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13. ABSTRACT *(Maximum 200 words)*

This paper summarizes and elaborates on a 4-year study of modern conventional ground operations (originally reported in 3 volumes: LMI FP703TR1/-TR2/-TR3, available separately in DTIC). The research reveals patterns of personnel battle casualty rates strongly associated with patterns of operations. This paper also discusses Operation Desert Storm rate outcomes in light of the study's prior insights into rate patterns. The research combines insights from military theory, history, and operations research to investigate a new and large body of empirical data (from WWII, Korea, Middle East, and National Training Center – much of it included in LMI-FP703TR1) on battle casualty rate behavior in modern operations. Findings include detailed and general rate characteristics associated qualitatively and quantitatively with major forms of operations. Qualitative indicators include critical operational parameters for rate assessment, and fundamental operational scenario characteristics. Quantitative indicators include probable ranges of average (mean) rates for army and corps-size forces for varying time periods and scenarios, distributions (max, 75, median, 25, min) of 1-day rates given those averages (for 5- and 10-day periods), measures of rate variability, rate frequencies, varying proportions of wounded casualties out of total, etc. Findings suggest that current U.S. and Allied casualty estimation methodologies and contemporary simulations fail to represent significant empirically-indicated rate patterns, and further suggest the character and degree of the misrepresentation. Improved approaches are described both to casualty estimation (to evaluate estimates made by whatever method or to construct estimates) and to help validate simulation output of personnel casualties.

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Uses in Casualty Estimation and Simulation Evaluation

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ABSTRACT

A 4-year study of modern ground operations reveals patterns of personnel battle casualty rates strongly associated with patterns of operations. The research combines insights from military theory, history, and operations research to investigate a new and large body of empirical data on battle casualty rate behavior in modern operations. Findings include detailed and general rate characteristics associated qualitatively and quantitatively with major forms of operations. Findings suggest that current casualty estimation methodologies and contemporary simulations fail to represent significant empirically-indicated rate patterns, and further suggest the character and degree of the misrepresentation. Improved approaches are described both to casualty estimation (to evaluate estimates made by whatever method or to construct estimates) and to help validate simulation output of casualties. Operation Desert Storm is discussed in light of the study's insights into rate patterns. General implications for future casualty rate expectations are discussed.

GROUND FORCES BATTLE CASUALTY RATE PATTERNS
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INTRODUCTION

The Gulf War is taken by some to be the exemplar of the high end of plausible post-Cold War conventional conflicts. Whatever the truth of that view, one feature of the Gulf War is incontestably part of post-Cold War era. Casualty estimation rose from an important but essentially obscure planner's question to a matter of pivotal concern at the highest political and military levels. Before, casualty estimation addressed possible combat results, was conducted mainly to size potential resource needs, and was handled deep within the bureaucracy. From now on, casualty estimation will play a major role in first-order decisions on whether and how to wage operations.

Casualty estimation will remain an essentially obscure, technical undertaking conducted within the bureaucracy. Yet those who decide policy — senior civilians and military alike, to include commanders — must be able to distinguish reliable from unreliable estimates among the seemingly endless array of rate possibilities. Distinctions will need to be made between estimates that are worst-case but realistic, estimates that are represented as sensibly conservative (or even worst-case) but are in fact so high as to be operationally absurd, and estimates that while admittedly optimistic are operationally realistic and even probable.

This article outlines and elaborates on research, conducted principally during the period 1987 to 1991, into patterns of ground forces casualty rates for modern conventional operations.[1] The research originally aimed to provide decisionmakers the means to evaluate casualty estimates. It eventually also provided both a means for constructing estimates and a number of tests useful for helping to validate the casualty output of combat simulations (and, insofar as casualty output itself reflects on the validity of a simulation's working, useful for helping to validate the simulations themselves). The ground of these results is a set of insights into the behavior of casualty rates in patterns and the magnitudes of rates inherent in those patterns. Put differently, the ground of the results is a set of insights into certain distinctive relationships between the character of casualty rates in patterns and the character of the operations they reflect.

The article is in six parts:

- an introduction to and overview of the research, including its genesis, character, and general results;

•a review of the empirical evidence of ground forces casualty rates in modern operations, centered on the issue of the two general kinds of rate patterns discerned in that evidence;

•a statement of the research's basic findings regarding contemporary casualty estimates and casualty rates as portrayed in simulations;

•an overview of the approaches to casualty estimation and to simulation validation offered now through the research;

•a discussion of how the Desert Storm casualty experience compares with the rate patterns previously uncovered in the research; and

•an amended statement of findings given the Desert Storm experience and in light of the post-Cold War security environment.

The research may most generally be characterized as an attempt to learn how to evaluate the operational reasonableness of casualty rate projections or depictions in order that senior planners might *during the critical early planning period* reach appropriate policy and planning judgments. The time for rate reasonableness is not just moments before D-Day, when the inputs are finalized.

RESEARCH OVERVIEW: GENESIS, CHARACTER, GENERAL RESULTS

This introduction is unusually long because of the unusually broad compass this research eventually entailed. The research began with a straightforward practical concern of senior DoD planners, steered deeply into basic research in order to understand certain of the phenomena at issue, and finally returned to the practical surface with suggested insights and approaches to better responding to the concern. While that much is not especially noteworthy, what was uncommon was the kind and degree of the research's return, and constant reference during its conduct, to fundamental issues regarding the nature of modern ground operations, the need for a new and significantly expanded set of basic data with which to study that nature, and the need for a comprehensive approach to that study itself which rests on combining military theory and history, operations research, and comparisons of extensive sets of empirical and nonempirical data.

The character and results of the research, even in their barest outline, are best understood with a view first to the origins and early shaping of the research. Here and throughout the article, it has been necessary for reasons of space to limit the discussion to what amounts often to mere tastes of, or allusions to, matters that require and were given fuller treatment in the study.

Genesis

By late 1986 concern about the credibility of U.S. casualty estimates had risen appreciably in the Office of the Secretary of Defense (OSD). Two concerns predominated. First, it was felt that, at the very least, rate estimates needed consistency: the same scenario should result over time in generally similar rate projections. In particular, the Force Management and Personnel (FM&P) secretariat was increasingly dubious of fluctuations in rate projections for scenarious which themselves did not change substantially over time.

Second, the view in OSD was that rate estimates should probably be higher, perhaps significantly higher, than those then current. The then-Assistant Secretary for Reserve Affairs (RA), James Webb, had just become alarmed to learn on a trip to Europe that some of our NATO allies' estimates for ground forces in a NATO contingency were in critical respects quite different than U.S. estimates for its forces in the same general scenario. And there was concern at FM&P (as well as in the Army casualty estimation community) that the large simulation used by the Army to project casualties for general planning and programing purposes treated certain major categories of casualties inadequately, or in fact excluded them.

The Logistics Management Institute (LMI) was asked by OSD in early 1987 to evaluate the reasonableness of DoD casualty estimates. "Reasonable" was taken in a 'ballpark' sense: were estimates credibly consistent with their scenarios? were estimates' magnitudes credible in the most general sense, or should they be significantly higher or lower? etc. Initially, all major types of casualty estimate (i.e., estimates of both battle casualties and of disease and nonbattle injury casualties, in both conventional and NBC environments) for all services in all theaters were to be considered. After a several-month survey, the project's focus was instead agreed to be first on battle casualties only (those casualties killed-, wounded-, and captured/missing-in-action) for ground forces in a conventional setting in Europe. The project's sponsors became the Assistant Secretaries of Defense for FM&P, for Health Affairs (HA), and for RA. Soon, the Joint Staff also showed an active interest.

The scoping decision rested on a number of early findings. The perceived inconsistency of estimates was easily established. On the other hand, trouble arose on the question of the estimates' magnitudes. LMI found strong indications **both** that certain major estimates ought to be significantly higher and that those estimates ought perhaps instead to be significantly lower. The perceptions, that is, were correct that major categories of casualties were inadequately treated or ignored (in fact, the misrepresentation was significantly worse than had been perceived). However, other indications — many of them concerns within the military operations research community, and given prominence during MORS symposia in 1985-87, about the possible exaggerations of combat events (e.g., pace and intensity) by simulations[2] — strongly pointed to another, and contrary, possibility: that the overall base magnitude of the estimates was itself so substantially overstated that even when the inadequately represented casualties were added, the corrected estimates should still be significantly lower.

Related findings further complicated the problem of coming to grips with the estimates' reasonableness. Existing data sets were highly inconsistent in their formative purposes, assumptions, and methodologies. Moreover, they often provided "data" that was in fact already significantly aggregated. Finally, most available data were tactical in character, and seemed inappropriate taken alone to support (or even serve as a primary check on) operational-level casualty estimates.

What was abundantly clear was that, if the question of the estimates' reasonableness were to be persuasively answerable at all, a study of rates needed to be conducted that returned to and addressed fundamentals. A study that had begun as a survey with the intention of arriving at a derivative assessment of the reasonableness of casualty estimates soon revealed instead a requirement for a basic research project.

Character of Research

The study needed to address at least five fundamentals.

First Fundamental: ***Operational Perspective***. The overall perspective of the study needed to comprehend the operational level of war while not forsaking the tactical level or submerging it from view. The problem of casualty estimation for a Cold War scenario in Europe was clearly a problem at the operational level, not one primarily at the tactical level. On the other hand, the danger had to be avoided of submerging into the operational perspective (in essence, hiding) certain vital casualty events at the tactical level — the most intense casualty experiences, their character and probable locations and frequency within a force — that are (or should be) a particular concern to planners in both the medical and personnel replacements communities. Thus, the data for the study must provide sufficient kinds and amounts of detail to reflect each level of war clearly and also — critically — to tie the two levels together.

The dearth of operational-level data already alluded to above pointed to the second fundamental (see below) — the need for large amounts of new data. But something else also rose into view with the distinction of the operational and tactical perspectives. A theoretical question was whether operational-level events are merely the sum of their tactical parts or are in fact more than those parts and thus separable and distinct in some basic sense. For example, do tactical "engagements" or "battles" — which obviously can occur within either a strictly tactical setting or an operational setting — have somehow distinguishable features, at least in terms of casualty rates, based on the setting in which they occur? The possibility was seen that tactical events, while clearly retaining their tactical scope and its features in both environments, might in a strictly tactical setting tend, as it were, toward independence — while tactical events in an operational setting would assume a more dependent status within the larger whole. If that were the case, the larger whole itself — operations — would manifest its own distinctiveness.

Two implications of this theoretical concern were clear: tactical casualty rate events could not necessarily be compared adequately on a strictly one-to-one basis when drawn from the two different settings; and representations of casualty rates at the operational level might fail in some fundamental way if they were merely aggregates of tactical events treated in essence independently. The study's approach to developing data and to thinking about its meaning must be structured to elucidate if possible what might be significant casualty rate distinctions not only between the operational and tactical levels but, more precisely, between operations, tactical events within those operations, and strictly-tactical events.

<u>Second Fundamental:</u> ***<u>Need for New Data</u>***. In order to view casualty rate behaviors at both the operational and tactical levels, a new and large set of "raw" data was needed. The requirement for new data derived from the fact that the various then-extant data sets were found during the survey to be based on numerous, and usually incommensurate, assumptions and methods. Clearly, the data needed to be commensurate. Beyond that, most available data sets were strictly or primarily tactical; and those that offered operational perspectives were composed of "data" that were either aggregated to near-uselessness or of quite dubious quality. A new data set constructed of commensurate 'bits' would, if it covered operational-level as well as tactical events, need to be large as well as new.

Based on theoretical considerations introduced above and further elaborated below (see Third and Fourth Fundamentals), it was sensed that a large data set properly conceived and constructed might reveal a deeper consistency among casualty rates. The many and disparate data sets then available had done little to reveal any such deeper consistency. What consistency had been observed was based on tactical events plus the apparent view that what was seen tactically was essentially paralleled operationally; at the same time, it was not uncommon for some observers to suspect that, given the different 'takes' on existing data offered by different analysts, casualty data perhaps merely suggested clutter rather than consistency.

Third Fundamental: ***Need for Empirical Basis***. The new data must be empirical. The difficulties in collecting valid empirical data were well known; however, they paled next to the difficulties inherent in the attempt to rely on data produced artificially, through one or another form of speculation — foremost among which, these days, would be simulation results.

The study was grounded in the view that casualty rates are so complex in their generation, and that we know so little of the actual relationships of the many dependent variables involved in their generation, that the only reliable sense of them is gained from their actual occurrence. Of course, the only genuine source of data on actual casualty occurrence is the historical record. The distant-second best source is in the form of realistic field exercises — not, obviously, in the sense of actual casualty occurrence but, insofar as an exercise is structured to provide a relatively realistic interaction of many of the dependent variables involved in actual casualty occurrence, in the sense at least of a check on the historical record.

A comment is appropriate on why the word "empirical" is used to describe the new data to be gathered, rather than merely "historical" and "exercise." Most completely put, empirical is used because it is believed that, if properly conceived and collected, the data will be direct evidence, in the sense of a close image, of the phenomenon of modern ground combat dynamics which is actual and takes the form of a whole that is seen episodically in history. That is, certain data 'rightly understood' are not primarily mere discrete records of what happened in this or that particular instance, and therefore merely dated accounts with only some antiquarian basis of interest. (To be sure, data from actual events in history and exercises can, and will, amount only to records of particulars if not conceived and collected properly.) Instead, proper data will immediately and concretely reflect the character of the underlying dynamics of modern ground combat operations. This sense is of course premised on the view that the ***nature*** of those combat dynamics — so to speak, the "look" of the dynamics of modern conventional ground operations — is itself essentially unchanged (as opposed to the manner or ways they are achieved or manifested, for example, as technology develops), at least for the set of operations we properly describe as modern.

Fourth Fundamental: ***The Phenomenon***. The most fundamental issue to be addressed was the basic nature or shape of the phenomenon in fact most at issue (even though it is so often treated or assumed merely as being the derivative or sum of other lesser events) in a study of casualty rates: the dynamics of modern ground operations.

This thorniest of difficulties surfaced early in the study with, as described above, the problems of incommensurate data sets. At bottom, a major reason for the very existence of the different sets, and for the perplexing ease with which analysts so often seemed to ignore the sets' differences, was that various studies of casualty rates had ultimately if unintentionally compared operational 'apples and oranges.' There seemed to be a forgetfulness at work, or an ignoring, of the kind and quality of operational phenomenon that most fundamentally gives rise to casualty numbers. Far from being simply an aggregation of the effects of separate material interactions in combat, the phenomenon most fundamentally at issue in casualty rates was seen to be a dynamic at work with its own shape and "anatomy."

Without commenting further here on this difficult and elusive topic of the nature of modern ground combat dynamics, the judgment was made early in the study that an approach was possible that suggests that nature in a relatively straightforward and helpful way. The approach was to try to capture visually the notional form of casualty rate experience in conventional ground operations. If such a form could be shown, it would serve to shape the study of casualty rates.

Note. The measure of rates used in this discussion is: Total Battle Casualties (TBC) per 1000 division-level personnel per Day (or TBC/1000/Day).

Figure 1 depicts the concept underlying the study's approach to ground forces casualty rates, thus to the collection and analysis of empirical evidence of their occurrence.

Figure 1 HERE

The notional pattern suggests, first, that for any given force there will be one or more sectors along its 'front' where casualties are highest at a particular time. Those sectors are the principal areas where one opponent attacks the other. To the flanks of such sectors will be areas of lower rates at that same time. Next, no matter whether one looks at the attack sector(s) or the flank sectors, casualty rates will vary over time in some way. Taking both points together, then, there will be *pulses* of rates evident on two axes, along the front and over time. The fact of pulses indicates the corresponding fact of some degree of *variability* in rates. This variability will also exist across the front and over time. Finally, returning to the question of the particular force involved, the characteristics of these pulses and variation of rates will differ across the several echelons. A single division's rate pulses and variations should look different in some way from those of an army group or of a battalion.

This perspective was judged to be the only proper basic guide for both the assemblage and the analysis of data reflecting the shape of the phenomenon of combat dynamics.

<u>Fifth Fundamental: ***Methodology***</u>. Finally, it was clear that standard methodologies would not, by themselves, be adequate to treat of casualty rates in light of the fundamentals that must guide the study. An appropriate approach to the problem needed to draw on insights from several parts of the methodological world and meld them into a single whole suited to the subject.

The basic requirement of the different approach was that it should, as it were, permit the shape of the basic combat phenomenon behind casualty rates to show itself through the rates — rather than impose on the phenomenon, through treatment of the rates, a character taken from the assumptions or perspectives underlying the methodological tools themselves. Data that were empirical must be permitted to "speak for themselves" while the observer remained open to whatever was "said." Thus, fundamental methodological concerns were at stake all the way from selection of the kinds and scopes of operations to be studied, to selection and collection and arraying of the data on those operations, to selection of methods for portraying the data quantitatively and approaches to considering it qualitatively.

The approach to the subject eventually combined insights from military *theory* and *history* and *operations research*. (It drew as well, as may be evident from the previous discussion, on certain themes in the history of philosophy to help shape that combination.) However, an intentional key to the approach was that it always remain true to straightforward, simple, and uncontroversial insights into the shape and structure of military operations.

The notional pattern of casualty rates expressed in Figure 1 was to be used as the organizing framework for the set of empirical data structured to display both broad fronts over long time periods and the operational details contained within those extensive experiences. The very simplicity of the military sense of the notional pattern was intended to guide consideration of the entire set of experiences without prejudice to whatever results might be forthcoming — as actual casualty rates displaced the notional pattern with a real-world picture of the overall shape and relative features of specific behaviors in rate dynamics.

A set of *three interlinked operational parameters*, already suggested in the notional graphic of rate patterns, was laid out as the key for the attempt to find whatever actual patterns might exist in the empirical evidence of casualty rates. Most generally put, those parameters were: (1) the force's size and composition by echelons; (2) the time period(s) considered; and (3) the overall operational scenario and its set of force mission/posture sectors as they evolve over the operation.

The set of parameters was a rough way to maintain a constant view of the 3-dimensional character of rates as they form an image of the combat dynamics of unfolding operations. In a sense, the set of parameters served a role in the attempt to make sense of the seemingly myriad and confusing bits of casualty rate data similar to the role played for operations planners by the Army's "METT-T" concept. And, in fact, rates did begin to make sense.

General Research Results

The more precise expression of the study's key concern — are casualty estimates reasonable? — was eventually judged to be: are projected casualty rates congruent with the operations they are purported to represent? The answer was eventually judged to rest in whether there are patterns of rates associated in some way systematically with operations such that a general but nevertheless articulated, and nonarbitrary, description of an operation will persuasively invoke a set of rate characteristics.

Two major issues were therefore judged early to be the necessary guides to the study of empirical data on modern conventional ground operations:

- Are there **patterns** of casualty rates strongly and persistently associated with kinds or patterns of operations which themselves persist?
- Does the empirical evidence support the widely held view that the **magnitude** of rates for modern operations is higher today, whatever the evidence on rate patterns, than previously?

The relationship of the two issues — of rate patterns and of rate magnitude — was critical. If (1) there were patterns of rates that persisted over time for modern conventional operations and (2) rate magnitudes for combat experiences at comparable spots within those patterns could be compared, then rate projections could be evaluated in terms of those patterns, adjusted as necessary for higher or lower rates according to evidence about rate magnitude.

The key to finding patterns and to measuring magnitudes would be to distinguish operational qualities using the interlinked operational parameters described above, and thus to reach the ability to compare likes to likes within the structure and flow of numerous actual operations.

Well before 1991, the study had clearly established both that patterns of rates do indeed exist for modern conventional ground operations and that the available empirical evidence does not support the view that rates for comparable conventional operational events have increased significantly since 1945.

__Rate Patterns__. Two kinds of patterns were found. The first kind was gleaned from observations of detailed (daily) rate behavior. The most general of these observations was that rates occur in pulses generally separated by relative pauses, and with a variability that can be dramatic even during periods of intense combat. Such general behavior was observed to occur, in essence, regardless of mission and posture. Various quantitative measures of these detailed rate behaviors revealed a series, or set of patterns, of relationships between rates and certain operational parameters. This first kind of rate pattern, which appeared to describe certain elemental behaviors present in at least some fashion in all operations, was termed "***underlying quantitative rate patterns***." Second, certain basic patterns (and even portions) of operations were observed to be closely associated with certain general ranges and characteristics of rates for at least relatively large forces. This second kind of rate pattern — literally, patterns of rates associated with patterns of operations — was termed, for brevity, "***rate patterns of operations***."

Rate Magnitude. The available empirical evidence of rates, even viewed conservatively, did not support the widely held view that personnel casualty rates have increased for comparable operational events with increases in weapons effectiveness.

Uses of the Research. The rate patterns and characteristics eventually established provide the basis for either evaluation or construction of casualty rate projections. They are, likewise, useful for evaluating the validity of simulation output as regards personnel casualty rates.

Most generally stated, the research enables planners or analysts — and senior decisionmakers, including commanders — to relate casualty rates to operations in ways that permit judgment of projected rates' reasonableness given the operation. Put differently, a rate projection may now be used to infer what kind and result of operation should reasonably have been its source — and, if learning that such an operation and result were not in fact used in the projection, knowledge of what operation and result were intended will now suggest the general characteristics of rates that ought to be associated with them.

It was found that representations of operational-level casualty rates, whether in the general form of official planning estimates or in the detailed output of simulations, almost entirely misrepresented the kinds of operations and results planners or analysts had attempted to represent.

THE EMPIRICAL EVIDENCE

This section first describes the research's general approach to studying and developing casualty rate data, and then describes what the data suggested as regards the two basic issues of rate patterns and magnitude.

General Approach

The study of data was structured with three reference points: rates from actual combat; rates from field exercises; rates as projected in the various casualty estimation methodologies. The first two taken together formed the set of empirical data, the heart of the study. Of course, the combat data were the only ones actually used for determining operational rate patterns and characteristics. The exercise rate results (which alone among the empirical data purported to show results between U.S. and Soviet-style forces using contemporary equipment and methods) were used only as a check for rate magnitude comparisons against comparable operational experiences from the set of actual combat data. The rate patterns thus established from the actual record of combat, and adjusted if necessary to reflect any evidence of significant magnitude shifts, were then to be compared to rates as depicted in casualty estimates.

In essence, always orienting by the interlinked operational parameters, the study sought to collect detailed casualty rate data and then match it to the course of actual operational events by overlaying it onto — in order to achieve a visual casualty rate picture of — the daily progress of organizations and units. The swath of events across broad frontages and long time periods was matched with casualty rate data for the major engaged echelons (multiple army groups down to divisions) and with operational maps depicting daily movements to division level. Within this broad horizon of events, "postholes" were 'sunk' in the form of detailed looks at particular battles — the "hot-spots" — in order to see the detailed structure of rates at those nodes, across the area and from high (up to army groups) to low (where possible, down to battalion). The postholes examined in the West ranged from true operational-level events, such as the entire Ardennes operation of 1944-45, to tactical-level events of corps- and division-size (or smaller) units. The postholes examined in the East were uniformly at the operational level, as presented in superb detail (with daily map depictions of events down to division and sometimes even regimental level) by the U.S. Army's Soviet Army Studies Office at Ft. Leavenworth.[3] The intent was to observe both the overall shape of the flow of casualty rates, and the nested details, across entire theaters and forces — in a sense, a "casualty topography."

Figure 2A/2B/2C, a series of three related maps, represents the kind of detailed tracking of operations undertaken for the set of

Eastern Front postholes. A daily look at the full operational-level picture was consulted (as in Fig. 2A). Operational main and supporting attack axes and sectors, and the related fixing and quiet sectors, were then also traced by day — at least to division level and, at critical nodes along tactical axes, to regimental level. Figures 2B and 2C depict events in an enlarged view of the operational main attack sector marked on 2A. The same general approach, using G-3 and G-2 operations maps (to division level), was performed for the Western experience. Again, the premium was on overlaying casualty rate data on the shape and structure of the operations as they evolved.

Figure 2A/B/C HERE

Without elaborating here why, the single day was taken to be the best measure of a "true" rate to be studied; only genuine single-day rates were used to support formal statistical analysis. Where data were available only for multiday periods — for example, most of the German data were available only in 10-day time periods — care was taken to ensure that operational "likes" from those experiences were correctly compared to operational "likes" from those other experiences where daily data were available (arranged to show 10-day moving average slices for these comparisons).

<u>Data: What Collected?</u>

Two of the three data reference points — historical data and field exercise data — formed the empirical record of rates used to address the two basic issues of patterns and magnitude. Patterns of rates were mainly addressed using the extensive World War II data, while data from the Korean War and the several Arab-Israeli wars were used (supported by the later field exercise data, described below) mainly to test for any significant rate increases for comparable operational events.

The Historical Data

Actual combat data were drawn from conventional operations in World War II, the Korea War, and the Arab-Israeli wars. (Note: reported data from Operation Desert Storm were later compared; see pp. 31 to 33 below.)

The data from WWII covered: (1) the entire Allied Western Front experience and the entire U.S. experience in Italy — by division (and grouped also by higher echelons) by day; (2) 26 major actions to serve as postholes within those two theaters and in North Africa (and, also, to represent both amphibious and Pacific island combat), the attempt in every case being to collect daily data on each participating echelon to (if possible) the battalion level; and (3) a major portion of the German experience, in all theaters but especially against Soviet operational practices and focused on some 15 major operations along the Eastern Front. The data were taken from original records archived in Washington, London, and Germany.

The amount of data collected was large. A sense of the amounts collected for broad fronts and long time periods can be gained from the U.S. data alone from the Western Front: 8,297 division-days; 2,222 corps-days, 804 army-days, and 212 army group-days — representing a force that grew to four field armies, 12 corps, and over 50 divisions covering some nine months of combat. Further, virtually the entire British experience on the Western Front (from Normandy through the Bulge period) was collected on the same basis. Finally, the collected German data covered more than 270 divisions (organized by corps and higher echelons) in 5,399 10-day blocks of data, plus data for other varying time periods, covering four years of war.

Posthole data from the Western Allies involved 72 divisions and yielded 386 division-days, 468 regimental[brigade]-days, and 531 battalion-days. German posthole data, inevitably less extensive and detailed, was nevertheless rich in representing the experience of units (in defense and on offense) in even the most intense Soviet main attack sectors, as well as in supporting attack and related sectors. Direct comparisons, in terms of the interlinked three operational parameters, were possible between Western Allied experience on offense and defense and German experience facing Soviet operational methods.

The Korean War data were taken from the Reister study, which had grouped the data in some 83 major actions. Only two of the actions provided data in a form appropriate for formal statistical treatment; thus only informal comparisons with WWII data were possible. (The effort to collect original daily unit data was abandoned when it was learned that around 1980 the Army had literally thrown away its previously, and carefully, collected set of such data.)

The Middle East data were from the Dupuy database. The 1967 and 1973 wars were deemed the most suitable for use. Of 52 battles, 37 were in the appropriate form (1-division/1-day) for formal statistical use while the others could be compared informally. The sample from WWII used in formal comparisons consisted of 122 1-division/1-day rate values drawn from U.S. experience on the Western

Front deemed roughly comparable operationally (i.e., in terms of the three parameters) to the Middle East events.

The Field Exercise Data

The collection of field exercise data covered the full set of U.S. Army National Training Center exercises conducted in 1985 through 1988. A sample of 139 battalion-level engagements was drawn from over 300 collected. The sample was balanced as to posture and unit types (mechanized versus armor, modernized versus nonmodernized, Blue versus Red). The sample from WWII used for formal comparisons consisted of 51 1-battalion/1-day rate values (out of the 531 collected overall), again deemed roughly comparable operationally to those represented in the NTC scenario.

The Two Kinds of Rate Patterns

The study's first major issue was whether the empirical evidence provided any indications of patterns of casualty rates for modern conventional ground operations, that is, of rate patterns common to all such operations. The finding was strongly in the affirmative.

The patterns of rates uncovered were, as suggested above, of two kinds: underlying quantitative rate patterns and rate patterns of operations. Each kind included more than one form. The feature common to the two kinds, and their forms, was the fact of what was termed rate pulses and pauses.

Rate Pulses and Pauses

The simplest statement of the occurrence of casualty rates is that they occur in stoccata fashion, with relatively higher rates separated by relatively lower rates. The higher rates, or rate "pulses," can and often do occur in clusters; but even a cluster of pulses [the cluster itself assumes the form of an overall pulse] can and often does contain relatively lower rates. Certainly, individual rate pulses (and clusters) are separated by relatively lower rate events. We termed these lower rate events "pauses" simply because they were initially measured over time (given that rate data are associated with and tracked most readily by individual organizations or units). It is critical, however, that neither pulses nor pauses be thought of only in temporal terms; they exist as well in a lateral (more generally, a spatial) sense. Taken together, the time and spatial dimensions in the data describe the volumetric sense first depicted in the notional casualty rate pattern in Figure 1.

Figure 3 HERE

Figures 3 and 4 illustrate actual rate pulses and pauses over time for different sized formations. Relatively dramatic variability in rates was expected for the smaller units. And indeed, brigades and battalions (not shown) exhibited still more dramatic rate pulses and pauses than divisions (such as the one shown). But it was especially interesting that even a force as large as an army (usually composed daily of from 10 to 15 divisions) illustrated fairly dramatic differences between daily rates, even during periods (seen more readily when a 10-day moving average rate is superimposed over the daily data) of intense combat.

Figure 4 HERE

Underlying Quantitative Rate Patterns

Daily rates were amenable to several quantitative displays or measures each of which presented an aspect-perspective on rate behavior and its constitutive pulses and pauses. Among the most prominent were: rate duration, rate variability, rate dispersion (skewness), and rate frequency.

For the sake of space, these four underlying quantitative patterns of *empirical* rates are represented later in this article (see Figures 12A, 13, 14A, and 15A), where they are contrasted to the comparable representations (Figures 12B, 13, 14B, and 15B) of the underlying patterns as produced in a *simulation*.

Some key observations on rate behavior in terms of the several quantitative measures of rates may be summarized as follows.

•*Rate Duration* (see Fig. 12A): the higher the magnitude of a rate, the shorter its duration; or, high rates are shortlived phenomena for any given combat experience. The number of consecutive days that rates tend to persist in the higher rate classes is quite low; in fact, the curve showing the relationship of rate class to consecutive days in rate class was nearly a negative exponential curve.

•*Rate Variability* (see Fig. 13, empirical data): the higher an average (mean) rate for a unit or organization over a given (significant but limited) number of days measured (we used 10 days), the greater will be the variability among the individual daily rates within the set of daily rates for that period. A highly useful measure of that rate variability is the standard deviation of the set of daily rates about the set's mean rate for the period, displayed in standard "x-bar, sigma" form. This relationship of variability to mean may be shown for different-sized forces (e.g., division or corps or army).

•*Rate Dispersion* (*Skewness* — see Fig. 14A): on any given day with intense combat for a given force, the force's overall rate will exhibit a dispersion of component major subunit rate experiences showing significant skewness: the difference between the median and maximum rates will far exceed the difference between the median and minimum rates.

•*Rate Frequency* (see Fig. 15A): the freqency of high-rate tactical events across an operational-level force, as a proportion of the force's tactical events, does not increase with an increase in the force's size; in fact, the frequency as a proportion generally declines as the force grows.

Summary of Underlying Quantitative Rate Patterns. As will be discussed further immediately below, such detailed quantitative patterns were initially thought to be by themselves heavily (if not wholly) explanatory of rate behavior. While that thought was premature (and was later amended to encompass primarily the rate behavior in one of two major kinds of operational scenario, plus a part of the rate behavior of the second scenario kind), these detailed rate patterns not only remain quite useful (as shown below) within a narrowed horizon; they also afford a view of what may be a critical rate pattern shift that suggests the operational nexus (a la breakpoint analysis) between the two forms of patterns of operations described below.

Figure 5 illustrates what was found to be the principal shift of detailed (division-day) rate experiences in an operational force when moving from a characteristic major offensive to a characteristic major defensive operation: the incidence of moderate rate events declines as a proportion of the whole set of events; but the 'movement' of rate events is to *both* extremes, to the low-rate as well as the high-rate arenas.

Figure 5 HERE

The shift shown in Figure 5 helps to explain both the skewness of rate experiences that is so fundamental to all operations (i.e., present in offensives and even more present in defensives) ***and*** the rate pattern distinctions described below as being most fundamentally associated with the two basic forms of operational scenarios ("continuous" versus "disrupted" fronts). At the appropriate point in the following discussion (at "The Two Scenarios' Distinctive Operational Features," p. 21), Figure 5 will be referenced again: the shift of rates to the extremes comes into play as the pivot of the scenarios' differences.

Rate Patterns of Operations

It was clear from the outset that the quantitative patterns just outlined would be extremely useful in explaining rate behavior, and thus in helping to critique the reasonableness of the character of rate projections. For example, it was immediately clear that the patterns were sufficiently clear and based on sufficient detail as to be highly useful for evaluating any body of rate data with comparable detail that could be portrayed in comparable ways: the obvious example being simulation output. However, a problem with the quantitative patterns arose from the very detail that made them otherwise so useful: planners do not normally deal with such detail, either in constructing rate projections or in evaluating projections made by others. Further, despite the excitement associated with the obvious usefulness of the quantitative patterns, it became increasingly evident that the problem normal planners might have with their detail was not their only limitation.

It became increasingly evident that the quantitative patterns depended on something else — as it were, something behind them. A deeper, more comprehensive kind of pattern was at work, and eventually also came to view.

The more straightforward aspects of that deeper pattern had always been both close at hand and considered useful — even if they were not originally suspected to be aspects of any deeper pattern. These aspects included the kinds of parameters that operations planners typically use to set their bearing: such as offensive versus defensive postures, and the kinds of missions (e.g., main versus supporting attacks, etc.) and thus sector types (in a linear or nonlinear sense) comprising operations. Of course, each combatant force needed to be considered in such terms in relation to its opponent. We initially summarized these terms by referring to the 'sector types' involved in projected operations.

Two more layers of the analysis were needed before the full deeper pattern, the second kind of pattern, was evident. First, the relationships of the various sector types were, of course, dependent on the overall scheme of maneuver projected, which defined the sectors (even for both combatants) in accordance with the operation's dynamics. That much was straightforward. But it was not until fairly well along in the research that sufficient looks at casualty experience data revealed, second, the pivotal roles of breakthrough and (even moreso) of encirclement/overrun events and a relationship between them beyond the obvious one. Where such events had previously been viewed as extremes or edges of possible casualty rate experience (for the defenders experiencing them), they came to be seen as central to a larger structure of operational patterns by unveiling another pattern dimension.

This deeper dimension rested ultimately in the defender's experience: whether the attacker was able to so break the defender's cohesion as to be able to send operational-level forces into the defender's rear areas before the defender could reestablish his defensive cohesion. If so, a casualty rate picture emerged that was distinctively different from that seen where defender cohesion was not broken. Comparison of the two broad operational circumstances in turn brought into focus the larger structure of patterns.

What emerged was a fundamental distinction between what were termed "continuous front" and "disrupted front" operational scenarios. The heart of the distinction lay in the relationship between (1) the attacking force's *energy* (as seen in force speed and power) and *form* (maneuver scheme and flow, if successful, to defender depths) and (2) the status of the defender's operational cohesion (in essence, the status of his energy and form) in resistance to the attack. Specifically, the two fundamental operational scenario types perceived were:

- **Continuous front scenarios**: the defender is able to maintain his defensive cohesion. Despite, in the worst case, what may be serious and deep attacker tactical penetrations, even causing significant defender withdrawals and confusion, the defender is still able to restore defensive cohesion before the attacker can penetrate and exploit energetically with operational-level forces.
- **Disrupted front scenarios**: the defender's cohesion is broken at least temporarily by the attacker's ability to penetrate the defense (usually by creating significant gaps) with operational-level forces. The more successful of such operations (the higher-order ones) also show the attacking forces exploiting the penetration(s) with catastrophic encirclements or overruns of additional, significant portions of the defensive force. Four levels (orders) of Disruption were eventually isolated, measured in terms of increasingly larger

portions of the defensive force catastrophically encircled or overrun (mainly in the operation's exploitation phase).

Several rate characteristics were found to be associated with the two general scenarios.

•*Ranges of rate magnitude* (again, for space reasons, reference is made to the left and center panels of Fig. 17): While both scenarios of course showed losing defender rates higher than successful attacker rates, the data also indicated that at the operational level the old (and, as it now appears, tactically-derived) rule of thumb of a 2-to-1 ratio of defender-to-attacker rates did not hold: for continuous front settings, worst-case attacker rates were nearly as high as worst-case defender rates; on the other hand, disrupted fronts distinctly showed a significantly increasing ratio of defender-to-attacker rates as the attacker more and more successfully combined energy and form of attack to reach defender depths with speed and power.[4] (*Note:* Fig. 17 reduces to one graphic sets of rate range information that the study shows in much greater detail — for forces in different postures and sector types both in disrupted front settings and, with greater articulation, in continuous front settings.) [It is also worth noting that the evidence showed — contrary, in part, to some traditional observations — that as FLOT movement increased, attacker TBC rates generally declined while defender rates generally increased. This observation must immediately be qualified by turning to the next subsection and its discussion (including Note 5) of shifting proportions of major casualty categories.]

•*Casualty types (KIA, WIA, MCIA) as proportions of TBC*: The other most notable feature of defender rates in disrupted fronts, in addition to their often soaring magnitude, was their significantly altered composition in terms of major casualty types as proportions of total battle casualties. First, the WIA/TBC ratio underwent a dramatic downward shift as compared, for example, to the ratio seen consistently for forces on the offensive in continuous front settings (which, as it turned out, had been the longstanding basis of U.S. and British casualty data). Where a continuous front offensive force would see WIA at a steady 70-80 percent of TBC, the higher-order disrupted fronts witnessed WIA at below 20 percent — and as the severity of these experiences increased, the data suggested something well below 20 percent. Second, the offsetting dramatic upward shift in KCMIA casualties as a proportion of TBC appeared in fact to be comprised mainly of missing-and-captured casualties, not of KIA. That is, the evidence was that while the proportion of WIAs dropped, the ratio of WIA:KIA did not change appreciably. In other words, the skyrocketing defender TBC rate was comprised mainly of

MCIA casualties.[5] It was of course significant that this major shift in casualty proportions (with MCIA offsetting and outdistancing KWIA) was indicated as well in what were termed 'worst-case' continuous front defensives, where the defender's cohesion was stretched to breaking. There, the WIA/TBC ratio was observed to drop to around 30-40 percent at the operational (army-size force) level.[6]

Figure 6 HERE

•*The two scenarios' distinctive operational features*: The data made clear, contrary to expections, that rates experienced in main attack breakthrough sectors, and indeed in the other major sector types (secondary attack, fixed, quiet), did not differ substantially between disrupted and continuous front settings (and, more specifically, between experience against Soviet and German or Western methods). The real operational basis of the distinction between the two scenarios was found in (1) the ability of the attacker to turn breakthrough main attack efforts into significant penetrations but, even moreso, in (2) the ability of the attacker to exploit those penetrations with operational-level forces to effect catastrophic encirclements or overruns of defenders (an effect that was aided of course by the number of successful penetrations). Thus, the decisive operational differences in the two scenarios were not found in the types of sectors along a front, or even in the rate experiences of defenders and attackers in those sectors — generally, up to the close of the breakthrough phase of an offensive. The primary differences arose in the exploitation phase if the attacking force was able, largely due to its deep-reaching and fast-moving operational formations, to effect catastrophic encirclements or overruns.

We may now refer again to Figure 5 above with more meaning. What seems to be involved in the scenario-shift from continuous to disrupted fronts may be explained in terms of the figure's depicted shifting 'mass' of rate experiences. As the shift of rates to the extremes marks the greater but nonfatal tension in a force in a continuous front scenario, so the disrupted front defender's fatal experience is marked by the attacker's ability to reach through the narrow but significant high-rate defender sectors (which become gaps) to the expanded *low-rate* (and, but less so, the moderate-rate) arena of defender units and to catastrophically encircle or overrun them.

Thus also, it becomes clearer how the underlying rate patterns may and may not be invoked. The details found in the underlying quantitative rate patterns are directly useful in critiquing representations of continuous front scenarios. And, while they are not immediately and fully representative of what occurs in disrupted front scenarios across the full force and experience, they do suggest the character of a significant portion of casualty rate events even there — again, generally up to the point of breakthrough.[7]

Summary of Rate Patterns of Operations. The analytic result of these observations was to establish far more concretely, and to articulate far more fully, the relationship between major patterns of rate characteristics and the major forms of modern conventional ground operations.

While this article's scope does not permit an adequate discussion of the analysis, the conclusion was reached on theoretical-doctrinal-structural grounds that the essential patterns of operational dynamics in modern ground war have not changed appreciably since 1945. The judgment was that, although the means have been partially altered, what may be termed the decisive formative dynamics of modern ground operations are illustrated clearly and instructively in exemplar operations in WWII.

Thus, the proper focus for casualty rate planners or analysts was seen to be on taking the force size and echelonment (configuration for operations) and then characterizing the force's major plausible operational prospects: using the general offensive or defensive projected scheme of maneuver as the initial framework, planners must assess the kinds, numbers and force compositions of the major operational sectors, and then track the plausible flows of general operational results along the several major axes; but the boundary framework for the analysis was found in characterizing the operation ultimately in terms of an overall projected scenario, whether that be a continuous or disrupted (and, for the latter, whether a low- or high-order) front. (Of course, these judgments would depend directly and heavily on input from the operations and intelligence portions of the planning staff as to "correlations of forces" and articulation of major possible schemes of maneuver and outcomes — an input to the rate projection process which, it must unfortunately be admitted, is usually refused or deflected, speaking practically, by the operations and intelligence communities.) The patterns of rates associated with such patterns of operations are strongly suggested in the empirical evidence: ranges of average rates, distributions of component rates within those averages, proportions of major casualty types for those averages and distributions, etc. Such rate-operations relationships being acceptably clear, the planner's or analyst's task becomes one of assembling the pieces as they suit the major plausible operationally-coherent wholes that are projected.

The other major research issue — rate magnitude (addressed next) — was concerned with the levels at which the rates associated with patterns of operations should be set.

Comparison of Rate Magnitudes

The second major issue in the study was whether the empirical evidence supported the view that casualty rates have risen significantly. The benchmark was World War II. The comparison periods were the Korean War, the Arab-Israeli Wars, and experience at the U.S. Army's National Training Center. The concept was to test at "hot spots" for evidence of any significant rate increases.

Data from the Korean War were not available in a form that would permit formal statistical comparison of that war to comparable evidence from World War II. The only comparisons possible were informal ones made on practical grounds after grouping similar sets of experiences. In all cases, the Korean data were no higher than the WWII data, and in most cases they were significantly lower.

The Arab-Israeli and NTC data permitted formal statistical comparison with the WWII data. Space prohibits a full discussion of the theoretical and other basic considerations behind the statistical approach used: the issue of populations versus samples, the tests appropriate to each, the hypotheses to be tested, the interpretations of results, etc. These are, of course, discussed in the study.

Still, two of these matters should be mentioned. First, in the case of each comparison, a subset of the World War II data was selected that was judged to be suitable for comparison with the more recent data sets. That is, the character of the later data sets — those sets' force sizes-echelons/time/scenario-sector characteristics — was the determinative factor in selecting appropriate WWII data subsets from the far-larger WWII overall experience. Second, the approach to the comparisons was conservative: the issue assessed was simply whether the more recent rates were significantly higher than the WWII data. This conservative approach was chosen so that, when the rate patterns were eventually employed to evaluate the reasonableness of projected rates, they would be at rate magnitudes at least as high as the WWII data rather than lower, so as to be as forgiving as possible of the projected rates.

The two sets of compared data are illustrated in Figures 7A/B and 8A/B. (The study provides comparison sets of histograms, survivor curves, and Tukey-style box plots, and the formal tests of hypotheses about the data, for each of the two comparisons.) For practical purposes, the differences between the later data (Middle East or NTC) and the earlier data (WWII) are negligible. The evidence was overwhelming that the empirical evidence does not support the view that casualty rates for ground forces — given roughly comparable experiences in terms of the three linked operational parameter groupings — have risen significantly over time for modern conventional operations.[8] (In fact, there were strong indicators pointing to the probability that rates for comparable experiences have fallen. But, in the context of the need to appraise the numerous planning projections for a "World War III"-size event, all of which projected rates higher than any empirical evidence appeared capable of supporting, a conservative approach was indicated and this possibility was not pursued.)

Figures 7A and 7B HERE
Figures 8A and 8B HERE

STUDY FINDINGS

This section focuses on findings in terms of rates patterns of operations. Rate patterns of operations are the principal concern of evaluations of casualty estimates, and of attempts to construct such estimates. (Once again for space reasons, observations about underlying quantitative patterns of rates — which largely help to account for the rate patterns of operations found in projections or estimates based on mathematical simulations — are left to a brief illustrative set of contrasts below under "[Better] Approaches to Validating Simulation Output," pp. 29-31.)

The study reached four general findings about casualty rate projections:

- Peak rates for operational-level forces were always too high for the scenario depicted;
- Peak rates for tactical-level forces were often too low for the scenario depicted;
- Peak rates did not reflect the significant shift downward in the ratio of WIA to TBC casualties that should be seen in certain depicted operational circumstances; and
- Rates over full planning time lines exhibited only single peak periods rather than the multiple peaks that ought to be seen.

Two common analytic failures were:

•Failure to distinguish between continuous-front and disrupted-front operational scenarios, and to look for the key distinguishing rate features of each; and

•Failure to consider adequately the effects on rates of force size and echelonment (configuration for operations), of the time period of rate measurement, and of the overall scheme of offensive or defensive maneuver (specifically noting its component operational sectors) and *its evolvement* into one of the two key overall operational scenarios.

The **magnitude** of the overstated operational-level peak rates was impressive. For example, the rate for the U.S. army-size force in Europe was judged to be about *twice* too high for the peak 10-day period given the kind of operational experience represented by planners along the projected time line. Bad as that was, the comparable rate for the full NATO force, once all nations' estimates were laid side-by-side, was as much as *four times* too high for its peak 10-day period — and nearly *two-and-one-half times* too high even if judged most conservatively for the overall planning scenario assumed by NATO planners.

Such overstatements were driving plans for sizing the overall medical force structure and flow of personnel replacements. Yet the only operational setting that the empirical evidence showed could possibly support such projected rates was a failed defensive in a higher-order Disrupted Front. The overstated casualty rates amounted in fact, in the peak month along the time lines, to tens of thousands of divisional personnel shown as casualties who ought to have been shown as trained personnel still on duty.

Nevertheless, peak tactical rates envisioned in the planning process were too low. For example, the U.S. peak corps 10-day rate ought to have been *over twice* higher than that projected by theater planners responsible for sizing the tactical-to-theater portion of the medical force structure and the in-theater personnel replacements flow. Worse still, no planners anywhere along the line had visibility on the truly daunting magnitude of probable maximum division-level rates, and their brigade/battalion component rates, that ought to be expected at the tactical "hot spots" within their larger operational-level planning horizons. With their planned peak 10-day corps rates already decidedly too low, there was no inkling in the planning process that a single division at the focal point of attack could expect a 1-day rate within a peak 10-day period corps experience some *5-to-15 times higher* than a *corrected* (i.e., higher) version of the corps 10-day rate.

On the other side of the ledger, official projections neither acknowledged the significant downward shift of WIA casualties as a proportion of the overall TBC rate during certain anticipated defensive peak experiences, nor included the multiple peaks that ought to be seen over a long planning time line such as those typically prepared for European and other scenarios.

Figures 9 and 10 graphically depict certain of these problems. Fig. 9 displays the highest 10-day peaks seen empirically for army-size forces on the offensive and defensive in a continuous-front scenario (left panel), and contrasts one simulation's depiction of such a force over a 60-day time line (right panel). Two features are notable: (1) where the empirical evidence shows 10-day peaks separated by multiday intervals at lesser rates (pauses), the simulation shows what (by virtue of their magnitudes) ought to be peaks as occurring back-to-back for the full 60 days; and (2) the magnitudes of these 10-day rates in the simulation output have not been experienced by army-size forces in continuous-front scenarios (which the simulation was supposed to represent) but only in severe disrupted-front experiences.

Figure 9 HERE

Fig. 10 then displays the simulation's output seen laterally across the full NATO force (for both the high- and low-rate 10-day periods within the 60-day time line) in contrast to a comparable actual rate experience also shown laterally (for the U.S. force during the worst 10 days of the Ardennes continuous-front defensive). The point is by no means that the simulation output ought to be identical to the Ardennes rates. Rather, the Ardennes provides some sense of the kinds of *proportions* that ought to be seen laterally among rates according to sector differences: corps-level main attack sector rates and rates in other kinds of sectors (supporting attack, fixed, etc.). In essence, the simulation output for the high 10-day rate period portrays the entire 600-kilometer NATO front as one massive corps-level main attack sector. That anchors the already-noted fact that the simulation shows unrelenting back-to-back 10-day peaks, without pauses, for the defensive force. The simulation portrays this defense as ultimately successful even though the overall defender casualty rate experience over the 60 days is decidedly worse than that suffered in the infamous destruction of Army Group Center.

Figure 10 HERE

BETTER APPROACHES TO CASUALTY ESTIMATION AND TO SIMULATON VALIDATION

At the study's completion in January 1991, two general kinds of improvements in the area of conventional ground forces casualty estimation were offered. First, several linked approaches to either evaluating or constructing casualty estimates were made available. Likewise, a set of tests and measures was suggested as a means to evaluate the validity of a simulation's casualty output.

This section outlines the two general sets of suggestions. The next section discusses Desert Storm in light of the study's prior findings, and suggests how those findings are qualified by Desert Storm.

Approaches to Evaluating or Constructing Casualty Estimates

Attempts to evaluate a casualty estimate for ground forces in conventional settings, whatever the method of the estimate's construction, must be based on judgments of whether the estimate credibly reflects the patterns and magnitudes of casualty rates found in modern conventional operations. Clearly, any attempt to construct such an estimate must also take its bearings from those patterns and the magnitudes inherent in them.

Of the two kinds of rate patterns at issue — the Underlying Quantitative Rate Patterns and the Rate Patterns of Operations — the latter are the more immediately useful for either constructing casualty estimates (without relying on simulations) or evaluating casualty estimates (whether or not based on simulations). That is, each of these tasks of evaluating or constructing casualty estimates must begin with reference to the Rate Patterns of Operations; then, in cases of evaluating estimates which provide sufficient daily rate detail (usually those based on simulation output), each might well also incorporate the Underlying Quantitative Rate Patterns as further reference.

Using the rate patterns and their magnitudes described in the study permits defining rate projections that are: empirically supportable, understandable in clear and simple operational terms, and performed with sufficient ease so that a range of projections may be made to account for the varied operational possibilities any commander or analyst knows are realistically conceivable.

The key is to define ranges of possible rates, and their distributions and related characteristics, in terms of the basic operational parameters laid out above: force size/echelons (operational configuration), time measured, and operational scenario/sectors (offensive or defensive scheme-of-maneuver and its flow).

The study defines a number of related portrayals of rate patterns and magnitudes, for both army- and corps-size forces. For example:

•For **CONTINUOUS FRONT SCENARIOS**, the study defines: **ranges** of average (mean) rates for an army or corps overall force over varying time periods and in different postures; probable general **distributions** of the sets of lower-echelon daily rates (mainly for divisions, but indications also are suggested for maneuver battalions) embedded within those longer-period overall force averages as shown in the defined ranges; likely **proportions** of the overall average rate experienced as KCMIA and WIA; and other **related illustrations** of the ways those daily and average rates could look (e.g., if viewed either over time or "laterally" along a broader 'front' of forces — linearity is not necessary, rather the array or schema of interlinked mission-postures, which in the past has usually been "linear" in conventional ground actions).

•For **DISRUPTED FRONT SCENARIOS**, the study provides **ranges** of rates for various portions of the defender or attacker experience in these by-definition fluid operations: rates for forces executing breakthroughs and exploitation during those phases, for forces elsewhere along the front (i.e., in different mission-posture 'sectors') during those phases, for the full force containing both sets of experiences, etc. Likely **proportions** of the overall force average rate experienced as KCMIA and WIA are also suggested. Necessarily, the information concerning rates in disrupted-front settings is not as detailed as that for continuous-front scenarios.

Figures 11A and 11B provide an example of some of the linked information sets made available to planners. In this case, the casualty rate information concerns a corps on the offensive in a continuous-front scenario. The concept is that the planner moves from (1) what is most generally known about the projected operational experience (in a straightfoward military sense) to (2) increasingly specific rate details (which are contained in interrelated figures and tables) about the projected experience. The planner thus first finds a plausible overall average rate for the corps's projected experience for the period in question, and then defines that same experience in the more detailed terms both of the distribution of the daily component (major subunit) rates over the period and of the proportions of the overall TBC rate falling into the KCMIA and WIA categories.

Figures 11A and 11B HERE

In this example, the planner is interested in rate possibilities if the corps experiences the worst probable 10-day rate for the offensive in a main attack. He finds a 10-day divisional force average rate for the corps (22/1000/day), and the indicated distribution of division 1-day rates within the corps (one division probably suffering a single day at approximately 109/1000/day, the median division 1-day rate at 19/1000/day, and the lower 25 percent of division 1-day rates falling between 0-and-6/1000/day). Finally, the planner finds that the corps's 10-day rate would probably be approximately 77 percent WIA.

The planner could further check rate possibilities by referring to rate ranges for other (shorter or longer) time periods. And, of course, the planner should wish to perform these checks for a number of potential combat outcomes which are believed realistically possible.

The study, that is, attempts to provide a guide by which militarily simple and clear operational possibilities (defined only in general terms using the interlinked three parameters) are translated both into empirically supportable *ranges* of average-rate possibilities and into empirically suggested *distributions* of the major subunit rate experiences, and general *proportions* of major casualty types, that would likely be contained within those broader rate averages.

Approaches to Validating Simulation Output

Attempts at validating a simulation ought to rest in important part on the apparent validity of the simulation's personnel casualty rate output. That output registers the effective interaction of the simulation's numerous parts: from inputs to assumptions to structure and working, etc. Of course, the character of the output does not trace directly to the quality of any particular among those parts. It is not an uncommon experiece, however, that despite the apparent quality of each piece and part of an intended product, the final product is not what was intended. Evaluation of the output is as necessary to the attempt to validate a simulation as judgments of any of its 'inputted' parts.

The study provides a series of general tests (sanity checks) of casualty rate output for army- and corps-size forces:

•***Rate Patterns of Operations***: The set of tests (for evaluating casualty estimates or constructing them, discussed above) measuring the general appropriateness of casualty rates for the general patterns of conventional operations depicted, assuming either a continuous or disrupted front:

•Ranges of average rates for 10-day (and other multiday) periods — these averages would be viewed in terms of the pulses and pauses to be expected both temporally and laterally (i.e., spatially) for a force; [Again, example comparisons of empirical and simulated rate patterns for army pulses are shown in Figures 9 and 10.]

•Distributions of daily division rates comprising the period rate averages within the above ranges (for continuous front settings); and

•General proportion of WIA as part of the overall TBC rate for the force during a key (usually peak rate) period.

•***Underlying Quantitative Rate Patterns***: A series of looks at the general character of the simulation's detailed rate output, assuming the scenario depicted is a continuous front and that division daily rates (and aggregates of same by corps or army, by day) are available:

•Duration (in consecutive days) of division rates in defined rate classes (e.g., comparing Figures 12A and 12B);

•Variability of daily division rates about a force's (division, corps, or army) mean rate during peak 10-day periods (e.g., Fig. 13 for corps-size forces);

•Dispersion of daily rates from high to low (e.g.: maximum, 90th percentile, median — as shown in Figures 14A and 14B); and

•Frequency of daily division rates as part of overall force (either in terms of the percentages of the overall force's set of daily division rates that fall daily into defined classes of rates, or as a count of the daily rates falling into each of those classes). Figures 15A and 15B contrast the empirical evidence for army- and army group-size forces versus a simulation's output for an army group-size force in terms of the percentage-of-force measure.

Figures 12A and 12B HERE
Figure 13 HERE
Figures 14A and 14B HERE
Figures 15A and 15B HERE

In deeper explanation of the simulation's output, Figures 16A and 16B return attention to the fundamental question of rate pulses and pauses, and of how contemporary simulations perform in reflecting that phenomenon.

Figures 16A and 16B HERE

OPERATION DESERT STORM

The casualty rate results for U.S. ground forces in Operation Desert Storm (ODS) at first certainly appeared anomalous. Even the most successful modern operational-level offensives to date had included at least some sectors where the attacking force suffered some significant rate of casualties, even if the overall attacker rate was relatively or even extremely low because of success generally. The most successful of such previous operations had shown a rate pattern of operations for the attacker's divisional force at some 3/1000/day for a 10-day period. For a U.S. divisional force in ODS of some 150,000 that would have meant some 4500 total battle casualties with (given a favorable but precedented ratio of KCMIA to TBC) some 900 to 1125 killed, captured or missing. The actual numbers turned out to be some 13 percent of that! As stated, that appeared surely anomalous.

Figure 17 shows in what sense the result was by no means anomalous. What occurred was a scenario shift: to Continuous Fronts and Disrupted Fronts is now added what will be termed the "Disintegrated Front." Yet, as already suggested above, a scenario shift does not mean a revolutionary departure from established patterns. Without question, the new scenario type merely — but of course significantly — elaborates on patterns well established in the two earlier fundamental modern ground war operational scenarios.

Figure 17 HERE

When considered in terms of casualty rate results, the disintegrated front is marked by both the collapse of the defender force with a heavy-to-near-total force battle casualty rate and a low-to-negligible battle casualty rate for the successful attacker. But it was *precisely* the increasingly greater ratio of defender-to-attacker TBC rates that also marked the key difference between continuous front and disrupted front scenarios when they were viewed in terms of patterns of rates associated with patterns of operations.

The disintegrated front occurs when the attacker is able, in essence, to place nearly his full force against nearly the defender's full depth nearly (for practical purposes) simultaneously. Where in continuous fronts attackers encounter literally continuous 'fronts' of resistance (that is, essentially unbroken defensive coherence); where in disrupted fronts attackers, while successfully penetrating narrowly and then exploiting with large-scale forces in expanding arrays, also encounter other large sectors ('fronts' or pockets) of resistance — instead of those experiences, in disintegrated fronts attackers essentially encounter no effective sectors of resistance, and are able to move to the enemy's full depth with virtually the full attacking force, virtually as fast as that force would be capable physically (i.e., without resistance) of reaching that depth. The defense literally disintegrates as decisive force is applied virtually-simultaneously across the defender's full depth.

The pattern of respective casualty rate results for attacker and defender is suggested by Figure 17. The disintegrated front is an extension of the continuous and disrupted fronts in the same sense as the rate patterns associated with disrupted front patterns of operations are clearly an extension, albeit an important one, of the rate patterns already detected in continuous front operations. Continuous fronts show an overlapping set of defender and attacker TBC rates on a 10-day peak-rate basis: 9-to-14/1000/day versus 6-to-12/1000/day (for army-size forces). As the figure also suggests, disrupted fronts begin with that same overlap, but clearly show their true character (in the higher-order disruption operations) as the attacker is increasingly successful in exploiting his breakthroughs with encirclements/overruns of increasingly larger portions of the defender force. The defender experiences in these disruption operations is marked not only by increasingly higher TBC rates but also, critically, by an increased proportion of missing-and-captured casualties as part of the rising TBC rates. Meanwhile, the disrupting attacker shows a reducing TBC rate. The two trend lines continue in their respective upward and downward directions as the attacker is capable of increasingly higher orders of offensive force "energy": measured in terms of increasing speed of operational result and depth of operational reach with decisive power — and, vitally, the near-simultaneity of all — against the defender.[9]

This trend line pattern had already been observed in the respective patterns of continuous-front and disrupted-front operations. The disintegrated front, rather than introducting a revolutionary phenomenon, reflects and extends the observed phenomenon. ODS, far from being an anomalous event, extends and thus confirms the set of insights into casualty rate patterns for modern conventional ground force operations.

FINDINGS AMENDED: THE FORESEEABLE FUTURE

The findings described above concerning rate patterns and their magnitudes, reached before Desert Storm, all stand. The patterns of rates are confirmed by extension in Desert Storm. However, the end of the Cold War (so long as that fact endures), and the realization through Desert Storm of the fuller structure of rate patterns of operations with the addition of disintegrated front operations (against Third World powers especially, and in the context of the end of the Cold War), suggest a revised planning focus within those earlier findings.

Where past planning keyed on defensive operations in a continuous front setting, most future planning should probably key on offensive operations to effect disrupted fronts — and, as the acme of success, even distintegrated fronts — against opponents. That is, the casualty rate patterns that probably ought to inform most planning for the foreseeable future — the exception might be illustrated by Korea — are decidedly different than those that ought to have governed past planning.

It seems highly likely that conventional operations in the post-Cold War period will be coalition operations conducted only after a belligerent power acts in a way that elicits a coalition's ad hoc formation and action in response. (Such a prospect includes an ad hoc assemblage for a particular occasion of some NATO reaction force drawn from its several potential member-nation participants.) The military component of the coalition's action is likely to be offensive in character, probably undertaken to dislodge the aggressor power from territory gained or to destroy the potential aggressor's conventional ability to conduct offensive operations across international borders. Short of these, the mission would be peace keeping.

In the former two cases, the casualty rate patterns most often to be consulted during planning will be those for offensive operations. The kind of offensive to be planned would be, in the worst probable case, that seen in disrupted front operations or, in the best case, in distintegrated front operations. In both cases, the empirical casualty rate patterns suggest distinctly lower rate magnitudes for the coalition force than those seen in planning during the Cold War period. In the case of peacekeeping operations, the rates would likely be extremely low as well: for example, casualties associated with occasional small-unit actions. The issue for these will be whether they are likely, Vietnam-style, to accumulate over time to the level of significant casualty numbers.

A prediction is ventured. It seems clear enough by now that a Vietnam-like presence, in size or duration or character, is distinctly not what senior decisionmakers would have in mind or support. The focus for most foreseeable planned uses of conventional ground forces will be on effecting high-order disrupted fronts or even on achieving disintegrated fronts against opponents. The projected operations may be large (ODS-like) or small (Panama-like). They will be undertaken only if they promise to be decisive, at least militarily, and quick.

The part of the casualty rate spectrum indicated in Figure 17 for offensive forces in such operations seems clear.

CONCLUSION

The post-Cold War era has already raised casualty estimation to an unprecedented visibility at the highest levels of policy decision. Yet current casualty estimation methodologies produce results that woefully misrepresent the empirically-indicated casualty rate patterns for modern ground operations.

Planners need at least to be able to define ranges of plausible average rates for overall forces (rather than merely point values), distributions of component rates within those averages (to identify "hot spot" possibilities and their weight across a force), and WIA/TBC ratios for those averages — all reflecting realistic projections of the three key interlinked operational parameters. Similarly, the validity of simulation casualty rate output needs to be evaluated against the same empirically-suggested rate patterns and characteristics. Most of all, a way must be found to establish persuasively the reasonableness of casualty estimates and of simulation output during times when policy and plans are set, rather than only after 'the facts are in' and forces begin to move.

Projections of casualty rate possibilities for ground forces must reflect the fundamental dynamics of modern operations. This research suggests a beginning — one hopefully grounded, as any beginning should be, in the nature of the real-world thing itself.

NOTES

1. Kuhn, George W. S. *Ground Forces Battle Casualty Rate Patterns: The Empirical Evidence* (September 1989); *Current Rate Projections Compared to the Empirical Evidence* (May 1990), and *Suggested Planning Considerations* (January 1991). Logistics Management Institute, 6400 Goldsboro Road, Bethesda, Maryland 20817-5886. [Tel: 301/320-7246]

2. These concerns in the military OR community were of long standing. However, they found focus in the mid-1980s when Air Force BG Leon Goodsen raised some disturbing speculations about the quality of portrayal of weapons effectiveness at the 1985 MORS Symposium. Over the next two years, related symposia were held: MORIMOC (1986) and JCHAMPS (1987). Descriptions at MORIMOC (e.g., by Moriarty and Lester) of tendencies in both analysis and models were echoed at JCHAMPS (e.g., by Reid) the following year. Other analysts doing suggestive related work at the time were David Rowland (comparisons of actual versus field exercise rate results) and Robert McQuie (comparisons of rates at actual unit breakpoints versus simulation definitions of rates at breakpoints). As noted in Note 8 below, all this rested on top of work that had been done more broadly on long term trends in actual ground forces casualty rates. And even a first reading of the superb 1952 study of WWII experience by Beebe and DeBakey, *Battle Casualties*, indicated strong supporting observations and data.

3. Particular gratitude is owed to COL David M. Glantz whose extraordinary studies of the Eastern Front provided much of the basis for this portion of the research, and who personally contributed to the work both from his encyclopedic knowledge of events and sources and from his own source collections.

4. The exception was suggested when the attacker succeeded in effecting a disrupted front but then, during exploitation, was foiled by superior defender reaction and in fact was suddenly faced with overextension, with a resulting reversal of rate experience as defenders successfully encircled the overextended attacker formations. Fig. 17 does not address this eventuality, as it seemed to be not only so unusual but so highly dependent on a combination of poor attacker planning and execution and superb defender responsiveness. In any event, it was seen only in the Disrupted Front I situation.

5. The increased proportion of MCIA of course included some degree of the KIA and WIA casualties. The data do not directly indicate the composition of the MCIA. However, there seems to be reason to believe that the traditional observation linking lower "casualty" rates in general to higher FLOT movement may come to bear here: in the case of defenders, it is not "total battle casualties" that decline with increased FLOT movement, but instead the incidence of KIA and WIA as a proportion of TBC; and this KWIA decline is not simply due to a merging of these casualties into an amorphous MCIA category (which, again, does occur to some extent), but also to an apparent absolute decline of KWIA as a proportion of TBC.

6. There was as well some indication in the data that the WIA/TBC ratio for the *attacker* also dropped in successful disrupted front offensives. The drop was not as great, declining from the 70-80 percent range (in continuous front offensives) to perhaps the 60 percent level for a force in exploitation. (Of course, the attacker TBC rate itself also dropped — significantly.) The explanation in both cases (defensive and offensive experiences) may be associated with the simple fact of increased FLOT movement, as well as with whether a force is losing or gaining ground.

7. Even after breakthrough, at least some rates in disrupted front operations continued to exhibit the kinds of underlying quantitative behavior (pulses/pauses, variability, short high-rate duration, etc.) seen in continuous front operations: e.g., in those sectors where the defense basically held and was not enveloped in the encirclement/overrun events; and for formations along main attack axes where exploiting forces experienced counterattack (i.e., for both the particular attackers and defenders involved — their general operational postures of course for the moment tactically reversed).

8. That personnel casualty rates have not risen since WWII should not be surprizing. Suggestions of their rise have been founded mainly on various measures of increased weapons effectiveness. Measures of weapons effectiveness have, correctly, relied on what might be termed technological approaches; thus measured, weapons are today obviously far superior to their predecessors in terms such as target identification and acquisition, weapon reach, penetration and effect, etc. However, what is not usually or adequately taken into account in attempts to characterize weapons effectiveness are the many counterbalancing effects of other considerations on the measure at issue: personnel casualty rates. As shown or commented upon in other previous studies of ground warfare (for example, in Quincy Wright's *A Study of War* in 1942 and later, of course in greater detail and richness, by T. N.

Dupuy, as in his 1986 *Attrition Data Handbook*), the steady rise over the long term in technological weapons effectiveness has not translated into a rise in average personnel casualty rates; in fact, the reverse has long been observed.

9. The ways to effect Disintegrated Fronts — that is, identification of the set of key, and repeatable, interdependent causal factors — are of course a central interest for future operational planning. A few comments and questions are briefly ventured. It may be doubted that ODS proves what air power advocates have so long sought evidence for, and in fact claimed widely of late: that air power alone is shown to be henceforth the decisive instrument of war. Would essentially the same disintegration of the defender force (and similar-order low attacker casualty rates) have occurred — in this war in this physical environment against this enemy — had the ground war begun, and been conducted in the same vigorous manner except with classically vigorous air *support*, on Day 5 (or, even allowing for ground forces redeployment, on Day 20) instead of on Day 39? The air effort could already have stripped the opponent of essential C3I integrity and decisively reduced the opponent's air arm. Air attacks against other key nodes (although obviously not the full set engaged, and reengaged, in an indefinite air campaign) would have been completed or in progress. In the main, what would be missing, in terms of the defender's ground force, as of Day 5 (or some other relatively early date) would be the long term air-inflicted attrition of static ground positions and support networks — and that steady attrition's no-doubt considerable effects on the morale of the Iraqi field force. It is arguable, however, that these latter morale effects would be offset to a significant extent, and perhaps completely, by the intensity and character of defender fear and confusion accompanying a furious air-ground offensive reaching rapidly to the defender's full depth. The question may be reversed: would essentially the same result (disintegrated front) have occurred had the ground forces been employed merely defensively against potential Iraqi ground threats to the ability of the air forces to operate at will and indefinitely — say, for one or more succeeding 38-day periods of air operations? The distinctiveness of a disintegrated front may rest more on the form and speed with which *decisive* force is brought to bear over the full depth of the defense. That decisiveness arguably proceeds not from force that just delivers steadily-mounting physical destruction and its attendant steadily-mounting sense of isolation and helplessness, but from force that *combines* physical destruction with the terrorized confusion of rapidly and constantly failing defensive efforts to cause an overwhelming sense among defenders that they must *now* either

surrender, flee, or die. (The theorist John R. Boyd — originally an air combat theorist — years ago offered rich insights into such matters.) On this view, the Disintegrated Front is, at its core, grounded in the immediacy and totality of collapsing Defender cohesion — which long term air-inflicted attrition may certainly help prepare, but which is neither necessarily (much less, wholly) dependent on such attrition nor primarily marked by it. Further speculation would seem warranted and useful.

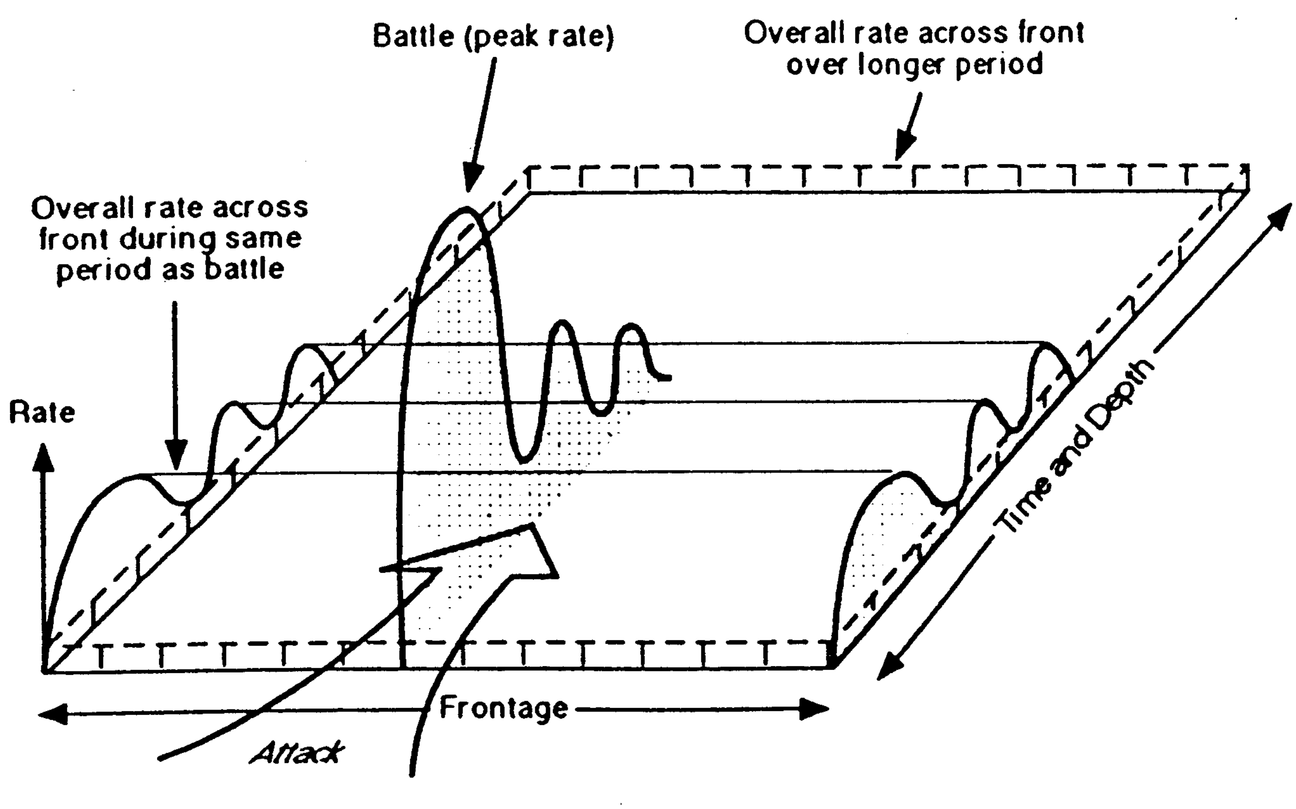


FIG. 1. NOTIONAL BATTLE CASUALTY RATE PATTERN

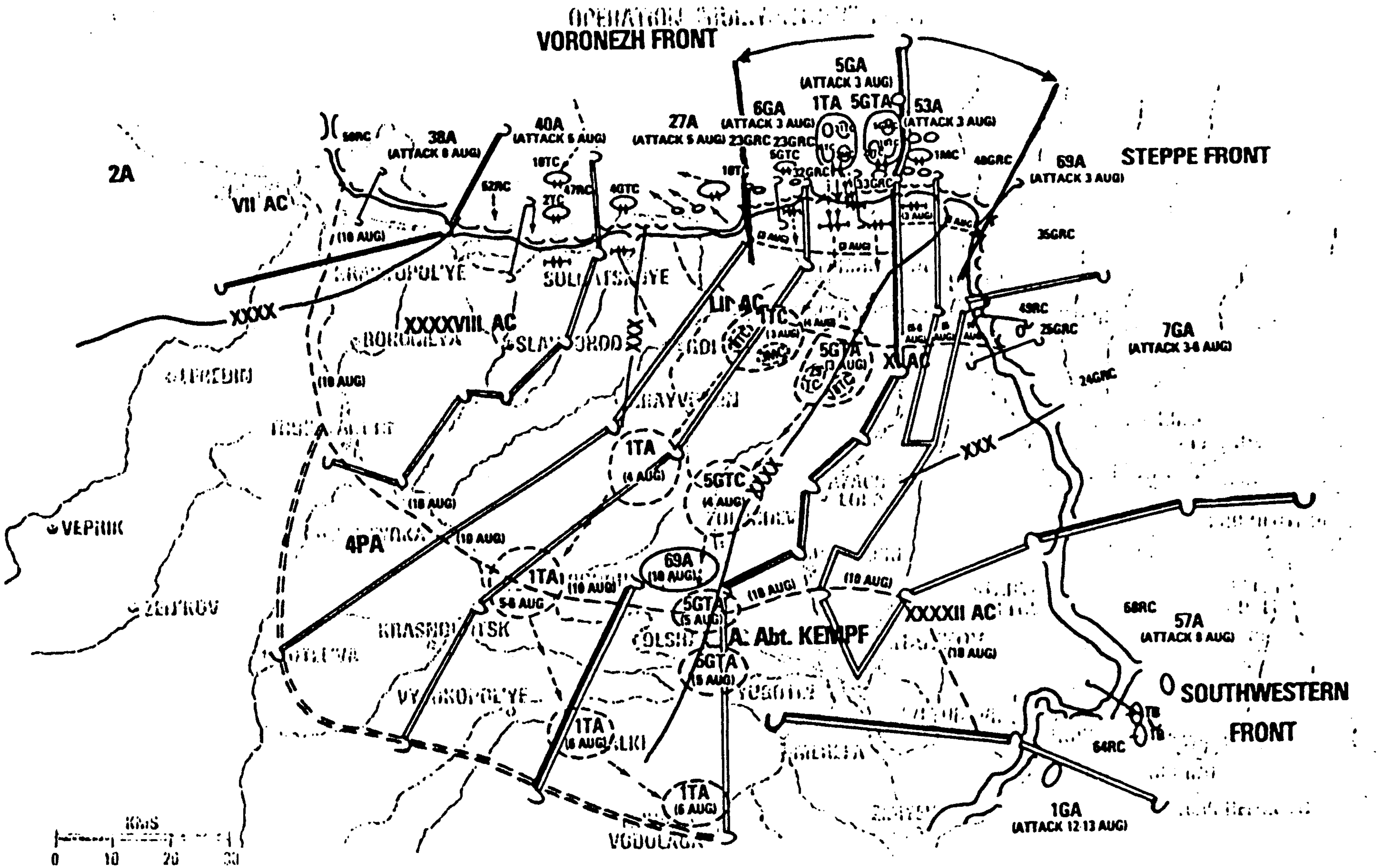


FIG. 2A. SAMPLE MAP TRACE: OVERALL OPERATIONAL-LEVEL FRONT

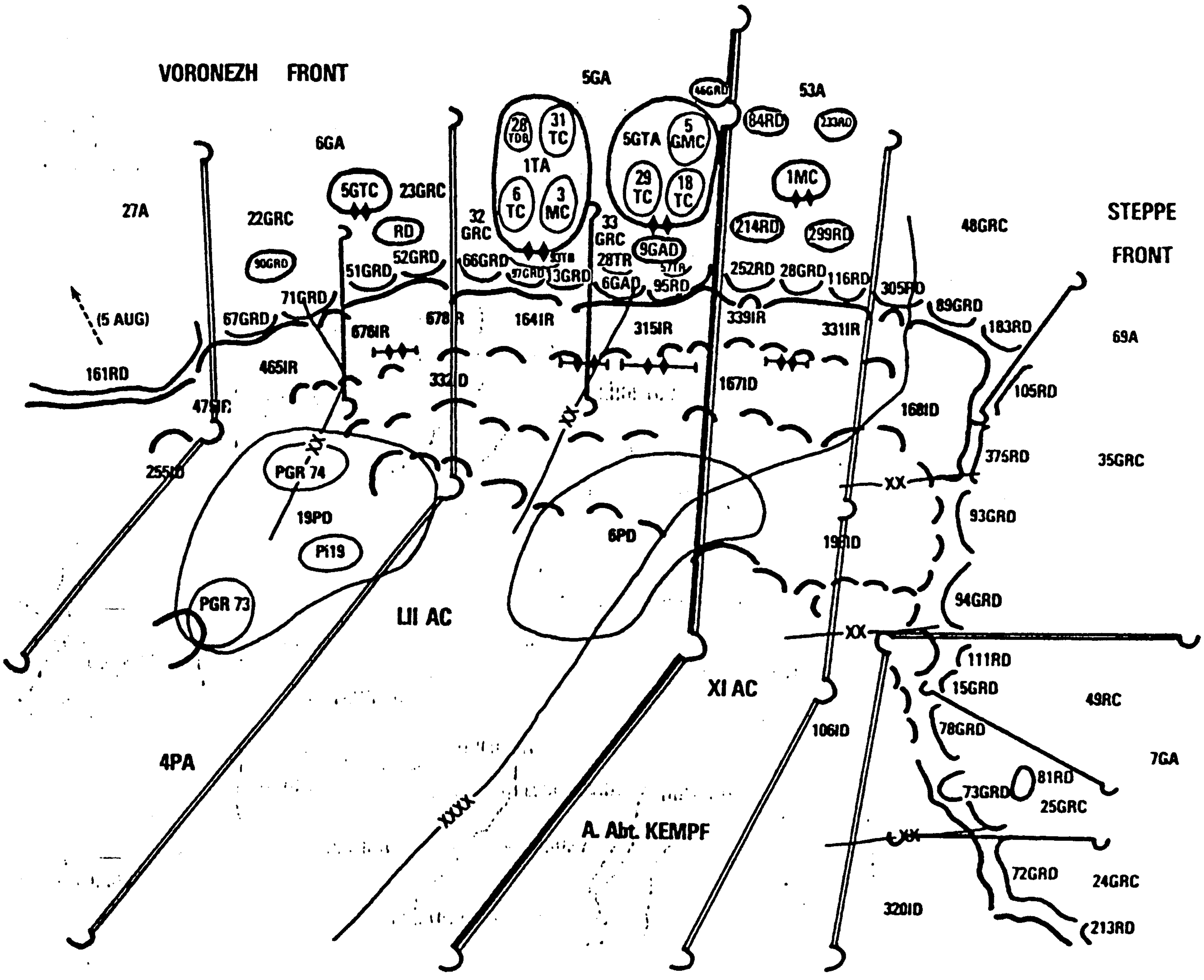


FIG. 2B. SAMPLE MAP TRACE: OPERATIONAL MAIN ATTACK SECTOR

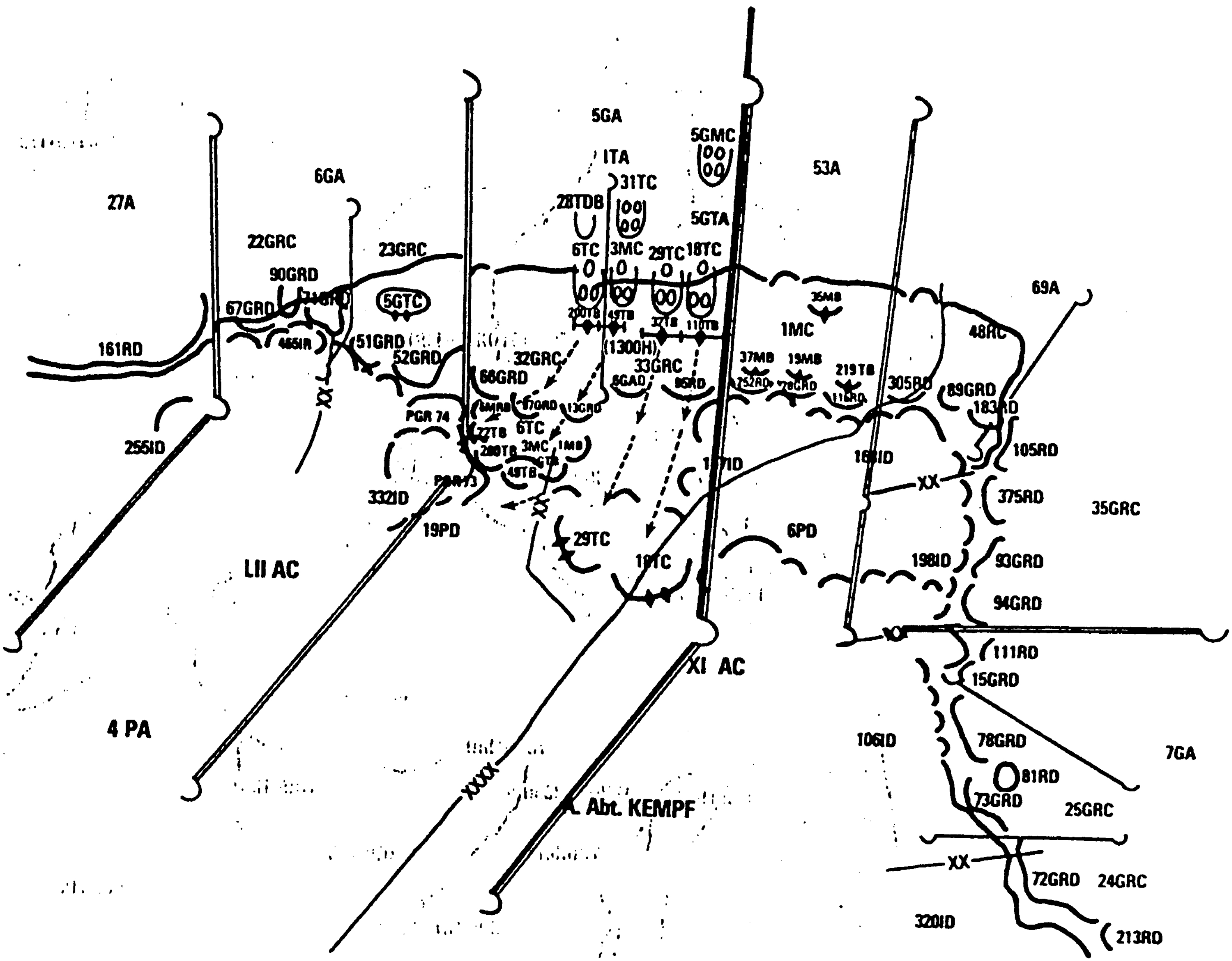


FIG. 2C. SAMPLE MAP TRACE: 1ST DAY PROGRESS ALONG OPERATIONAL MAIN ATTACK AXIS

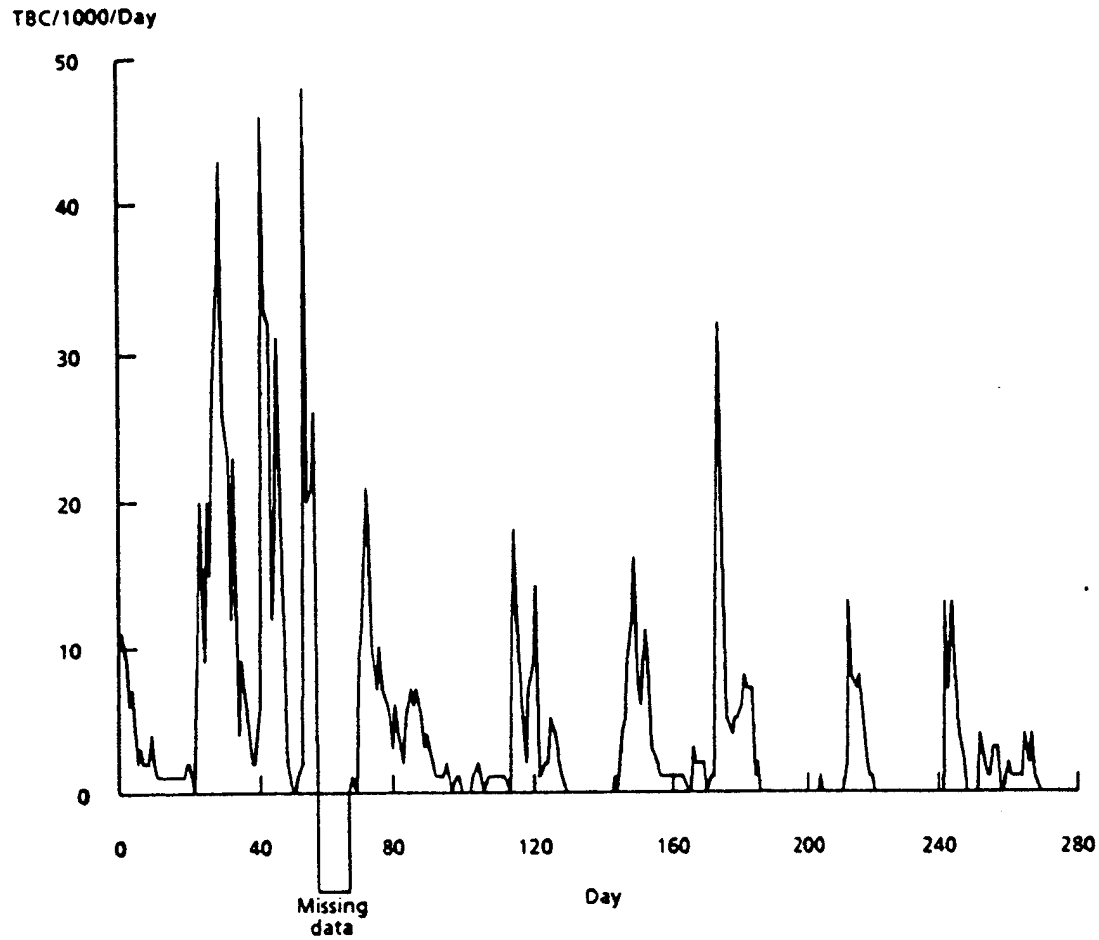


FIG. 3. 30th U.S. INFANTRY DIVISION (1944-1945)
TBC per 1000 personnel per day

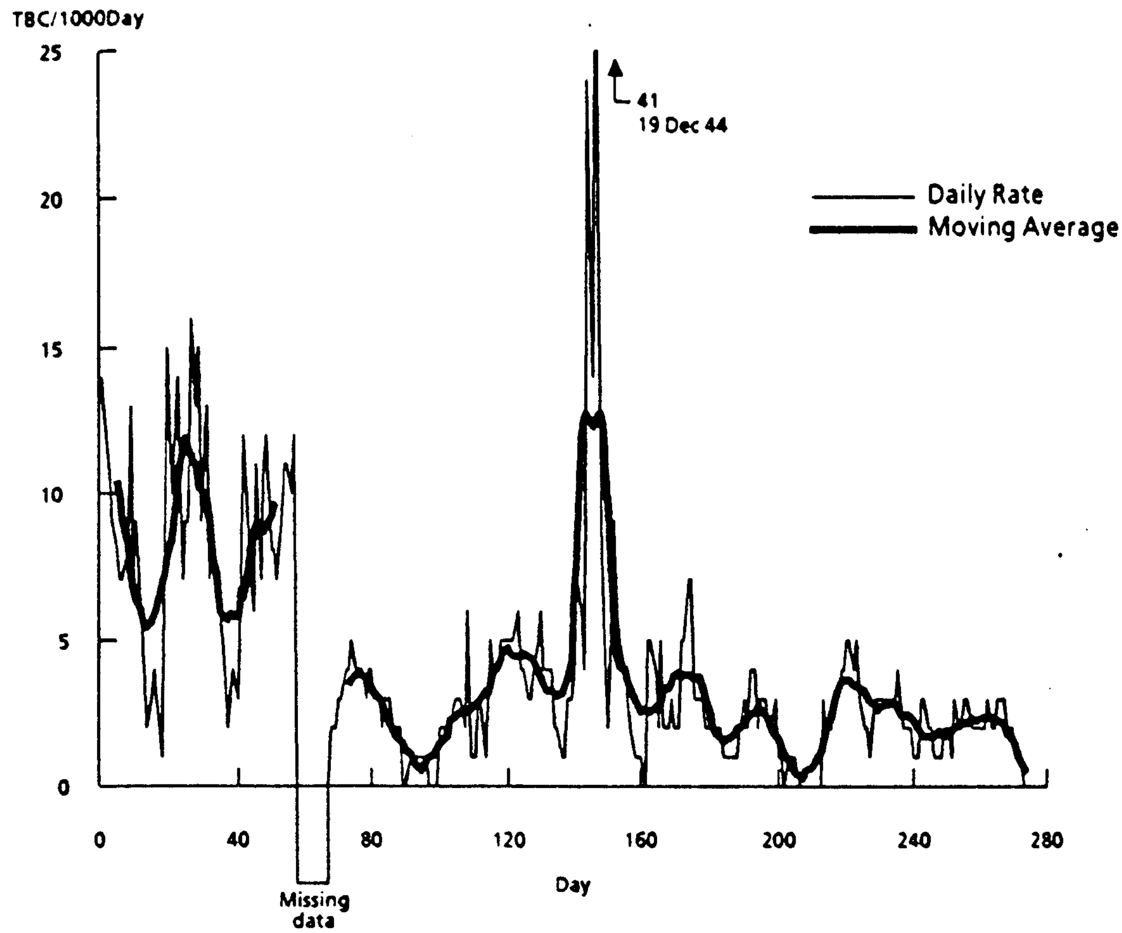


FIG. 4. 1st U.S. ARMY (1944-1945)
Daily and moving 10-Day average rates for TBC for division-level personnel

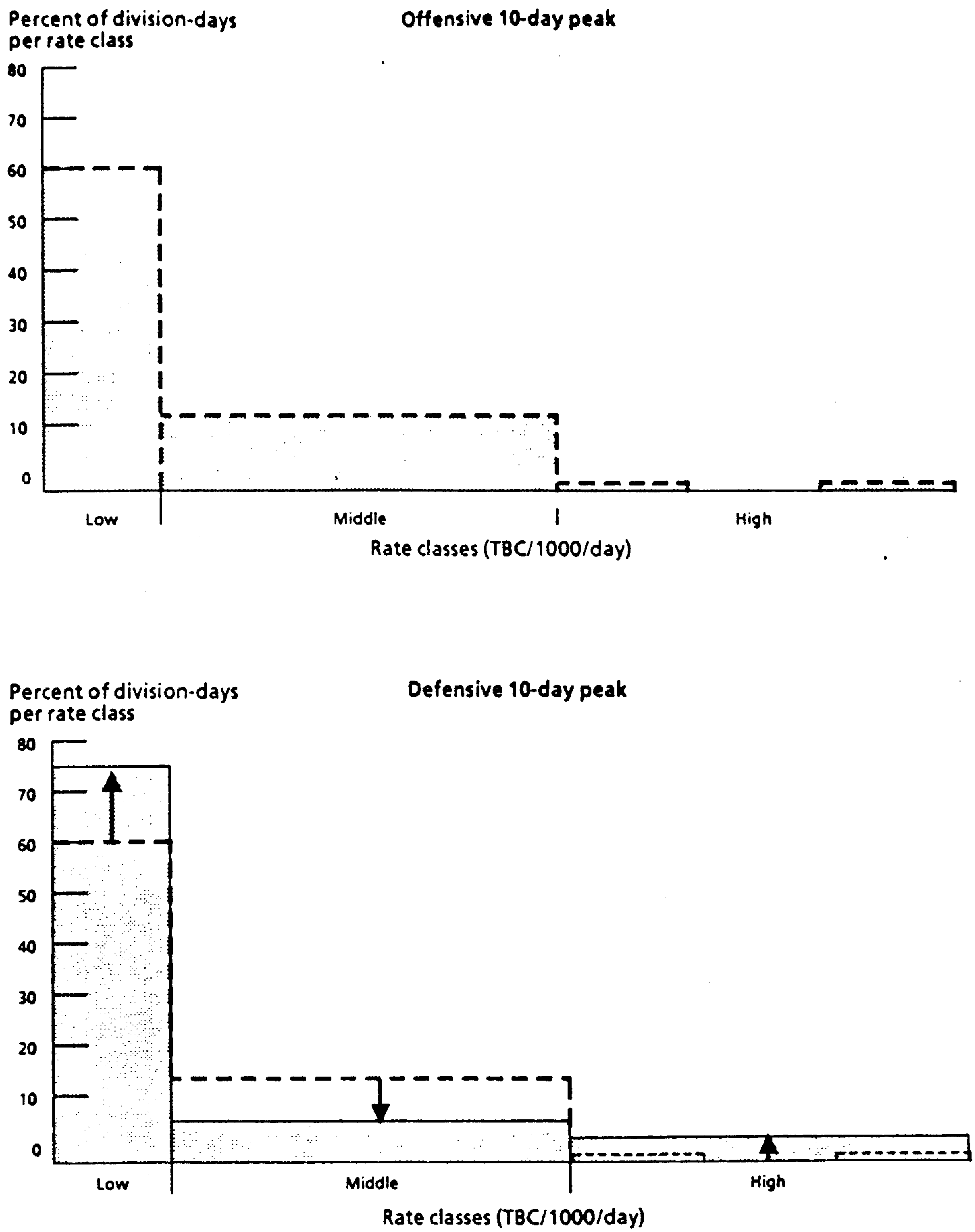


FIG. 5. CHANGE IN NOTIONAL PROBABILITY MASS OF RATE DISTRIBUTION FOR ARMY-SIZE FORCE GOING FROM OFFENSIVE TO DEFENSIVE 10-DAY PEAK

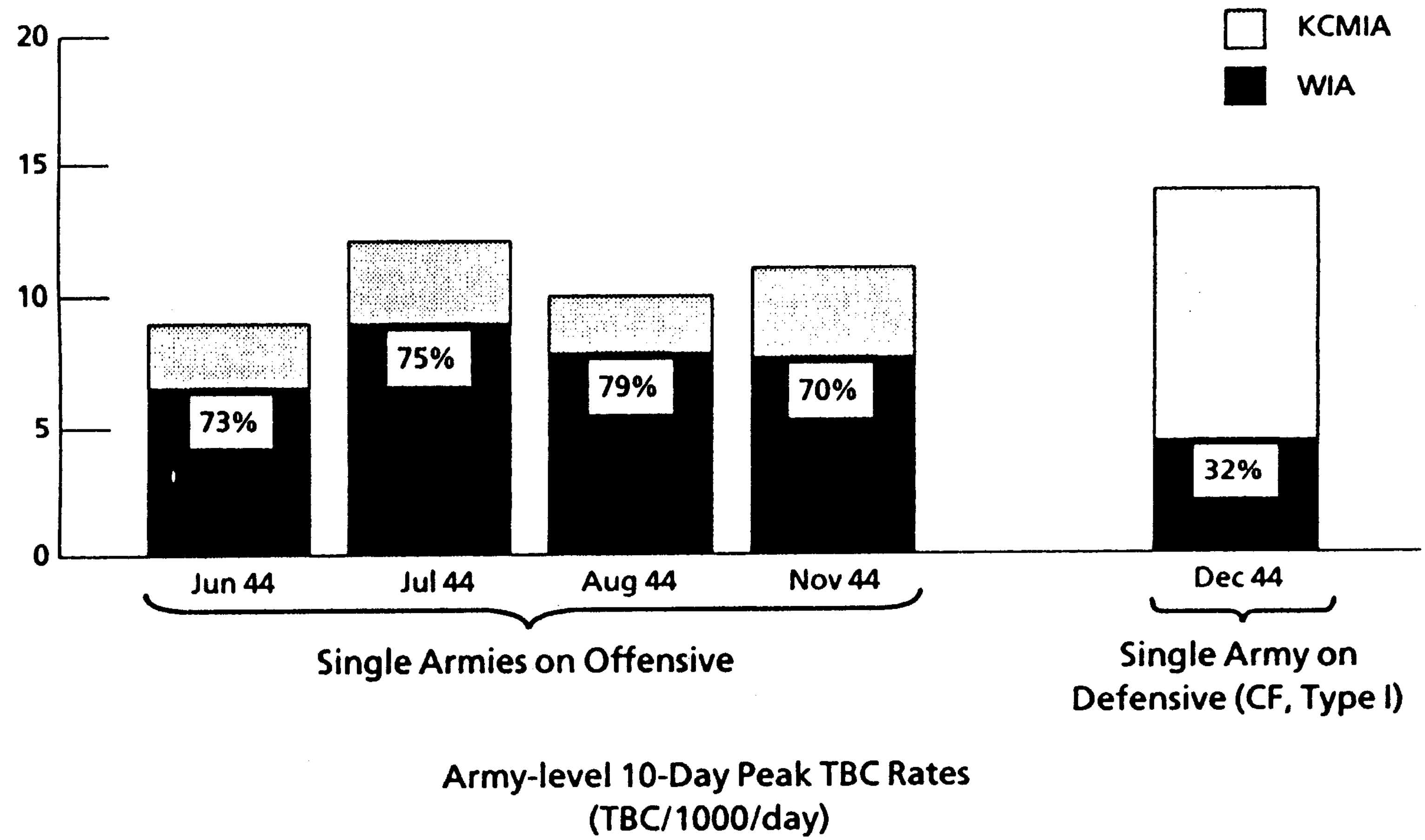


FIG. 6 THE EMPIRICAL EVIDENCE SHIFT IN WIA PROPORTION OF TBC

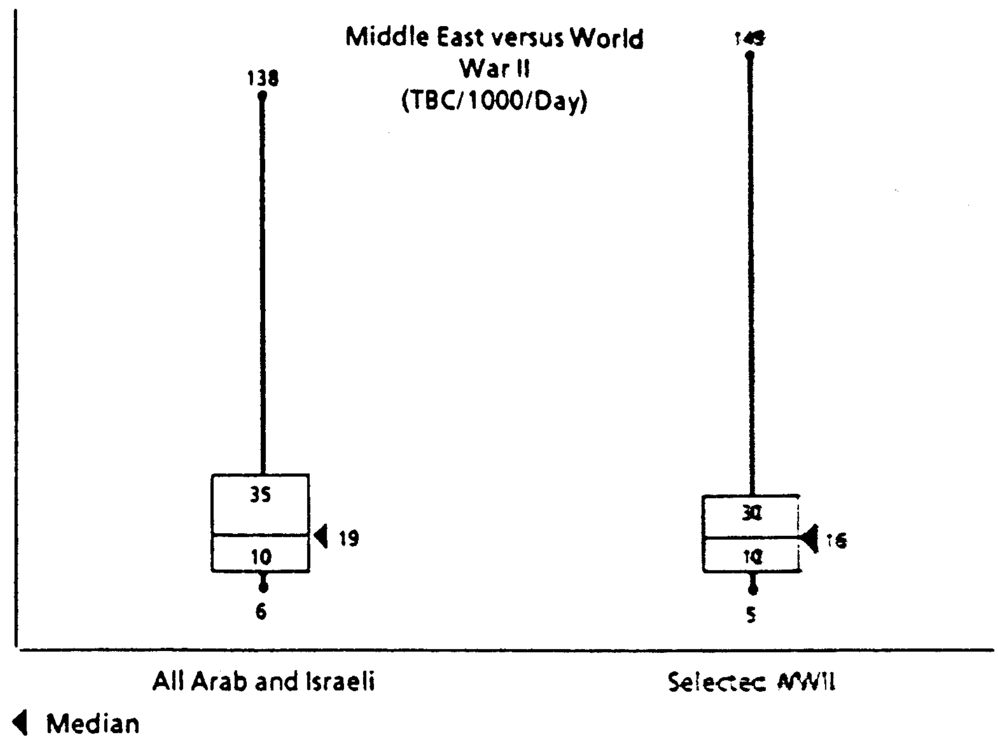


FIG. 7A. BOX PLOTS OF SINGLE-DIVISION/SINGLE-DAY CASUALTY RATES

Middle East vs WWII
(Division, 1-Day)

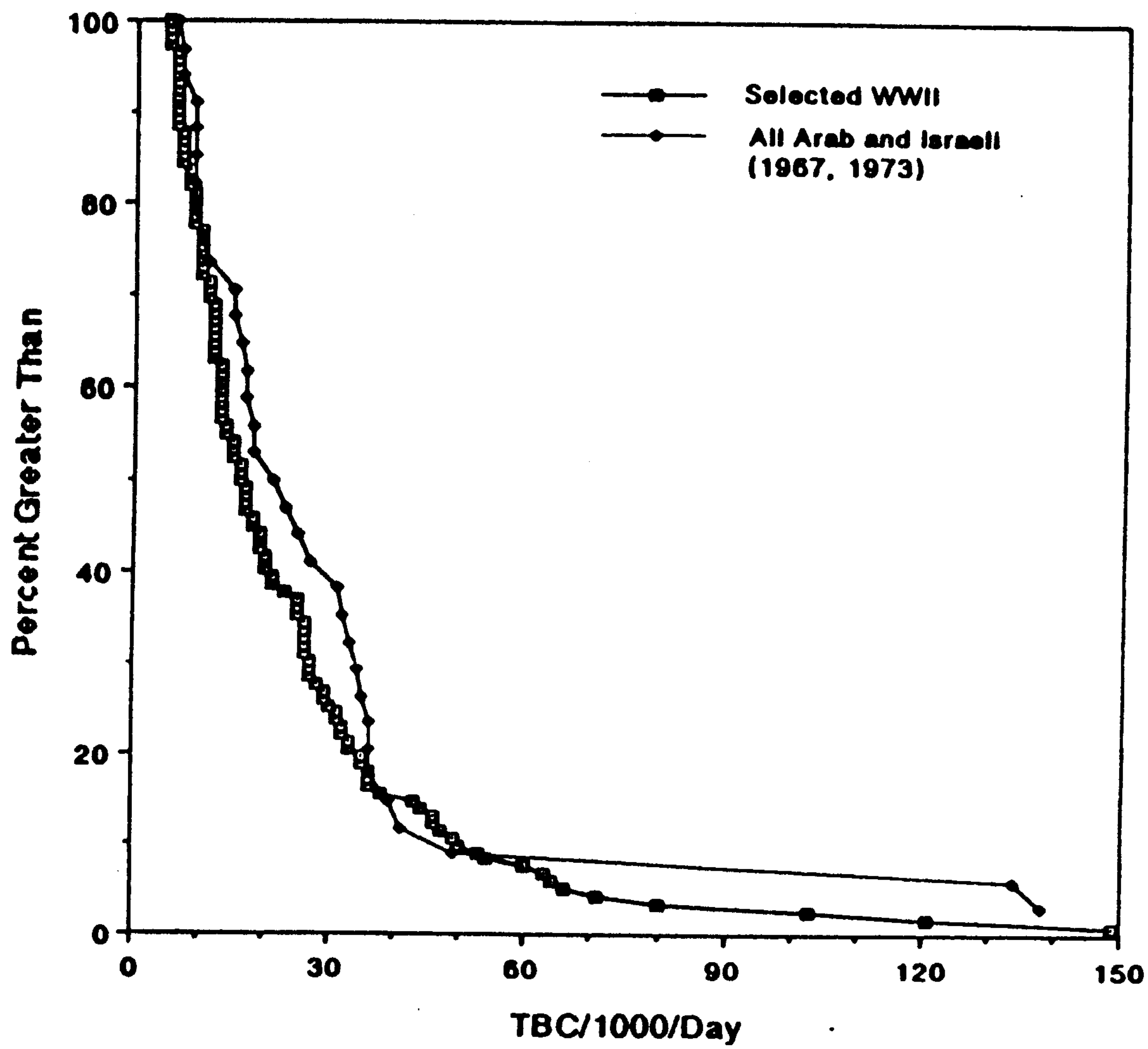


FIG. 7B. SURVIVOR CURVE OF TBC RATES

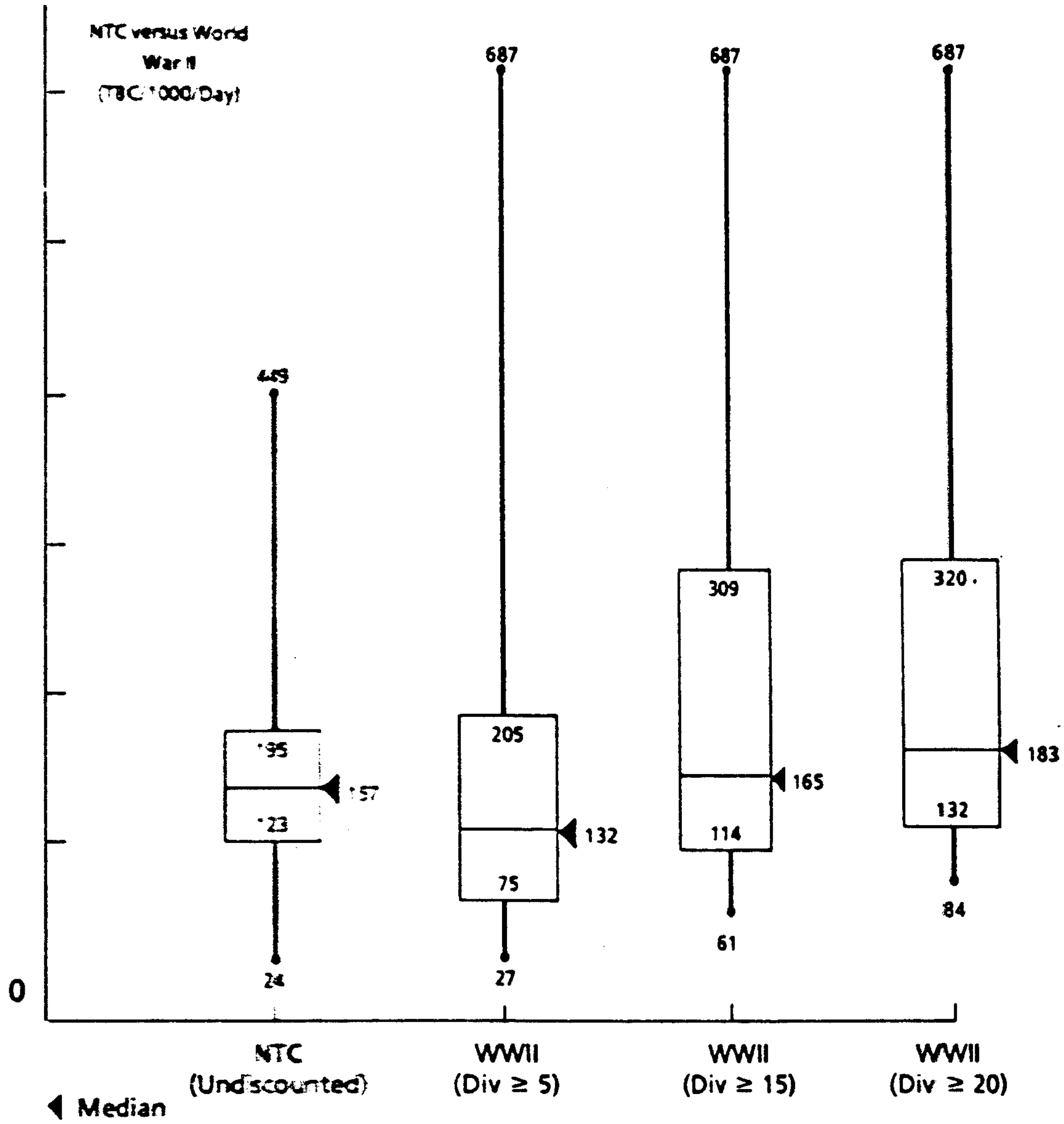


FIG. 8A. BOX PLOTS OF NTC AND WORLD WAR II BATTALION CASUALTY RATES

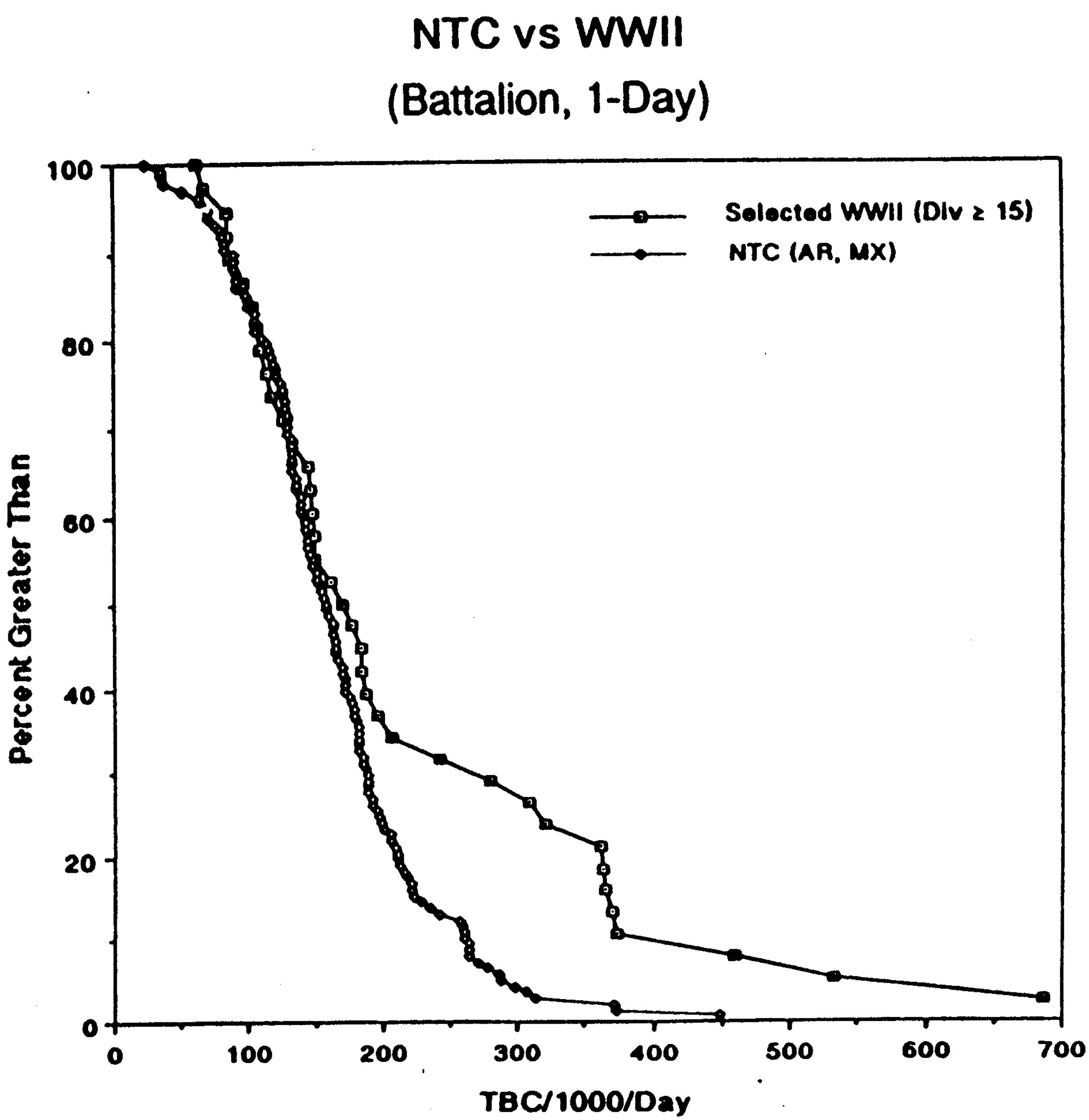
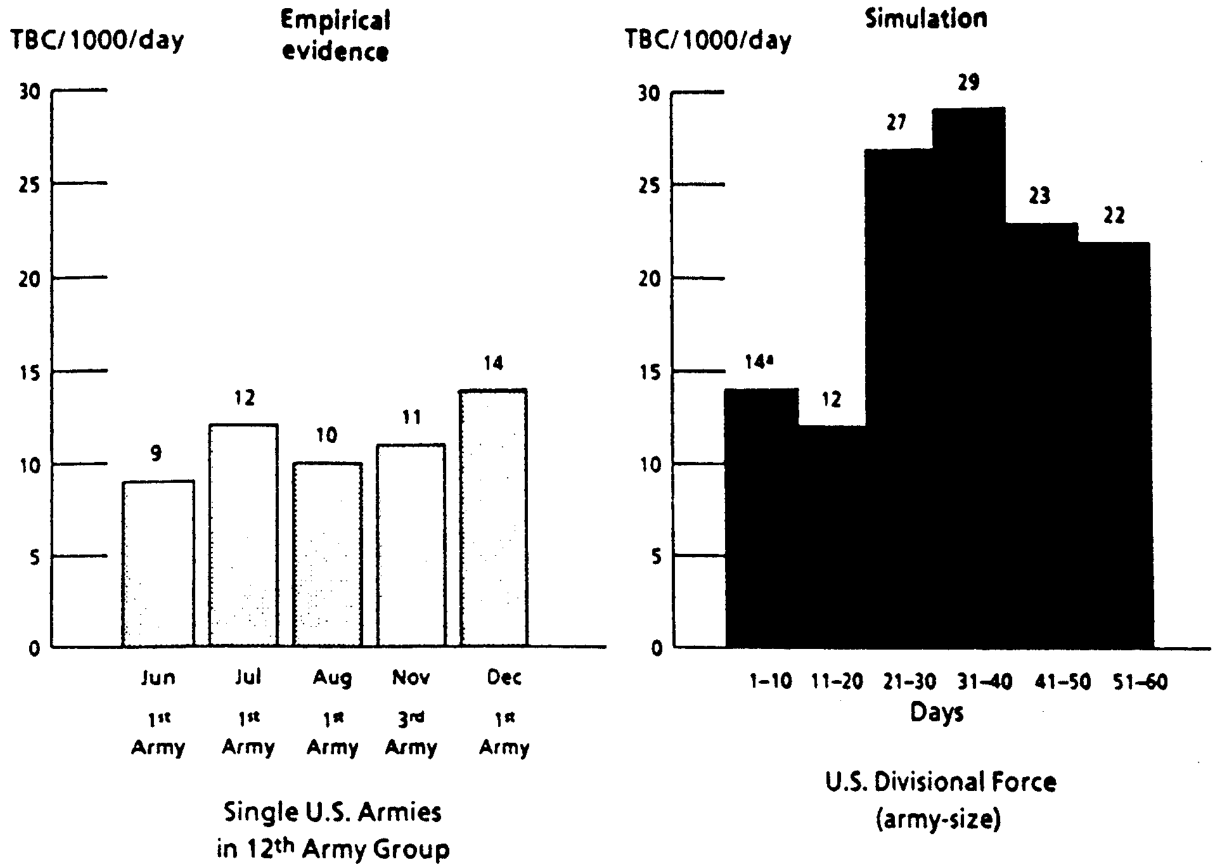
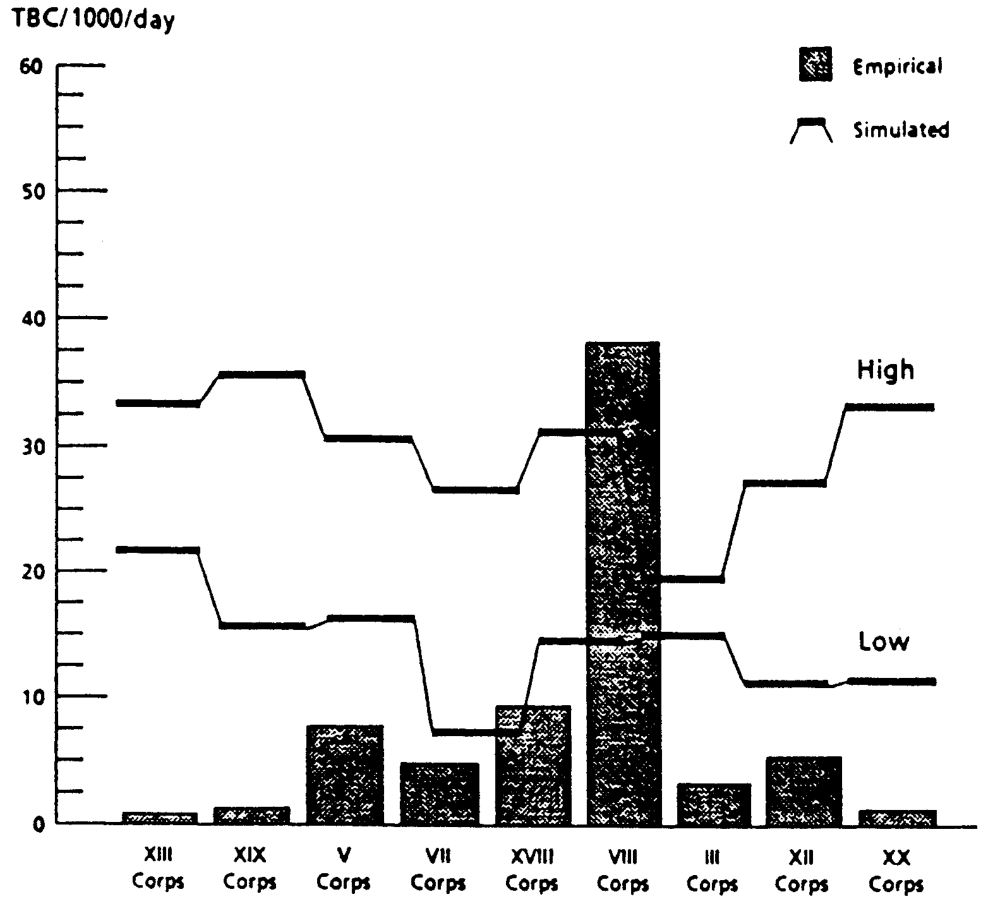


FIG. 8B. SURVIVOR CURVE OF TBC RATES



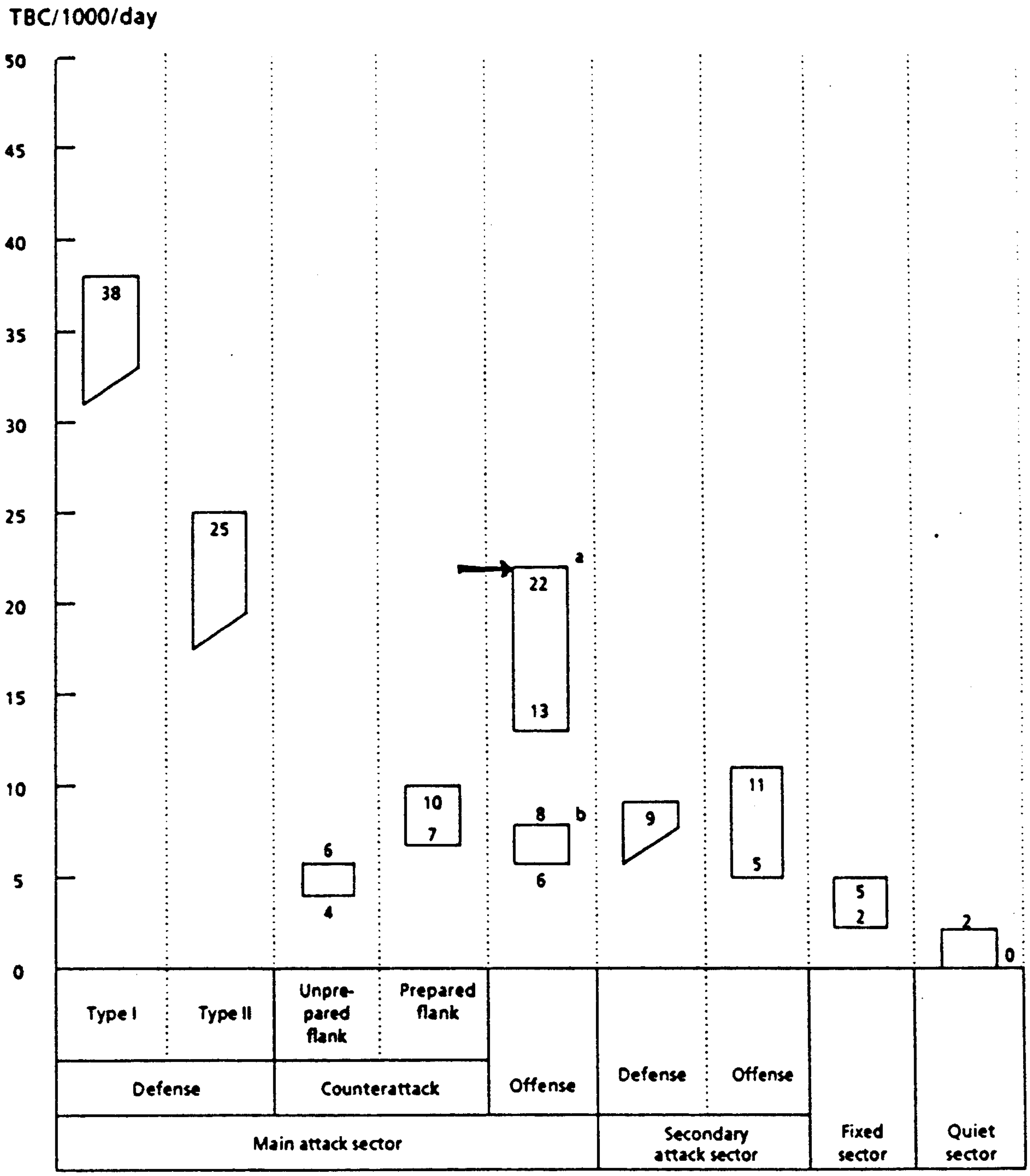
[a] Force in first 10 days not of full army size.

FIG. 9. COMPARISON OF EMPIRICAL EVIDENCE AND SIMULATION RESULTS [Army-level 10-day peak rates (TBC/1000/day)]



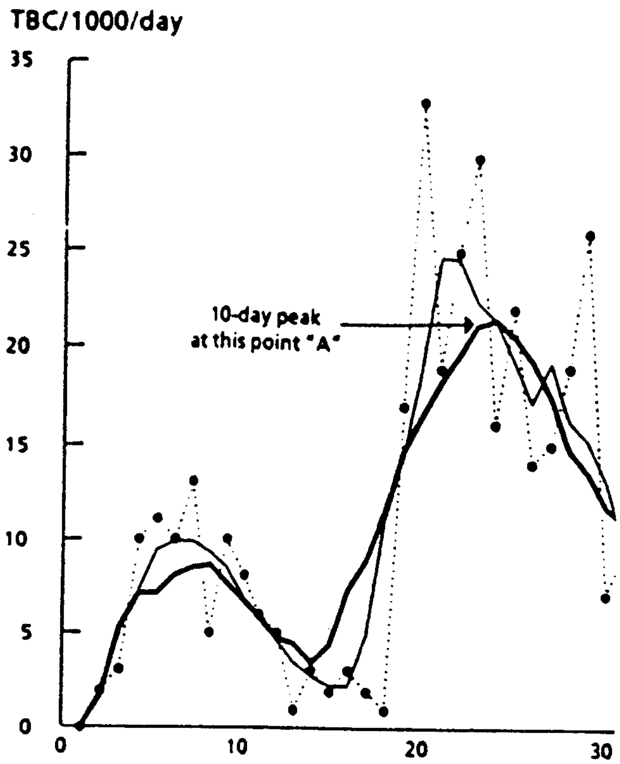
Note: Empirical data for corps in 12th U.S. Army Group, 16 – 25 December 1944 (locations on 25 December). Simulated data for corps during "high" and "low" TBC rate periods for full NATO force.

FIG. 10. COMPARISON OF CORPS 10-DAY CASUALTY RATES



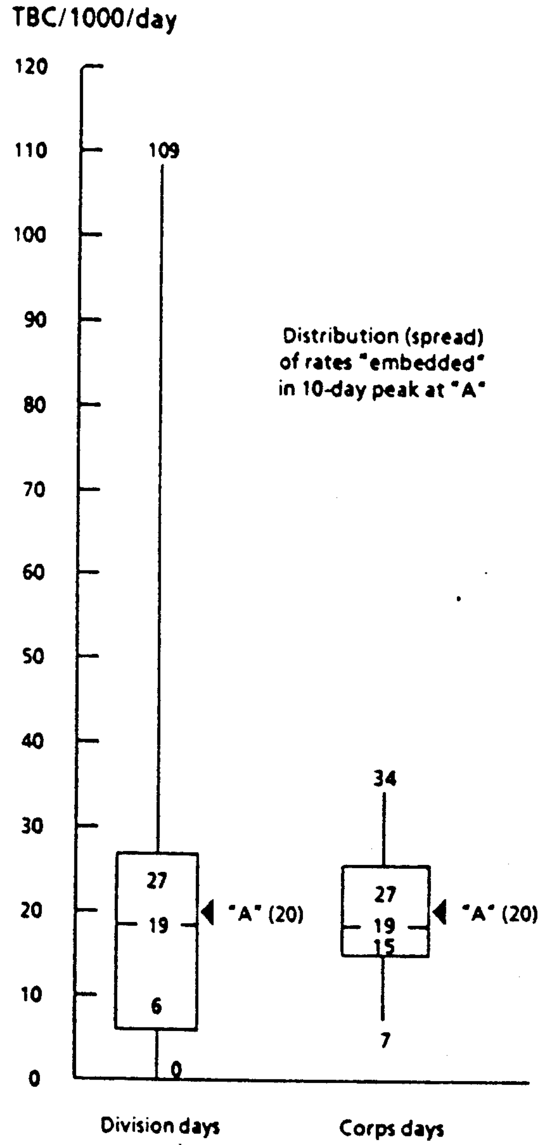
[a] Cases of low or relatively low FLOT movement.
[b] Cases of breakthrough (relatively significant FLOT movement) – but still in a continuous-front setting.

**FIG. 11A. RANGES OF 10-DAY PULSE RATES, CORPS-SIZE FORCE
(Assuming continuous front)**



Proportion of force days (division days) and rate averages per rate class		
Rate class (TBC/1000/day)	Percent of observations	Mean TBC rate (TBC/1000/day)
≥40	8	63
10 to <40	56	23
<10	36	5

Casualty rates by category (per 1000/day – divisional force)			
TBC	KCMIA	WIA	WIA/TBC ratio
20.0	4.6	15.5	.77



Notes: The data sets displayed here are taken from: curve display, Figure 2-24 and other distributions, Table 2-9.

The slight difference between the mean rates of "A" in the rate curve and the distribution (rate spreads shown in Tukey plots) is due to slight computational differences in two programs producing the data.

FIG. 11B. ILLUSTRATIVE EXTRACTS SHOWING RELATION BETWEEN PULSE RATES AND ASSOCIATED RATE DISTRIBUTIONS – CORPS OFFENSIVE (WORST-CASE), MAIN ATTACK SECTOR (Assuming continuous front)

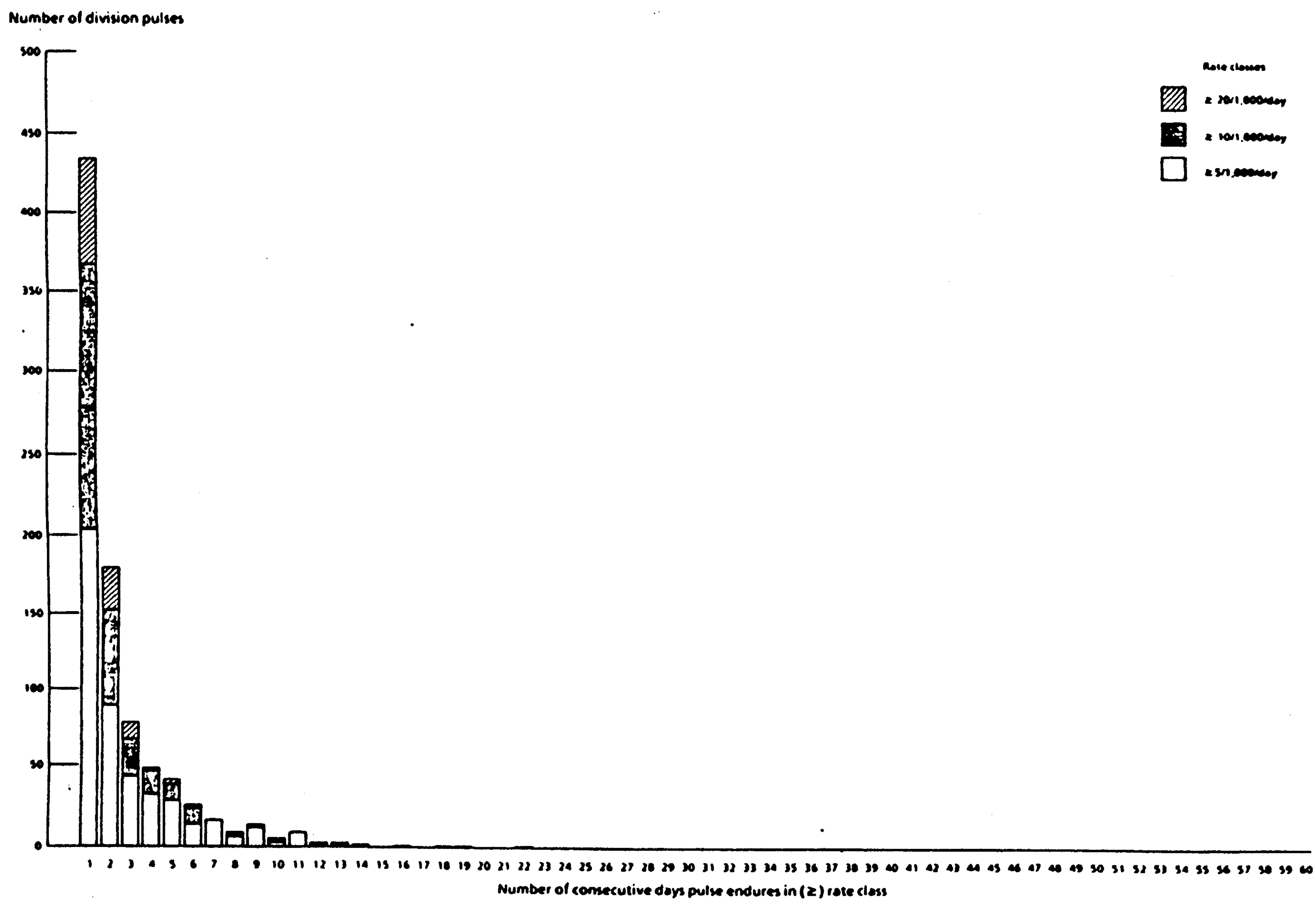


FIG. 12A. DURATION OF DIVISION PULSES BY RATE CLASS
— EMPIRICAL EVIDENCE —

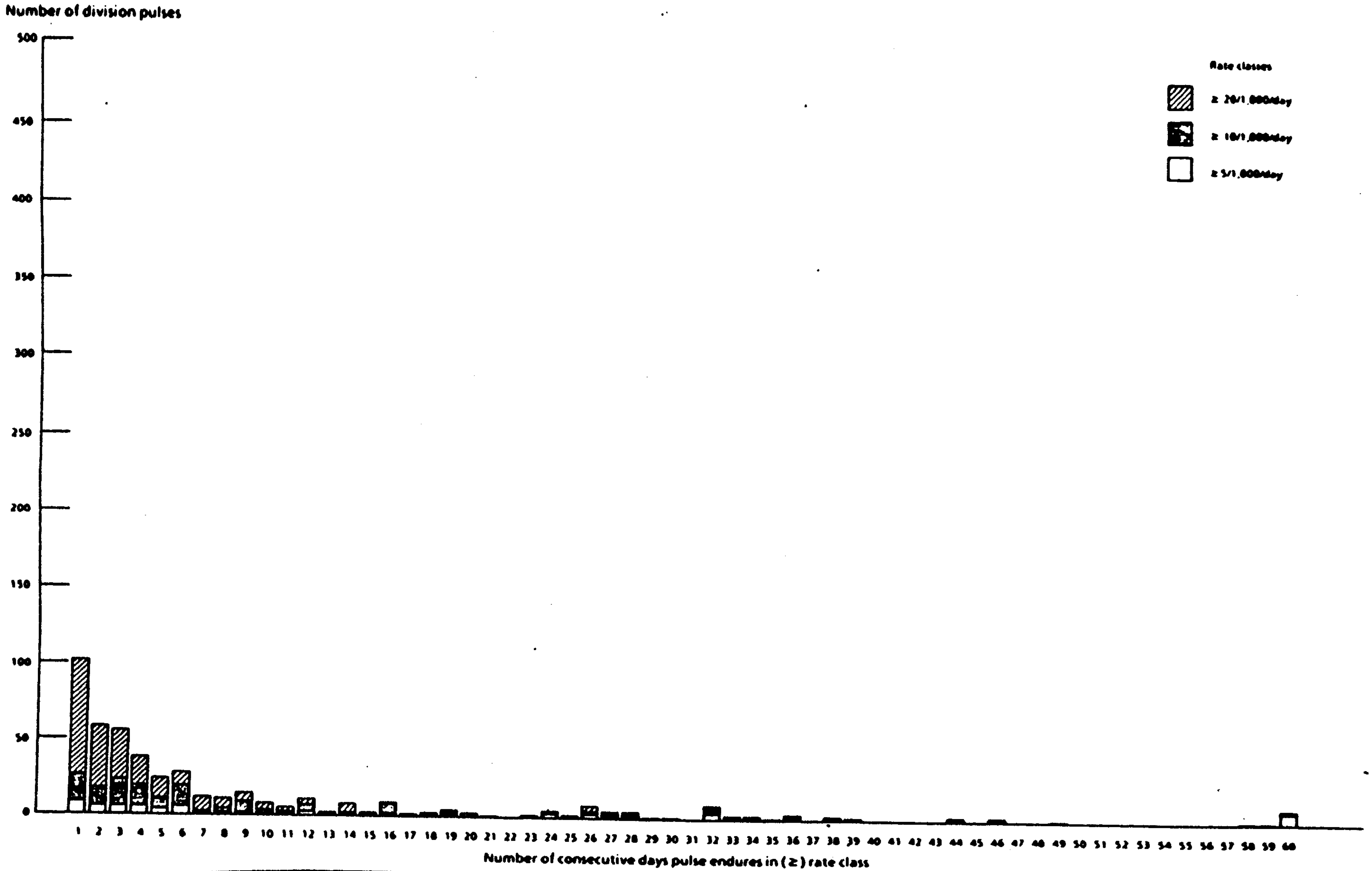


FIG. 12B. DURATION OF DIVISION PULSES BY RATE CLASS
— SIMULATION —

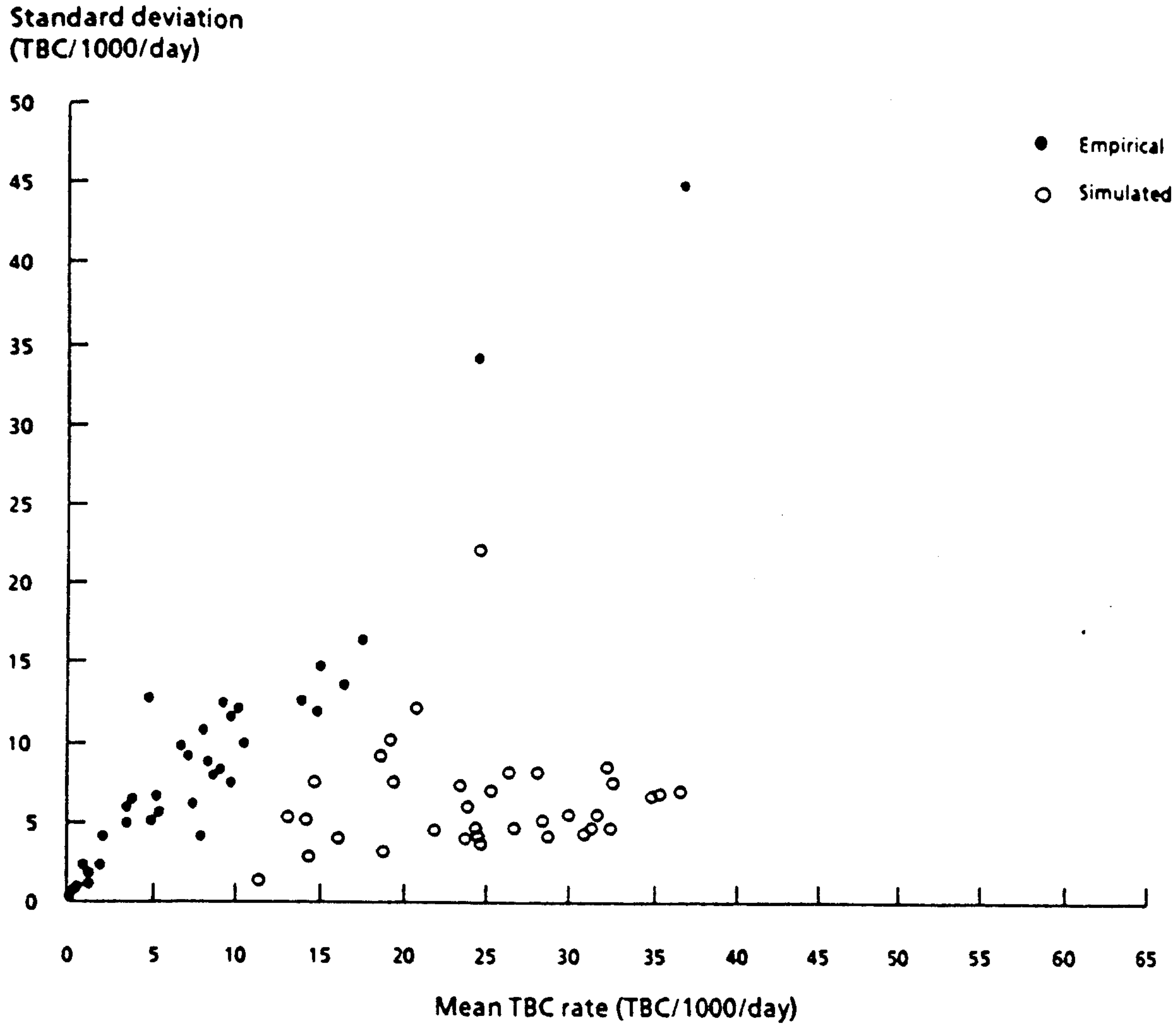
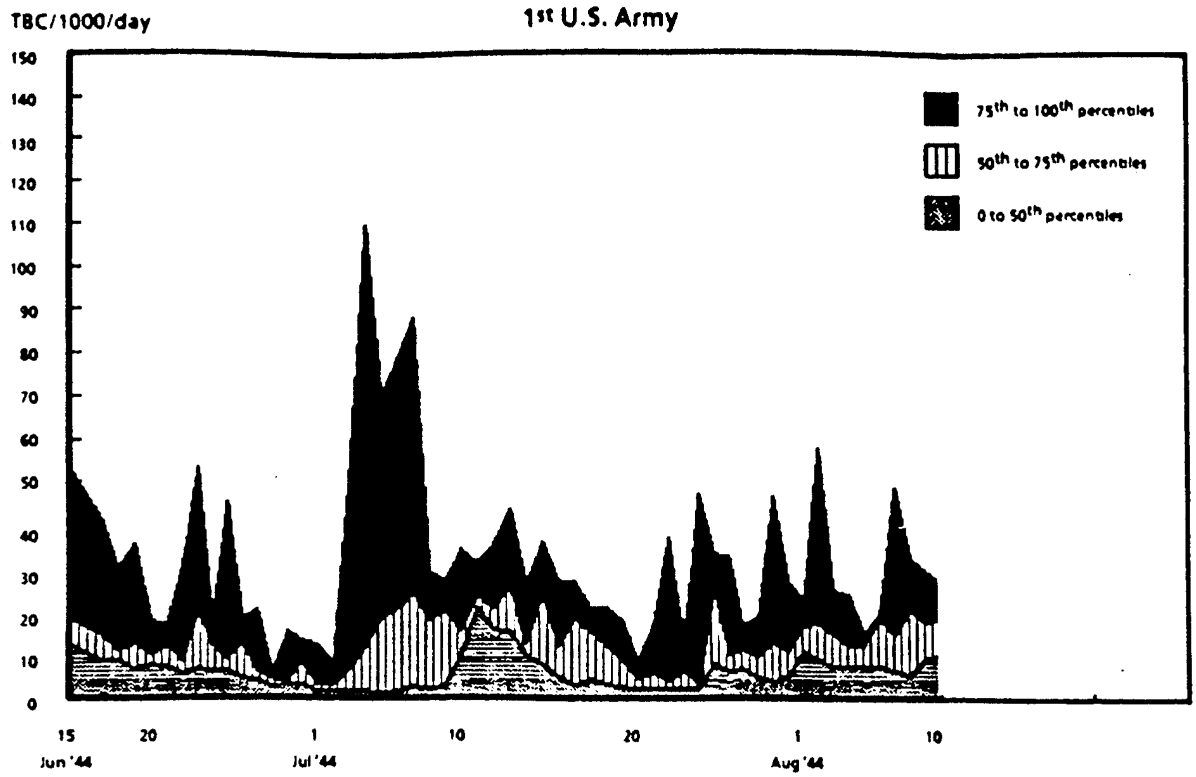


FIG. 13. MEAN AND STANDARD DEVIATION FOR 35 10-DAY CORPS PULSES
(Empirical and simulated)



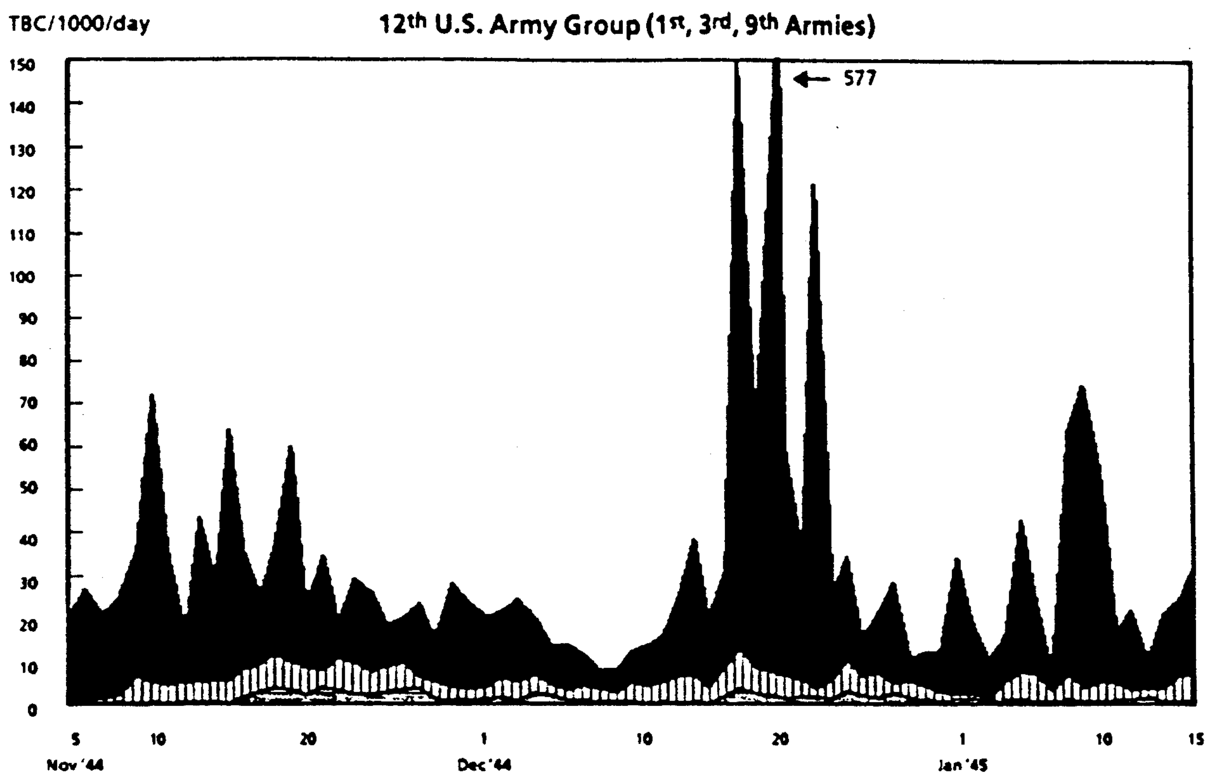


FIG. 14A. EMPIRICAL THEATER FORCE DAILY CASUALTY EXPERIENCE

(Distribution of force's division TBC rates by day)

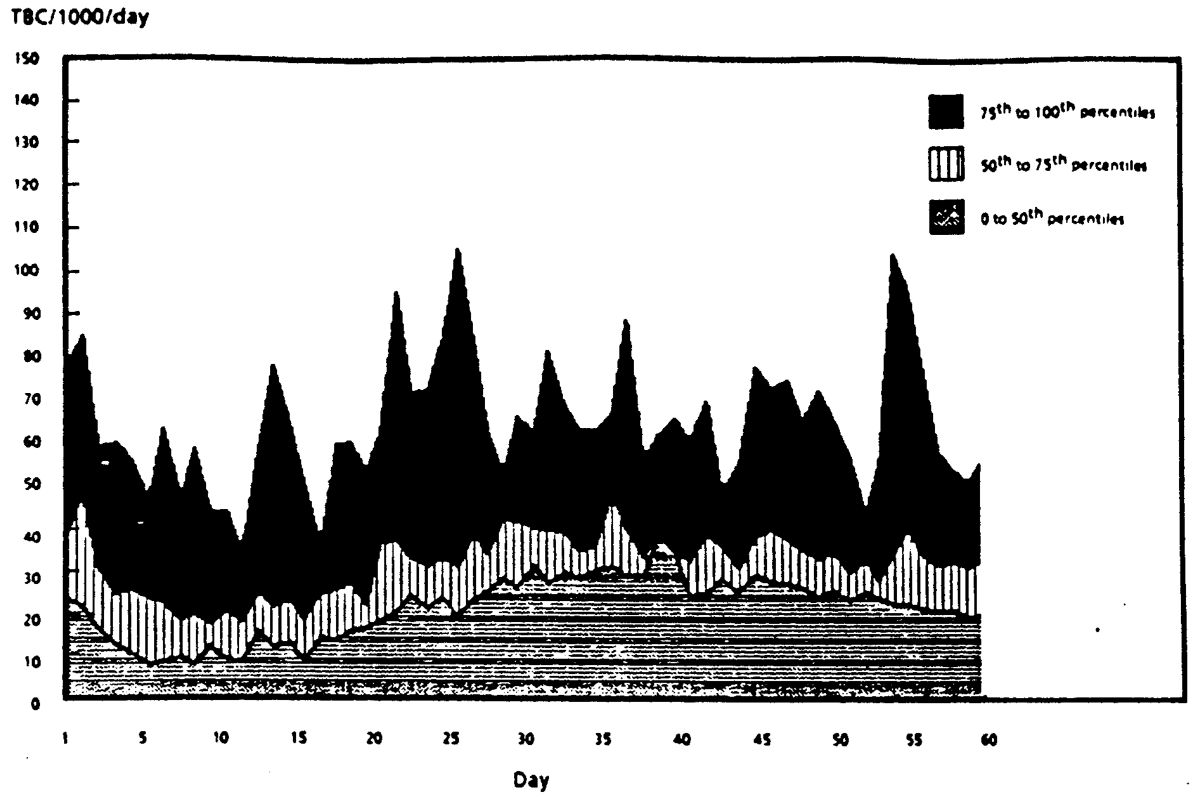


FIG. 14B. SIMULATED THEATER FORCE DAILY CASUALTY EXPERIENCE
(Distribution of force's division TBC rates by day)

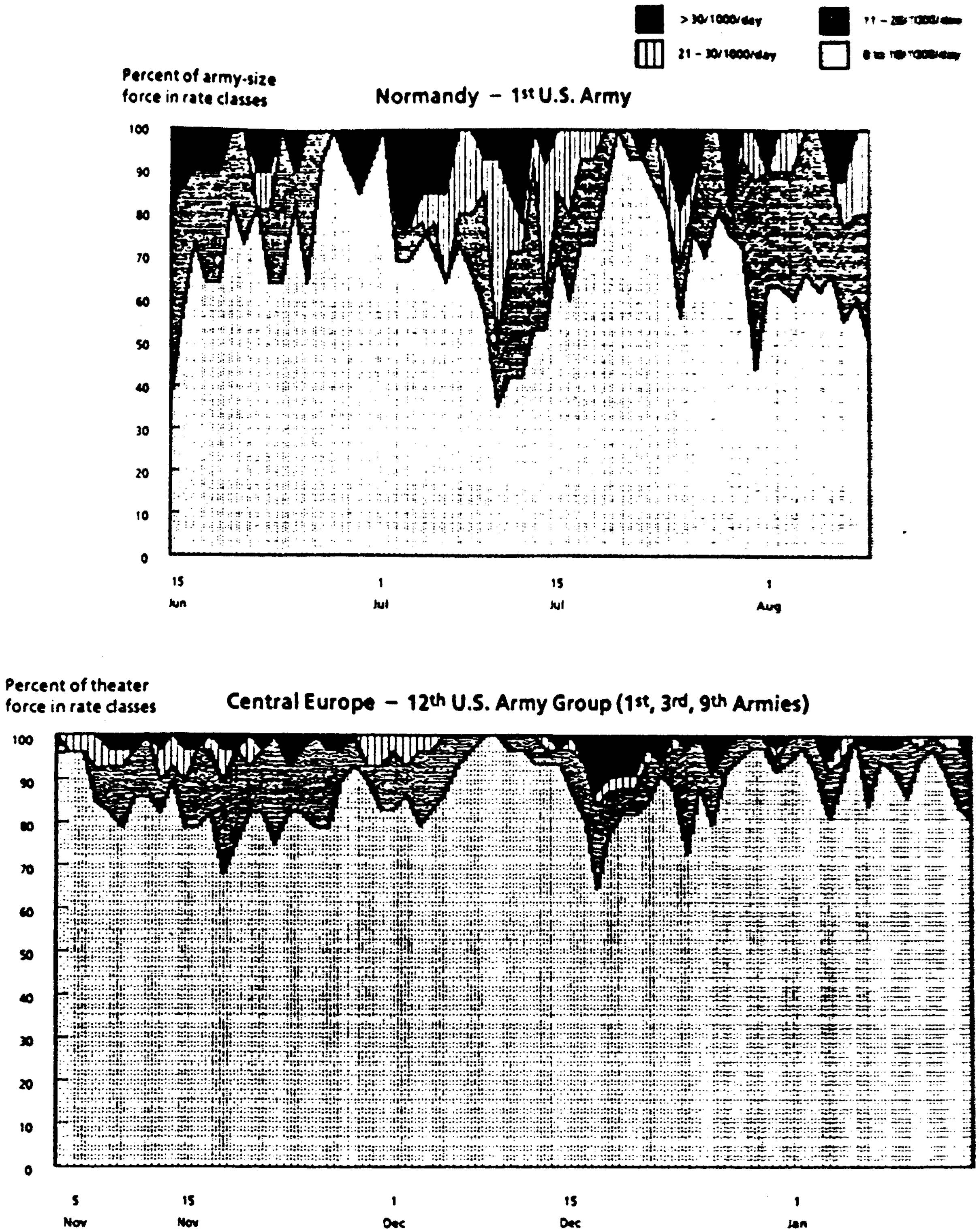


FIG. 15A. PERCENT OF THEATER FORCE (DIVISIONS) BY RATE CLASS BY DAY

(Two focused time periods – 57 and 72 days)

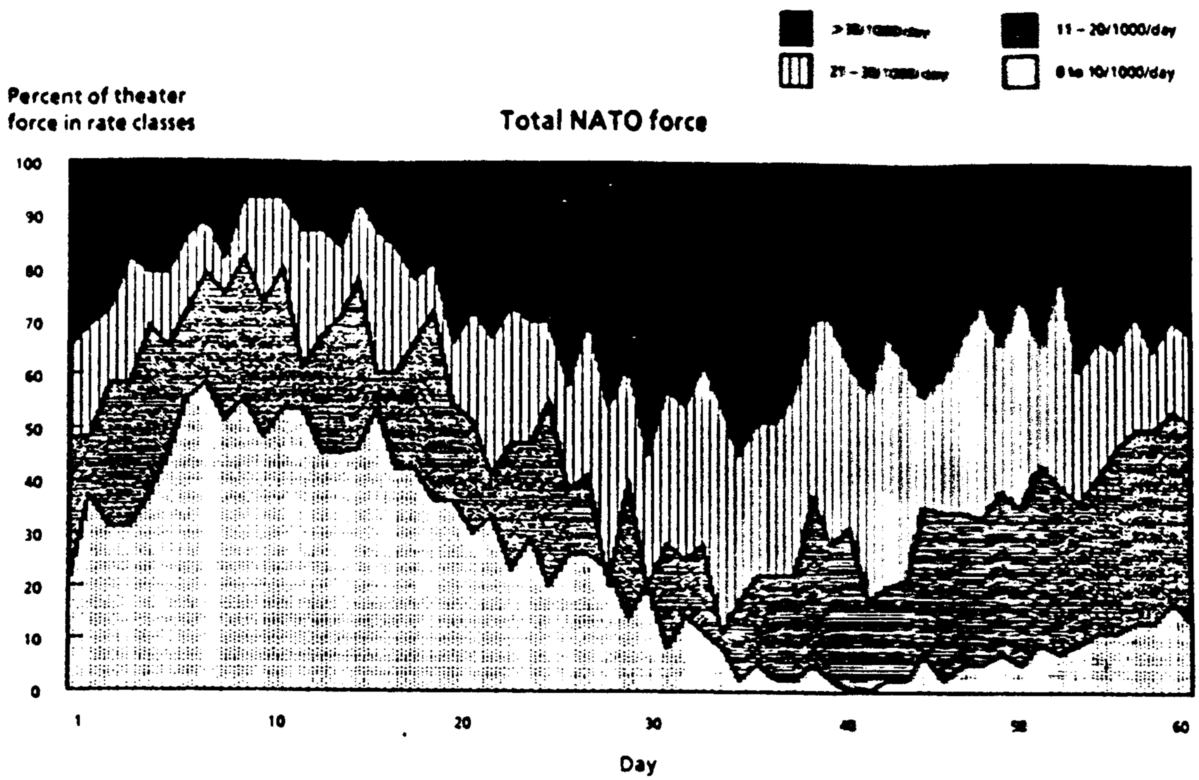


FIG. 15B. PERCENT OF THEATER FORCE (DIVISIONS) BY RATE CLASS BY DAY SIMULATION RESULTS

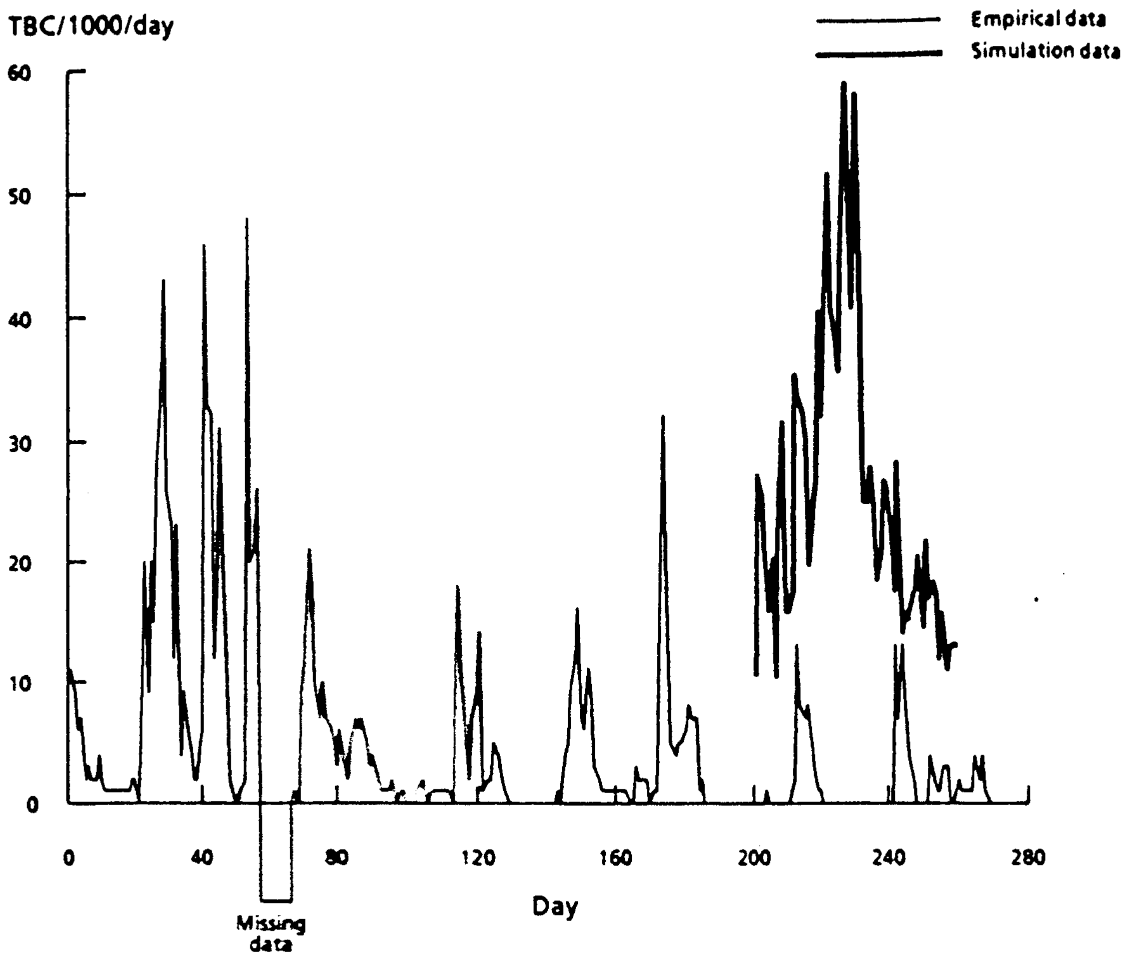


FIG. 16A. SIMULATION VERSUS EMPIRICAL EVIDENCE OF DAILY TBC RATE FOR SINGLE DIVISION

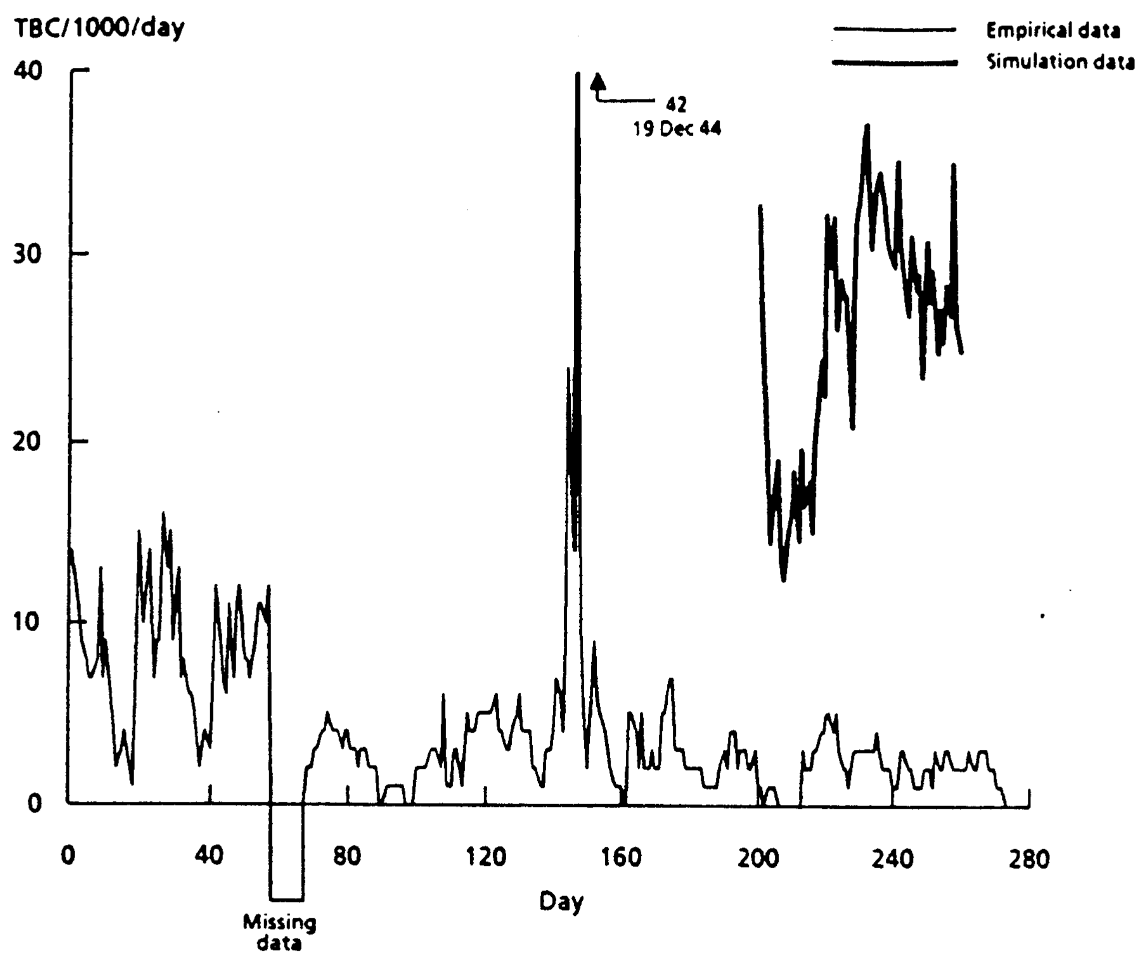


FIG. 16B. SIMULATION VERSUS EMPIRICAL EVIDENCE OF DAILY TBC RATE FOR SINGLE ARMY

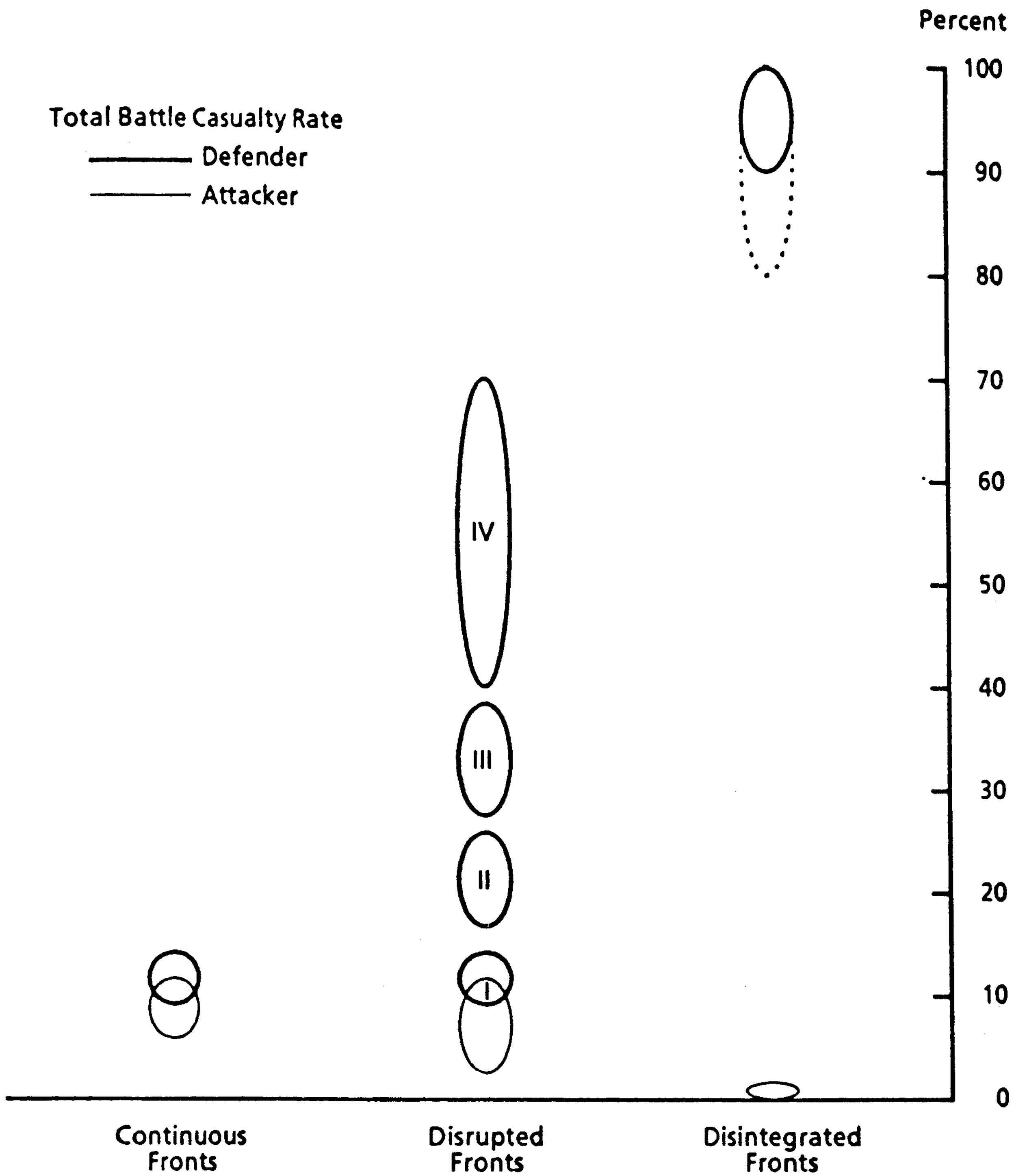


FIG. 17. SUGGESTED CASUALTY RATE RANGE RELATIONSHIPS
(Army-size Forces, 10-day)