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MATHEMATICAL MODELS FOR PREDICTION OF NEUROPSYCHIATRIC AND OTHER NON-BATTLE CASULATIES IN HIGH INTENSITY COMBAT

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Historical data on combat-produced neuropsychiatric (NP) casualties, from several sources, are mathematically fit to functions which depend upon time in combat, wounded in action rate, type of unit, and others. Data from World II are contrasted with data from Israeli conflicts to derive the functional dependence of combat intensity. The final results are presented as closed form equations which can be used as estimates for NP casualties in quantitative warfare simulations.

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I. INTRODUCTION

1. Background

The effort reported here was accomplished under the sponsorship of the Weapons Effects Division (WED), Defense Nuclear Agency as part of a project to take advantage of new data made available by the Defense Nuclear Agency's Intermediate Dose Panel (IDP).

The IDP was assembled by the Biomedical Effects Directorate of the Defense Nuclear Agency to assess the performance degradation of combat troops, crews and entire units when exposed to ionizing radiation doses between 75 and 4500 centigray (cGy) free-in- air (FIA) on a nuclear battlefield. The first phase of the work of this panel included a major research effort by military, government and civilian scientists, and was completed after four intensive years of field work and study.[1] [2] [3] It also included a complete, up-to-date reanalysis of incapacitation data from primate research at the Armed Forces Radiobiological Research Institute, Bethesda, MD (AFRRI). The IDP effort made possible a sensitivity study to determine the impact of this superior data upon our perception of the nuclear battlefield. That study, which formed the major part of the WED project, is presented in a separate (classified) report.[4]

One of the efforts in the IDP program began to address the problem of psychological effects of nuclear warfare. Here, as in the case of biological effects, no direct combat data on nuclear

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1. Anno, G.H., Wilson, D.B., Dore, M.A.,"Acute Radiation Effects on Individual Crewmember Performance", Defense Nuclear Agency report, DNA-TR-85-52, August 1984

2. Anno, G.H. and Wilson, D.B.,"Severity Levels and Symptom Complexes for Acute Radiation Sickness: Description and Quantification", Pacific-Sierra Research Corporation report, PSR-1597, November 1985

3. Baum, S.J., Anno, G.H., Young, R.W and Withers, H.R., "Symptomology of Acute Radiation Effects in Humans after Exposure to Doses of 75 to 4500 rads (cGy) Free-in-Air", Pacific-Sierra Research Corporation report, PSR-581, June 1983

4. Klopcic, J.T. and Levin, S.G.,"Effects of Intermediate Nuclear Dose Data Upon Assessment of Military Unit Survivability", BRL report, in publication.

warfare exist. However, it is widely agreed[5] that the psychological effects of nuclear warfare would quantitatively, but not qualitatively, differ from high intensity conventional combat. Therefore, a reasonable approach to estimating psychological effects is to numerically model such effects for conventional combat, where data is available. Estimates for nuclear combat can then be found by extrapolating such models into nuclear scenarios.

This report describes the first stage of such an effort, the development of a numerical model of neuropsychological casualties from conventional, high intensity combat.

2. Scope of This Report

There is an enormous library of literature on neuropsychiatric (NP) casualties. The authors have reviewed many of these with a view to predicting casualties in a future war rather than to understand the underlying causes, recommend treatment methods or rotation policies, etc. In the present report, applicable data has been extracted from these reports and attempts have been made to fit the data with mathematical functions. Such equations should find application in predicting casualties for studies and wargames, as well as helping to gain a better understanding of the dependency of the number of such casualties upon various battlefield factors.

NOTE: Throughout this report, data pertaining to NP casualties include only those having a psychiatric disorder considered disabling enough by the attending medical officer to remove the individual from combat duty. It does not include AWOL cases, self-inflicted wounds, and soldiers who were not fit for combat and were administratively transferred to non-combat units, but were not officially listed as NP casualties.

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5. Symposium on Psychological Effects of Tactical Nuclear Warfare, Armed Forces Radiobiological Research Institute, Bethesda MD., 11-13 March 1986

Four reports - Beebe and Appel,[6] Vineberg,[7] Marlowe[8] and Belenky[9] - form the basis of the work here. The first and second reports contain a great deal of statistical material useful for prediction. Reference [9] provides data for updating to a high intensity war.

3. Abbreviations

In the text that follows, several abbreviations will be used, such as:

IIA - Injured in Action

KIA - Killed in Action

MIA - Missing in Action

WIA - Wounded in Action

POW - Prisoner of War

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6. Beebe, G.W., and Appel, J.W., "Variation in Psychological Tolerance to Ground Combat in World War II," NAS, Washington, D.C.

7. Vineberg, R., "Human Factors in Tactical Nuclear Combat," TR-65-2, Human Resources Research Office, Washington, D.C., April, 1965.

8. Marlowe, D.H., "Cohesion, Anticipated Breakdown and Endurance in Battle: Considerations for Severe and High Intensity Combat," Walter Reed Institute of Research, Washington, D.C.: DRAFT, 1983.

9. Belenky, G.L., Tyner, C.F., and Sodetz, F.J., "Israeli Battle Shock Casualties: 1973 and 1982," WRAIR Report NP-83-003, Washington, D.C., 1983.

4. Background

The men who reached combat in WWII and subsequent wars, were a highly selected group. In WWII, 12 percent of all men examined were rejected for neuropsychiatric reasons: this constituted 38 percent of all those rejected for any reason. Subsequently, during training and after assignment to units, men who were not thought to be suitable for combat were assigned to non-combat units or to headquarters or administrative units.

Despite this selection process, 10 to 16 percent of those chosen for combat positions were subsequently removed from combat on psychiatric grounds. This compares to 16-17 percent KIA and 30-48 percent removed due to wounds and other combat-related casualty mechanisms. This high rate of NP cases is considered to be a "normal reaction to abnormal stress." It is not the weaklings nor cowards who "crack," according to General Menninger; it is the cream of American manhood. Therefore, one can safely assume that any future war of the kind envisioned in Central Europe, involving conditions and stresses more severe than those encountered in WWII, would result in significant numbers of NP casualties.

Data from the Korean War and from the Viet Nam conflict are not considered appropriate for predicting NP casualties in a Central European war because of the differences in the type of combat. In Viet Nam, there were few combat engagements in which our troops faced sustained shelling and large numbers of combat casualties. Similarly, in Korea, there were few NP casualties, even though our troops were in retreat at times. One feature of both wars was the rotation policy that was credited with reducing NP casualties by giving the troops a permanent relief from combat to anticipate. The fighting men in WWII did not have this: only death, debilitating wounds or serious non-battle injuries could provide relief from combat.

II. NP CASUALTIES: HISTORICAL DATA

1. NP Casualties in Combat Units Based on WWII data.

The attrition rate from all causes in combat units in the European Theater of Operations (ETO) was 50 percent by the 18th combat day, 75 percent by day 34, and 83-92 percent by day 50 of combat, according to Beebe (p.143). Using life-table methods of projection and assuming no replacements, Beebe (p.192) showed that the breaking point of the median man was 80 combat days; i.e., 50 percent of soldiers who survived 80 days of combat would have become NP casualties.

NOTE: Here and subsequently in this report, a combat day will be defined as a day in which at least one member of the company is killed or wounded. A calendar day is counted from the time the division enters combat, or when an individual joins his company already in combat.

The most comprehensive analysis of NP casualties was done on a sample of 2500 cases from so-called "high risk" MOSs. This sampling, done on the basis of Army records and some follow-up, traced each soldier from time of entry into the Army until death or discharge. They were selected from 150 rifle companies in ETO and 50 rifle companies in the Mediterranean Theater of Operations (MTO). The high risk sample was used to assure a more uniform exposure to risk. Table 1 below presents the risk of each of the high-risk MOSs relative to average risk (100) of KIA or WIA in an infantry division.

TABLE 1. List of High Risk MOSs (Beebe and Appel, p.5)[6]

Fraction	MOS	MOS Serial No.	Rel. Risk
0.080	Ammunition Handler	504	132
0.065	Gunner	603	134
0.065	Light Machine Gunner	604	134
0.065	Heavy Machine Gunner	605	134
0.065	Light Mortar Crewman	607	134
0.029	Platoon Sergeant	651	155
0.014	Section Leader	652	151
0.181	Squad Leader	653	212
0.530	Rifleman	745	432
0.101	Automatic Rifleman	746	280

a. **Combat Casualties.** The average WIA rate for ETO infantry in WWII (Ref.4) was 2.32/1000 men/calendar day. The average WIA rate for the selected divisions (Ref. 4) was 3.05/1000 men/calendar day. The "high risk" MOS group had a WIA rate of 7.3/1000 men/calendar day, 2.4 times the average divisional WIA rate. The WIA rate in terms of combat days was 26.46 WIA/1000 men/combat day. For the ETO one could convert (Beebe, p.59) WIA rates into total battle casualty rates by multiplying WIA by 1.4.

Beebe (p.153) showed, in his cohort study, that the rate of WIA decreased for a given group of infantry as they became "battle wise" and perhaps more cautious and fearful (p.54). His expression for all battle casualties is:

$$Y' = 44 - 0.38\ D$$

$$D < 80$$

where Y' is in casualties per 1000 men per day and D is the number of days of combat. Converting this to WIA per 1000 men per day, we have:

$$Y = \frac{Y'}{1.4} = 31.43 - 0.27\ D \qquad (1)$$

b. **Neuropsychiatric Rates.** The most consistent finding of the Beebe study was that NP casualty rates rose with increasing or lengthening stress. The severity of stress was measured by number of casualties or by number of combat days.

In a table (p.35), Beebe and Appel present NP casualties in terms of calendar and combat days. Their data are presented in the following table in terms of combat days:

TABLE 2. NP Casualties versus Days of Combat

Combat Days	(Midpoint)	NP Cas./1000 men/Day
1 - 10	6	3.6
11 - 20	16	3.87
21 - 30	26	7.52
31 - 50	41	8.41
51 - 80	66	10.43

By inspection of the data in Table 2, we note that the number of NP casualties per time is an exponential function of the form:

$$f(D) = K_1 - K_2 \exp(-K_3\ D) \qquad (2)$$

Fitting such a function to the data in Table 2, we obtain:

$$\text{NP Casualties/1000/Combat day} = 10.8 - 9.6 \exp(-0.04\ D) \quad (3)$$

Beebe's data and the curve of equation 3 are shown in Figure 1. These data show that the NP casualties increase monotonically as the number of days in combat increases up to a maximum of 10.8 per 1000 men per combat day under average (for ETO WWII) circumstances. At combat day zero, equation 3 predicts 1.2 NP casualties/1000/day, which could be attributed to enemy shelling, fear of battle, etc.

Appel[10] showed that the NP rate for soldiers stationed in Alaska was 0.028/1000/calendar day. In the continental U.S. and for non-combat personnel overseas, the rates ranged from 0.10/1000/calendar day to 0.19/1000/calendar day. This shows that a curve of NP casualties/1000/calendar day should not go to zero casualties at day zero.

Vineberg took the weekly NP and WIA casualty figures from the Surgeon General's reports, and calculated linear regression curves for NP casualties as a function of WIA/1000/calendar day for each of 13 divisions. The divisions include non-combat (low risk) as well as high risk infantry soldiers which may have caused the rates to be lower than those predicted by Beebe. Vineberg does not present the original observations but asserts that the data are linear. The linear functions are shown in Figure 2. The equation for the average NP rate as a function of WIA for the 13 divisions is:

$$\text{NP/1000} = 4.5 + 0.14\ \text{WIA/1000 men} \quad (4)$$

Beebe showed that the ratio of NP/WIA decreased in ETO beginning in 1945 and attributes it to the anticipation of the end of combat. However, Vineberg used ETO data on casualties that extend into 1945, so that his NP/WIA rates may therefore be biased downward.

Equation 4 shows that NP casualties increase as WIA casualties increase and equation 3 shows that NP casualties increase as the number of days of combat increase. Equation 4 may underestimate NP casualties because it "averages in" combat and non-combat soldiers in infantry divisions and it uses data that extend into 1945.

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10. Appel, J.W. and Beebe, G.W., "Preventive Psychiatry," JAMA-131, 1946, pp.1469-1475

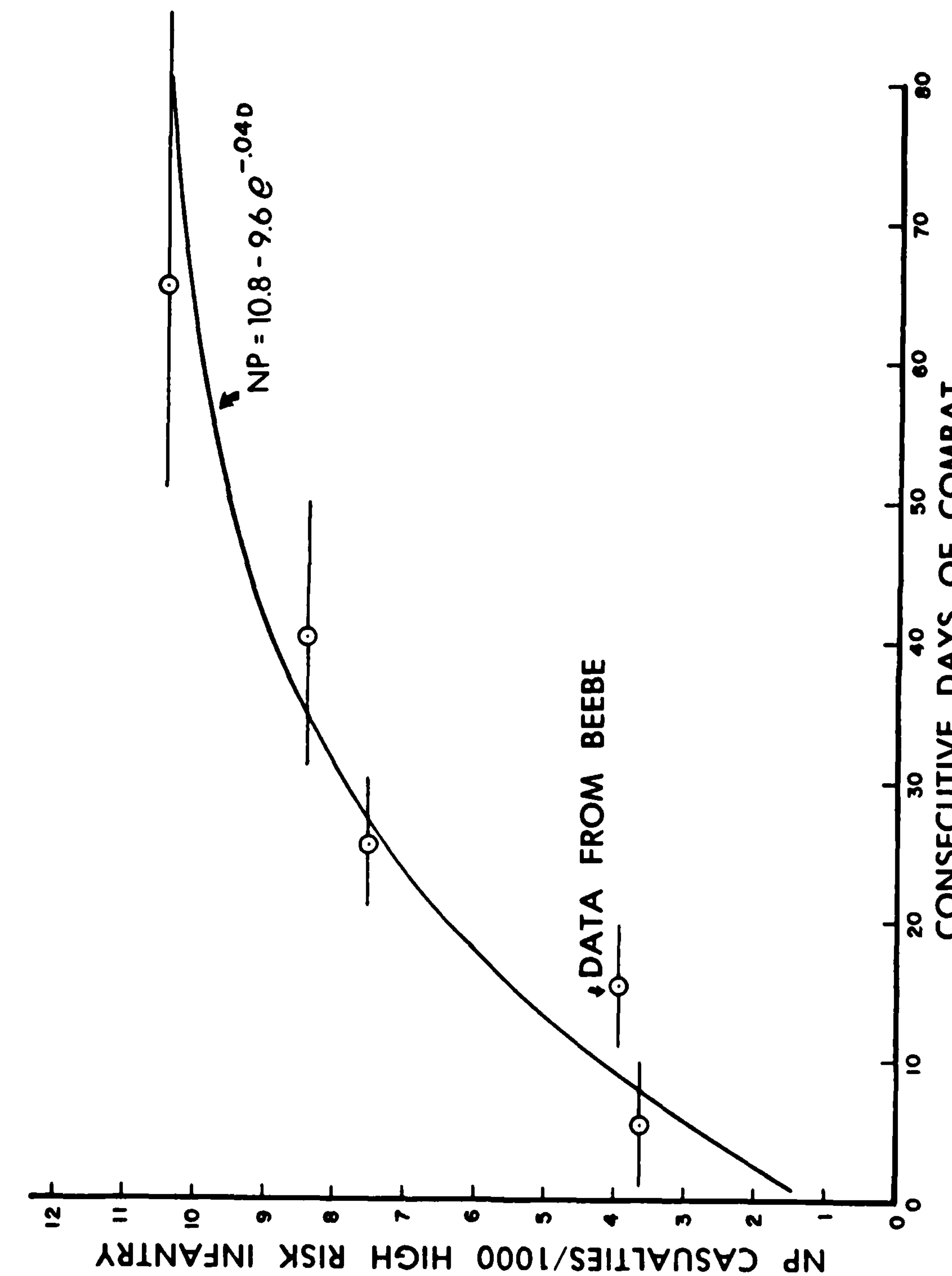

Figure 1. Number of First Neuropsychiatric Departures per 1000 Men Versus Consecutive Combat Days

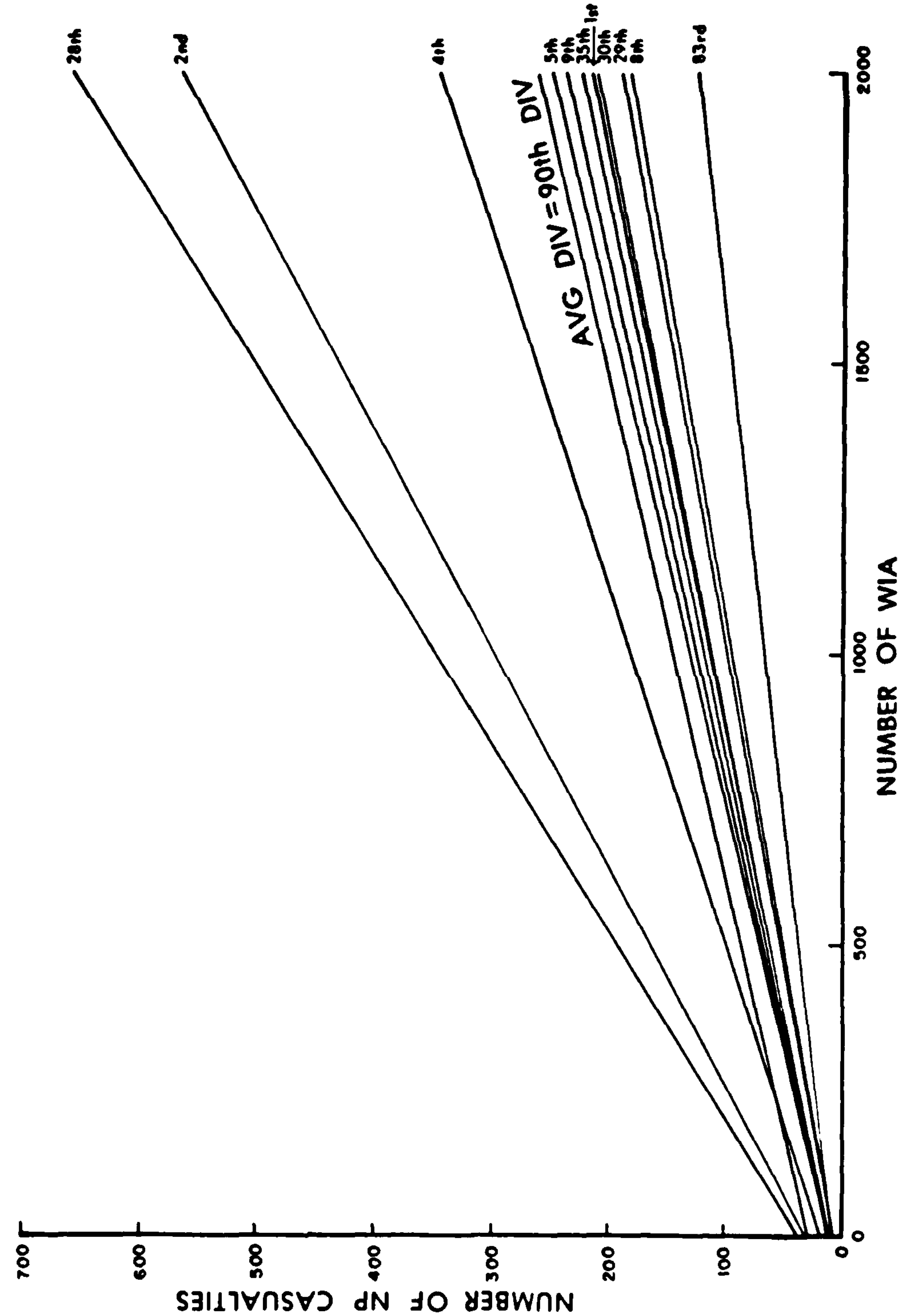

Figure 2. Neuropsychiatric Casualties Versus WIA for 13 Infantry Divisions, ETO, WWII, 1944

Using the constant WIA rate of 26.46 WIA/1000/combat day and equation 3, which expresses NP casualties/1000/combat day, we can estimate the NP/WIA as a function of combat days:

$$\frac{NP}{WIA} = \frac{10.8 - 9.6\exp(-.04D)\ NP/1000men/combat\ day}{26.46\ WIA/1000men/combat\ day}$$

or

$$\frac{NP}{WIA} = 0.408 - 0.363\ \exp(-.04\ D) \qquad (5)$$

The preceding equation applies to an infantry unit consisting of high risk MOS soldiers. It is assumed that the unit frequently receives replacements for the wounded. If we must assume that there are no replacements and therefore that the same soldiers are engaged in combat, then equation 2, which predicts a decreasing WIA rate as a function of combat days, applies. In the no-replacement case, the ratio NP/WIA becomes:

$$\frac{NP}{WIA} = \frac{10.8 - 9.6\ \exp(-.04D)\ NP/1000/combat\ day}{31.43 - .27D\ WIA/1000/combat\ day} \qquad (6)$$

These functions, evaluated for combat days 0 through 80, are presented in Table 3 and Figure 3, which also contrast the NP/WIA rates predicted by equations 5 and 6 with the constant value of 21 percent from Beebe.

TABLE 3. Estimated NP, WIA and NP/WIA as Function of Combat Day

Combat Day	Eq. 2 WIA/Day	Constant WIA/Day	Eq. 3 NP/Day	Eq. 6* %NP/WIA	Constant** %NP/WIA
0	31.4	26.46	1.20	3.8	4.8
1	31.1	26.46	1.58	5.1	6.0
5	30.6	26.46	2.90	9.5	11.0
10	28.7	26.46	4.36	15.2	16.5
20	26.0	26.46	6.49	24.9	24.5
30	23.3	26.46	7.91	33.9	29.9
40	20.6	26.46	8.86	43.0	33.4
50	17.9	26.46	9.50	53.1	35.9
60	15.2	26.46	9.93	65.3	37.5
70	11.9	26.46	10.21	85.8	38.6
80	9.0	26.46	10.41	106.2	39.4

* Assumes original cohort with no replacements.
** Assumes frequent replacement of all casualties.

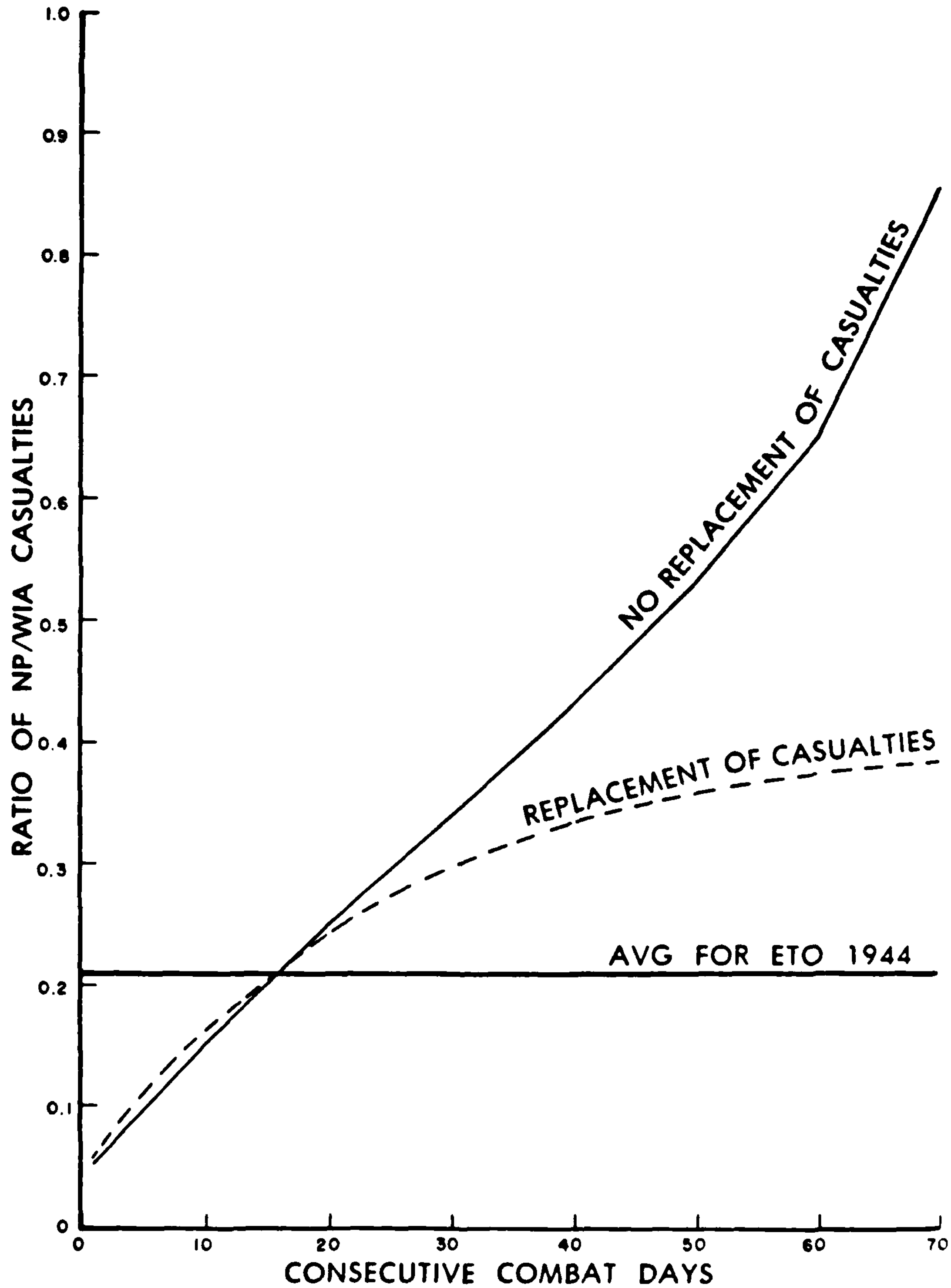

Figure 3. Ratio of NP Casualties to WIA Versus Number of Consecutive Combat Days

c. **NP Casualties for Other Combat Units.** Vineberg[7] (p.85) presents linear equations using least square fits to data on NP versus WIA for 13 Infantry, six Armored, and two Airborne Divisions in ETO combat during WWII. The averages are shown in Figure 4 and are compared with the infantry data. Data on specific engagements, taken from Marlowe by Mullins and Glass,[11] are also plotted in Figure 4. (These data are presented in Table 4.)

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11. Mullins, J.R. and Glass, A.J., in "A History of Neuropsychiatry in WWII. Vol. II, Overseas Theater," U.S. Government Printing Office,1967.

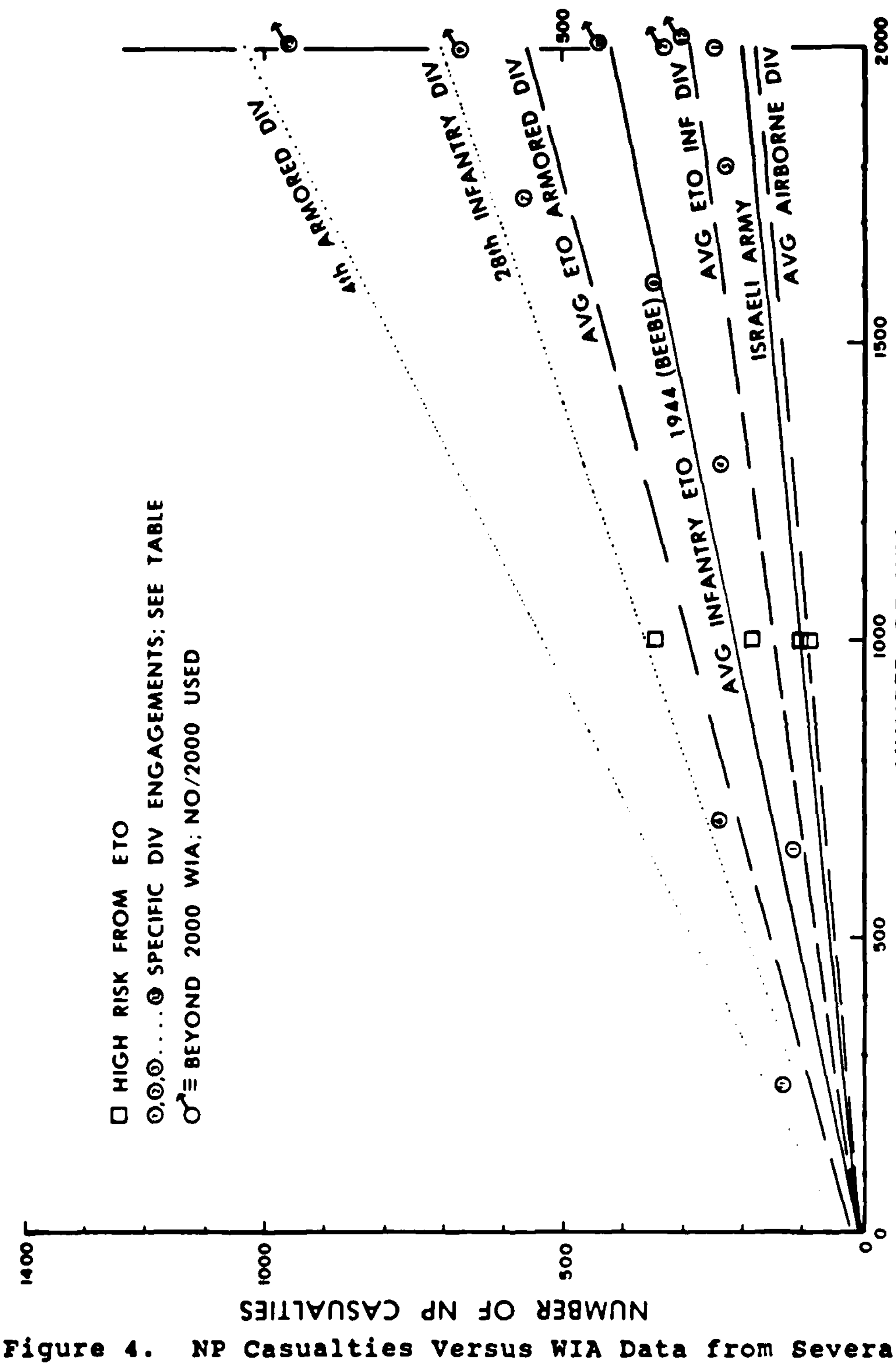

Figure 4. NP Casualties Versus WIA Data from Several Sources

TABLE 4. Individual Divisions and Their NP/WIA in Specific Engagements

*	Unit, Battle and Time Period	No.Days	No.WIA	No.NP	NP
1	86th Div Gustav line 11-14May	4	2000	250	
2	86th Div Gustav line 11May-10Jun	30	4000	623	
3	88th Div Gustav line 11-14May	4	650	125	
4	88th Div Gustav line 11May-10Jun	30	1300	248	
5	34th Inf Gustav line 25Jun-29Jul	36	1800	235	
6	91st Div Cecine River 12Jul-15Aug	35	700	250	
7	88th Div Volterra 1-31Jul	23	1750	564	
8	34th Div Gothic line 13Sep-26Oct	44	1600	346	
9	91st Div Gothic line 13Sep-26Oct	44	2700	919	
10	88th Div Gothic line 13Sep-26Oct	44	3600	817	
11	1st ArmDiv Gothic line 13Sep-26Oct	44	250	137	
12	85th Div Gothic line 13Sep-22Nov	71	4000	597	
13	6th Marine Okinawa 12-21May	10	2662	1289	

* Plot symbols used in Figure 4.

The numbers of combat casualties were lower but the NP/WIA rates consistently higher for the armored divisions than for the infantry divisions. By contrast, the two Airborne Divisions suffered high numbers of casualties but had consistently lower NP/WIA rates. The Airborne Divisions are considered examples of elite troops whose NP/WIA were about half the rate for conventional infantry. This observation is consistent with the views expressed by Marlowe (3) in discussing the NP rates for elite divisions in the Israeli Defense Force.

The equations for the 3 types of divisions are:

Ave. Infantry Division: NP casualties = 4.5 + 0.14 WIA (4)

Avg. Armored Division: NP casualties = 11.7 + 0.26 WIA (7)

Avg. Airborne Division: NP casualties = 1.8 + 0.09 WIA (8)

There are no in-depth studies of Armored and Airborne divisions, so we must rely on the data from Vineberg to represent them.

It was previously shown that the Vineberg data on infantry may have underestimated the more detailed work by Beebe. Furthermore, we would like to formulate equations for other combat units in the form of equations 5 and 6, which permit the NP/WIA rates to change as a function of the number of days of combat. In order to do this, we can express equations 7 and 8 as multiples of equation 4. These multipliers can then be applied to equations 5 and 6.

2. NP Casualties Based on Israeli Combat Experience

Summarized below are the major battle characteristics that might bear on the numbers of WIA and NP casualties in a future high intensity war. The Israeli data are contrasted to the WWII, Korean and Viet Nam experiences of U.S. forces.

The information presented in Table 5 below is taken from Belenky, et al., and from discussions with D.H. Marlow, Walter Reed Army Institute of Research (WRAIR), and R. Gal, Israeli Defense Forces (IDF).

TABLE 5. Differences Between WWII and Israeli Combat Experience that could affect NP and WIA Estimates

Combat Factors	WWII	Israeli Conflicts
Typical Pulses (attacks) per day	1 (MTO) 2-3 (ETO) 4 (Normandy)	6-7
Relative Firepower	1	10*
Accuracy of Fire (Probability of hit)	.05	.80-.85
Lethality of New Weaponry	-	e.g., One strafing run: 200 WIA+KIA/4 sec.
Duration of Wars	4-5 years	1982: 20-30 days 6-7 high intensity days 1973: 19 days 8-10 high intensity days
Combat days per calendar day	MTO 1/7.8 ETO 1/3.6	1/2
NP/WIA	ETO: 0.28 Armor 0.14 Infantry 0.09 Airborne	Lebanon 1982: 0.25 Yom Kippur 1973: 0.30 (All ground forces)

* e.g., Bar Lev Line-Artillery fired 10,000 rounds in 2 min

The NP/WIA ratio seen in Israeli combat units varies from 30 to 50, depending upon the source of information, with 100 percent reported in some units. The most reliable sources - Belenky (8) and Marlowe (3) - put the ratio at 30 to 50 percent in the 1973 Arab-Israeli (Yom Kippur) War. The war lasted 19 days, with 8 or 9 high intensity combat days. These sources confirm the WWII observation that the elite forces had the lowest NP/WIA ratio and that tank crews had the highest NP/WIA ratio. Furthermore, Israelis had NP cases among the logistic support units: while the absolute number of such cases (about 10 percent of the total Israeli casualties) was not high, the ratio of NP to WIA ranged from 2:1 to 3:1! That is, there were 2 to 3 times as many neuropsychiatric casualties as physically wounded (contrasted to the 1:3 - 1:8 for fighting troops).

III. COMPARISON of ISRAELI and U.S. ENGAGEMENTS

1. Unique Characteristics of the Israeli Experiences

- In the Israel Wars about 10 percent of the NP casualties had also been WIA with many of the breakdowns occurring after the soldier had been wounded.

- Post-traumatic-stress disorder or delayed battle shock was observed in many soldiers who "broke-down" when they received their first phone call from home or when on their first leave.

- Because the Israeli wars were very short compared to wars in which the U.S. has been engaged., the average Israeli fighter was greener than his American counterpart.

- Many of the NP cases happened after the troops had been engaged in sustained fierce combat for 48 to 72 hours, with little or no sleep. Actual combat was seldom sustained so long in WWII, with situations like that of the American divisions in the Battle of the Bulge being rare.

- In the 1973 (Yom Kippur) war, Israeli soldiers generally felt that they were fighting to protect their families and homes. In the 1982 (Lebanon) war, many Israelis felt that their government was wrong. In spite of this, the NP/WIA ratio in similar fighting was higher in the 1973 than in the 1982 war.

- The Israeli NP casualties did not show the "Combat Fatigue" characteristics seen in American NP casualties in WWII after 15 to 30 combat days. The Israelis called their cases, which were observed as early as two hours into intense combat, "battle shock."

2. Similar Observations from Israeli and U.S. Experiences

- Green divisions meeting powerful enemy forces for the first time tended to have high numbers of NP casualties.

- Higher intensity combat is associated with earlier occurrence of NP casualties.

- Elite troops suffer fewer NP casualties than regular combat troops.

- Among the conventional fighting forces in the Yom Kippur War, the armored forces had the highest NP/WIA ratio, the artillery was intermediate and the infantry had the lowest proportion of NP cases per WIA. This mirrors the U.S distribution in WWII.

- The conditions that were most often associated with the occurrence of an NP casualty were the near-miss of an incoming round and the sight of a buddy or an officer killed or wounded nearby. (Note: This could also account for high NP cases in the armored forces where proximity is forced by vehicular constraints.)

- A sense of helplessness and a feeling of isolation are associated with NP cases.

IV. ISRAELI WAR EXPERIENCE in TERMS of a COMBAT NP MODEL

The data and calculations for WWII neuropsychiatric casualties were obtained and published in detailed form. The Israelis, because of security, have released only a modest amount of data and a number of assumptions must be made in order to obtain the same kind of estimates as were gotten from the WWII data. In particular, we assume:

- The Israeli forces were in these proportions:

    - Infantry - 40%

    - Tanks - 40%

    - Artillery - 15%

    - Special forces - 5%

- The NP casualties can be expressed relative to the infantry:

    - Infantry = x

    - Tanks = 2x

    - Artillery = 1.5x

    - Special forces = .5x

These assumptions, based on the best available sources, permit us to predict NP/WIA for the various ground forces in current, high intensity warfare. Using the above assumptions, plus the estimate of 5815 ground forces WIA in the 1973 war, with 30 percent NP casualties, we can form the following estimates:

TABLE 6. Estimated NP and WIA Casualties in 1973 Israeli War

	Overall	Infantry	Tanks	Artillery	Special Forces
WIA	5815	2326	2326	872	291
NP	1744	481	962	271	30
NP/WIA	0.30	0.21	0.41	0.31	0.10
K_1*	0.637	0.430	0.889	0.640	0.201
K_2*	0.614	0.407	0.866	0.617	0.178
K_3*	0.15	0.15	0.15	0.15	0.15

* Parameters of corresponding exponential function (equation)

A few more assumptions are needed before we can apply the Israeli data to the general model being developed here.

1. The Israeli Yom Kippur War is a model for future U.S. land combat; e.g., in Central Europe, because of large tank forces, current weaponry, and terrain.

2. The Israeli NP and WIA data are a model for overall land combat forces, not high-risk MOSs.

3. The functional form of the increase in NP cases with length of time in combat is the same as in WWII; however, the actual rate of increase is faster.

We now proceed to extend the WWII model to higher intensity. Intensity of combat was "measured" by the number of WIA or WIA/1000 men/combat day in WWII. In the current high technology era, the increased firepower, accuracy and lethality of weaponry and the greater number of "pulses" per day must change our concept of intensity of combat. Concurrently, previous models of NP casualties must be revised because of the differences associated with this quantitatively higher intensity. An analogy for the difference between high intensity versus WWII intensity is the difference between a 100 yard dash, in which runners totally exhaust their energy in a brief time, and a marathon, in which participants run at a slower pace, conserving energy and basing strategy on a long race.

In the preceding sections, analyses by Beebe were shown to project that, for WWII, 50 percent of all surviving combat troops would have become NP casualties by combat day 85. The projection is based on life-table methods and uses a logarithmic scale for NP cases. This leads to the exponential model of NP cases as a function of combat days. If, because of the high intensity of combat, the Beebe-Appel life table curve (Figure 1) were steeper, i.e., reached 50 percent break-down in less time, then the number of NP casualties per day/1000 men would also rise more steeply:

This is consistent with the data from the Israeli wars.

To express this phenomenon mathematically, we begin with equation 5. In equation 5, NP/WIA is presented as a function that increases with number of company combat days. Using the same functional form as equation 5, we can obtain estimates of NP/WIA as a function of days in combat. However, for the high-intensity case, we want the function to have an average over the 9 day high-intensity combat days that is equal to the averages estimated in Table 6 above. We therefore need the integral of the following function:

$$f(D) = NP/WIA = K_1 - K_2 \exp(-K_3 D) \tag{9}$$

$$\int f(D)dD = \int [K_1 - K_2 \exp(-K_3 D)]dD$$

$$= [K_1 D + (K_2/K_3) \exp(-K_3 D)] \tag{10}$$

$$= 9K_1 + (K_2/K_3) [\exp(-9K_3) - 1] \tag{11}$$

Furthermore, we want the rate to rise such that the rate reaches, say 95 percent of maximum at about 20 days which would make the constant $K_3 = 0.15$. Equation 11 becomes

$$\int f(D)dD = 9K_1 + K_2 [\exp(-1.35) - 1] / 0.1$$

$$= 9K_1 - 0.7408 K_2 / 0.15 \tag{12}$$

To solve for K_1, divide Equation 12 by 9 and set it equal to the averages obtained in Table 6 above. Use the additional constraint that equation 12 go through 2.3 percent at day zero, i.e., that $K_2 = K_1 - 0.023$. The equation becomes:

$$\int \frac{f(D)dD}{9} = K_1 - (K_1 - 0.023) \frac{0.7408}{9\ (0.15)}$$

$$= K_1 - 0.5487 K_1 + 0.0126$$

$$\frac{NP}{WIA} = 0.4513 K_1 + 0.0126$$

$$K_1 = [(NP/WIA) - 0.0126]/0.4513 \tag{13}$$

$$K_2 = K_1 - 0.023$$

The coefficients calculated by this method all go through 0.023 or 2.3 percent at D=0. They reach an asymptote which is K_1 and they reach approximately 95 percent of the value of K_1 at Day 20.

The curves obtained by substituting the coefficients shown in table 6, into equation 9 gives NP/WIA as a changing function of day. The five curves calculated using the coefficients in Table 6, which assumes an overall NP/WIA of 3:10, are presented in Figure 5.

V. OTHER NON-COMBAT LOSSES

There are many reasons other than WIA, KIA or neuropsychiatric for a soldier to be removed from combat. The table below from Beebe lists the percentages of first departures from combat, realizing that 30-60 percent of these departures, excluding KIA, POW, MIA, rotation, change MOS and transfer to non-combat, do return to combat.

TABLE 7. First Departure from Combat: Breakdown of Battle and Non-battle Losses, Percentage

Battle Casualties	ETO	MTO
KIA	12.0	9.7
WIA, IIA	53.2	31.0
POW, MIA	7.8	5.1
Total Battle Losses	73.0	45.8
Medical		
NP	6.9	5.7
Other: Sick, SIW	16.8	37.5
MOS Changed	1.5	3.8
Reassigned Non-Combat	0.8	3.4
Other Admin & Disciplinary		
AWOL, Discipline	0.5	2.4
Rotation	0.4	1.3
Total Non-Battle Losses	26.9	54.1

The preceding table shows that 25 to 50 percent of first departures from combat are attributable to causes other than enemy action.

Several authors writing about NP losses have said that as non-battle losses increase, NP losses decrease and vice versa. They claim that some men who would have become NP casualties, instead, have gotten frostbite, or self-inflicted wounds (SIW),

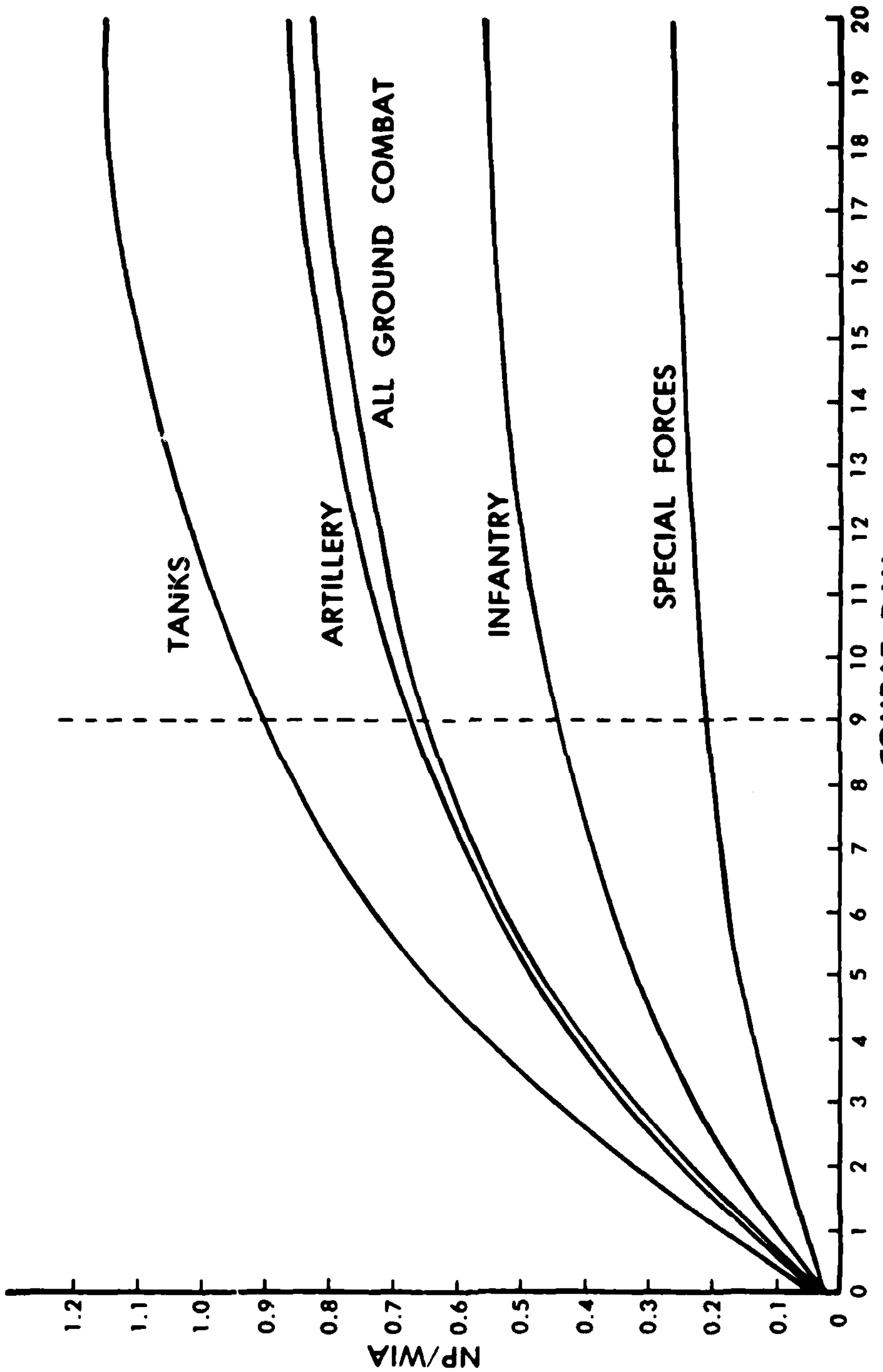

Figure 5. Predicted NP/WIA Versus Combat Day for Ground Combat Forces

or went AWOL or reported to sick call for a variety of other reasons - often repeatedly. They have also asserted that in outfits where the C.O.is perceptive, he will have men transferred to non-combat units or have MOS changes in far greater numbers than other, similar units. These units often showed lower NP rates than other, similar divisions. The only available information about non-combat losses was gathered by Beebe (p.157,159). He presents the data given below:

TABLE 8. ETO Departure: High Risk MOS Infantry

	per Combat day	per Calendar day
All Battle Departures	36.2	10.1
WIA, Departures only	25.0	7.2
Non-Battle Departures	15.67	4.35

The non-battle casualties can be expressed as a fixed proportion of WIA departures:

$$\text{Infantry non-battle departures (including NP)} = 0.606 \text{ WIA} \quad (14)$$

Equations 5 and 6 show that NP casualties increase as a proportion of WIA and also increase as the number of combat days increases. In Equation 5 NP casualties reach 39.4 percent of WIA by combat day 80 and in Equation 6, NP casualties were 106.2 percent by day 80. The 106 percent is conceivable, even though the average non-battle departures are only 60.6 percent of the WIA. However, such a high NP rate is highly unlikely, even in a protracted, high intensity war, because at 50 combat days, an original battalion of 1000 men would be reduced to 100 - 200 men. At 80 days, 50 to 100 men only remain. Equation 6 should not be used beyond 50 combat days for the foregoing reasons. If this restriction is followed, then the NP casualties are always less than the total infantry non-battle casualties.

To estimate proportion of non-battle departures other than NP, Equation 5 or 6 can be subtracted from Equation 11.

VI. RETURN to DUTY

In the ETO and the MTO, many of the combat infantry soldiers were able to return to combat after first departure. Beebe has presented data (Figure 5) showing the proportion of those who return to combat versus time away from combat. If we multiply the percentage returning by the proportion-versus time, we can estimate proportion returning as a function of time.

Using the data from Beebe, p.64, we know that:

- 40% of those WIA return to combat
- 50% of NP cases return to combat
- 60% of other medical cases return to combat

These data refer to first departure only, but in a brief, high intensity conflict, most likely there would only be time for one departure and return.

The data of Figure 5 and the percentages returning can be represented by simple functions that are good approximations over the range 5 to 60 calendar days.

Proportion returning to duty by calendar day d after departing:

$$\text{NP returnees} = 0.5\ [1-\exp(-0.13\ d)] \qquad (15)$$

$$\text{Other medical returnees} = 0.60\ [0.90 - 0.80\ \exp(-0.08\ d)$$

$$= 0.54 - [0.48\ \exp(-0.08\ d)] \qquad (16)$$

$$\text{WIA+IIA returnees} = .40\ (0.5 + 0.767\ d) = 0.2 + (0.307\ d) \qquad (17)$$

VII. SUMMARY

Based on best available statistical data from ETO in WWII, and from Israeli 1973 and 1982 combat experience, numerical estimates and equations have been developed in this report for predicting numbers of individuals that would be expected to become NP casualties as a function of days of combat and numbers of WIA. Other non-combat casualties and their return to combat are similarly predicted. This has been done for infantry, armored, artillery and airborne divisions. The data utilized to arrive at the estimates presented in this report are from the best available sources. The assumptions have been reviewed by experts and the predictions have been examined for reasonableness.

The WWII data are used for low intensity combat predictions and the Israeli Yom Kippur War data are used for high intensity combat predictions. Because of the paucity of the Israeli data, the functional forms (e.g., exponential increase in NP/WIA as a function of time) are based on the WWII data, but the numbers are from the Israeli data. The equations that predict these casualties are repeated below:

For low intensity (WWII) combat:

Ratio of NP casualties to WIA based on 1000/combat day

$$NP/WIA = 0.408 - 0.363 \exp(-.04\ D) \quad (5)$$

D = Combat Day

This is valid for units with frequent replacements.

Ratio of NP casualties to WIA based on 1000 men per Combat Day:

$$NP/WIA = \frac{10.8 - 9.6 \exp(-0.04\ D)}{31.43 - 0.27\ D} \quad (6)$$

The preceding is applicable to units without replacement.

For armored divisions, multiply equation 5 or 6 by 2.0.

For airborne divisions, multiply equation 5 or 6 by 0.5.

For high intensity (Israeli) combat:

NP/WIA as a function of day of combat for all soldiers in a unit (not just high risk MOS) presented as a single equation:

$$NP/WIA = K_1 - K_2 \exp(-K_3\ D) \quad (9)$$

The coefficients K_1, K_2, and K_3 for overall ground combat forces, infantry, tanks, artillery, and special forces are presented in Table 6.

Estimates of the number of other non-battle casualties have been developed here and can be expressed as:

Total infantry non-battle departures (incl. NP) = 0.606 WIA

Finally, estimates of the proportions of individuals that would be expected to return to combat following departure as NP casualties, WIA + IIA casualties, and for other medical reasons can be expressed in the following equations:

For proportion returning to duty by day d after departure

$$\text{NP returnees} = 0.5\ [1 - \exp(-0.13\ d)] \tag{15}$$

$$\text{Other medical returnees} = 0.54 - 0.48\ \exp(-0.08\ d) \tag{16}$$

$$\text{WIA + IIA returnees} = 0.2 - 0.307\ d \tag{17}$$

$$d = \text{calendar day}$$

Finally, two caveats must be applied to all results and conclusions found in this report.

1. These are predictions based on previous combat experience. They are our best estimates, but may change if the assumed conditions are different in a hypothetical future war.

2. These equations are NOT intended to predict NP or other casualties in battles in which tactical nuclear weapons are used.

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