Journal of the Operations
Research Society
Vol. 6, No. 1, April, 1981

—Research Paper—

On an Analytical Quick Game to Investigate the Battle Effectiveness of Forward Defence Concepts

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Abstract

The so-called *"Quick Game"*—models resemble a central element within the *Compound Gaming* approach of military systems analysis proposed by Huber [1, 2]. This paper introduces such an analytical model designed to investigate the battle-effectiveness of alternative army structures. The nature of its results is discussed from numerical experiments covering the (German) Army Structure 4, Loser's Area Coverage Defence Concept, and Afheldt's Area Defence Concept. It turns out that Löser's concept promises to have a comparatively high potential to stabilize the early conventional forward defence, hence being an interesting alternative for further analysis in depth.

Übersicht

Im Rahmen des von Huber [1, 2] vorgeschlagenen *Experimenteverbundes* der militärischen Systemanalyse spielen sogenannte *"Quick Game"*—Modelle eine zentrale Rolle. Vorliegender Beitrag stellt ein derartiges analytisches Modell zur Untersuchung der Gefechtswirksamkeit alternativer Heeresstrukturen vor. Die Nature der Ergebnisse wird anhand von Rechenexperimenten zur Heeresstruktur 4, zur raumdeckenden Verteidigung nach Löser und zur Raumverteidigung nach Afheldt illustriert. Es zeigt sich, daß Löser's Konzept ein vergleichsweise hohes Potential zur Stabilisierung der frühen konventionellen Vorneverteidigung erwarten läßt und somit eine interessante Alternative für vertiefte Untersuchungen ist.

1. INTRODUCTION

In order to improve the systems analysis support of force structure planning, HUBER [1, 2] proposes the approach of *"Compound Gaming"* which integrates military exercises, combat experiments, and formal battle simulations into a system of mutually complementary military games (see also HOFMANN and HUBER [3]). Within that approach, the so-called *"Quick Games"* resemble a central element. They comprise analytical battle models designed to help

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the force structure planner to identify, despite the rather immense variability of his planning problem, dominant alternatives for further refined analyses. Such a model is discussed in the following paper. It is to provide trend information on how technical, tactical, and structural system parameters affect the effectiveness of alternative army structures for the early forward defence battle in Central Europe.

2. THE MODEL

Force level and *terrain* represent the two principal parameters to describe the progress of battle. Analytical battle models explicate the dependence of these variables on the (independent) tactical, technical, and structural parameters of the forces and systems involved (e.g. see BERKOVITZ and DRESHER [4], BONDER [5], HUBER and WOBITH [6]). Thus, the battle model described here comprises two submodels, an *attrition* model and a *movement* model. The attrition model describes the fire-fight between the elements of an attacking Soviet motor-rifle division and those of the opposing land forces of the NATO-defenders in terms of heterogeneous LANCHESTER-differential equations. The movement model controls the opponents' movements through breakpoint criteria and determines the attack velocity from a functional relationship between movement rate and losses.

2.1 The Attrition Equations

Consistent with the basic assumptions underlying the LANCHESTER-equations [7], the model determines attrition from direct fire systems (e.g. tanks, armoured personnel carriers, infantry fighting vehicles, ATGM) using the *square law* and from indirect fire systems (artillery, mortars) using the *linear law*. Since we assume that the attrition effects of various different weapon system types employed by either side against a particular target type of the opponent are *additive* (no synergistic effects), these laws may be written as

$$\frac{dx_i}{dt}=-\sum_{j=1}^{n}\Psi_{ij}a^D{}_{ij}(t_E)\varepsilon^Y{}_j(t_E)y_j \text{ with } x_i(0)=x_{i0} \text{ for } i=1,\cdots\cdots,m$$
$$\frac{dy_j}{dt}=-\sum_{i=1}^{m}\phi_{ji}b^D{}_{ji}(t_E)\varepsilon^X{}_i(t_E)x_i \text{ with } y_j(0)=y_{j0} \text{ for } j=1,\cdots\cdots,n \tag{1}$$

in case of attrition due to direct (D) fire and

$$\frac{dx_i}{dt}=-x_i\sum_{j=1}^{n}\Psi_{ij}a^I{}_{ij}y_j \text{ with } x_i(0)=x_{i0} \text{ for } i=1,\cdots\cdots,m$$
$$\frac{dy_j}{dt}=-y_j\sum_{i=1}^{m}\phi_{ji}b^I{}_{ji}x_i \text{ with } y_j(0)=y_{j0} \text{ for } j=1,\cdots\cdots,n \tag{2}$$

in case of attrition due to indirect (I) fire (see also BRACKNEY [8] and TAYLOR [9]). Hereby we have

$$x_i=\sum_{j=1}^{n}x_{ji} \text{ for } i=1,\cdots\cdots,m$$
$$y_j=\sum_{i=1}^{m}y_{ij} \text{ for } j=1,\cdots\cdots,n. \tag{3}$$

In these equations x_i and y_j denote the number of live weapon systems or targets of types

X_i and Y_j of the NATO-defenders X and the Soviet attackers Y. The *allocation* factors $\Psi_{ij}=y_{ij}/y_j$ and $\phi_{ji}=x_{ji}/x_i$ denote the fractions of Y_j engaging X_i and of X_i engaging Y_j, $\varepsilon^Y{}_j$ and $\varepsilon^X{}_i$ the fractions of (direct fire) systems Y_j and X_i being blinded by or hiding in smoke. a_{ij} and b_{ji} are the so-called LANCHESTER-attrition rate coefficients. For the direct fire systems they are given by

$$\left.\begin{aligned} a^D{}_{ij}(t_E) &= \begin{cases} 0 & \text{for } 0 \leq t_E \leq T^Y{}_R \\ a^D{}_{ij} & \text{for } T^Y{}_R < t_E \leq T_E \end{cases} \\ b^D{}_{ji}(t_E) &= b^D{}_{ji} \end{aligned}\right\} \qquad (4.1)$$

with $a^D{}_{ij}$ and, in the analogous manner, $b^D{}_{ji}$ resulting from

$$\left.\begin{aligned} a^D{}_{ij} &= I^Y{}_j a_{ij}(r) \\ a_{ij}(r) &= \alpha_{ij}(r)(1-f^{Y_j}{}_I)[1-[(y_0-y)/(y_0-y_{BP})]^{\mu_Y}] \\ \alpha_{ij}(r) &= \frac{1}{E[T_{ij}]}\left(1-\frac{r}{R_j}\right)^{\mu_j} \end{aligned}\right\} \qquad (4.2)$$

For the indirect fire systems we have

$$a^I{}_{ij} = I^Y{}_j(1-f^{Y_j}{}_I)\frac{\upsilon_j a_{Lij}}{A_{X_i}}. \qquad (4.3)$$

The smoke factor $\varepsilon^Y{}_j$ (and in the analogous manner $\varepsilon^X{}_j$) is given by

$$\varepsilon^Y{}_j(t_E) = \begin{cases} \varepsilon^Y{}_j & \text{for } 0 \leq t_E \leq T^Y{}_{Sj} \\ 1 & \text{for } T^Y{}_{Sj} < t_E \leq T_E \end{cases} \qquad (5)$$

In equations (4) and (5) we denote by

r = average battle range between X and Y
R_j = maximum range of weapon systems Y_j
$I^Y{}_j$ = intelligence factor (actual fraction of Y_j engaging X_i)
y_{BP} = force level at which the battle is broken off (breakpoint)
$f^{Y_j}{}_I$ = fraction of weapon systems Y_j being (on the average) inactive at any time
μ_Y = exponent controlling the loss-dependent degradation in firing efficiency
μ_j = exponent controlling the range-dependency of the attrition-rate coefficient
$E[T_{ij}]$ = expected time for weapon system Y_j to kill target X_i
t_E = elapsed engagement time
T_E = engagement duration
$T^Y{}_R$ = attacker reaction time (in each engagement)
$T^Y{}_{Sj}$ = duration of smoke effects on system Y_j
υ_j = tactical firing rate of weapon system Y_j
a_{Lij} = lethal radius of Y_j warheads against X_i targets
A_{X_i} = deployment area of X_i targets.

To solve the equations (1) and (2), a time-step integration procedure by BONDER and FARRELL [10] is used. For a more detailed discussion of the attrition model the reader is referred to [11].

2.2 The Movement Model

Movement is essentially characterized by its *direction* and its *rate* (e.g. see GOAD [12]).

Consistent with its rather high level of abstraction the model assumes that both opponents maintain their original direction of movement perpendicular to the straight demarcation line which initially separated the antagonistic camps. With respect to the movement rate of the force elements, the model accounts for terrain trafficability, visibility, and, in case of the attacking party, for the amount of resistance offered by the opponent. The distance travelled within a time period Δt by unopposed elements is thus given by

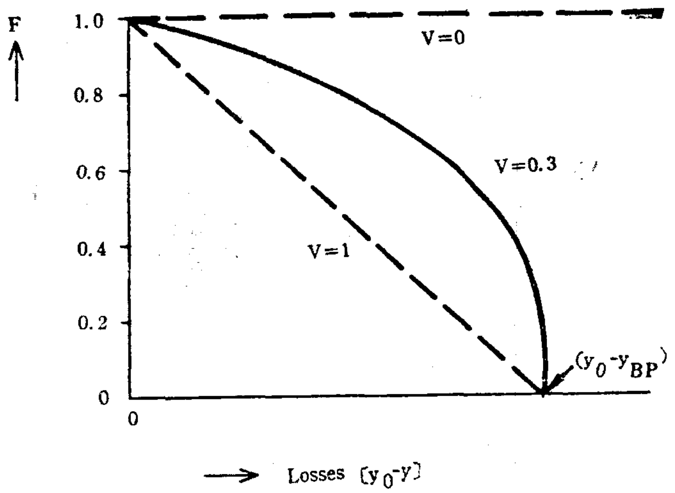
$$\Delta s = v_{0f} g m \Delta t \tag{6}$$

v_{0f} denotes the unopposed movement rate under "normal" conditions, g and m represent factors which account for other than normal terrain and visibility conditions.

In case the attacking party is under fire its movement is described by the "normal" opposed movement rate v_0 which reduces monotonously as the attacker's losses increase. This loss-dependent reduction is, for side Y, given by

$$f = \left(\frac{y - y_{BP}}{y_0 - y_{BP}}\right)^{\nu} \text{ with } y_0 = y(0) \text{ and } 0 \leq \nu \leq 1. \tag{7}$$

The analogue equation holds for side X. The exponent ν characterizes the reduction process (linear for $\nu=1$, nonlinear for $0<\nu<1$, no reduction for $\nu=0$; see also Fig. 1).



〈**Fig. 1**〉 Loss-dependent Reduction of the Attack Velocity

When the attacker's force level approaches the breakpoint y_{BP} the attack finally stalls. Thus, the distance covered in time period Δt by the attacker when in contact with the defender results as

$$\Delta s = \begin{cases} v_0[(y - y_{BP})/(y_0 - y_{BP})]^{\nu} g m \Delta t & \text{for } y_{BP} < y \leq y_0 \\ 0 & \text{for } y \leq y_{BP} \end{cases} \tag{8}$$

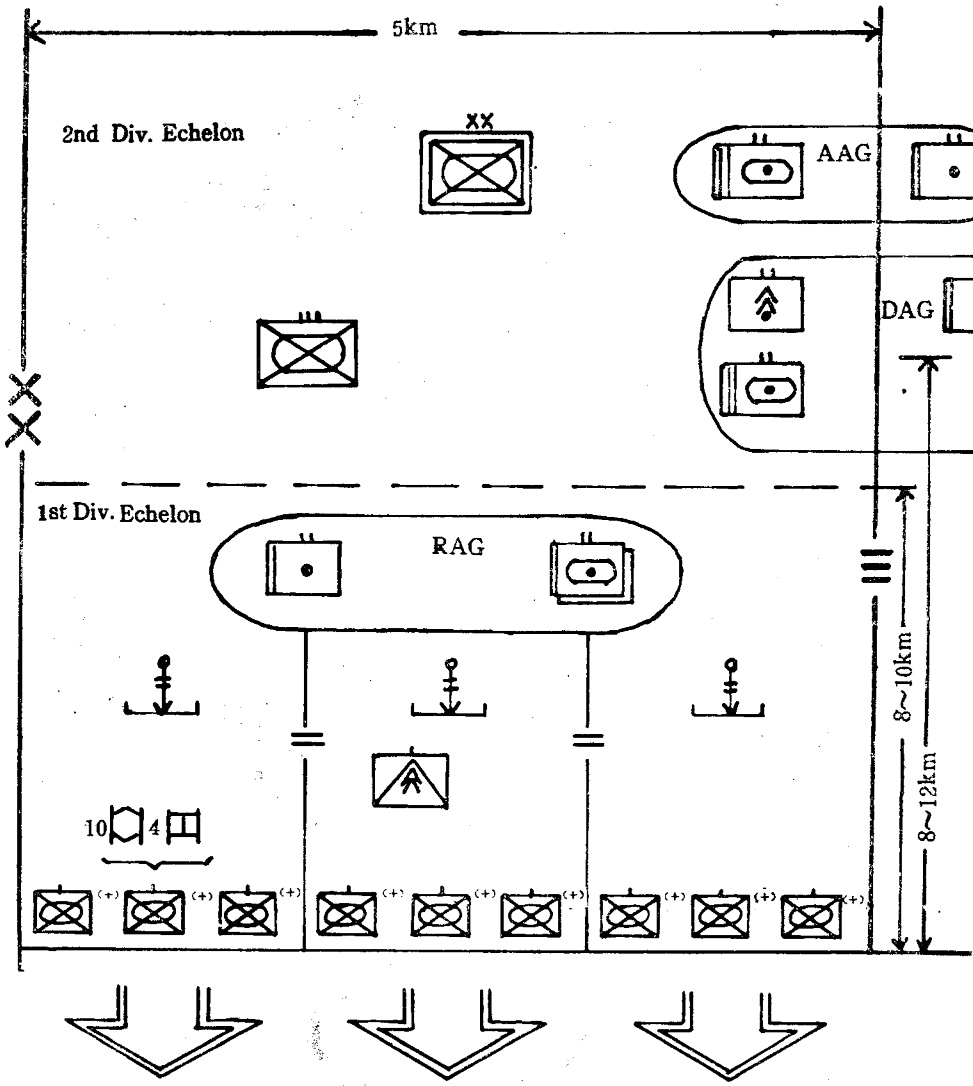
Therefore, at the end of each integration time step Δt for the attrition equations (1) and (2), the combat range between the opposing units of X and Y is updated by Δs.

Minefields cause the attacker to stop, break off the engagement, and seek cover as soon as the mines are noticed from the loss of a certain number of armoured vehicles. The attack is resumed after the minefield has been (partially) cleared by engineers. The delay time is an input to the model depending on both, the size and the density of the respective minefield.

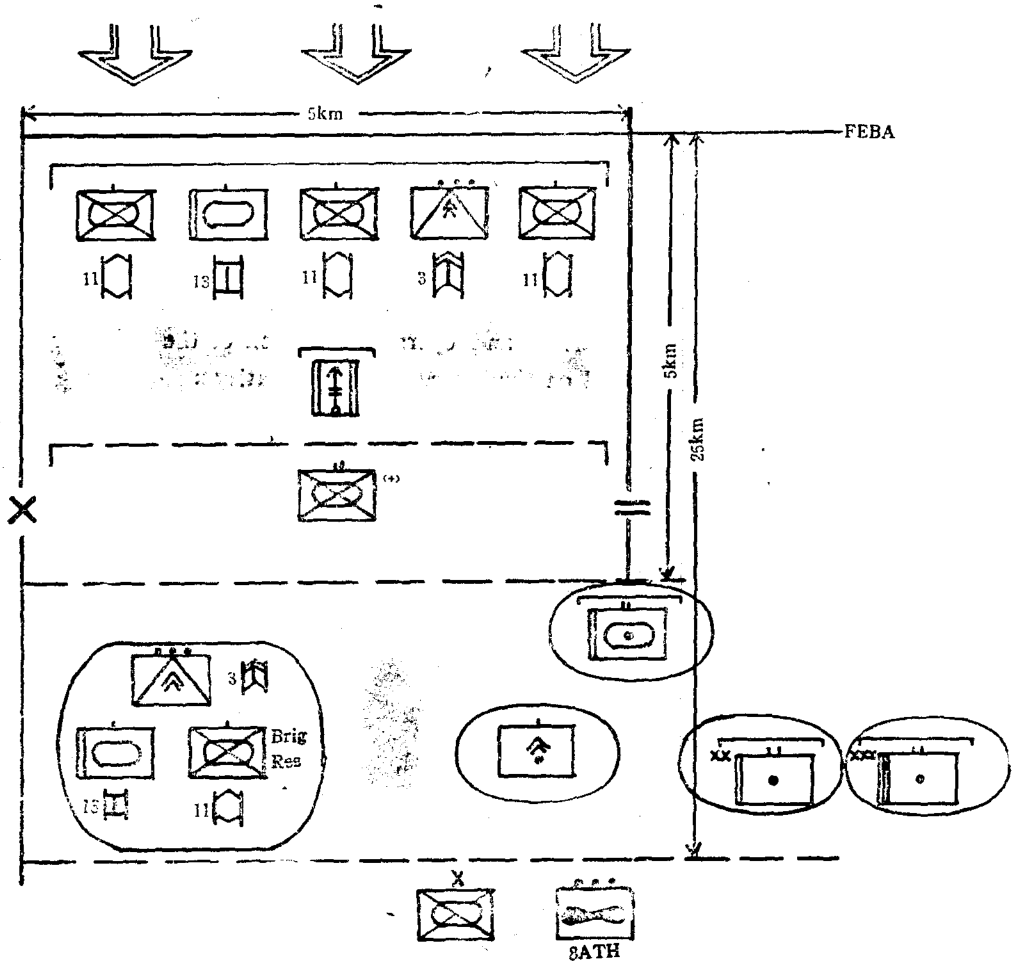
3. SOME EXAMPLES

To test the model, more than 100 battles between the first and second echelon regiments of an attacking Soviet motor-rifle division (see Fig. 2) and several alternative options for the NATO defences have sofar been simulated on the computer of the German Armed Forces University Munich (Burroughs 7800). The CPU-time requirements varied between 10 seconds and 4 minutes depending on the organizational and operational option of the defender forces. The NATO-options investigated are based on three structural alternatives:

(1) The *German Army Structure* 4 (alternative A; see [13, 14]). The defender forces comprise



⟨Fig. 2⟩ Attacker Posture



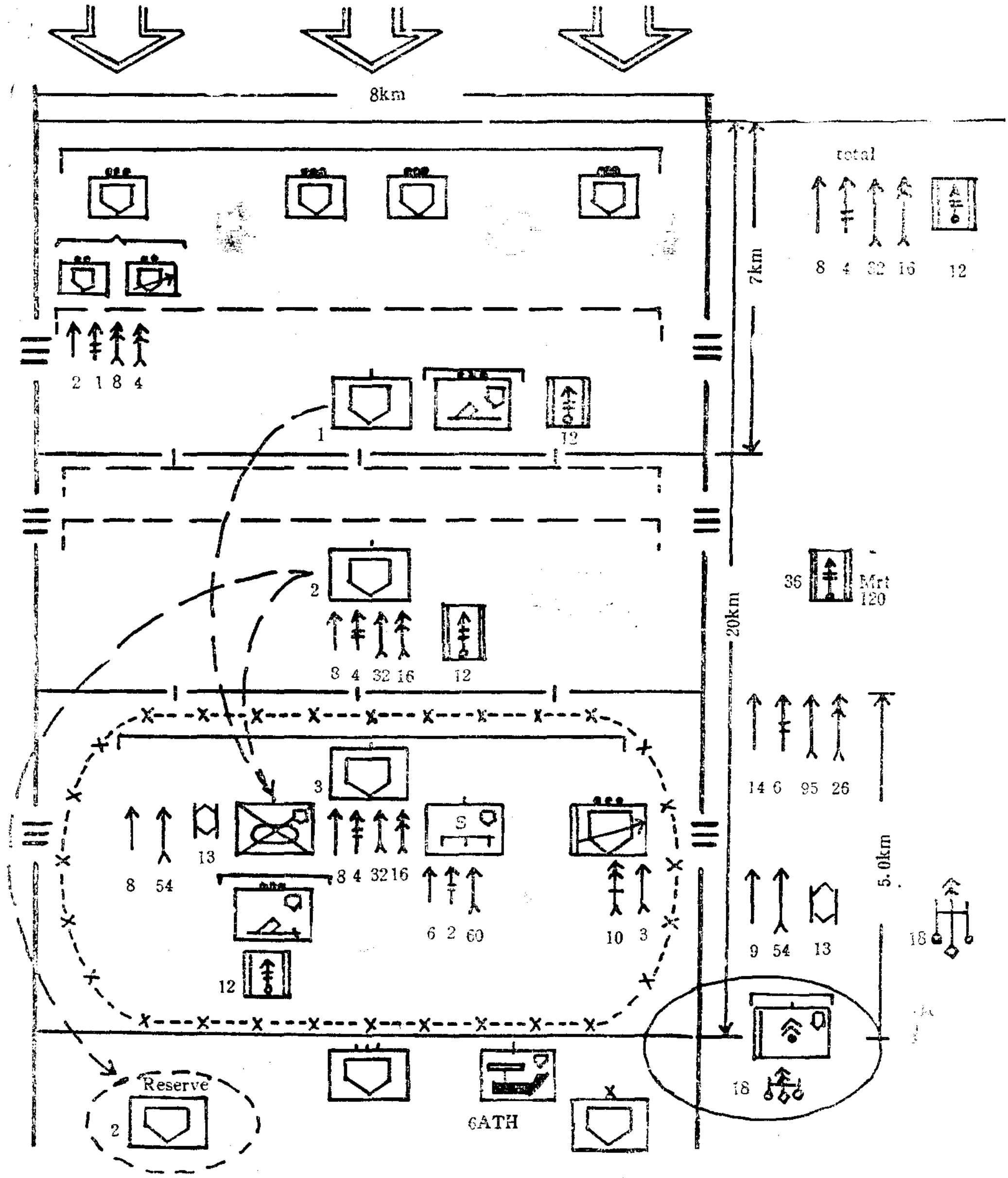
⟨**Fig. 3**⟩ Defender Posture-Alternative *A*

one reinforced armoured infantry battalion (verstPzGrenBtl) proportionately supported by the brigade forces and by the divisional artillery (see Fig. 3).

(2) The *Area Coverage Defence Concept* (alternative B) proposed by LÖSER as of November 1979 [15]. There, border defence forces (Grenzverteidigungskräfte) organized into battalionsize Jagdkampfgruppen (JgKpfGrp = three companies) deploy over a depth of 80—90 km. Each JgKpfGrp covers an area of 8 km frontage and 20 km depth (see Fig. 4).

(3) The *Area Defence Concept* (alternative C) proposed by AFHELDT as of January 1980 [16]. The defender forces comprise 4 light infantry battalions (JgBtl) deployed sequentially over a depth of 90 km and covering a frontage of 17.5 km each (see Fig. 5).

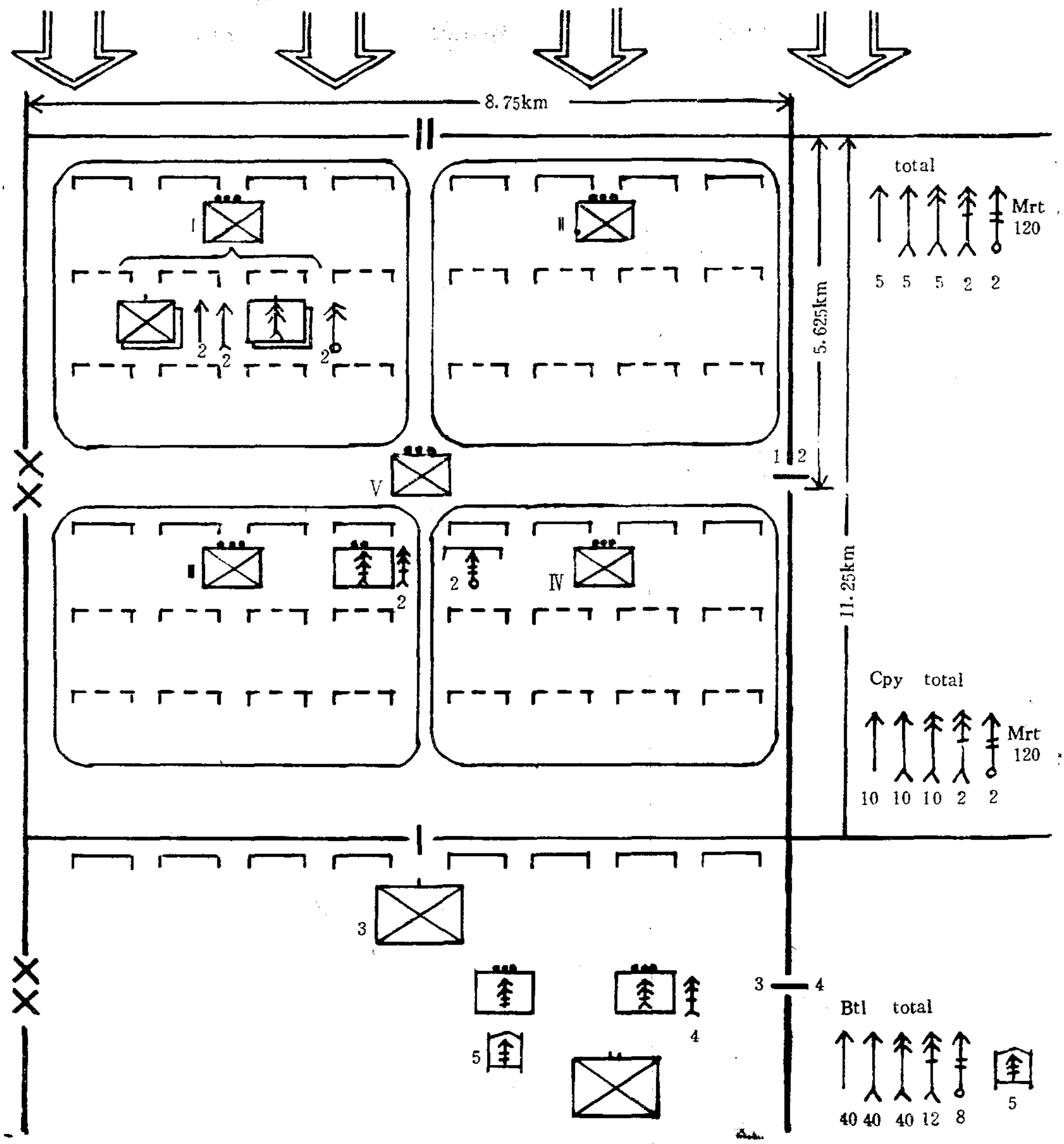
Contrary to alternative *A* in which the defending forces essentially seek one early decisive battle, the operational concepts of alternatives *B* and *C* are based on a tactic that attempts to attrite the attacker through a multitude of small and short engagements which the NATO battle teams fight from a network of prepared and concealed defence positions. It exploits BONDER's [5] observation that the instantaneous defender/offender-exchange rate as defined



〈Fig. 4〉 Defender Posture-Alternative B

by the quotient of the fractional loss rates dy/ydt of the attacker and dx/xdt of the defender decreases exponentially as a function of the elapsed battle time[1]. Concepts similar to those of alternatives *B* and *C* have been discussed by FULLER [18] as early as 1944, and proposed anew in the United States by CARMICHAEL [19], KEYES [20], and KLEINSTIVER [21] in the early seventies. Also, the *Distributed Area Defence*-concept described by PAXON, WEINER and WISE [22] belongs in that category. Alternative *C* exhibits similarities to

1) Huber discusses an analytical model which reproduces that effect by employing a time-variable Lanchester-attrition-rate coefficient for the attacker (see [2] p. 138 and [17] pp. 195-197).



⟨**Fig. 5**⟩ Defender Posture-Alternative C

CHANNON's 1972 proposal of a *Technological Guerilla* [23]. However, contrary to AFHELDT's *Techno-Commandos*, CHANNON's *Fighting Teams* are distinguished by a high tactical mobility (trail-bikes and helicopters). In the United Kingdom, similar thoughts have apparently been pursued for some time. The field experiment *"Goodwood"* organized as part of the 1980 NATO-exercise *Crusader* 80 seemed to have served the purpose of testing the results of prior operational research studies,

3.1 The Operational Concepts

Even though the three alternatives may differ perhaps considerably with respect to a timely deployment of the forces in case of a surprise attack, we postulate sufficient strategic warning so that all preparations necessary for an organized defence are accomplished in each case.

3.1.1 Alternative A

It is assumed that the forward elements of the NATO covering force successfully engage the Soviet reconnaissance forces so that the exact location of NATO's main force defence positions remains unknown to the attackers. Simultaneously, the covering force's resistance provokes increased Soviet artillery support which permits the defenders to identify the Soviet artillery positions. Thus, the initial situation for the main force attack in our model is characterized by massive Soviet artillery action against suspected NATO positions to which the defender's artillery responds with counter-artillery fire. When the attacking Soviet (reinforced) motor-rifle battalions of the first echelon regiment, advancing three abreast (see Fig. 2), get within firing range of the concealed firing positions of the NATO forces, the four companies of the (reinforced) armoured infantry battalion and the battalion anti-tank platoon simultaneously open fire (see Fig. 3). After a certain reaction time, the motor-rifle battalions respond with direct fire of their own. The direct fire engagement between the opponents is supported by indirect fire with priority on anti-tank weapons. During the fire-fight, the Soviet motor-rifle units advance at a terrain- and loss dependent movement rate (see section 2.2).

The model permits the defending forces several tactical support options. Depending on their losses, they may request the brigade reserves (two companies and one anti-tank platoon) to join the battalion forces. They also may deploy minefields in front of their positions, request anti-tank helicopter support, or apply smoke screens to attain a better instantaneous force ratio. When their losses become too high, the defending forces break off the engagement and withdraw (possibly under smoke cover) to resume the battle from their rear positions.

Should the attacker's first echelon forces be attrited down to their breakpoint, the second echelon forces are brought into action and continue the battle without delay. While the first echelon's maneuver forces are phased out, its indirect fire systems continue the battle together with those of the second echelon.

The battle terminates either when the defending NATO forces reach their breakpoint, or when the attacking motor-rifle division attains its objective (i.e., breaks through the rear line of the NATO defences), or when the attack stalls due to the second echelon of the motor-rifle division being attrited down to its breakpoint.

3.1.2 Alternative B

In alternative B, the Jagdkampfgruppe (JgKpfGrp) covering a 8 km wide sector deploys its three companies in tandem over a depth of 20 km. Within their 7 km deep *attrition zones*, the battle teams of the two forward companies (8 squads per company) fight a delaying battle from prepared and concealed defence positions. Hereby, in each attrition zone the teams fall back through, on the average, three alternative defence positions distributed over the attrition zones. When leaving the rear position in its attrition zone, the forward company's teams withdraw to the so-called *reinforced zone* within the rearward 5—6 km of the JgKpfGrp's 20 km deep area of operations. There, together with the teams of the third company they resume the battle after the attackers have penetrated the attrition zone of the second company. When the second company withdraws, its teams become the JgKpfGrp's reserves eventually augmenting the teams of the first and third company in the defence of the reinforced zone. When the forward JgKpfGrp breaks, the attacker is confronted by the second (and eventually by the third and fourth) JgKpfGrp of the border defence forces each fighting in identical fashion.

3.1.3 Alternative C

In alternative C, each of the four light infantry battalions (JgBtl) deployed in tandem over a depth of 90 km consists of four companies deployed two abreast and two in tandem. The same deployment holds for four platoons within each company with the fifth platoon being allocated as the situation requires (see Fig. 5). Thus, the platoons (4 demi-squads each) are assigned 4—4.5 km wide and 5—6 km deep areas of operation. Within that area their battle teams fight from prepared defence positions falling back through, on the average, two alternate defence positions in order to repeatedly exploit defender's first-shot advantage. Subsequently, the teams move into prestocked hideouts (Within the area of operation assigned to the respective platoon) from which they continue their operations in the attacker's rear against second echelon forces.

3.2 Selected Results

In order to illustrate the type of information which may be extracted from numerical experiments by means of *Quick Games* we shall discuss some results obtained from experiments performed on the alternatives described above. The attrition-rate coefficients a_{ij} and b_{ji} underlying these experiments have been determined from unclassified technical and performance data of the systems X_i and Y_j shown in Fig. 2—5. Therefore, they represent crude estimates only which do, however, reflect the principal capabilities of the respective systems sufficiently well with regard to the very purposes which quick game models are meant to support (see also HUBER [1], p. 38 and [2], p. 140). For each experiment, tactical and technical system parameters have been varied such as to provide some trend information on the comparative battle effectiveness of the alternatives A, B, and C. From the set of experiments carried out sofar we have selected the following:

Alternative A

(A1) The reinforced armoured infantry battalion defends its sector without employing mines and not being supported by the brigade reserves. The range at which its elements (simultaneously) open fire at the approaching elements of the Soviet motor-rifle division is set at 1500 m. Whenever the engagement range drops down to 300 m or the battalion's actual strength is reduced by 33%, the battalion withdraws (two times at most) to resume the defensive battle approximately 2500 m further back. The Soviet penetration depth and the elapsed battle time at which the engagement terminates in experiment A1 (*reference case*) have been selected to define the units of our distance scale (DU) and time scale (TU).

(A2) Here, the defenders have deployed a mine field 700 m in front of their forward positions. The open fire range is set at 800 m. The attackers halt their advance to clear the minefield after they lost one main battle tank (MBT) and one armoured personnel carrier (APC) due to mines. It is assumed that it takes the attackers about two TU to clear the mine field.

(A3) This experiment differs from A2 in that the brigade reserves (1 tank company, 1 armoured infantry company, 1 anti-tank platoon) and one flight of 6 anti-tank helicopters support the battalion as soon as its initial strength is reduced by 25%.

Alternative B

(B1) The JgKpfGrp has no mines available. In their attrition zones and in the reinforced zone, the battle teams of its three companies disengage and fall back to their next alternate defence position as soon as they suffered 10% losses or when the engagement range reduces to 300 m. From each defence position, the open fire range for the battle teams is set at 1500 m.

(B2) Here, the defenders deploy mines 700 m in front of all defence positions in the first attrition zone, in front of two thirds of the defence positions in the second attrition zone, and once in front of the reinforced zone. Thus, the attacking elements have to traverse an average of 6 minefields each at a loss of one MBT and one APC and being delayed by two TU. The open fire range for the battle teams is set at 800 m. Otherwise, conditions are the same in case B1.

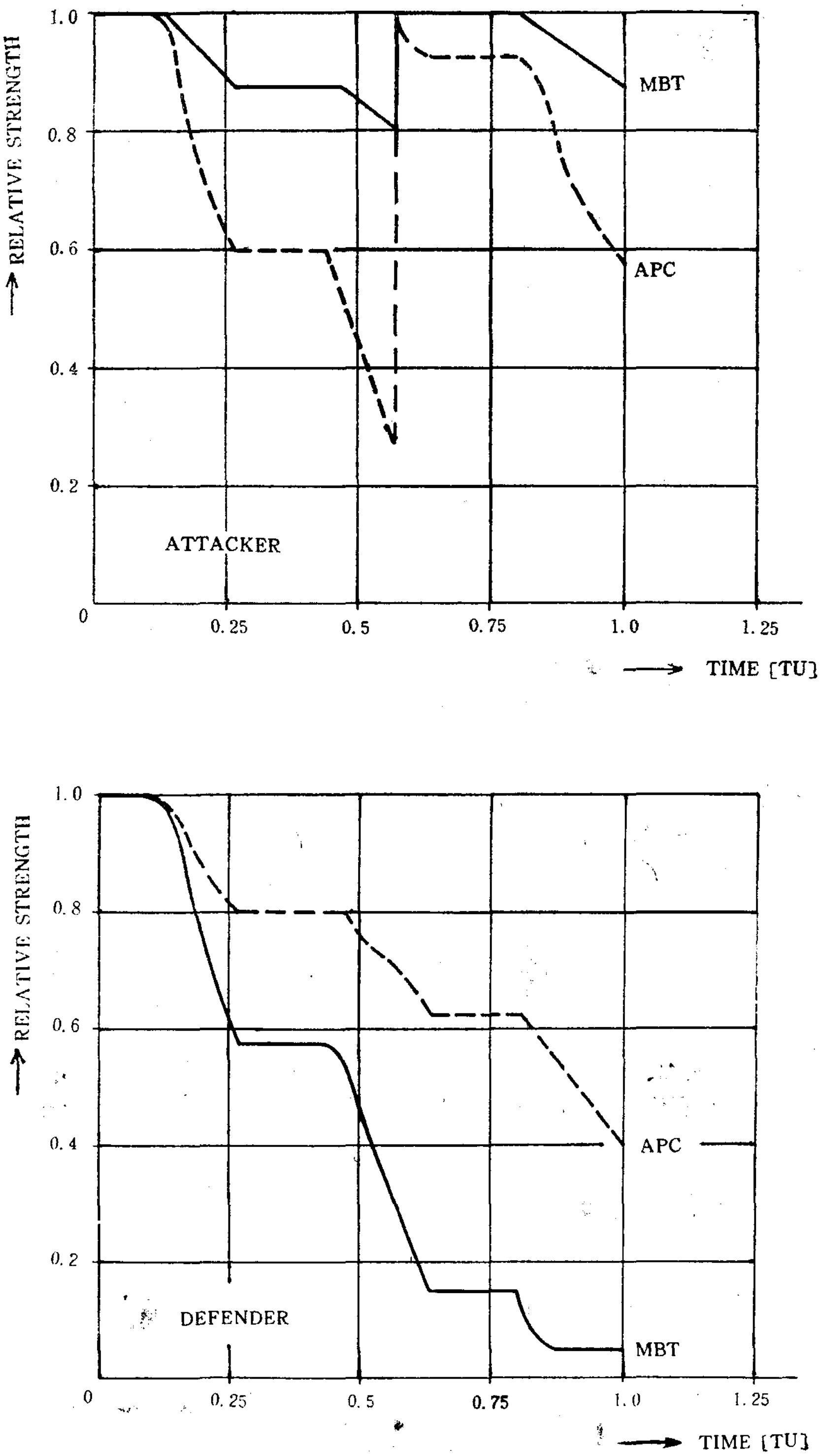
Alternative C

(C1) The battle teams of the light infantry battalions open fire whenever the range to attacking Soviet elements is 1500 m. They disengage and fall back to their next alternate position (two times on the average before hiding) when they suffered 10% losses, or when the engagement range is down to 300 m, or when the firefight in one position lasts 30 minutes.

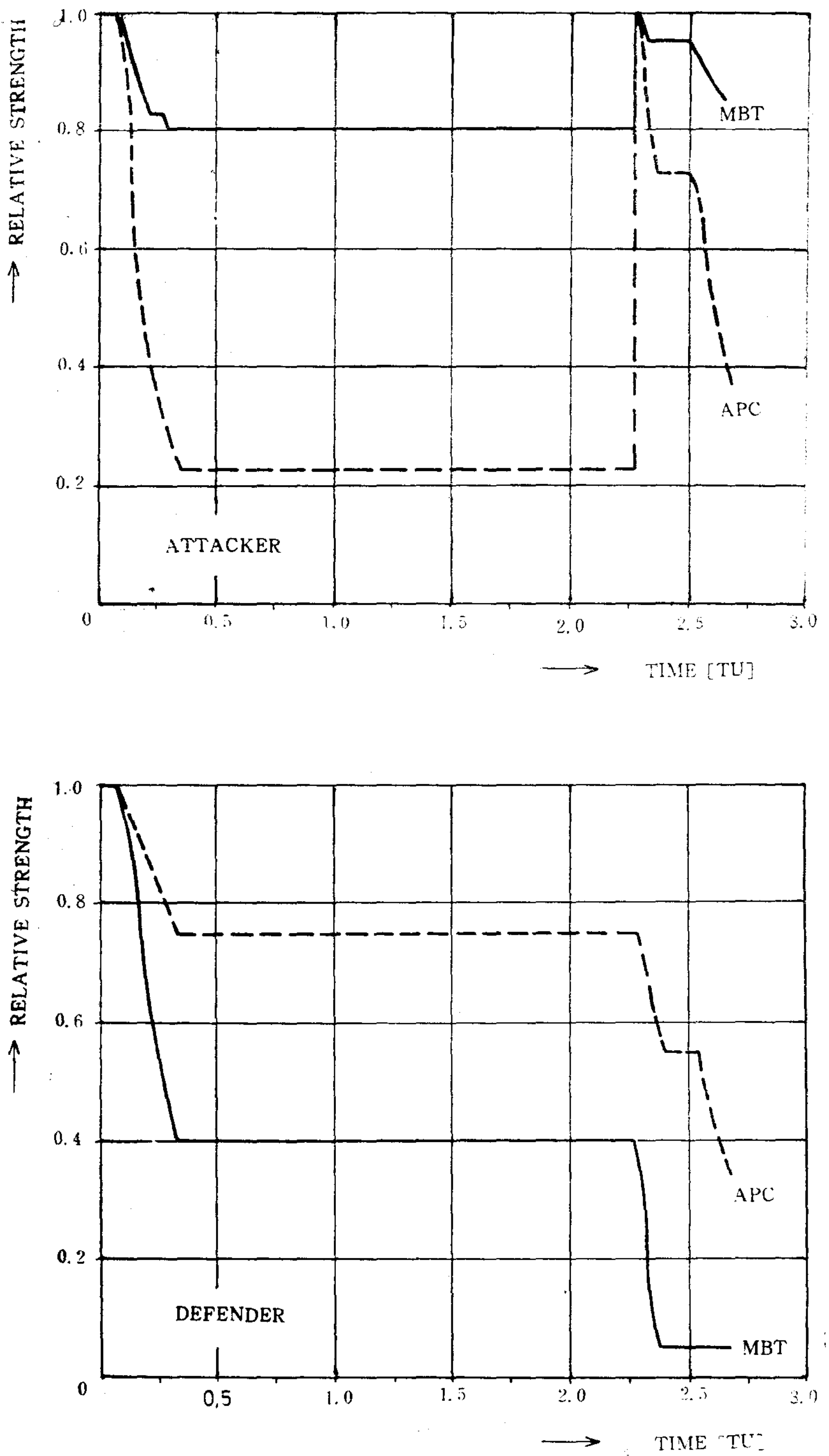
(C2) Similar to case B2, the teams deploy mines 700 m in front of their positions. Thus, in each battalion area, the attackers are confronted by an average of 12 mine obstacles each of which causes the loss of one MBT and one APC and a delay of approximately 1. 5 TU. The open fire range from each defence position is set at 800 m. All other conditions are identical to those in experiment C1.

Fig. 6. 1—6. 3 show, for both opponents, the relative numerical strengths of the two main direct fire systems during the experiments. We notice that in both, the reference case A1 and the case A2, the defence collapses at between 60—90% losses in APC's and MBT's for the defender and at between 20—80% losses in MBT's and APC's for the attacking motor-rifle division's first echelon, and between 10—40% respective losses for the second echelon.

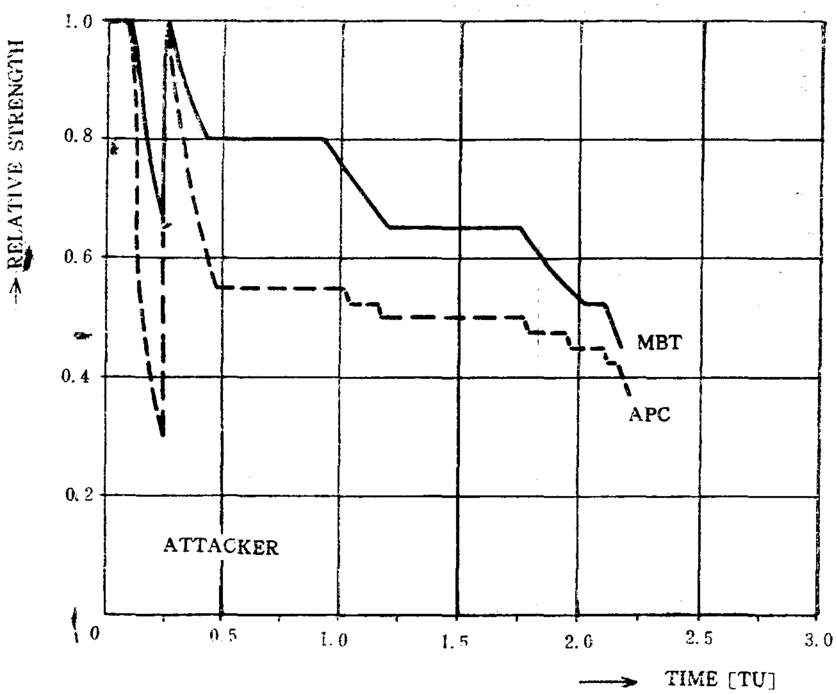
However, in case A2 the employment of mines delays the collapse by a time factor of 2—3. The horizontal sections in the attrition curves are indicative of either a disengagement and

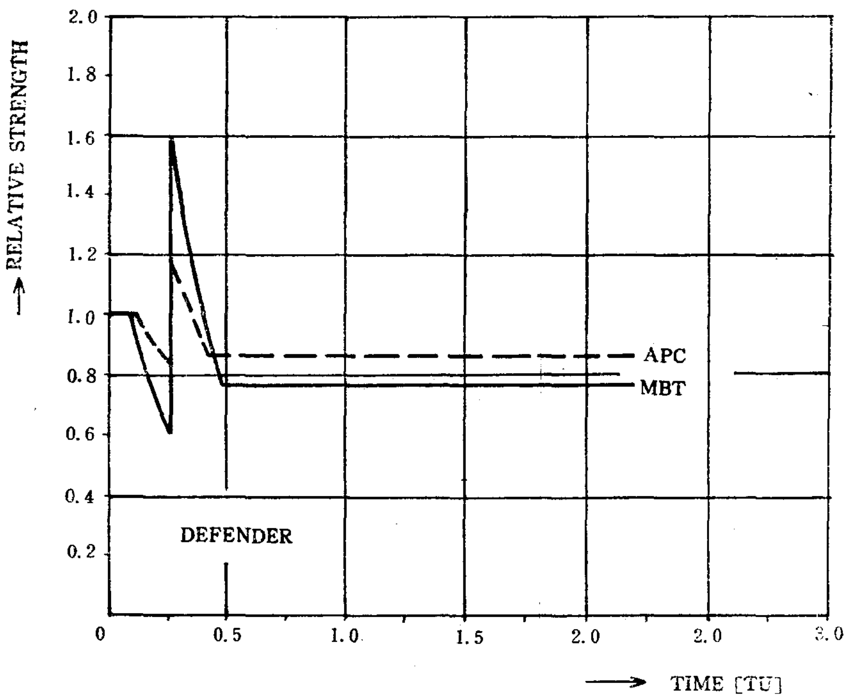


〈Fig. 6.1〉 Force Levels Case A.1



〈Fig. 6.2〉 Force Levels Case A.2





〈**Fig. 6.3**〉 Force Levels Case A.3

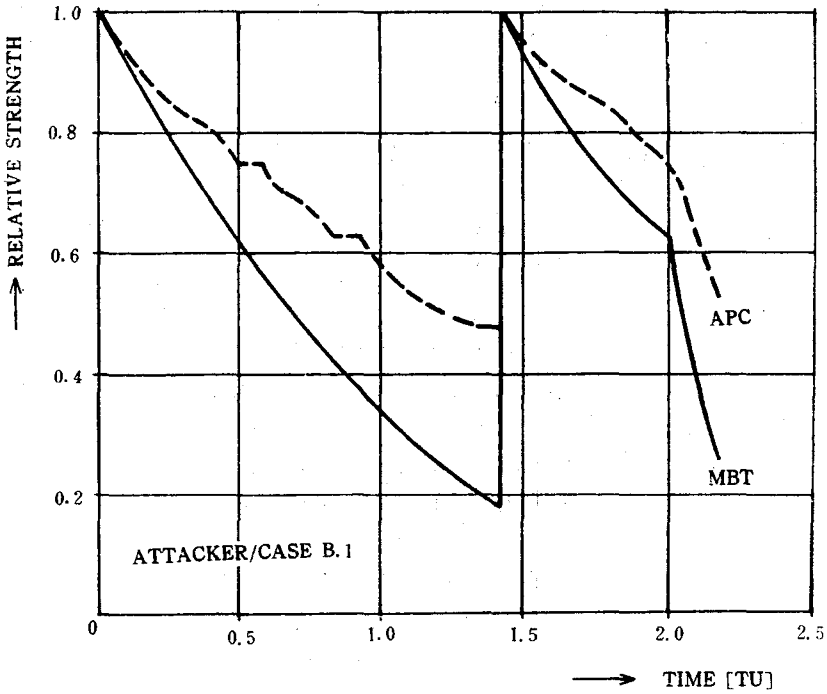
change of position by the defender or of the attacker waiting for a minefield to be cleared. The higher attacker attrition rates in the firefights of case A2 (steeper attrition curves as compared to A1) are caused by the mine effects in combination with the shorter open fire range.

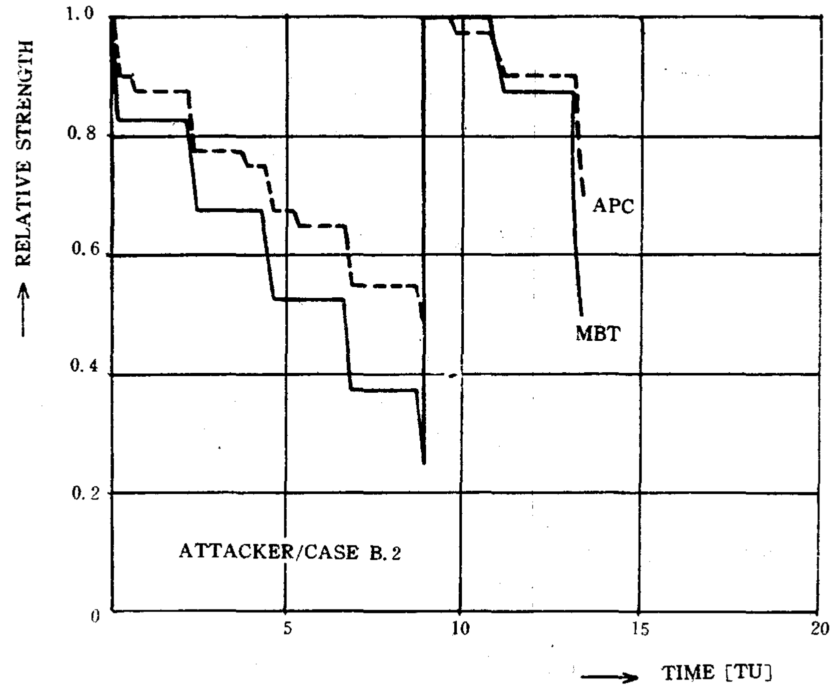
In its sector, the defending armoured infantry battalion may halt the motor-rifle division's attack only if, in addition to employing mines, the battalion is supported by all the brigade reserves rather early in the battle (see Fig. 6.3). Hereby, a decisive contribution is apparently made by the anti-tank helicopters which may attrite the attacker's elements (halting covered up in front of the minefields) rather more effectively than the defender's indirect fire systems.

The results for alternatives A do not alter significantly if, in our experiments, we assume both opponents to be equipped with later technology weapons, or if we mount more ATGM's on the defender's APC's. In general, the results seem to indicate that the verstPzGrenBtl of the *Heeresstruktur* 4 hardly has the means available to thwart an attack of the strength assumed in our experiments. Even if it does by being allocated all the brigade's reserves, its attrition must be expected to be sufficiently high to render it incapable of further action prior to the availability of replacements on a major scale.

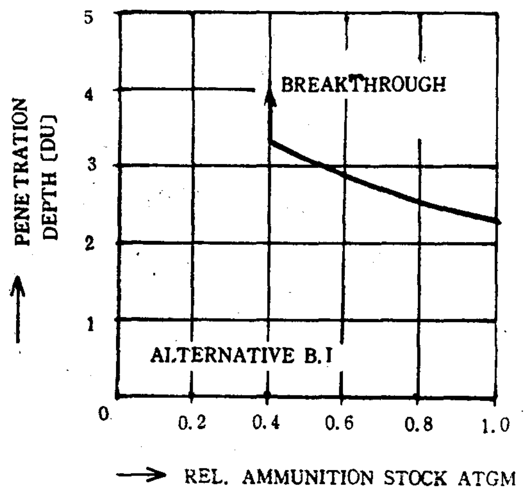
The attrition of the attacker's main systems in the two experiments of alternative B is given in Fig. 7.1 (the defender's attrition is omitted since it amounts to at most 20% for the JgKpfGrp at the time when the divisional attack stalls). As compared to alternative A, we notice a significantly reduced attrition rate as a result of the defender's typical tactics in those cases which foresee a frequent and early change of defence positions. After having introduced the second echelon at an elapsed battle time of about 1.5 TU when the defenders have no mines available and at about 9 TU when they employ mines, the second echelon's attack finally stalls after 2.2 and 13 TU respectively in the JgKpfGrp's reinforced zone. Since the defender's direct fire systems were assumed to be largely ineffective against the motor-rifle elements halting in cover before minefields, mines in alternative B are of a rather minor impact on the attacker's attrition as compared to the cases of alternative A where the defenders have considerably more indirect fire systems available. However, consistent with our assumptions on the time required to clear minefields, the employment of mines *significantly* increase battle time.

Typical sensitivities of experiment outcomes to variations in assumed parameter values are shown in Fig. 7.2 and 7.3 for the opposed normal movement rate v_0 and the availability level of ATGM munitions in the defence positions. E.g. if that availability level were down to 40% (of the assumed level), or if the attacker were able to triple his attack velocity, a breakthrough must be expected. The latter sensitivity emphasizes that the effectiveness of alternative B-type concepts is not the least due to the timely availability of a sufficient number of mines. Further sensitivity analyses have also shown that alternative B is rather insensitive to an increase in Soviet artillery. Even if the Soviets were to triple their artillery, the JgKpfGrp may still be expected to halt the divisional attack. But if the Soviets could increase their units' numerical strength by a factor of two without simultaneously in-

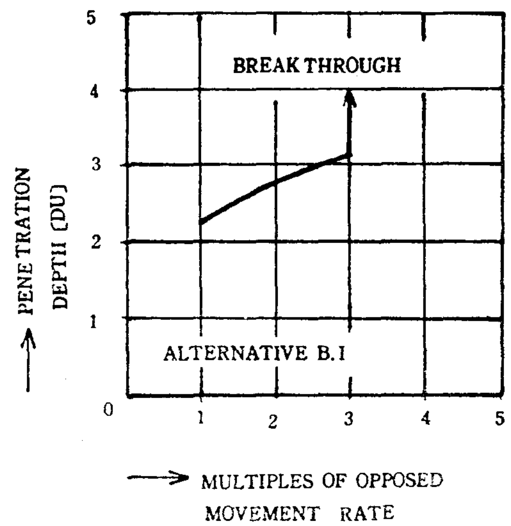




〈**Fig. 7.1**〉 Attacker Force Levels-Alternative B



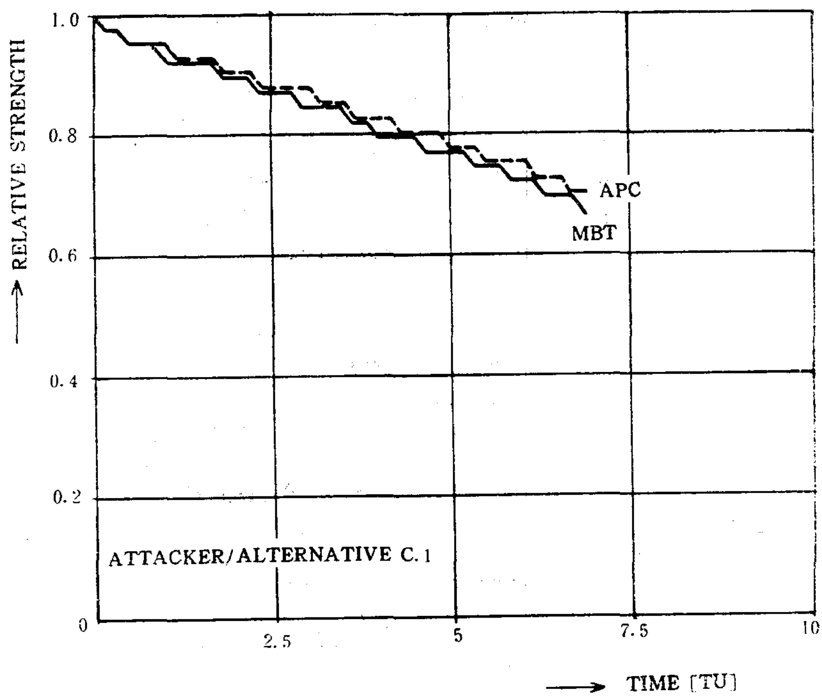
〈Fig. 7.2〉 Influence of ATGM Availability on the Attacker's Penetration Depth

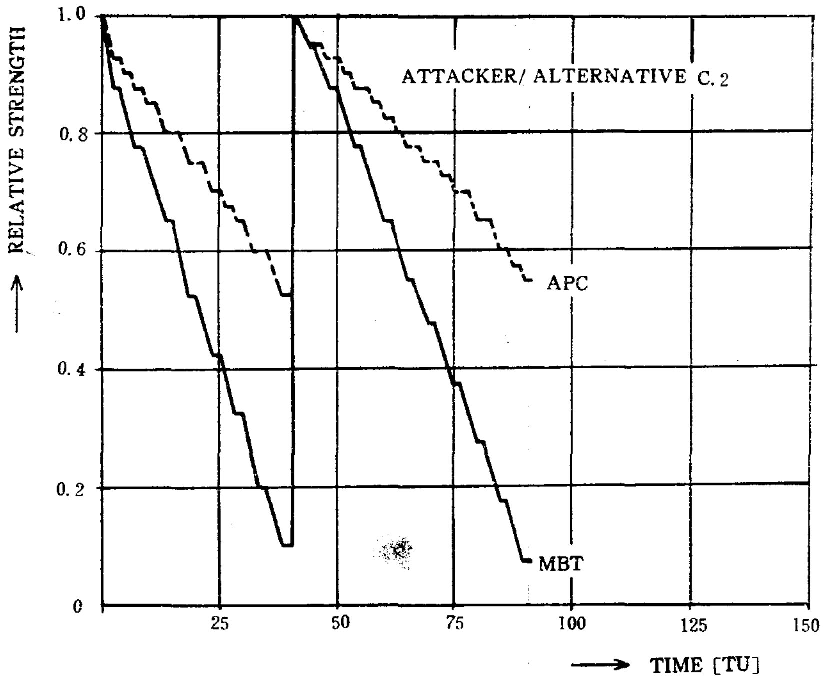


〈Fig. 7.3〉 Influence of the Movement Rate on the Penetration Depth

creasing their vulnerability, the second echelon forces of the first division would likely break through the forward JgKpfGrp.

The attacker attrition rates resulting from experiments with alternative C (see Fig. 8) are almost identical to those of the comparable cases of alternative B. However, contrary to case B1 where the attack is halted by the forward JgKpfGrp, in case C1 even the motor-rifle division's first echelon must be expected to fight its way through the sequence of the four light infantry battalions of alternative C to eventually accomplish a break-through after an elapsed time of about 7 TU. Only the intensive employment of mines by the defenders may bring about that division's defeat after close to 90 TU (see also Fig. 9, case C2). But, if the friendly teams operating in the enemy's rear can be largely neutralized, a Soviet break-through





〈**Fig. 8**〉 Attacker Force Levels-Alternative C must be expected despite of employment of mines. Also, if the attacking forces would be increased by 50%, a type C-defence network must be expected to be eventually penetrated regardless of the availability of mines. An inavailability of mines may only be compensated for by more than doubling the density of the defender's forces conditional to their vulnerability remaining unchanged.

3.3 A Preliminary Assessment

Conditional to the basic assumptions underlying the scenarios of the experiments discussed above we may conclude:

(1) With respect to the average rate of territorial loss as the ultimate criterion proposed by HUBER (see [1], pp. 18—20 and [2], p. 139) for the assessment of (non-nuclear) theater forces, alternatives B and C appear to be rather similar[2] and significantly superior to alternative A. For B and C, the respective value amounts to less than 20% of the value for alternative A. However, for identical defender force sizes the territorial losses to be expected in case of alternative C far exceed those in case of alternative B (see Fig. 9).

(2) With respect to the development of the attacker/defender force ratio, alternative B is unquestionably superior. This is obvious from Fig. 10 in which the quotient between the relative numerical strengths of attacker and defender is plotted as a function of elapsed battle time for the cases in which the defenders did not deploy mines[3]. While the force ratio improves exponentially in favour of the attacker under alternative A, alternative B results in a similar improvement in favour of the defender. For alternative C, the attacker/defender force ratio remains essentially unchanged at best, and improves exponentially in favour of the attacker at worst.[4]

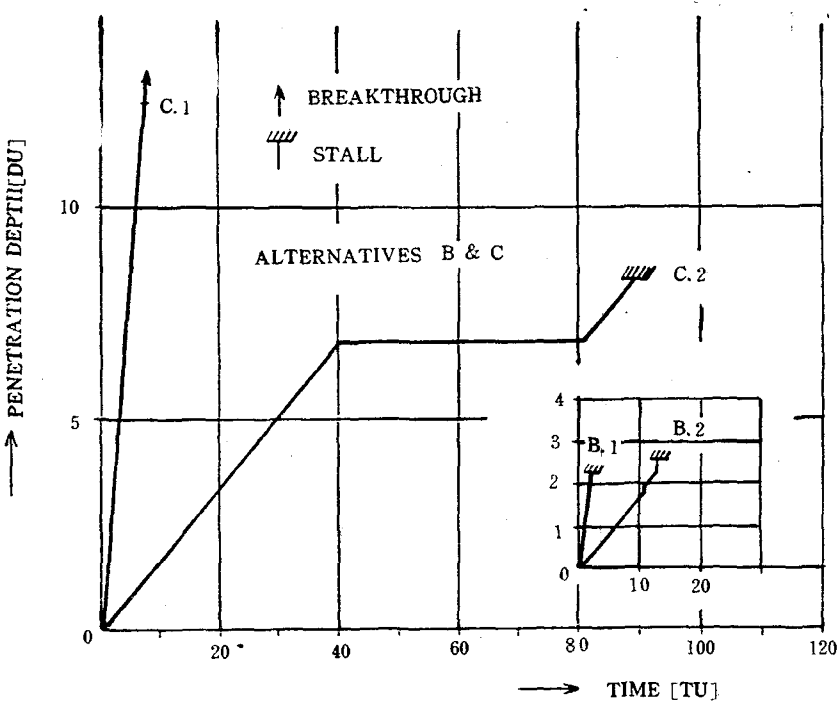
(3) From the results of the experiments on alternative B we may deduce that also another motor-rifle division (second echelon of a Soviet army) and, very likely, even two further divisions of another army (second echelon of a Soviet front) can be expected to be attrited when attempting to fight their way through the fully deployed border defence forces of alternative B. But in case of alternative C a Soviet break-through must be expected to be accomplished at least by another division following the first one.

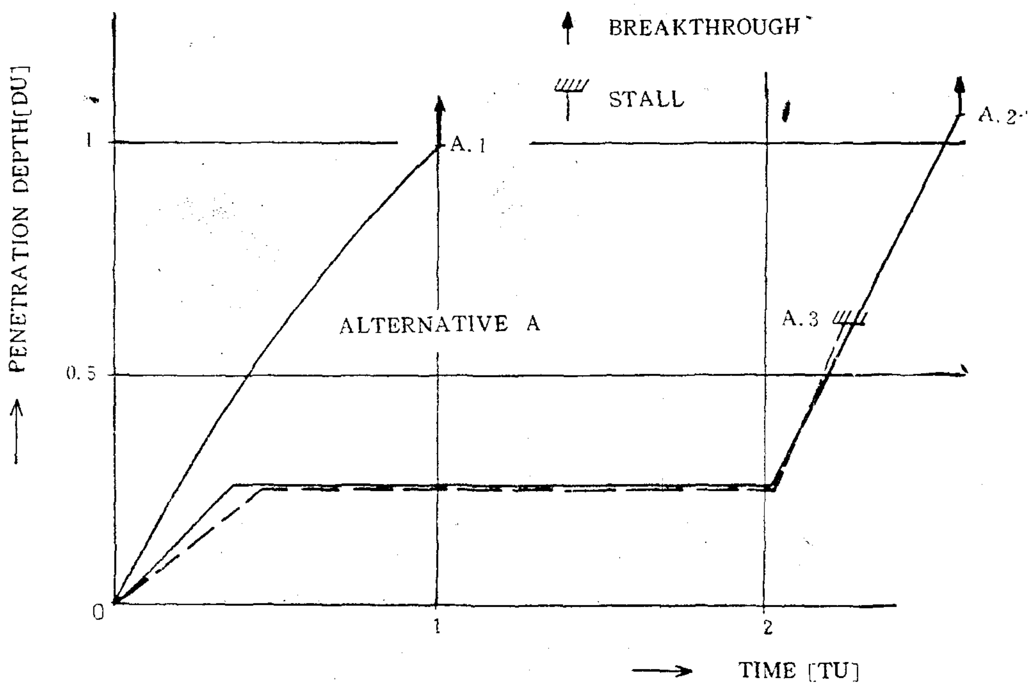
(4) Thus, for more detailed analyses concepts based on alternative *B* should be given priority. In case our assumption of sufficient strategic warning is correct so that a full deployment of the border defence forces can be accomplished prior to the opening of hostilities, a significant gain in time may be accomplished for an organized deployment of counter-

2) In our experiments sofar we have assumed identical movement patterns for the attackers in both cases. This is perhaps a rather pessimistic assumption from the viewpoint of a defender operating according to alternative D. If the Soviets should not be able to neutralize those NATO battle teams operating in their rear, they might be forced into much more careful movements thus reducing the assumed movement rates v_{0f} and v_0 and perhaps also modifying the functional dependency between opposed movement rate and losses (i.e., change of exponent ν; see section 2.2). In that case, the slopes of the curves for alternative C in Fig. 9 should be less steep so that Fig. 9 might indeed only reflect the pessimistic case where the Soviets succeed to neutralize all NATO battle teams in their rear.

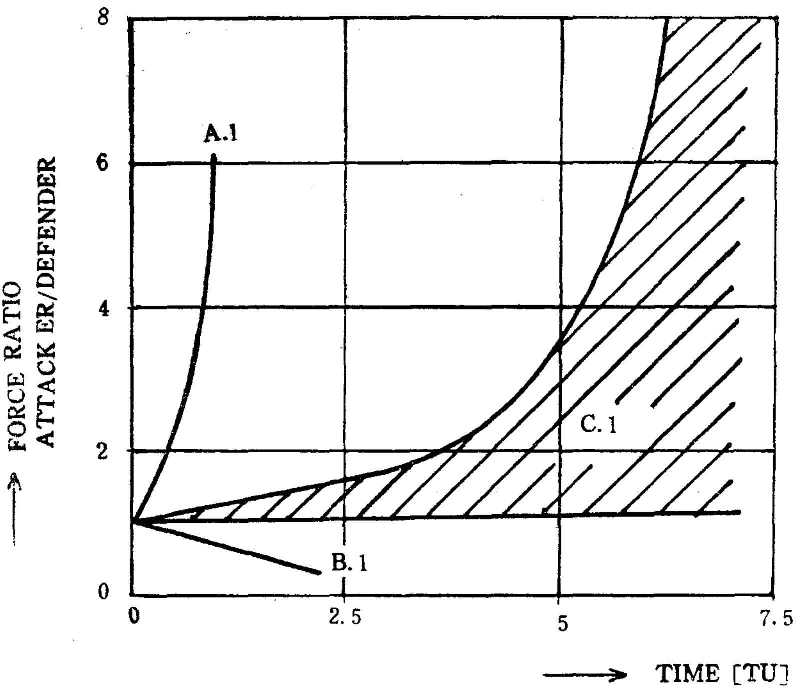
3) Deployment of minefields would essentially only shift the curves to the right.

4) The lower boundary of the uncertainty area in Fig. 10 corresponds to the case when the effectiveness of the NATO battle teams operating in the Soviet rear is maintained. The upper one corresponds to the case when these teams are fully neutralized.





〈**Fig. 9**〉 Soviet Penetration Depth



⟨**Fig. 10**⟩ Force Ratio

attack forces and also for overseas reserves[5]. The risk that this assumption may prove wrong appears considerably lower for alternative B than for alternative A.

(5) But for a final assessment of the alternatives we need to also consider the impact of the opponents, tactical air forces and their operational doctrines. The results shown in this paper already point out some interdependencies between army and air force structures and operational doctrines. E.g., with respect to maximizing the time to an eventual breakthrough, air operations need to emphasize *Close Support* missions (in particular counter-artillery) in case the army has adopted alternative A. In case of alternative B, air operations to secure and maintain *air superiority* over the assembly areas of the NATO counter-attack forces and reserves might be given first priority perhaps followed by missions against the Soviet communication lines and second echelon forces (see also LÖSER [24, 25]).

4. OUTLOOK

Even though the results presented here are certainly not sufficient for a final assessment of our options, if only for reasons of input reliability and accuracy, they nevertheless illustrate rather well the type of information to be generated by the *"Quick Games"* of military systems analysis. Rather quickly they do show the defence planner the impact of important

5) The first results on the British field experiment "*Goodwood*" published in the press appear to support that conclusion (e.g., see POTYKA: Bilanz der NATO-Herbstmanöver—Der Golfsack des Infanteristen. Süddeutsche Zeitung Nr. 224, 27/28 Sep. 1980, p. 3).

technical, tactical, and structural system parameters so that he may rationally reduce the (theoretically) immense variability of his planning problems to a size that can be handled by more refined analyses.

The model introduced here is but an initial prototype of an analytical land battle game. As does the analogous air war model proposed by HUBER in 1978 [26], it needs further testing and refinement with respect to both, methodological aspects as well as the incorporation of other important processes and effects (e.g. those of hand held infantry weapons). Also, the extension of such *Quick Games* to simultaneously consider land and air systems and operations is necessary to test the substitutability among air and land resources as a basis for comprehensive (ground/air) system trade-offs. Such trade-offs are mandatory for the design of an effective force in view of the ever increasing cost of modern weaponry[6]. HUBER and TAYLOR have formulated a first model version for such an extended game as a basis for a respective methodological research project [28].

References

[1] Huber, R.K.: A Systems Analyst's View on Force Structure Planning. Lectures on Systems Analysis, Korea Institute for Defense Analyses, Seoul, Korea 1980, pp. 67-116.

[2] Huber, R.K.: Die Systemanalyse in der Verteidigungs—planung—Eine Kritik und ein Vorschlag aus systemanalytischer Sicht. Wehrwissenschaftliche Rundschau 5 (1980), pp. 133-143.

[3] Hofmann, H.W., Huber, R.K.: Übungen und operationsanalytische Studien als integrale Bestandteile der Verteidigungsplanung. Truppenpraxis 10 (1976), pp. 698-705.

[4] Berkovitz, L.D., Dresher, M.: A Game Theory Analysis of Tactical Air War. Operations Research 7 (1959), pp. 599-620.

[5] Bonder, S.: Changing Army OR. Keynote Address, 16th AORS, 1977.

[6] Huber, R.K., Wobith, B.: Spiele der militärischen Systemanalyse—Ziele, Entwicklung, Anwendungen. In: Operationsanalytische Spiele für die Verteidigung (Huber, Niemeyer, Hofmann Hrsg.), München-Wien 1979, pp. 21-45.

[7] Lanchester, F.W.: Aircraft in Warfare: The Dawn of the Fourth Arm—No. V, The Principle of Concentration. Engineering 98 (1914), pp. 422-423.

[8] Brackney, H.: The Dynamics of Military Combat. Operations Research 7 (1959), pp. 30-44.

[9] Taylor, J.G.: Attrition Modelling. In: Operationsanalytische Spiele für die Verteidigung (Huber, Niemeyer, Hofmann Eds.). München-Wien 1979, pp. 139-189.

[10] Bonder, S., Farrell, R.: Development of Models for Defense Systems Planning—SRL 2147-TR 70-2, University of Michigan, Ann Arbor, Michigan, 1970.

[11] Steiger, K.: Bewertung unterschiedlicher Landstreitkräftekonzeptionen durch modifizierte Lanchester-Ab-nutzungsmodelle. Diplomarbeit, Fachbereich Informatik, HSBw München,

6) E. g., Deitchmann points out that, with a view to the sortie attrition rates to be expected for air operations in Central Europe, the resources necessary to provide the air systems required for the neutralization of typical mobile ground systems may far exceed the resources necessary to procure those (ground) systems (see [27], p. 40).

September 1979.
[12] Goad, R.: The Modelling of Movement in Tactical Games. In: Operational Research Games for Defense (Huber, Niemeyer, Hofmann Eds.), München-Wien 1979, pp. 190-214.
[13] BMVg: Weißbuch 1979 zur Sicherheit der Bundesrepublik Deutschland und zur Entwicklung der Bundeswehr. Bonn 1979, pp. 148-153.
[14] BMVg: Informations—und Pressestab, Pressereferat VI/13: Die neue Struktur des Heeres. Material für die Presse, Bonn, November 1978.
[15] Löser, H.-J.: Vorneverteidigung der Bundesrepublik Deutschland? Ein Beitrag zur Strategiediskussion im NATO-Bündnis. Österreichische Militärische Zeitschrift, Heft 2 (1980), pp. 116-123.
[16] Afheldt, H.: Verteidigung und Frieden, München-Wien 1977.
[17] Huber, R.K.: An Introduction to Mathematical Battle Models. Lectures on Systems Analysis, Korea Institute for Defense Analyses, Seoul. Korea 1980, pp. 120-204.
[18] Fuller, J.F.C.: Armor and Counter Armor, Part 3: Defense Against Armored Attack. Infantry Journal, May 1944, pp. 39-43.
[19] Carmichael, R.: Force-Oriented Defense. Infantry, May-June 1972.
[20] Keyes, J.: Tactics for the Force Oriented Defense. Infantry, July-August 1972, pp. 23-27.
[21] Kleinstiver, L.W.: The Archipelago Defense. Infantry, March 1974, pp. 26-32.
[22] Paxson, E.W.,: Weiner, U.G., Wise, R.A.: Interactions Between Tactics and Technology in Ground Warfare. Rand Report R-2377-ARPA, January 1979.
[23] Channon, J.: Boris Popov and the Electric Piranha. Military Review, August 1978, pp. 36-46.
[24[Löser, H.-J.,: "Raumdeckende Verteidigung" gegen "Raumgreifende Operationen". Europäische Wehrkunde 9 (1977), pp. 444 ff.
[25] Löser, H.-J.: Überleben ohne Atomkrieg. Allgemeine Schweizerische Militärzeitschrift, Nr. 4 (Aqril 1980), pp. 181-187.
[26] Huber, R.K.: Ein analytischer Ansatz zur Untersuchung langfristiger Zielvorstellungen der Luftrüstungsplanung. In: Systemanalysen für die Luftrüstung (Huber, Dathe Hrsg.), München-Wien 1978.
[27] Deitchman, S.J.: The Future of Tactical Air Power in Land Warfare. Astronautics & Aeronautics, Vol. 18, July/August 1980, pp. 34-53.
[28] Huber, R.K., Taylor, J.G.: On a Tactical Air War Analysis Game. Bericht Nr. 8006, Fachbereich Informatik, HSBw München 1980.