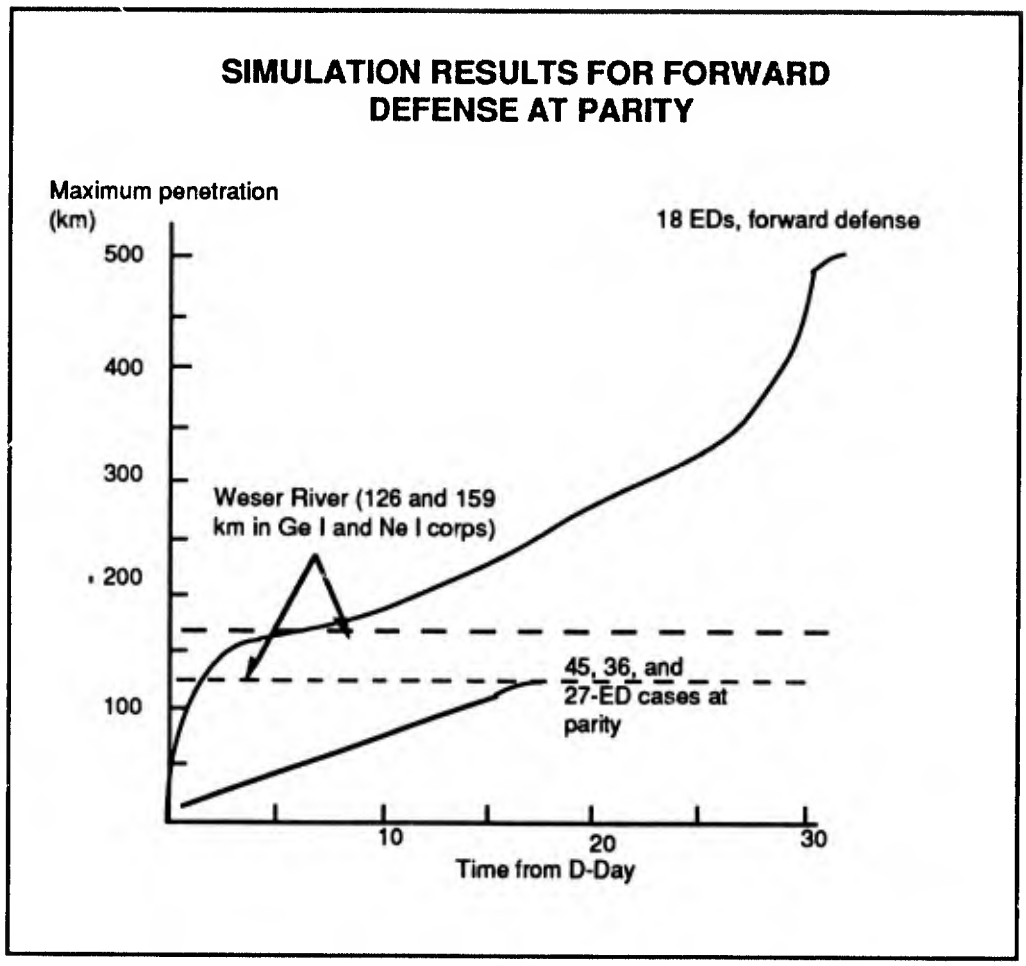

Fig. 43

division from reserves). In both cases, the Pact is denied a strategic victory. In the latter case, a forward defense proves possible, although some losses occur (we did not simulate counterattacks in this phase of our work). In both cases the theater force ratio is shifting with time toward NATO.

In the delay-strategy case (something that harks back to the 1960s), the defense denies the attacker its breakthrough by refusing to hold ground. This slows the Pact's movement rate, because the Pact forces are continuously engaged in assaults, although with lower-level engagements and quicker successes than if the defense had more forces available. By the time the Pact forces reach the Weser River, NATO has had a week to bring in reserves and develop prepared defenses at an excellent defense line. An additional factor here is that the terrain becomes more defense favorable in the approach

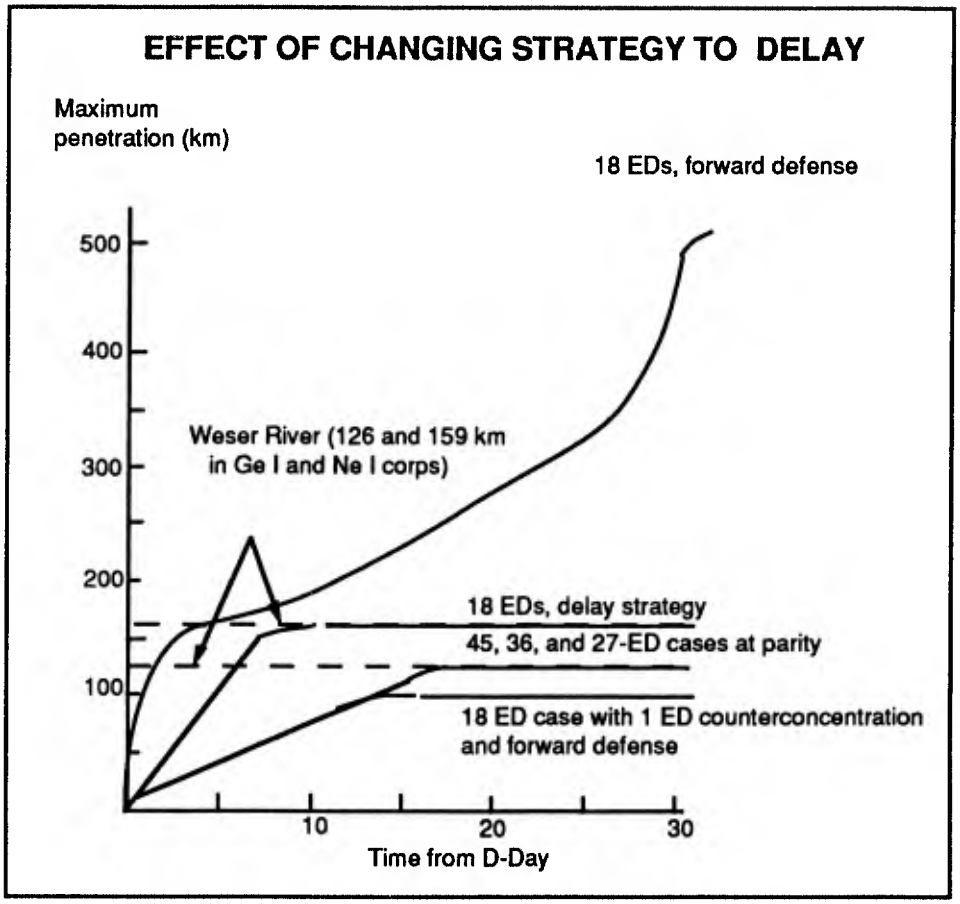

Fig. 44

to the river, channelizing the Pact forces and limiting the Pact's ability to put forces on line. The net effect, in the simulation, is that NATO is able to hold at the Weser. Moreover, although not shown in this slide, the theater force ratio shifts in favor of NATO, because the Pact's unsuccessful attack operations have been at the price of an adverse exchange ratio. The D+30 ratio is about 0.76.

In the second case, in which NATO does some modest early counterconcentration (but still has no prepared defenses on the border), NATO is able to conduct a forward defense, although losing ground for the first two weeks. Again, the theater force ratio is worsening for the Pact while its lines are getting longer. Counterattacks would be quite plausible. In cases in which NATO reacts sooner and more decisively to the Pact's concentration of forces, NATO holds at or near the border (not shown).

We are now exploring a wide range of cases at the level of 18 divisions for each side. These include cases with varied assumptions about: (a) the effectiveness of the

delay operation (notoriously difficult to conduct), (b) the significance of NATO preferentially defending key lines of advance (e.g., even one additional division in the sector initially has a major benefit), (c) the potential effects of airpower, and (d) Pact strategies for bypassing some of the Weser River defenses along the basic approach axis. In addition, we are exploring defensive strategies that include counterattacks onto the flanks of the Pact thrust. This work is best done in a "gaming mode" in which we proceed day by day, adjusting the force orders appropriately and, when necessary, manipulating the combat model to represent different assumptions about the execution of the counterattack. We are also studying alternative Soviet concepts of operations that would not require as large-scale concentrations of force. Relevant discussions here include Karber (1984), Glantz (1989), Donnelly (1988), and Hines (1988). Interestingly, however, many of the related innovations the Soviets have been experimenting with in the last decade are being undercut by Gorbachev's recent unilateral initiatives (Karber, 1989) and would be further undercut by stabilizing measures such as the pullback of attack infrastructure and the preferential reduction of Soviet forces in Eastern Europe. In essence, many of these alternative concepts depend sensitively upon achieving operational and tactical surprise.

From a theoretical perspective, all of this should be considered to be grounds for optimism about stability at low force levels (Fig. 45). In essence, the conclusion is that unless the defender is foolish enough to try to carry out a rigid, narrowly defined, forward defense under all circumstances, even with clearly inadequate forces, he "should" be able to prevent decisive penetrations, improve the force ratio to his advantage, and perhaps launch counteroffensive operations (with the advantage of shorter and less vulnerable lines of communication). At even lower force levels, the whole issue diminishes in importance. For example, if there were one soldier on each side, then either side could penetrate at will to arbitrary depths, but neither side could "win." While this might at first appear to be a frivolous limit, think next of the force requirements for merely securing and occupying territory. It quickly becomes clear that at sufficiently low force levels, the force structure is effectively secure.

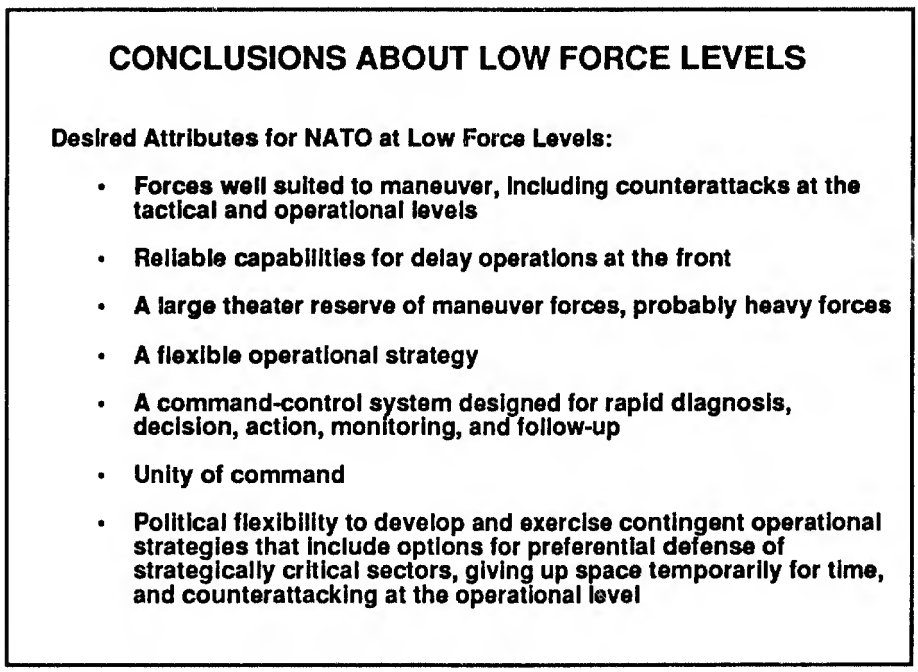

Fig. 45

All of this said, it is now necessary to post a long list of caveats, because what "ought to be" and what "is" are often different. Many defenders have lost wars even though they were not seriously outgunned, or in some cases actually had the advantage. There are strong political forces encouraging foolish strategies. Figure 45 summarizes the attributes our analysis suggests are desirable for stability at low force levels. However reasonable they may appear analytically, they are in stark contrast with many views about what kinds of capabilities are desirable or undesirable for stability. In particular, they do not look at all like the usual concepts of "defensive defense," which are oriented toward successful attrition-focused operations at the front carried out with relatively light and relatively static forces. Nor do the needed command-and-control arrangements (e.g., unity of command) look anything like NATO's current layer-cake

system with rather independent corps and army groups.[22] And so on. Most importantly, perhaps, it is widely believed that NATO's strategy demands a rigid forward defense, even though, as we noted earlier, this is a misrepresentation of both MC 14/3 operational planning at the time flexible response strategy was introduced, and current realities.

---

[22]Although we did not analyze technical command-and-control capabilities in this study, Army sponsored work by RAND colleague Ed Cesar suggests that it will probably be important to preferentially protect capabilities for tactical command and control, especially since a corp's capabilities to cover a large frontage and to conduct complex maneuvers with widely separated units depend on the density of its command-and-control assets.

VI. IMPLICATIONS FOR THE VIENNA NEGOTIATIONS

In this part of the Note we shall make a number of suggestions for the current CFE and CSBM negotiations being conducted in Vienna, suggestions motivated by our analysis of the effects of theater force ratio and low force levels, as well as by more general concerns about stability.

Figure 46 summarizes some "operational arms control measures" ("stabilizing measures") that could supplement the structural measures such as the call for reductions to parity in selected equipment levels. Although the measures have been suggested previously, they are especially relevant here because of the need (demonstrated in the earlier figures) to assure that the defender has time to observe and respond to attack preparations (e.g., counterconcentrating) and to assure reasonable parity in the theater force ratio vs. time.[23]

STABILIZING MEASURES NEEDED

OBJECTIVES:

- **Improve defender preparations:**
  - **–Increase time and visibility of attack preparations, and assure that they would be recognized as unambiguously hostile**
  - **–*Provide time to counterconcentrate* before war starts**
- **Assure *dynamic parity***

MEASURES

- **Withdraw "excess" artillery ammunition and other attack infrastructure**
- **Preferentially reduce Soviet forces in Eastern Europe (e.g., 30% rule), without accepting pullbacks of non-FRG NATO forces**
- **Constrain time and details of large-scale exercises in forward areas (e.g., require announcements and prohibit some attack-critical activities during exercises)**
- **Limit the number of active and high-readiness reserve units potentially available for the Central Region**

Fig. 46

[23]As discussed in Davis (1989), the generic objectives of the stabilizing measures should be to (a) avoid strategic and operational surprise, (b) raise risks for the attacker (including risks of preemptive air strikes interdicting attack forces and logistics units en route to the front), and (c) improve the defender's tactical odds.

The first measure involves dismantling "attack infrastructure" (e.g., withdrawing "excess" artillery ammunition, bridging equipment, and perhaps mobile SAMs from forward areas).[24] The second measure involves turning Eastern Europe into something more like a buffer serving the security interests of both sides. The East European nations could continue to be part of the Pact, but both they and we would greatly prefer that there be many fewer Soviet forces there. From NATO's point of view, a reduced level (in percentage terms) of Soviet forces there would increase the time available to observe, diagnose, and react to a developing attack—preferentially defending the most likely attack corridors. This, in addition to the long-emphasized objective of ruling out "surprise attacks" (i.e., short-mobilization attacks in which NATO is caught unprepared). The third measure would also help here. Note that we are not proposing bans on large exercises, since that might hurt NATO. Instead, we are proposing bans on "comprehensive" exercises in which all the combined arms elements are participating.

The last measure addresses the issue of maintaining approximate parity during a force-generation process. If all forces were active there would be no problem, but given a mix of active, ready reserve, and deep reserves adding up to the totals already under discussion in the CFE talks, there could be major disparities in the D-Day theater force ratio. To avoid this we would need to have comparable structures with respect to the active/ready-reserve/deep-reserve mix. (Another problem, which we do not discuss here, is the role of out-of-area forces being employed in the Central Region from, say, the Eastern or Southern regions of the Soviet Union).

Figure 47 illustrates how significant a disparity in the dynamics of force generation could be. It assumes that the Pact has more forces in a rapidly mobilizable state of readiness, so that by D-Day it can have a force ratio, temporarily, of 1.5:1. In the example, it is assumed that the Pact would choose to have D-Day about M +32. Again, the figure is merely illustrative.

Figure 48, based on an earlier one, indicates just how serious a temporary force ratio disadvantage of 1.5:1 could be. The feasibility of gaining a strategically decisive victory would be much greater for an attack with three or four main thrusts rather than the one or at most two possible at parity. This coupled with D-Day force levels at or below the operational minimum could be catastrophic, while at force levels above the

---

[24]See Galvin (1988b) for related comments. Ambassador James Goodby has also proposed such measures, as has Ambassador Jonathan Dean, although Dean has also proposed a variety of withdrawal zones (Dean, 1989) that we believe are probably undesirable for reasons discussed in Davis (1989).

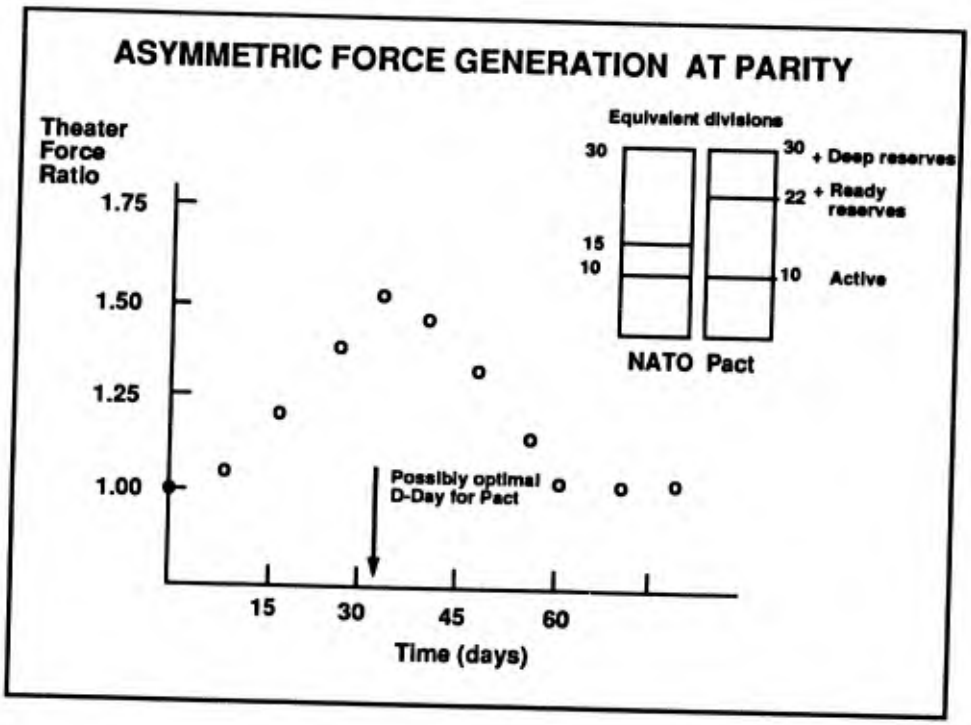
ASYMMETRIC FORCE GENERATION AT PARITY
Theater Force Ratio
1.75
1.50
1.25
1.00
Possibly optimal D-Day for Pact
15
30
45
60
Time (days)
Equivalent divisions
30
30
+ Deep reserves
22
+ Ready reserves
15
10
10
Active
NATO
Pact

Fig. 47

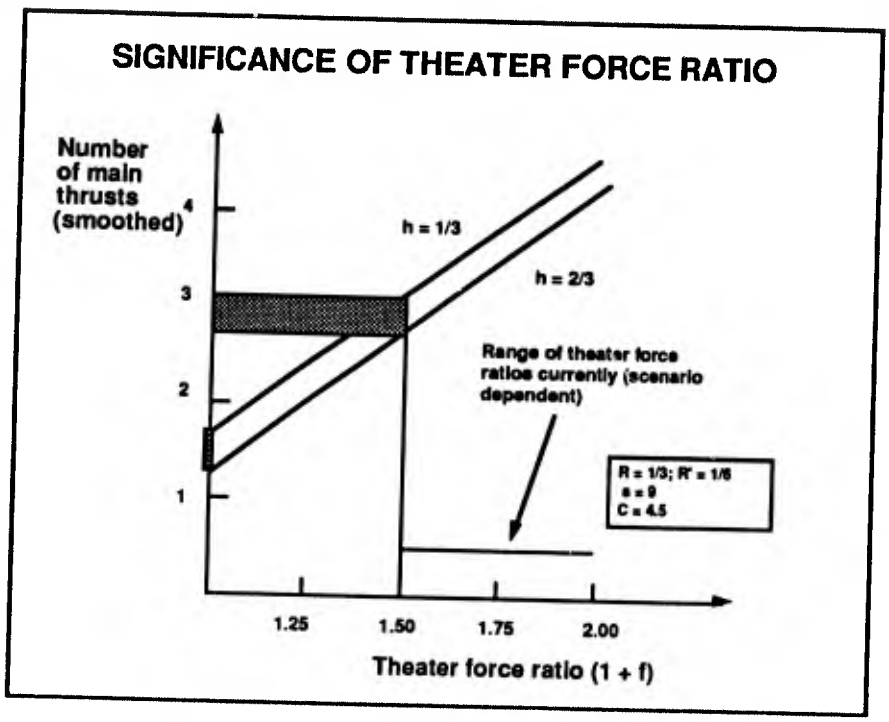
SIGNIFICANCE OF THEATER FORCE RATIO
Number of main thrusts (smoothed)
4
3
2
1
h = 1/3
h = 2/3
Range of theater force ratios currently (scenario dependent)
R = 1/3; R' = 1/6
s = 9
C = 4.5
1.25
1.50
1.75
2.00
Theater force ratio (1 + f)

Fig. 48

operational minimum the defense might succeed. A key factor here would be whether NATO had its minimum tactical density of forces at D-Day. If so, those forces might be expected to hold until the reserves were available.[25]

We have not sought to define readiness categories in our research, believing that developing treaty language was probably better done within the government, where information is more readily available and timely, and where the nuances of current positions are better known. Nonetheless, it may be useful for us to sketch the type of thing we have in mind.

The problem being addressed here is preventing the Pact from having superior theater force ratios at D-Day by virtue of having better force-generation rates. If they had

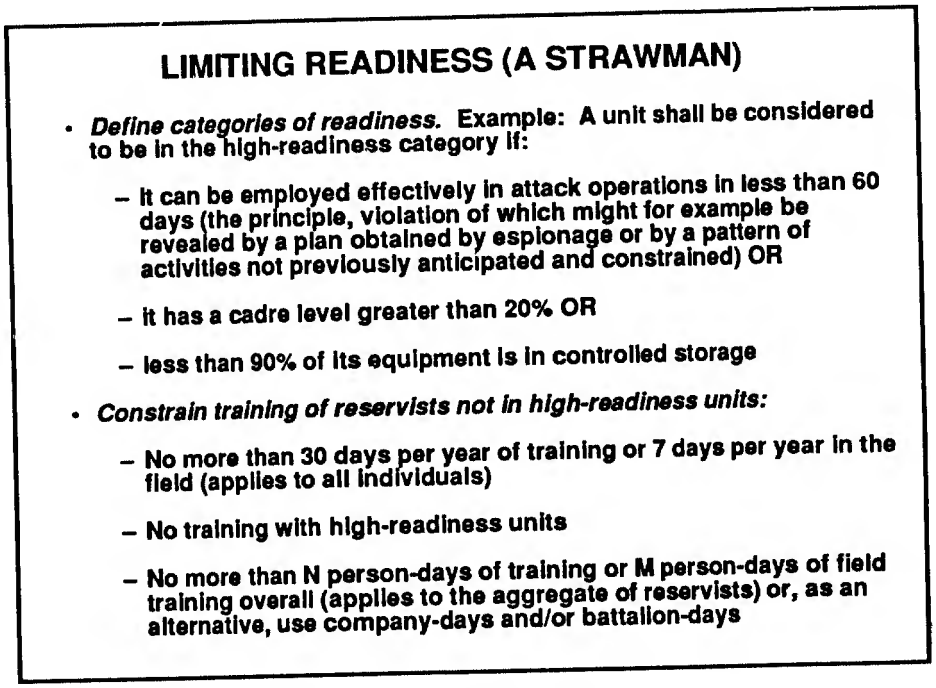

Fig. 49

[25]It is possible in simulations to miss seeing the significance of reduced defender densities. In particular, if one focuses on cases in which the defender avoids operational surprise, prepares defenses, and counterconcentrates effectively, the defender's prospects are rather good, even at a theater force ratio of 1.5:1. However, when one examines highly plausible excursions with multiscenario analytic war gaming as discussed in Davis (1989), one soon sees how fragile the defense may be at low force levels. Excursions may involve postulating greater-than-expected offensive success on even one of the several attack sectors, delay in building barriers, sluggish command-control, or "laws of war" that are somewhat less adverse to the attacker than those commonly used.

better rates, it would be because they had more forces in an active or ready-reserve status, as distinct from "deep reserves" such as the "Category III units" alluded to in unclassified publications, units that might need 25–90 days of mobilization and training before they could be effectively employed in assault operations. The key, then, would be to impose a ceiling on the number of active and ready-reserve units (or on the equipment associated with such units). As Fig. 49 suggests, units could be counted as highly ready if they triggered any of a number of criteria, including one criterion of principle and numerous criteria of a more objective nature. All the numbers in this chart are purely illustrative, and not the result of any deep analysis. We include them merely to provide a strong image of what we have in mind.

VII. NEXT STEPS

All interim analysis must end with a call for more work, and we wish no exception here, especially since the analytic community has so little experience examining the

ADDITIONAL ANALYSIS NEEDED

- More precise estimates of the operational minimum based on inputs from field commanders with varied assumptions about:
  - –Threat (size vs. time, character, etc.)
  - –Doctrine and strategy
  - –Time of year (affects usable frontage)
  - –Composition of own forces
- Minimum force size for plausible invasion given problems of control and occupation, with varied assumptions about:
  - –Force generation time for low-readiness reserves and occupation-capable forces
- Implications of strategic geography for:
  - –Potentially decisive attack corridors
  - –Feasibility of preferential defense (type force as well as quantity)
  - –Enhancing feasibility of initial defenses based on delay
- Hybrid defense planning concepts that include "defensive defense" infantry and obstacles and highly mobile and counterattack-capable heavy forces

Much more extensive gaming and analysis at low force levels:

- –Impact of more detailed maneuver (network model)
- –Alternative concepts of operations (both sides) and tailored threat forces not relying upon large operational force ratios
- –Gaming of counterattack (to include logistic considerations)
- –Thinly manned forward defense zones for delay and attrition
- –Value of limited preferential defense, timely C3I, etc.

- More quantitative assessment of various operational arms control measures involving forward-deployed artillery ammunition, the Soviet percentage of Pact forces in Eastern Europe, and readiness
- Alternative NATO command structures for low force levels
- Tabletop analyzer for proposals: terrain-adjusted force ratio by corps sector vs. time, breakdowns by region, etc.
- Global analyses (i.e., with redeployment of forces from beyond the Central Region)
- Assessment of force-posture stability for lesser strategies (e.g., Hamburg grab or GDR liberation)

Fig. 50

military problems of defense at low force levels. Figure 50, which we offer without discussion, summarizes briefly some important areas needing additional work. Our conclusions from the interim work are given in the Summary at the beginning of this Note and will not be repeated here.

BIBLIOGRAPHY

Allen, Patrick, and Barry Wilson, 1987, *Secondary Land Theater Model*, The RAND Corporation, N-2625-NA, July.

Bennett, Bruce Wm., Carl Jones, Arthur Bullock, and Paul K. Davis, 1988, *Main Theater Warfare Modeling in the RAND Strategy Assessment System 3.0*, The RAND Corporation, N-2743-NA, September.

Blackwill, Robert D.,1988, "Conventional Stability Talks: Specific Approaches to Conventional Arms Control in Europe," *Survival*,, September/October, pp. 429–447.

Brzezinski, Zbigniew, 1986, *Game Plan: How to Conduct the U.S.-Soviet Contest*, Atlantic Monthly Press.

Cohen, Elliot A., 1989, "Reassessing Net Assessment," *International Security*, Vol. 13, No. 4, Spring.

Congressional Budget Office, 1988, *U.S. Ground Forces and the Conventional Balance in Europe*, Government Printing Office.

Davis, Paul K., 1988, *Toward a Conceptual Framework for Operational Arms Control in Europe's Central Region*, The RAND Corporation, R-3704-USDP, November.

Davis, Paul K., 1989, *Studying First-Strike Stability with Knowledge-Based Models of Human Decisionmaking*, The RAND Corporation, R-3689-CC, April.

Davis, Paul K., 1988, *The Role of Uncertainty in Assessing the NATO-Pact Central Region Balance*, The RAND Corporation, N-2839-RC, December.

Dean, Jonathan, 1989, "How to Reduce NATO and Warsaw Pact Forces," *Survival*, March/April, pp. 109ff.

Donnelly, Christopher, 1988, *Red Banner: The Soviet Military System in Peace and War*, Jane's Information Group Ltd., Sentinel House, Coulsdon, Surrey (UK).

Dupuy, T.N., and Paul Martell, 1982, *Great Battles on the Eastern Front*, Bobbs-Merrill, Indianapolis.

Epstein, Joshua M., 1989, "The 3:1 Rule, the Adaptive Dynamic Model, and the Future of Security Studies," and "Reassessing Net Assessment," both articles in *International Security*, Vol. 13, No. 4, Spring.

Flanagan, Stephen J. and Andrew Hamilton, 1988, "Arms Control and Stability in Europe," *Survival*, September/October, pp. 448–464.

Galvin, General John R., 1989a, "Some Thoughts on Conventional Arms Control," *Survival*, March/April, pp. 99–198.

Galvin, General John R., 1989b, "Transcript of SACEUR's Remarks to the Royal United Services Institute (RUSI)," London, England, 18 May.

Glantz, Colonel David M., 1989, *Soviet Operational Art and Tactics in an Era of Reform*, Soviet Army Studies Office, U.S. Army Combined Arms Center, Fort Leavenworth, Kansas.

Hamilton, Andrew, 1985, "Redressing the Conventional Balance: NATO's Reserve Military Manpower," *International Security*, Vol. 10, No. 1, Summer.

Hines, John, 1988, "How Much Is Enough for Theater War?: The Soviet Approach to Sufficiency of Conventional Forces in Europe," in *NATO-Warsaw Pact Conventional Force Balance: Papers for U.S. and Soviet Perspectives Workshops*, U.S. General Accounting Office, GAO/NSIAN-89-23B.

Huber, Reiner K., 1988, "On Structural Prerequisites to Strategic Stability in Europe Without Nuclear Weapons: Conclusions from the Analysis of a Model of Conventional Conflict," *Systems Research*, Vol. 5, No. 3, pp. 211ff.

Karber, Phillip A.,1989, *Strategic Significance of the Western Conventional Arms Control Proposal in the Context of the Gorbachev Unilateral Reductions and the CFE Negotiations in Vienna*, testimony before the Senate Armed Services Committee, April 6.

Karber, Phillip, 1984, "The Strategy: In Defense of Forward Defense," *Armed Forces Journal International*, May, pp. 27ff

Kent, G. . ., R. J. DeValk, and D. E. Thaler, 1988, *A Calculus of First-Strike Stability (A Criterion for Evaluating Strategic Forces)*, The RAND Corporation, N-2526-AF, June.

Kokoshin, Andrei and V. V. Larianov, 1988, "The Confrontation of Conventional Forces in the Context of Ensuring Strategic Stability," FBIS-SOV-88-140A, July 21.

Liddell Hart, B. H., 1960, *Deterrent or Defense: A Fresh Look at the West's Military Position*, Praeger, New York.

Mako, William P.,1983, *U.S. Ground Forces and the Defense of Central Europe*, The Brookings Institution, Washington, D.C.

Mearsheimer, John J., 1989, "Assessing the Conventional Balance: The 3:1 Rule and Its Critics," and "Reassessing Net Assessment," both articles in *International Security*, Vol. 13, No. 4, Spring.

Mearsheimer, John J., 1982, "Why the Soviets Can't Win Quickly in Central Europe," *International Security*, Vol. 7, No.1, pp. 3ff.

Office of the Assistant Secretary of Defense for Program Analysis and Evaluation (OSD/PA&E), 1979, "NATO Center Region Military Balance Study: 1978–1984." The principal author was Richard Kugler.

Office of the Secretary of Defense (OSD/ISP/NP), 1989, "NATO's Conventional Arms Control Proposal in Question and Answer Style," March 8. Includes unclassified statements of NATO and WTO proposals as transmitted from the U.S. Mission in Vienna on March 6, 1989.

Posen, Barry R., 1989, "Reassessing Net Assessment, " *International Security*, Vol. 13, No. 4, Spring.

Posen, 1985, "The Warsaw Pact and NATO Cases in Detail," Appendix A in *Alternative Military Strategies for the Future*, edited by Keith A. Dunn and William O. Staudenmaier, Westview Press, Boulder, Colorado.

Rohn, Lauri, *Conventional Forces in Europe: A New Approach to the Balance, Stability, and Arms Control*, The RAND Corporation R-3732-USDP/AF, forthcoming (based on a PhD dissertation for the RAND Graduate School of Policy Studies).

Ruiz Palmer, Diego A., 1984 "The Forces: National Contributions," *Armed Forces Journal International*, May, pp. 27 ff.

Thomson, James A., 1988, *An Unfavorable Situation: NATO and the Conventional Balance*, The RAND Corporation, N-2842-FF/RC, November.

Warner, Edward L., and David A. Ochmanek, 1989, *Next Moves*, Council on Foreign Relations, New York.

Wendt, James (1989), not yet published Army-sponsored RAND research on comparative U.S. and Soviet capabilities to redeploy forces to the Central Region .

Watman, Kenneth, unpublished work on integrating conventional arms control and force enhancements in NATO.

Wilkening, Dean A., and Kenneth Watman, 1986, *Strategic Defenses and First-Srike Stability*, The RAND Corporation, R-3412-FF/RC, November.