91 Conventional Attrition and Battle Termination Criteria: Feasibility of a ~~Manual~~ Naval QJM Methodology Interim Report & Final Draft Report

CONVENTIONAL ATTRITION AND BATTLE TERMINATION CRITERIA

FEASIBILITY OF A NAVAL QJM METHODOLOGY

Draft Final Report

Prepared for the Defense Nuclear Agency
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This part of the study tests the feasibility of developing a methodology for the simulation of naval engagements. It attempts to develop factors that, when applied to ship firepower scores, replicate the outcome of historical naval engagements.

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FEASIBILITY OF A NAVAL QJM METHODOLOGY

INTRODUCTION

General

The objective of this sub-study is to "review the data available. . .to determine if methodologies comparable to the Quantified Judgment Method can be developed for naval warfare."

In pursuing this objective, HERO has done the following:

- Surveyed the availability of data relating to modern experience of naval surface warfare;
- Surveyed the availability of data for surface-air-subsurface operations in World War II.

In an interim report to DNA, dated December 1981, HERO reported on a preliminary survey of data relating to surface, naval air, and subsurface operations, noting that there is extensive and detailed data available. (See Appendix A.)

As a basis for determining the possibility of elaborating a QJM-type methodology for naval warfare, it was decided that the first step should be to determine if a naval surface battle of the World War I era could be replicated, and the second step should be to determine if comparable data for replicating more sophisticated World War II operations could be found. This approach was deemed to be as fully responsive to the stated task as possible within the limitation of time and funds available.

World War I Data

It was determined that data of detail and precision comparable to the requirements of the ground warfare QJM was available for the Battle of Jutland, May 31, 1916, in the following sources:

Holloway Frost, The Battle of Jutland

John Irving, The Smokescreen of Jutland

H.W. Wilson, Battleships in Action, Vol. II.
Jane's Fighting Ships, 1914.
Jane's Fighting Ships, 1919.

Developing and Testing a Surface Methodology

Most of the remainder of this report is devoted to the development of a methodology for replicating naval surface warfare of the type exemplified by the Battle of Jutland, and the testing of that methodology with detailed data for that battle.

Availability of Data for Tri-dimensional Methodology

A survey was made of World War II data suitable for expanding and elaborating the surface methodology to represent naval air and submarine operations. It is obvious from the results of this survey that there is ample data to accomplish this.

Participants

Participating in the preparation of this report on a naval warfare simulation methodology were the following members of the HERO staff: T.N. Dupuy, Col., USA, Ret., Executive Director; Edward Oppenheimer, Project Coordinator; Brian R. Bader, Research Assistant; and Grace P. Hayes, Editor. Serving as a consultant was Denton W. West, Capt. USN, Ret.

I. A CONCEPT FOR A NAVAL QJM METHODOLOGY

Essence of the Land Combat QJM

The essence of the Quantified Judgment Model (QJM) methodology for replication and simulation of land combat can be summarized as follows:

1. Lethality values for weapons (also called "proving ground" values) are calculated in accordance with a procedure that relates the characteristics of weapons to their capability to inflict casualties on ground personnel in normal combat deployments. The resulting value is called an Operational Lethality Index or OLI. Values are calculated for motile, i.e., non-inherently mobile, weapons and for mobile fighting machines (such as tanks or aircraft) which incorporate weapons in a mobile combat entity.

2. The value of each weapon for a specific engagement situation is modified by environmental factors (such as weather, terrain, season) which are applicable for the situation or circumstances and which have a direct effect on the effectiveness of the weapons. For the application of these factors, weapons are divided into six categories: infantry, antitank, artillery, air defense artillery, armor, and close air support. The factors are applied to weapons' OLI totals in each category. The sum of the weapons OLI values of the six categories of weapons is termed Force Strength, and given the symbol S.

3. To determine the actual combat power potential of a force under existing combat circumstances, the force strength value is multiplied by all applicable operational variable factors. These include mobility, defensive posture, vulnerability, weather (relating to the force as a whole), terrain (relating to the force as a whole), surprise, leadership, and training. The product of force strength and all applicable operational factors is combat power potential, or P.

4. The combat power potentials of the two opposing forces are compared by a combat power ratio, or P/P. If P_a (for the attacker) is greater than P_d (for the defender), then $P_a/P_d > 1$, and the attacker should be successful; if $P_a/P_d < 1$, then the defender should be successful.

5. The outcome of a land engagement is calculated in terms of three measures of effectiveness:

a. Relative Mission Accomplishment (MF). This is a judgmental value assigned on the basis of an analysis of the engagement narrative. Values are from 1 to 10.

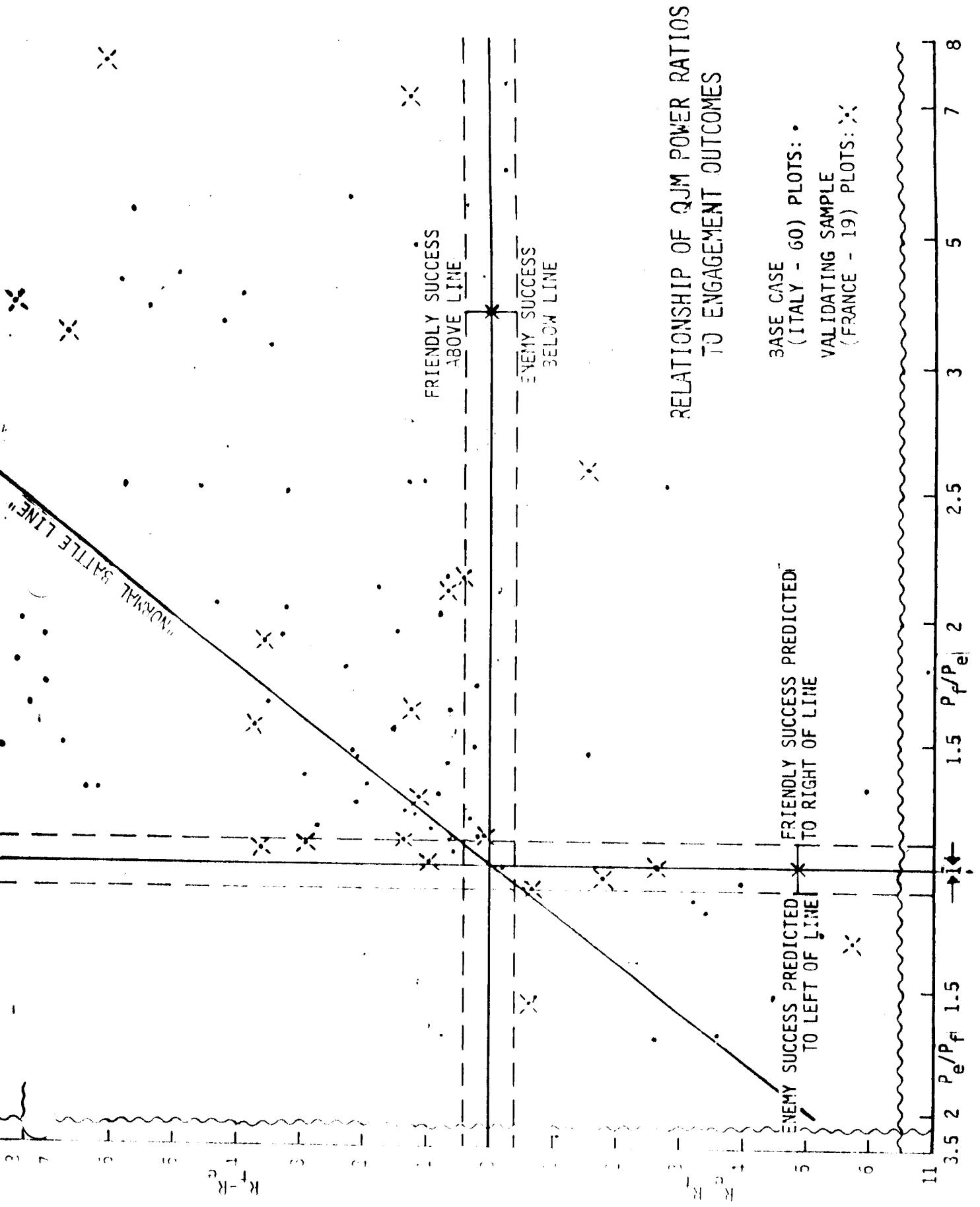
b. Spatial Effectiveness (Eff_{se}). This is calculated from an empirically-derived formula designed to reflect the ground-holding and/or ground-gaining capability of the opponents.

c. Casualty Effectiveness (Eff_{cas}). This is calculated from an empirically-derived formula designed to relate the casualties incurred by one side to the casualties of the other side, and to the starting strengths of both sides.

6. A Result value (R) for each side is calculated by adding the three calculated measures of effectiveness, as follows: $R = MF + Eff_{se} + Eff_{cas}$. The overall outcome value is $R_{attacker} - R_{defender}$. (A ratio cannot be used because negative values can be obtained from both the Spatial and Casualty formulae.)

Once these calculations are performed, each engagement can be plotted on a graph with P/P as the abscissa and R-R the ordinate. (See Figure 1 for an example.) A line from the origin representing the mean of the plots provides a "normal battle line", establishing the average, or standard, relationship of combat power ratio and outcome value. The formula for this straight line is $P/P = [(R-R)/5] + 1$. Thus the effective combat power ratio for an engagement (PR/PR) can be calculated by this formula. If PR/PR and P/P are identical, the engagement plots on the normal battle line, and the relative combat effectiveness

Figure 1


RELATIONSHIP OF QJM POWER RATIOS
TO ENGAGEMENT OUTCOMES
BASE CASE
(ITALY - 60) PLOTS: •
VALIDATING SAMPLE
(FRANCE - 19) PLOTS: ×
FRIENDLY SUCCESS
ABOVE LINE
ENEMY SUCCESS
BELOW LINE
FRIENDLY SUCCESS PREDICTED
TO RIGHT OF LINE
ENEMY SUCCESS PREDICTED
TO LEFT OF LINE
"NORMAL BATTLE LINE"
P_e/P_f
P_f/P_e
3.5 2 1.5
1.5 2 2.5 3 5 7 8

of the two opponents equals 1.0, the forces being equally combat effective. If PR/PR does not equal P/P, then the relative combat effectiveness (CEV) can be calculated as follows: CEV = (PR/PR)/(P/P).

An example. Let us assume that the combat power ratio of the attacker to the defender (P_a/P_d) is 1.5. Let us assume result values as follows:

Attacker mission accomplishment: 6

Spatial effectiveness: 1.3

Casualty effectiveness: -2.1

This makes $R_a = 6 + 1.3 \times -2.1 = 5.2$

Defender mission accomplishment: 4

Spatial effectiveness: -0.9

Casualty effectiveness: 1.2

This makes $R_d = 4 - 0.9 + 1.2 = 4.3$

$R_a - R_d = 0.9$

$PR_a/PR_d = 0.9/5 + 1 = 1.18$

CEV = 1.18/1.5 = 0.79

Thus the relative combat effectiveness of attacker to defender is 0.79; relative combat effectiveness and the relative capability of two forces to inflict casualties on each other. The ratio of casualty-inflicting capabilities is, on the average, the square of the CEV. Thus in the case in point, the ratio of casualty-inflicting capabilities of defender to attacker would be likely to be 1.27^2, or about 1.61.

Adaptability to Naval QJM Methodology

The naval QJM methodology presented here has been developed on the assumption that naval combat can be replicated or simulated in the same general procedure. There are obvious differences in weaponry, in the nature and specific effects of environmental variables, and in the nature and specific effects of operational variables.

A different method for assessing the outcome will have to be devised for naval warfare, since in a naval engagement casualties do not have the same importance that they do in a land engagement, and gaining of surface space has virtually none. Since missions or objectives are usually to damage or sink the enemy's ships, damage inflicted or sustained is considered the most important measure of effectiveness in naval warfare.

To test the possible utility of such a methodology and its applicability to naval warfare, it was decided to initiate the development with naval surface warfare only. If such a methodology appears feasible for naval surface warfare, then it presumably should be possible to elaborate the methodology to give due consideration to all three-dimensional aspects of modern naval warfare.

The Basic Naval QJM Methodology

The first step in the naval QJM methodology involves the quantification of weapons and ship OLI values for vessels on each side. Weapons values are first calculated by means of formulae designed to represent the lethality of naval guns and torpedoes. From these values it then becomes possible to calculate OLI values for individual ships. Next, these ship values are added up on each side to give an unmodified, or raw, OLI value for the fleet, squadron, group, or force (hereafter called force). This raw value shows the theoretical firepower or combat power of the force, but does not reflect the actual circumstances of combat.

For example, if, in a hypothetical naval engagement, the Blue Force has three battleships, each with an OLI value of 110,000, and ten destroyers valued at 11,000 apiece, the total raw power of the Blue Force will be (3 x 110,000) + (10 x 11,000) or 440,000. If the opposing Red Force has two battleships at 100,000 OLI each and ten destroyers at 10,000 OLI each, its raw power will be (2 x 100,000) + (10 x 10,000) or 300,000. Then, in an unweighted firepower comparison, the

Blue Force has an advantage over the Red Force by a factor of 1.47 (440,000/300,000).

HERO's land QJM is based on the historically demonstrated fact that the raw power of forces engaged in combat does not alone determine the development and outcome of battle. Factors such as weather, terrain, leadership, and training also influence battle outcomes. In the land model, environmental and operational factors (the latter include such considerations as surprise, leadership, and training) are applied to modify the proving ground, or raw power values to get a value for the combat power potential, reflecting the actual combat capability of the force under the specific circumstances of a battle. It appears evident that both environmental and operational variables must shape the nature and outcomes of naval combat.

The most important environmental factors modifying naval surface combat appear to be: 1) the position (elevation and bearing) of the sun, 2) the force and direction of the wind, 3) the condition of the sea, and 4) visibility.

If in the hypothetical engagement between Blue and Red forces, the sea is calm and the visibility excellent, then values of 1.0 are assigned for these factors for both forces. But both the direction of the wind and the position of the sun could favor one of the opponents more than the other. If the sun is behind the Red force, making it a better target, then the capability of the Blue force is enhanced by a value found in Table 1. If the wind is blowing away from the Red force toward the Blue force, smoke will interfere with vision of the Red force, and its capability is degraded by a factor to be found in Table 2. If the factor for sun is 1.2 and the factor for wind is 0.50 then the raw QJM value of the Blue force is modified to a force strength (S) value of 528,000 (440,000 x 1.2) while S for the Red force become 150,000 (300,000 x 0.50).

The most important operational factors affecting naval surface battle outcomes appear to be: force mobility, surprise, leadership, training, hazards to navigation (including mines),

Table 1

POSITION OF SUN*

Bearing with Respect to Guns (degrees)	Elevation		
	0-30°	30°-60°	60°-90°
315-45	1.4	1.2	1.0
45-90	1.2	1.0	1.0
90-270	1.0	1.0	1.0
270-315	1.2	1.0	1.0

*Applicable only on a clear day.

The effect of the sun on visually-directed gunnery is not a simple matter. A table prepared for a clear, cloudless day (such as was the case at Coronel in 1916) will not provide factors equally applicable to a sunlit but slightly hazy day (such as was the case at the Battle of Jutland). Because of the haze, at midafternoon of a long day in northern latitudes, the force to the west (British) was at a disadvantage, because the vessels were clearly visible to the force to the east (German), who could not be seen so clearly by the British because of the combination of the sun's position and a low mist on the eastern horizon. Had there been no haze, the sun would have been in the eyes of the Germans, and both forces would have been almost equally illuminated, until the sun sank so low that the force to the west was outlined against it.

Thus tables for the combined effect of sun and haze on visibility and gunnery will have to be more complex than the simple Table 1 used in this feasibility study. That such tables can be produced is unquestionable, however, and thus Table 1 is adequate for the feasibility assessment in this study.

Table 2

DIRECTION AND FORCE OF WIND

Bearing with Respect to Target (degrees)	Force of Wind (Knots)			
	0-10	10-30	30-60	Over 60
0-45	0.5	0.7	0.8	0.9
45-75	0.6	0.8	0.9	1.0
75-90	0.7	0.9	1.0	1.0
90-180	1.0	1.0	1.0	1.0

and force vulnerability. In the land combat QJM there are procedures for calculating force mobility, force vulnerability, and surprise. There is no procedure yet for calculating leadership and training, although a composite of these and other intangible factors can be calculated, and is called relative combat effectiveness (CEV). None of these factors seem to have played an important role at Jutland, with the exception of leadership and training (both of which seem to have favored the Germans). Therefore, for initial calculations, they have all arbitrarily been given a value of 1.0, and a CEV is calculated later. Thus, in the example given in the preceding paragraph, with operational variables having a value of 1.0, a Combat Power ratio of 3.52 (Blue to Red) or 0.28 (Red to Blue) is calculated. The previous firepower advantage of the Blue force over the Red force (1.47) has been increased by the circumstances of the battle to a preponderance of 3.52.

The next procedure in the methodology is to devise a way to measure damage. Then, once the damage on both sides has been calculated, a ratio of damage inflicted (DI) can be calculated. Presumably, the ratios of battle damage inflicted on each other by the opposing forces should be roughly proportional to the combat power ratio. If there is any significant difference in these ratios it can be presumed that this is due to a difference in relative combat effectiveness, and a CEV can be calculated.

II. DEVELOPING THE METHODOLOGY

Calculation of Naval Gun OLIs

As in the land warfare model, the first step in analysis of a naval engagement is calculation of Operational Lethality Indexes (OLIs) for the various weapons of the opposing forces. The total OLI value for a warship is calculated by a formula which aggregates the values of its various weapons in relation to other characteristics.

The two principal weapons used in surface engagements in World War I were guns and torpedoes. (Mines, which also could

influence the outcomes of surface engagements, are tentatively included in the operational factor for obstacles.) To calculate OLIs for naval guns, the following seven characteristics have been recognized:

Strikes per Hour (SH). This is the practical sustained rate of fire for a weapon on a per-hour basis. Larger caliber guns have greater destructive potential than their smaller counterparts, but at the cost of a loss of rapidity of fire. Since rates of fire for naval and land guns are roughly the same, the value of this factor is determined by the graph in Figure 2, which in turn is based on US Army FM 6-20, Artillery Tactics and Techniques. On this graph a curve giving the SH values of a wide range of calibers is plotted.

Projectile Weight (WT). This is the weight in pounds of a gun's armor-piercing projectile. The overall destructive power of a naval gun is directly related to the size of the projectile that it fires. The square root of the projectile weight is used to represent this weapon characteristic. This is a rough approximation of the value recommended in Joint Munition Effectiveness Manual Air-to-Surface - Target Vulnerability (U) NAV AIR 00-130-AFR-1, Book II, Appendix B, Blast Methodology.

Armor Piercing Capability (APC). In naval warfare the heavy armor plating of captial ships makes it necessary for a projectile to penetrate a considerable amount of steel before it explodes, in order to inflict maximum damage on its target. The following table (based on a graph from Fletcher Pratt's naval wargame)* shows inches of armor piercing capability (APC) by projectiles of different calibers at optimal ranges.

Table 3

Shell Size	APC	Shell Size	APC
16"	18"	8"	5"
15"	17"	7.5"	4"
14"	16.2"	6"	3"
13"	13"	5.5"	2.6"
12"	12"	5"	2"
11"	11"	4"	1.6"
10"	8"	3"	1"

*Donald F. Featherstone, Naval Wargames (London, 1965).

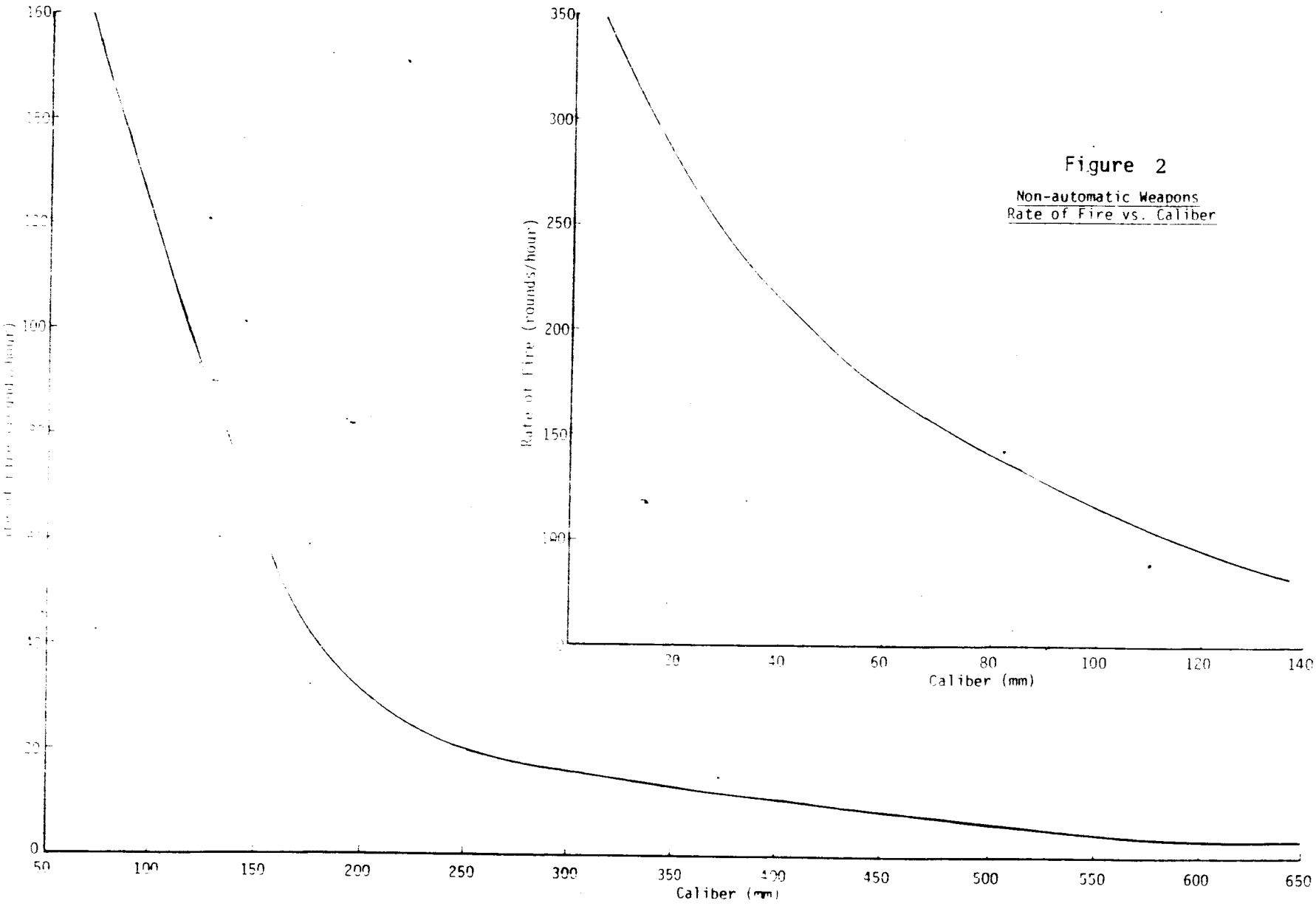


Figure 2

Non-automatic Weapons
Rate of Fire vs. Caliber

Values for shell sizes not included in this table were found by interpolation.

Accuracy (A). Like the accuracy factor in the land weapons OLI equation, this is a judgmental factor, based on a scale from 0.50 to 1.0. Since some types of guns are inherently more accurate than others, this factor was deemed essential for this feasibility study. However, a more precise value can be determined from test and proving ground data.

Reliability (RL). This too is a judgmental factor, chosen on a scale from 0.50 to 1.0, the higher value reflecting a more reliable weapon. A weapon's tendencies to jam or malfunction, its ability to operate efficiently under adverse weather conditions, the quality of its ammunition, its ease of operation, and other similar factors are reflected in this value. This factor can also be given greater precision from test and proving ground data.

Muzzle Velocity (MV). This factor, measured in meters per second, not only is a consideration in a gun's effective range, it also affects both accuracy and time in flight.

Caliber (CAL). The caliber of a gun in millimeters is essential to calculate the muzzle velocity effect as it relates to range. This range/muzzle velocity effect is calculated in the same fashion as for the land OJM.

A tentative equation to represent a naval gun's Operational Lethality Index (or OLI) is as follows:

$$W(\text{naval}) = \frac{\sqrt{SH \times \sqrt{WT} \times APC \times A \times RL \times (.0007 \times MV \times \sqrt{CAL})}}{20} \times 15$$

SH = Strikes per Hour
WT = Projectile Weight (in pounds)
APC = Armor Piercing Capability (in inches)
A = Accuracy
RL = Reliability
MV = Muzzle Velocity (in meters/second)
CAL = Caliber of muzzle diameter (in millimeters)

Since this procedure for calculating the OLI of naval guns does not include the intermediate step of calculation of a Theoretical Lethality Index (TLI), which is based upon hypothetical human targets in mass array, two constant factors are used to provide values that are more easily managed, and that have dimensions comparable to land weapons' OLIs*.

Using the seven variables and the equation described above, consistent relative values for naval gun OLIs can be calculated. Table 4 lists some OLI values for selected British and German guns in service at Jutland. Each gun is presented with its calculated OLI and the values of the individual factors as derived from its characteristics. The data is taken from the 1914 and 1919 editions of Jane's Fighting Ships.

It is useful to compare the characteristics of a British naval gun and a German naval gun, as shown in Table 4.

Strikes per hour of the British 13.5" gun are calculated as 14 according to the graph in Figure 2. For the German 12" gun this value is 16. Since both are heavy guns of comparable caliber the small difference in rates of fire seems reasonable. (The effect of size on strikes per hour can be seen readily by comparing the values for a German 4.1" and 12" projectile; the smaller gun has a much higher rate of fire.)

The British 13.5" projectile weighs 1,250 pounds and its German 12" counterpart, 1,014, a difference of 236 pounds. From Table 3 the armor-piercing capability for the larger British gun is 14" of penetration; for the German 12" gun the value is 12". Muzzle velocity, however, is higher for the smaller German shell, 893 meters per second compared to 826, a difference of 67 meters per second. Higher muzzle velocity provides a greater kinetic energy at a given range for a projectile. This in turn increases a gun's damage potential. This is one of three reasons why the OLI of the German gun is greater than that of the British weapon; the two other reasons are accuracy and reliability of its ammunition.

---

* This equation will require further study, to assure both its relationship to land warfare OLI values, and its appropriateness for naval warfare. When revised the relationships will be in metric system dimensions.

Table 4

OLIs FOR SOME WORLD WAR I NAVAL GUNS

Gun	Br. 15" 42 cal.	Br. 13.5" 45 cal.	Br. 6" 50 cal.	Ger. 12" 50 cal.	Ger. 11" 50 cal.	Ger. 9.4" 40 cal.	Ger. 4.1" 40 cal.
SH	12	14	65	16	18	22	120
WT	1,920	1,250	100	1,014	760	352	35.2
APC	17	14	3	12	11	7	1.6
RL	0.8	0.8	0.8	0.9	0.9	0.9	0.9
A	0.85	0.85	0.85	0.9	0.9	0.9	0.9
V	812	826	948	893	893	843	843
Cal	380	343	152	305	280	240	105
OLI	870	753	349	780	721	491	250

A study of gun performance at Jutland shows that the German guns were generally superior to the British guns in the very important categories of accuracy and reliability of their armor-piercing projectiles.

German salvos (due to greater accuracy) tended to land together with much less dispersion than the British projectiles. There is general agreement among analysts that the smaller dispersion (due in part to higher muzzle velocity and in part to better manufacturing) was important in the sinking of one and possibly two British battle cruisers. The dispersion pattern was the main basis for assigning an accuracy factor of 0.9 to the German 12" gun, compared to the factor of 0.85 for the British 13.5" gun.

Reports from German naval leaders after the battle indicated that many British shells failed to penetrate ships' armor before exploding, the result of faulty fuzes. This was a major reason why German ships suffered less damage than the British ones. The German battle cruisers withstood repeated hits, but lost only one of their number. For this reason reliability values of 0.8 and 0.9 have been assigned to the British and German weapons respectively.

Calculation of Torpedo OLIs

The quantification of the operational lethality of a torpedo is based upon considerations similar to those used for the naval gun OLI equation. The following five factors are considered the most important relating to torpedo performance and damage potential.

Warhead Weight. The torpedo formula uses the square root of the weapon's warhead weight in pounds. It is assumed that the greater the charge, the more damage the weapon is likely to inflict.

Speed. Measured in knots, this factor is included to give a higher value to faster torpedoes. The higher the torpedo speed the less chance the target has to take successful evasive action, and the greater the kinetic energy.

Accuracy. This is a judgmental factor using a scale from 0.50 to 1.0. Because of different guidance and homing systems the accuracy of torpedoes is not standard, and such a range appears to be reasonable. Again, proving ground and test data can provide values with assured validity.

Reliability. This is another judgmental factor, based on a scale from 0.50 to 1.0 and included to reflect the increase in lethality of more reliable torpedoes.

Maximum Range. Some measure of a torpedo's range is required, since range directly influences the area within which a torpedo can be expected to hit its target. For purposes of comparison, the torpedo lethality equation uses the maximum range of the weapon (measured in kilometers).

The equation for a torpedo's Operational Lethality Index is as follows:

$$W(\text{torpedo}) = \frac{7 \times \sqrt{WT} \times SP \times RL \times A \times (1 + \sqrt{RN})}{20}$$

WT = Warhead Weight (in pounds)
SP = Speed at Maximum Range (in knots)
RL = Reliability
A = Accuracy
RN = Maximum Range (in kilometers)

Again, as is the case with the naval gun OLI equation, the torpedo OLI has been calculated without the intermediate step of calculation of a Theoretical Lethality Index. Therefore, a constant factor is used in the equation's denominator to provide values that are directly relatable to those of naval guns and land weapons.

Table 5 shows values for the factors and OLIs of the four types of torpedoes used at Jutland by both adversaries. An asterisk indicates an estimated value based on interpolation using known data from other torpedoes. The data comes from the 1914 and 1919 editions of Jane's Fighting Ships.

The larger, faster torpedoes with greater range have higher OLIs. Accuracy and reliability factors have been estimated and could be improved by incorporation of test data.

Table 5

OLIs FOR WORLD WAR I TORPEDOES

Make or Model	21" Whitehead (Br.)	18" R.G.F. New (Br.)	19.7" G VII (Ger.)	17.7" G/125 (Ger.)
WT	500*	325*	430	308
SP	30	30*	28	24
RL	0.9	0.9	0.9	0.9
A	0.5	0.5	0.5	0.5
RN	11	7	11	6.56
OLI Value	456	310	404	236

* Estimated.

Calculation of Warship OLIs

Once OLI values for guns and torpedoes are calculated, it is possible to calculate an overall OLI value for a warship. Weapons values are combined with factors representing performance and defensive characteristics to get a figure that represents the overall value of a warship as a fighting system.

There are six performance and defensive factors used in the warship OLI equation.

Weapons Values. These are calculated as discussed above.

Fire Control. This is a judgmental factor based on a scale from 0.50 to 1.0. Differences in fire control systems on warships of various nations make this a necessary factor. Availability of radar or optical range finders, for example, would be reflected in this value. Test data would permit calculation of valid figures for this factor.

Speed. The square root of a ship's maximum speed, measured in knots, is used in the warship OLI equation. Speed is a characteristic that influences offensive and defensive capabilities. A ship with greater maximum speed has the advantage over slower ships in maneuvering for tactically advantageous positions.

Displacement. Measured in tons, this is the standard displacement of a warship and a reliable gauge of a warship's ability to absorb punishment, when considered in connection with both armor and compartmentation.

Belt, Deck and Turret Armor. Capital ships have armor protection concentrated over these three main areas to protect their vital workings from damage by enemy projectiles and torpedoes. Smaller warships, like heavy and light cruisers, often have thinner armor belts and plates in similar areas. In the warship OLI equation, the armor's thickness in these vital areas is measured in inches. The values are squared and then multiplied by 100. This assures adequate representation of the principal defensive characteristic of capital ships.

Compartmentation. Like armor plating, a ship's construction is an important element in its capability to absorb punishment. The number of watertight compartments, placement of bulkheads, and similar characteristics are covered in the warship OLI equation by this judgmental factor. A procedure for calculating this has not yet been determined.

An overall firepower value for a warship's weapons is calculated as follows:

Guns are grouped in batteries by caliber and type. The values of all of the weapons in a battery are combined, with due consideration to a practical application of the law of diminishing returns. If a battery has fewer than two guns, then the full value of the weapon is used, once for a single gun battery, twice for a two gun battery. If the battery has three guns, two full values and half the full value of the third are used. With batteries composed of three or more guns (as is usually the case on modern warships) the first three guns are calculated in the above manner, and one-third of the full value of the additional weapons is added. For example, on a ship with ten 12" guns in the main battery, each gun valued at 700 OLI, the equation for a modified weapon value looks like this: $(2 \times 700) + (0.5 \times 700) + [(7 \times (0.33 \times 700)]$ or 3,367.

The warship OLI equation is as follows:

$$OLI(Ws) = (\Sigma W \times FC \times \sqrt{SP}) + (2 \times DISP) + COMP + (100 \times BA^2) + (100 \times DA^2) + (100 \times TA^2)$$

ΣW = Sum of the gun and torpedo OLI values
FC = Fire Control
SP = Speed (in knots)
DISP = Standard displacement (in tons)
COMP = Compartmentation
BA = Belt Armor
DA = Deck Armor
TA = Main Battery Turret Armor

Using this equation, the OLIs from selected ships at Jutland were calculated and are presented in Table 6.

Table 6

SELECTED SHIPS AT JUTLAND

Ship	Size of Main Battery & no. of guns OLI	Size of Second. Battery & no. of guns OLI	Size of Torpedoes & no. of tubes OLI	FC	Speed	Displ.	Belt	Deck	Turret	Com.	OLI
König (BB)	10 x 12" (780 ea.)	14 x 6" (370)	5 x 19.7" (404)	1	21.5	25,500	14"	3"	12"	1	119,733
Moltke (BC)	10 x 11" (721)	12 x 6" (370)	4 x 19.7" (404)	1	27	23,000	11"	3"	8"	1	99,878
Wiesbaden* (CL)	10 x 4.1" (250)	--	2 x 17.7" (236)	1	24.5	3,600	3"	2"	1"	1	16,888
V 44 (DD)	3 x 3.4" (150)	--	6 x 19.7" (404)	1	34	725	0	0	0	1	11,858
Malaya (BB)	8 x 15" (870)	12 x 6" (349)	4 x 21" (456)	1	25	27,500	13"	3.25"	11"	1	119,106
Lion (BC)	8 x 13.5" (753)	16 x 4" (235)	3 x 21" (456)	1	28	26,350	9"	2.5"	9"	1	100,536
Warrior (CA)	6 x 9.2" (459)	4 x 7.5" (354)	3 x 18" (310)	1	22.3	13,550	6"	1.5"	8"	1	53,280

* An older, slower CL.

In the examples in Table 6, a German battleship (Kӧnig class) has an OLI value approximately 10 times that of a destroyer. The fast battle cruisers, with their reduced armor, have values about one sixth less than the Kӧnig. A heavily armored cruiser, the Warrior, has a value slightly less than half the battleship's OLI. Further calculations of OLIs give consistent results, with destroyer values around 12,000, light cruiser values about 25,000, and battle cruiser and battleship values between 100,000 and 120,000.

Equal values are assigned all ships for the compartmentation and fire control factors, since accurate data on these characteristics is not readily available.

The formula appears to recognize the most important factors, but it cannot be considered more than tentative. Although it seems to work nicely with the Jutland ships and the selected engagements, many more engagements would have to be analyzed before it could be assumed with confidence that no other factors are significant enough in their effects to warrant inclusion.

Damage Assessment

In assessing damage to warships, two types of hits are considered: (1) those damaging guns of the main battery, and (2) all other hits. If a main battery gun is hit and incapacitated, then its OLI value is used as the basis for determining the amount of damage. For a general hit on a ship, the damage is calculated using the OLI value of the gun firing the shell.

Since a ship's OLI value is worth more than the sum of its gun OLIs, a factor was chosen to modify the gun values used in determining damage. For incapacitating hits on main battery guns the damage value is ten times the value of the knocked out gun. Damage is determined for other hits by multiplying the OLI value of the gun firing the shell by a factor of five.

The Von der Tann, which had all of her main battery knocked out during the battle, is used to test calculation of the damage assessment for hits on guns in a ship's main battery. The Seydlitz, which received 21 hits and still limped home to port, is used to test the damage assessment for hits that caused damage but did not necessarily knock out a gun. The OLI value for the Von der Tann was 83,501 and for one of her individual 11" guns, 697. For the Seydlitz, the overall value was 103,878.

In the case of the Von der Tann, after all of her main battery was knocked out she still retained much of her secondary battery, and used it against smaller British ships. She also took part in the famous "death ride" of the German battle cruisers, and by her presence was a target for the British capital ships. Thus she indirectly contributed to the overall OLI value of the German battle cruiser squadron by attracting fire that otherwise would have been concentrated against the other four battle cruisers.

It seems reasonable to assume that loss of a ship's main battery will reduce the total OLI value of the ship by more than the calculated OLI value of the guns, probably by as much as two thirds.

In the case of the Von der Tann this value is 55,612 (83,501 x .666). The remaining value of the ship (27,889) represents the firepower of secondary batteries and (at least in this example) the residual value of the ships as a target for enemy fire.

The total OLI value of the eight guns in the Von der Tann's main battery is 5,576 (8 x 697). Assuming that they in fact contribute two-thirds of the fighting value of the ship, this value is enhanced by approximately a factor of 10 (55,612/ 5,576 = 9.97). The factor used for damage to one of a battle cruiser's main guns, therefore, is 10. Any other damage is estimated separately.

For the effect of other hits not damaging main battery guns, the battle cruiser Seydlitz's experience is used. The Seydlitz demonstrated that she had been able to absorb hits from 21 heavy caliber shells, and still reach port, even though in very badly damaged condition. If it is arbitrarily assumed that, with her remaining armament, she still had a value of one-tenth of her original OLI value, then the 21 hits were responsible for inflicting total OLI damage of 93,490 (0.9 x 103,878). These hits came from 13.5" and 15" British guns with an average OLI value of 812. For 21 hits the value is 17,052 (21 x 812). Thus the factor applicable to the effect of these hits on the Seydlitz averaged about 5.48 for each hit (93,490/17,052). This suggests that a factor of 5.0 for each hit is reasonable.

Damage from a torpedo hit poses a more difficult problem. In his book, The Battle of Jutland, Frost suggests that such a hit is about five times the value of a hit from a major caliber gun. On this basis the factor for a torpedo hit should be about 25.0, to be applied to the OLI value of the torpedo. This factor was tested in the case of a torpedo hit which sank the German destroyer V-29. The OLI damage value, using the 25.0 factor, is 11,400 (25 x 456). The value of the destroyer is 12,000.

It is evident from the experience of adapting the QJM methodology to a specific example in naval warfare that the time periods for engagements in a naval QJM will have to be much shorter than is usual for land warfare. As major forces change course, or move in or out of range of each other, or major ships are sunk or severely damaged, the circumstances of the engagement change. Thus the model must be able to accomodate itself to new and different assessments for engagements (or actions within engagements) lasting a few hours or even a few minutes.

III. APPLICATION OF METHODOLOGY TO SURFACE COMBAT: THE BATTLE OF JUTLAND

Background

In the evening of 30 May 1916 Admiral Sir John Jellicoe, Commander of the British Grand Fleet, having received intelligence of unusual activity in the German ports, led his Battle Fleet out of Scapa Flow in anticipation of a long-awaited naval encounter with the German High Seas Fleet. Less than an hour later the British Battle Cruiser Fleet, under Vice Admiral Sir David Beatty, sailed from Rosyth. By the next morning almost all operational forces of the Royal Navy in the North Sea area were at sea.

The activity reported by British intelligence was related to preparations by the German High Seas Fleet, commanded by Vice Admiral Reinhard Scheer, to put to sea, in execution of a plan to steam north toward the Skaggerak, hoping to lure the British battle cruisers or some other element of the Grand Fleet out to their destruction. Unaware that most of the Grand Fleet was already at sea, the Germans set out at 3:00 AM on 31 May. The scouting force of battle cruisers, commanded by Vice Admiral Franz Hipper, were in the lead, with Scheer and the main body following an hour and a half later.

At about 2:15 PM, Beatty, who had been proceeding on a course slightly north of east into the central regions of the North Sea, turned north for an assigned rendezvous with Jellicoe's force, which then was about 70 miles north northeast, proceeding roughly southeast. Still unknown to each other, Hipper's flagship, the Lützow, was 45 miles to the east of Beatty's flagship, the Lion. Following the British turn, both battle cruiser forces were heading generally north on converging courses.

Within minutes British scouting destroyers sighted German cruisers, and the German fleet also received reports of enemy ships. Hipper sighted the British battle cruisers at 3:20 PM,

a few minutes before Beatty became aware of his approach. Hipper changed course at once to southeast, to try to lead the British, then headed northeast, toward Scheer, who was still some distance away. At about 3:30, Beatty, sighting the Germans, also changed course to the east and then southeast, so that the two battle cruiser fleets were soon on almost parallel courses, both heading toward the approaching Scheer.

Visibility was good on the surface, but low clouds and mist limited aerial observation. German gunners had a slight advantage over the British, for the brighter western sky made the British ships more clearly visible than the grey German ships against the grey sky to the east. And the wind, generally out of the west, blew smoke across the line of sight of the British gunners.

The First Battle Cruiser Engagement - 3:38-4:05 PM

Beatty deployed his battle cruisers in a line-ahead formation, with his flagship, the Lion (eight 13.5" guns), in the van, followed by her sister ship, the Princess Royal. Then in order steamed the Queen Mary (eight 13.5" guns), the Tiger, with similar armament, and finally the sister ships New Zealand and Indefatigable, each with eight 12" guns. Hipper's ships were deployed in the same type of formation, with the Lützow (eight 12" guns), the flagship, in the lead, followed by her sister ship, the Derfflinger. Then followed the Seydlitz, the Moltke and the Von der Tann, each armed with 11" guns, the first two with ten and the last with only eight.

Initial fire distribution for the Germans covered every British battle cruiser except the New Zealand, Hipper preferring to keep all of a ship's guns on one target. The British ships should have been able to cover every German ship, with a double concentration on one. But a faulty fire distribution signal from Beatty left the Derfflinger free from enemy fire until almost 4:00 PM. This meant, however, that the Lützow and the Moltke were fired on by two British ships each.

The Lion was probably the first ship hit when, at 3:51, two 12" shells from the Lützow scored. These were followed by as many as seven more in the next quarter hour, including one that permanently disabled a turret. The Princess Royal, immediately behind, was struck by five 12" shells from the Derfflinger. Two turrets were hit (one temporarily disabled), and her main fire control was put out of action for about twenty minutes. Other hits pierced a funnel and foremast. The Tiger received nine 11" hits, which caused serious damage amidships and temporarily knocked out two turrets. Of the first five British ships in line, only the New Zealand and the Queen Mary remained unscathed.

In a duel between the Indefatigable and the Von der Tann, neither ship scored a hit until around 4:04 PM. Then, the German ship found the range and scored six hits. An explosion in a turret started fires that spread quickly to the Indefatigable's magazine, which was not separated by an adequate fireproof barrier from the turret's ammunition handling room. A massive explosion followed, and the Indefatigable disappeared, taking all but two sailors with her to the bottom of the sea.

On the German side, the Lützow and Derfflinger were each hit once around 4:00 by 13.5" shells which caused only minor damage. The Seydlitz received her first hits of the day when two 13.5" projectiles from the Queen Mary knocked out one main battery turret. These were the only hits on the German battle cruisers during the initial exchange of fire.

In the first 17 minutes, the British lost one battle cruiser and eight main battery turrets, and received a total of 29 hits from heavy caliber shells. For the Germans, the damage was only four hits from heavy projectiles and one main battery turret out of action. Two defects in the British ships had much to do with the disproportionate damage. The British shells were equipped with defective fuzes which sometimes caused them to explode before penetration and practically without damaging their targets. One battle cruiser and her crew had been sacrificed to the inadequacy of screening in the connecting passageway between magazines and turrets.

As shown in Table 7, the total unmodified OLI of the six British battle cruisers was 556,252. Applying the factors in accordance with the conditions of battle, the force strength and combat power became 278,126. For the Germans these figures are 500,349 and 600,419. The ratio of OLIs, which is 1.11% in favor of the British, becomes a German advantage of 2.16 in combat power.

The damage done to each ship in the first engagement, lasting from 3:45 to 4:05 PM, is shown in Table 8. Total damage suffered by the British ships, or inflicted by the Germans, is 205,029, while that suffered by the Germans, inflicted by the British, is 25,715. The ratio of these gives a damage-inflicting capability of 7.97:1 in favor of the Germans, exceeding the combat power ratio of 2.16 by a factor of 3.69.

The Second Battle Cruiser Engagement - 4:05-4:30 PM

Starting at about 4:05 PM, four battleships of the Queen Elizabeth class (in order, Barham, Malaya, Warspite, and Valiant) joined up with Beatty's battle cruisers. Fire from these ships' 15" guns was directed on the last two German battle cruisers in line, the Moltke and the Von der Tann. Hit by three 15" shells, the Von der Tann shipped 600 tons of water through a hole caused by a shell penetration near the waterline. Two other hits pierced two turrets and put them out of action, and a third turret was disabled by a loss of power. The Moltke received one 15" hit from the Barham, and two 12" shells from the Tiger, sustaining substantial damage. The Lützow and the Seydlitz were each hit by a 13.5" shell and received minor damage. Two hits on the Derfflinger brought the German sustained hit total to ten for the period between 4:05 and 4:30. Three main battery turrets (all on the Von der Tann) were disabled.

German fire continued to be effective in this second engagement. The Lion and the Princess Royal took two and three hits respectively from 12" shells. Substantial damage was caused to the Lion; damage to the Princess Royal was less

Table 7

FIRST BATTLE CRUISER ENGAGEMENT AT JUTLAND
3:45 - 4:05 PM 31 May 1916

The Combat Power Ratio

Ship (armament)	OLI		Sun's Position		Wind		Sea Condition		Visibility		S		Leadership		Surprise		Training		P
GERMAN																			
Lützow (8x12")	106,546	x	1.2	x	1	x	1	x	1	=	127,855	x	1	x	1	x	1	=	127,855
Derfflinger (8x12")	106,546	x	1.2	x	1	x	1	x	1	=	127,855	x	1	x	1	x	1	=	127,855
Seydlitz (10x11")	103,878	x	1.2	x	1	x	1	x	1	=	124,654	x	1	x	1	x	1	=	124,654
Moltke (10x11")	99,878	x	1.2	x	1	x	1	x	1	=	119,854	x	1	x	1	x	1	=	119,854
Von der Tann (8x11")	83,501	x	1.2	x	1	x	1	x	1	=	100,201	x	1	x	1	x	1	=	100,201
German Total	500,349										600,419=S								600,419=P
BRITISH																			
Lion (8x13.5")	100,536	x	1	x	.5	x	1	x	1	=	50,268	x	1	x	1	x	1	=	50,268
Princess Royal (8x13.5")	100,536	x	1	x	.5	x	1	x	1	=	50,268	x	1	x	1	x	1	=	50,268
Queen Mary (8x13.5")	104,836	x	1	x	.5	x	1	x	1	=	52,418	x	1	x	1	x	1	=	52,418
Tiger (8x13.5")	104,836	x	1	x	.5	x	1	x	1	=	52,418	x	1	x	1	x	1	=	52,418
New Zealand (8x12")	72,754	x	1	x	.5	x	1	x	1	=	36,377	x	1	x	1	x	1	=	36,377
Indefatigable	72,754	x	1	x	.5	x	1	x	1	=	36,377	x	1	x	1	x	1	=	36,377
British Total	556,252										278,126=S								278,126=P

Force Strength Ratio: 2.16 $\left(\frac{600,419}{278,126}\right)$ Combat Power Ratio: 2.16 $\left(\frac{600,419}{278,126}\right)$

Table 8

FIRST BATTLE CRUISER ENGAGEMENT-DAMAGE ASSESSMENT

Ship	Main Bty	Hits Elsewhere	Factor	OLI	Damage
GERMAN					
Seydlitz		1	5	753	3,765
	2		10	721	14,420
					18,185
Lützow		1	5	753	3,765
Derfflinger		1	5	753	3,765
TOTAL, German Damage					25,715
BRITISH					
Lion	2		10	753	15,060
		8	5	780	31,200
					46,260
Princess Royal	2		10	753	15,060
		4	5	780	15,600
					30,660
Tiger	4		10	753	30,120
		7	5	721	25,235
					55,355
Indefatigable		sunk			75,754
TOTAL, British Damage					205,029

severe. The Tiger also received minor damage when two 11" projectiles from the Moltke hit at about 4:25. Fire from the Von der Tann scored one 11" hit each on the New Zealand and the Barham. And shells from the Derfflinger, now under fire after a brief respite at the beginning of the battle, hit the Queen Mary with eight 12" projectiles, smashing her decks, port broadside battery, and a main battery turret. In a catastrophe similar to the one that befell the Indefatigable a few minutes earlier, a powder flash ignited the Queen Mary's inadequately protected magazine, and the ship blew up. Only 19 men managed to escape.

When the engagement ended at 4:30, the results had continued to favor the Germans. Ten hits in all were made on German ships, with the loss of three main battery turrets and their six guns. Seventeen hits struck the British ships, and one battle cruiser, with eight 12" guns, was sunk.

As shown in Table 9, the OLI values for the two forces were altered by the damage and losses suffered in the first engagement and by the addition of four British battleships. The German OLI was 474,634, and the British 827,647, which gave the British a firepower advantage of 1.74. Modified by the sun and the wind, which had shifted slightly and so increased the factor to 0.6, the figures for combat power become British 496,588 and German 569,561, giving the advantage to the Germans, at 1.15.

Table 10 shows the damage suffered by the ships of both sides in this engagement. The total suffered by the Germans is calculated at 68,760, while the British total is approximately twice as much, 138,516. This makes the damage-inflicting capability ratio 2.01 in favor of the Germans, exceeding the combat power ratio of 1.15 by a factor of 1.75.

The Destroyer Action - 4:30-4:48 PM

At about 4:30 a brief lull took place in the firing between the capital ships. Destroyer commanders on both sides issued

Table 9

SECOND BATTLE CRUISER ENGAGEMENT AT JUTLAND
4:05 - 4:30 PM 31 May 1916

The Combat Power Ratio

Ship (armament)	OLI		Sun's Position		Wind		Sea Condition		Visibility		S		Leadership		Surprise		Training		P
GERMAN																			
Lützow (8x12")	102,781	x	1.2	x	1	x	1	x	1	=	123,337	x	1	x	1	x	1	=	123,337
Derfflinger (8x12")	102,781	x	1.2	x	1	x	1	x	1	=	123,337	x	1	x	1	x	1	=	123,337
Seydlitz (10x11")	85,693	x	1.2	x	1	x	1	x	1	=	102,832	x	1	x	1	x	1	=	102,832
Moltke (10x11")	99,878	x	1.2	x	1	x	1	x	1	=	119,854	x	1	x	1	x	1	=	119,854
Von der Tann (8x11")	83,501	x	1.2	x	1	x	1	x	1	=	100,201	x	1	x	1	x	1	=	100,201
German Total:	474,634										569,561=S								569,561=P
BRITISH																			
Lion (8x13.5")	84,276	x	1	x	.6	x	1	x	1	=	32,566	x	1	x	1	x	1	=	32,566
Princess Royal (8x13.5")	69,876	x	1	x	.6	x	1	x	1	=	41,926	x	1	x	1	x	1	=	41,926
Queen Mary (8x13.5")	104,638	x	1	x	.6	x	1	x	1	=	62,902	x	1	x	1	x	1	=	62,906
Tiger (8x13.5")	49,481	x	1	x	.6	x	1	x	1	=	29,689	x	1	x	1	x	1	=	29,289
New Zealand (8x12")	72,754	x	1	x	.6	x	1	x	1	=	43,652	x	1	x	1	x	1	=	43,652
Barham (8x15")	119,106	x	1	x	.6	x	1	x	1	=	71,464	x	1	x	1	x	1	=	71,464
Malaya (8x15")	119,106	x	1	x	.6	x	1	x	1	=	71,464	x	1	x	1	x	1	=	71,464
Valiant (8x15")	119,106	x	1	x	.6	x	1	x	1	=	71,464	x	1	x	1	x	1	=	71,464
Warspite (8x15")	119,106	x	1	x	.6	x	1	x	1	=	71,464	x	1	x	1	x	1	=	71,464
British Total:	827,647										496,588=S				P/P = 1.15				496,588=P
											569,561 / 496,588								569,561 / 496,588

Table 10

SECOND BATTLE CRUISER ENGAGEMENT - DAMAGE ASSESSMENT

Ship	Hits*	Factor	OLI	Damage
GERMAN				
Lützow	1	5	753	3,765
Derfflinger	2	4	753	7,530
Seydlitz	1	5	753	3,765
Moltke	2 1	5 5	753 870	11,800
Von der Tann	6	10	697	41,820
TOTAL, German Damage				68,760
BRITISH				
Lion	2	5	780	7,800
Princess Royal	3	5	780	11,700
Tiger	2	5	721	7,210
New Zealand	1	5	697	3,485
Barham	1	5	697	3,485
Queen Mary		sunk		104,836
TOTAL, British Damage				138,516

*No hits on main battery.

orders for torpedo attacks on the opposing battle cruisers. But what were planned as swift strikes against the larger ships rapidly disintegrated into fierce small ship skirmishes as the destroyers on each side found themselves face to face with enemy destroyers blocking the way to primary targets.

Eleven German destroyers, carrying on the average three 3.4" guns and six 19.7" torpedo tubes each, attacked Beatty's force. They were supported by gunfire from the light cruiser Regensburg and four large G-Type destroyers (each with four 4.1" guns and six 19.7" torpedo tubes). Simultaneously, eight British Admiralty M-Type destroyers, armed with three 4" guns and four 21" torpedo tubes, headed toward the German battle cruisers. Supporting the small destroyers were two ex-Turkish destroyers with five 4" guns and four 21" torpedo tubes, and the light cruiser Nottingham.

Ranges were so short that the position of the sun gave no advantage to the German destroyers, as it had earlier to the battle cruisers. The German ships fired ten torpedoes at the British battle cruisers at about 4:35. There were no hits. At about the same time, a torpedo, one of five fired by British destroyers, struck the V-29, causing fatal damage. The V-27 was hit by two 4" shells in her engine room, which cut her steam line and left her dead in the water. Both ships sank within minutes (one by fire from friendly destroyers to prevent capture), their crews rescued by other German destroyers.

The British destroyers suffered moderate damage. At 4:35, the Nomad was hit by four 3.4" shells, one in her engine room, and she stopped dead in the water. Critically damaged, she still remained afloat. (Within an hour, the main battle lines had changed course from southeast to northwest, and German battleships steaming up from the south sank her.) At 4:48, a sister ship, the Obdurate, was hit by two 4.1" projectiles which caused minimal damage.

At about 4:32 PM, after a two minute pause in the firing, Hipper and Beatty started up another exchange of heavy gunfire. The four Queen Elizabeth battleships were too far out of range for the German guns, and even the British 15" shells were unable, for a while, to make their mark in the renewed fighting.

The Princess Royal and the Tiger had minor damage from 11" shells between 4:32 and 4:34, one striking the Princess Royal and three the Tiger. Six minutes later Beatty spotted Scheer's battleships steaming toward his battle cruisers, and ordered a reverse in course. The trap had been sprung, and he realized it, but at the same time he knew that, with luck, the German ships could be lured unaware to their doom at the hands of Jellicoe's main force. Just as Beatty's battle cruisers commenced their turn, the Lion and the Tiger were again hit. The Lützow landed two 12" shells on the Lion, starting fires in her sick bay. The Tiger was hit by two 11" projectiles from the Seydlitz, bringing her total in the renewed firing to five. In this exchange of gunfire, no German capital ships were hit.

Altogether, in the period between 4:30 and 4:48 PM the German forces lost one destroyer to enemy fire (a torpedo) and sank another one themselves after it had received two hits from British 4" guns. The British had one destroyer stopped by four 3.4" shells and another with minor damage from two 4" shells. The Tiger was hit by five 11" projectiles altogether, while the Princess Royal received one hit from a similar gun. And finally the Lion, already heavily hit, received two 12" shells.

Again recognizing damage and losses in the earlier engagement and new ships joining the battle, the British total OLI value, as shown in Table 11, was 372,253. The German total was 623,951. Since neither wind nor sun was a factor in this engagement, the total combat power for each is the same as the total OLI, and the combat power ratio is 1.68 in favor of the Germans. One of the German destroyers was sunk and another suffered four hits (not considered sunk here, since she was still afloat when the engagement ended), making the total damage suffered by the German ships 14,325, as shown in Table 12. The British force totalled 35,925. Again the damage ratio favored the Germans, this time by a factor of 1.68. This exceeds the combat power ratio by a factor of 1.49.

Table 11

DESTROYER ACTION AT JUTLAND
4:30 - 4:48 PM 31 May 1916

The Combat Power Ratio

Ship (armament)	OLI		Sun's Position		Wind		Sea Condition		Visibility		S		Leadership		Surprise		Training		P
GERMAN																			
Lützow (8x12")	99,016	x	1	x	1	x	1	x	1	=	99,016	x	1	x	1	x	1	=	99,016
Derfflinger (8x12")	95,251	x	1	x	1	x	1	x	1	=	95,251	x	1	x	1	x	1	=	95,251
Seydlitz (10x11")	81,928	x	1	x	1	x	1	x	1	=	81,928	x	1	x	1	x	1	=	81,928
Moltke (10x11")	87,998	x	1	x	1	x	1	x	1	=	87,998	x	1	x	1	x	1	=	87,998
Von der Tann (8x11")	41,681	x	1	x	1	x	1	x	1	=	41,681	x	1	x	1	x	1	=	41,681
Destroyers (15)	194,665	x	1	x	1	x	1	x	1	=	194,665	x	1	x	1	x	1	=	194,665
Regensburg	23,412	x	1	x	1	x	1	x	1	=	23,412	x	1	x	1	x	1	=	23,412
German Total	623,951										623,951=S								623,951=P
BRITISH																			
Lion (3x13.5")	46,476	x	1	x	1	x	1	x	1	=	46,476	x	1	x	1	x	1	=	46,476
Princess Royal (8x13.5")	58,176	x	1	x	1	x	1	x	1	=	58,176	x	1	x	1	x	1	=	58,176
Tiger (8x13.5")	42,271	x	1	x	1	x	1	x	1	=	42,271	x	1	x	1	x	1	=	42,271
New Zealand (8x12")	69,269	x	1	x	1	x	1	x	1	=	69,269	x	1	x	1	x	1	=	69,269
Destroyers (15)	131,230	x	1	x	1	x	1	x	1	=	131,280	x	1	x	1	x	1	=	131,280
Nottingham	24,781	x	1	x	1	x	1	x	1	=	24,781	x	1	x	1	x	1	=	24,781
British Total	372,253										372,253=S		P/P = 1.68						372,253=P
											$\frac{623,951}{372,253}$								$\frac{623,951}{372,253}$

Table 12

DESTROYER ACTION - DAMAGE ASSESSMENT

Ship	Hits*	Factor	OLI	Damage
GERMAN				
V-27	2	5	235	2,350
V-29		sunk		11,975
TOTAL, German Damage				14,325
BRITISH				
Nomad	4	5	185	3,700
Obdurate	2	5	250	2,500
Lion	2	5	780	7,800
Princess Royal	1	5	7,800	3,900
Tiger	5	5	721	18,025
TOTAL, British Damage				35,925

*No hits on main battery.

Calculation of Outcome and Relative Combat Effectiveness

Application to Naval Methodology. A suitable means for calculating the outcome of a naval engagement has not yet been determined. However, we have developed a methodology for calculating combat power and relative combat power, and also for assessing damage, and calculating a relative damage-inflicting ratio. If it is assumed that the relationship of the ratio of damage-inflicting performance (DI) to the combat power ratio is an exponential relationship such as is found in land combat, then a CEV can be calculated, as follows: $DI_{red}/DI_{blue} = (PR_{red}/PR_{blue})^2$. Once PR/PR is calculated, the CEV can be calculated as in the land simulation: CEV = (PR/PR)/(P/P).

The Jutland Example. In reviewing the secondary sources on the Battle of Jutland, and before undertaking a quantitative analysis, the HERO researchers arbitrarily assessed the quality of British leadership (Beatty) as 0.7 on a scale of 0.1 to 1.0; German leadership (Hipper) was assessed as 0.8. Applying the same scalar measure to training, the British were assessed at 0.8, the Germans at 0.9. If leadership and training are the only bases for relative combat effectiveness (and they are certainly the most important) the combined value for the Germans would be 0.72; for the British 0.56. Thus the German CEV_g is 1.29, and for the British, CEV_b is 0.78. Thus, on the basis of a subjective, historical assessment, we should expect that the calculations for DI, and P/P, should provide a result approximately as follows:

$$(CEV)^2 = DI/DI = (1.29)^2 = 1.66$$

Returning to the analyses of the three engagements, the three DI/DI values were as follows:

First battle cruiser engagement:	3.68
Second battle cruiser engagement:	1.75
Destroyer engagement:	1.49

Applying the above formula of the relationship of damage to CEV, we can calculate CEVs for the three engagements as follows:

First battle cruiser engagement: $CEV = \sqrt{3.68} = 1.92$
Second battle cruiser engagement: $CEV = \sqrt{1.75} = 1.32$
Destroyer engagement: $CEV = \sqrt{1.49} = 1.22$

The second and third of these CEV calculations compare very favorably with the judgmental CEV calculation of 1.29. The considerably higher German CEV value in the first battle cruiser engagement suggests that German performance was better than average, or British performance worse than average, or that the Germans were more favored by chance; or (which is most likely) some combination of all three.

IV. BASIS FOR THREE DIMENSIONAL NAVAL COMBAT METHODOLOGY

General

It is evident from the preceding discussion that a methodology comparable to the QJM can be developed for the replication of surface naval warfare. Obviously the methodology presented on the previous pages will require both refinement and extensive testing before its reliability and value can be assessed.

Research has also revealed that there is sufficient data available for World War II battles, some involving only surface vessels, some surface vessels and aircraft, and some surface vessels and submarines, to permit the testing and elaboration of the methodology presented in this report. A brief summary of the availability of such data follows:

Archival Data. The primary written sources for most of the naval engagements in World War II are kept in the Naval archives in the Washington Navy Yard. These include action reports of sea engagements prepared by individual US ships and various fleet organizations. The information that these records contain varies both in length and in type. For example,

the action report entitled, "Commander in Chief, U.S. Pacific Fleet, Serial 00412, January 6, 1943, Solomons Islands Campaign, Battle of Santa Cruz, 26 October 1943," is a detailed compendium of the action reports of all the ships involved in the entire Battle of Santa Cruz. It includes the estimated damage to enemy ships and aircraft, damage to US ships and aircraft, the effectiveness of antiaircraft fire, hour by hour reports from ship's logs, charts of ships' movements, and chronologies of events, including ships' speeds and course changes. Most of the action reports include personnel losses, in come cases even describing types of wounds.

Extensive Japanese records are also at the Navy Yard, but unfortunately the majority of them have never been translated. Therefore they are unavailable to the researcher who does not possess the ability to read Japanese. There are some notable exceptions to this, however, and for a number of engagements both translated Japanese data and US data are available. Time did not permit any research into these records other than to find that they too are varied in length and scope, but they seem to be reliable. In addition to these records there are some translated records, including action reports of individual capital ships for assorted lengths of time. These records do not include carrier action reports. There also are a few Tabular Records of Movement (TROMs) that have been translated into English. These are less detailed than the action reports but do give some information, such as casualties, which would otherwise be unavailable.

In addition to the records kept at the Navy Yard, there are some scattered records elsewhere. In the Library of Congress there is a complete series of Japanese Monographs. These vary widely in scope, contents, quality, translation, and editing. On the whole the translated monographs provide a reasonable check on other data that is recorded in the action reports.

One indication of the nature and volume of both US data and translated Japanese data available is shown in Appendix B, Documents Relating to the Battle of Leyte Gulf. Comparable data

is available for the battles of Coral Sea, Midway, and the Philippine Sea; however, there is no complete list in this form for these battles.

Processed Data. There has been considerable analysis of World War II naval data by the operations research community, both within and without the Government. Some of the reports are available at the Defense Technical Information Service. A particularly good source of such data is the combined files of the Operations Evaluation Group (OEG) and its successor organization, the Center for Naval Analyses (CNA). These include:

1. Computer records of naval analyses. These are printout sheets of data that were stored in an early IBM data processor during World War II. (See Appendix C.)

2. German, Japanese, and Italian submarine losses. This document gives the date, cause, and position of all Axis submarine sinkings during World War II.

3. The effectiveness of kamikazes. This shows the percentages of kamikaze attacks that succeeded, the tactics used, and the ships that were sunk.

4. US tactical orders and doctrine.

5. Information bulletins. These are on a wide variety of subjects, such as the effectiveness of antiaircraft fire aboard US ships and the effectiveness of British submarines, 1940-41.

6. Battle operations reports. The one examined covered operations in the Gilbert Islands in November 1943. It appeared to be largely a compendium of action reports.

Also in these fields are reports and data relating to combat since World War II, including a review of naval support operations during the Vietnam War.

V. CONCLUSIONS

It is concluded that:

- The consistent results from the Naval gun and warship OLI equations and the values calculated for damage assessment demonstrate that it is feasible to develop a methodology to simulate naval surface warfare. Obviously improved and more detailed equations will be possible with more time for study by naval warfare specialists.
- This first attempt indicates that it is feasible to develop a methodology to simulate naval surface warfare.
- On the basis established here, using data from World War II engagements, a methodology can be developed that will include the weapons and ships and aircraft of that era.
- The historically-based methodology thus developed can be modified to simulate modern and future naval warfare.

It is recommended that this approach be followed in a follow-on study.

Appendix A

CONVENTIONAL ATTRITION AND BATTLE TERMINATION CRITERIA

Interim Report

Prepared for the Defense Nuclear Agency
under Contract No. DNA001-81-C-0283

December 1981

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CONVENTIONAL ATTRITION AND BATTLE TERMINATION CRITERIA

Interim Report

Contract No. DNA001-81-C-0283

The Historical Evaluation and Research Organization (HERO) first became involved in the PACOM TNF Improvement Study (prepared jointly by Science Applications, Inc., BDM Corporation, R&D Associates, Systems Planning and Analysis and TRW) when a report entitled Conventional Warfare Damage and Casualty Trends, written by W.C. Yengst and T.G. Smolin of Science Applications, Inc., was reviewed by the HERO staff at the request of the Defense Nuclear Agency. Serious errors and deficiencies were found in the report and its conclusions. Specific comments were submitted to the Defense Nuclear Agency, sponsor of the project, both orally and in writing. It was demonstrated that since the PACOM study is based on the SAI report, its conclusions and recommendations are based on a false hypothesis.

The PACOM Study includes several scenarios involving land combat, in which advance rates of an attacker are predicted, and casualty rates of both sides are assessed. In one week, a team of HERO researchers took the raw data of force arrays from the Northeast Asia scenario, developed inputs for the Quantified Judgment Model (QJM), and ran the main effort of that scenario. The results were dramatically different from the results that had been predicted by the original PACOM TNF Improvement study. As a result of these preliminary investigations DNA assigned to HERO four tasks:

1. Use the QJM and the HERO data base to reassess the land engagements developed for the original study.
2. Compare HERO results with those of the PACOM study, compare the two methodologies that led to these results, and identify the problems with the methodologies.

3. Evaluate the validity of using casualties, equipment losses, and collateral damage as criteria for conflict termination.

4. Review the data available and determine if comparable methodologies can be developed for naval warfare.

Progress on these four tasks is summarized below.

1. Reassessment of Land Engagements.

The Northeast Scenario.

The conditions pertaining during the operation were reviewed to identify the operational and environmental factors that are relevant to the Quantified Judgment Model (QJM). Values for these factors were determined and are ready for the computer analysis. For all conventional weapons that are in the inventories of the opposing forces and will be used in the scenarios, Operations Lethality Indexes have been calculated. Running of the scenarios (without surprise and with substantial surprise) is awaiting receipt of tables of organization and equipment from the Defense Nuclear Agency.

The Southwest Scenario

Operational and environmental factors have been identified and values determined as for the northeast scenario. Some OLIs have been calculated. Completion of this step awaits the receipt of significant data and particularly of the relevant tables of organization and equipment, without which preparations for the QJM analyses cannot be completed.

2. Comparison and Analysis of Methodologies.

Task 2 cannot be begun until after Task 1 has been completed.

3. Evaluation of War Termination Methodologies.

a. As indicated above, a review of the SAI report indicated that the hypothesis on the relationship between casualty levels and war termination derived from a methodology that was seriously flawed and that consequently the hypothesis itself is not useful.

b. HERO has sought to learn whether another, valid methodology can be developed for using casualty levels, equipment losses, and collateral damage as indicators of the imminence of war termination. Such a methodology would have obvious operational value. The first step in

the search for a valid methodology has been a survey of literature in the field of war termination studies. From a preliminary survey a bibliography of pertinent works has been prepared. It is attached as Annex A. All but one of the works in this bibliography has been located and carefully examined.

c. On the basis of this literature survey it may be said that, although several mathematical models for war termination have been devised by various authors, there is none that is valid and useful, except for heuristic purposes. None can claim to be valid for predictive purposes. Specifically, neither of two models based on a relationship between casualties and war termination (Klingberg 1966 and Voevodsky 1969) has won acceptance by analysts in the field, and neither appears promising to HERO researchers on the basis of preliminary examination.

d. In continuing its research on war termination HERO will focus its efforts on those past conflicts that appear relevant to PACOM concerns. Some useful conclusions are anticipated, but it must be stated that, given the nature of the factors affecting war termination, a valid quantitative model (in which levels of casualties, equipment loss, and collateral damage can be used as adequately reliable predictors of war termination) may not be attainable.

e. HERO's research will seek other possible indicators and possible relationships among indicators that will help policymakers forecast the likelihood of a participant's seeking termination of war.

4. Data for Development of a Naval Attrition Model.

Research was done at the Washington Navy Yard and The Army Library. The purpose of the research was to determine if there is data available from which a deterministic model to project casualties in naval engagements might be developed, and then validated by the results of actual historical engagements. It was determined that there is enough data on individual ships to evaluate quantitatively their effectiveness as offensive weapons platforms, and their ability to survive any type of attack. There are sufficient records in the Navy archives to validate any model developed. The following is a tentative list of inputs that would be required for an attrition model. The list is in

four categories: ships' data, weapons data, environmental data, and operational data.

A. Ships' Data

1. Speed
2. Type of propulsion
3. Complement
4. Range
5. Displacement
6. Armor
7. EW Capacity
8. Number and types of weapons
9. Ammunition quantities, rounds by type
10. Vulnerability of explosive storage (Magazines, POL)
11. Watertight compartments
12. Damage control
13. Number and capacity of bilge pumps
14. Number of screws or water jets
15. Crew experience
16. Turning radius

B. Weapons Data

1. Aircraft (by Type)
   a. number
   b. launching speed
   c. rate of climb
   d. operational ceiling
   e. number and type of weapons (broken down and quantified under criteria to be developed.
   f. EW capacity
   g. range
   h. weight
2. Guns (Types by caliber)
   a. number
   b. rate of fire
   c. targets/strike

d. relative incapacitating effect.
e. effective range
f. muzzle velocity
g. accuracy
h. reliability
i. number of barrels
j. number of charges

3. Torpedoes and Missiles(by Type)
a. number
b. diameter
c. targets/strike
d. effective range
e. maximum speed
f. reliability
g. type of guidance
h. warhead weight
i. fuel
j. mixture method
k. type of fuze
l. type of launch platform
m. warhead dynamics

4. Mines (by Type)
a. number
b. yield (in terms of tons of TNT)

5. Bombs (by Type)
a. number
b. guidance
c. yield
d. weight

C. Environmental Data
1. weather
2. sea
3. visibility
4. cloud ceiling
5. day/night
6. season

7. sun position
8. air superiority
9. minefields

D. Operational Data

1. total size of force
2. types of units in force
3. formation
4. surprise
5. national combat effectiveness
6. logistics
7. fire control method
8. weather
9. seas
10. air superiority
11. vulnerability

Appendix B*

Documents Relating to the Battle of Leyte Gulf, 1944, at the Naval Records Center.

1. INDEX TO LEYTE GULF TRANSLATIONS

2. BACKGRUUND OF LEYTE GULF BATTLE - (Monograph of Japanese Second Demobilization Bureau (Translated by Tanaka)

3. COMMENTS, ETC., SENIOR OFFICER'S - Contains full and partial translations from diaries, histories, reports and private papers of Former Japanese Officials and Officers concerning Leyte Gulf operations

4. MISCELLANEOUS ORDERS AND DISPATCHES - Translated excerpts from war diaries, orders, plans, dispatches, logs, action reports, intelligence estimates, etc., of various forces, units, and ships, concerning the Battle of Leyte, Oct 1944

5. FIRST MOBILE FLEET (Main Body) - Translations of excerpts from war diaries, action reports, messages, etc., of the First Mobile Fleet, Oct 1944

6. CARDIV 3 MAIN FORCE - Translated excerpts from war diaries and action reports of Japanese Ships ZUIHO, CHITOSE, ZUDKAKU and 653rd Air Group Planes on CRUDIV 3, Oct 1944

7. CARDIV 4 (Main Force) - Contains translated excerpts from CARIDV 4 action report, 24-25 Oct 1944; Hyuga action report, mesadge log and war diary, 17-31 Oct 1944; also ISE action report and message log

8. CORTIDV 31 (Main Force) - Contains translated extracts from war diary of Escort Squadron 31; action report, operation log and war diary of ISUZA; actionrreport, message log and war diary OYODO, Oct 1944. Includes charts, etc.

9. DESRON 11 (Main Body) - Translated extracts from war diaries, orders, dispatches, etc., concerning movements of DESRON 11 ships. Includes tables

*Prepared for Samuel E. Morison.

10. DESDIV 41 and 61 (Main Force) - Contains table of movement of DESRON 41 and DESRON 61 ships, from war diary of DESRON 10, Oct 1944. Also contains extracts from DD SHIMOTSUKI action report, 25 Oct 1944

11. SUPPLY FORCE (Main Body) - Contains translated extracts from action report of Mobile Force Supply Force and war diary of NICHIE MARU, Oct 1944

12. 1st STRIKING FORCE - Contains excerpts from Battle Summary of First Divisionary Attack Force, Operation Sho; action reports of various Japanese ships - NAGATO, YAHAGI MYOKO, SUZUYA, KIYOSHIMO, AKISHIMO, TONE, MUSASHI, KISHINAMI, OKINAMI, and KONGO. Also war diaries and message logs, Oct 1944.

13. BATDIV 3, FIRST STRIKING FORCE - Contains extracts from action reports, war diaries, communications logs, etc., of BATDIV 1. Includes action reports of MUSASHI, NAGATO and YAMATO, Oct 1944

14. BATDIV 3, FIRST STRIKING FORCE - Extracts from operations of First Striking Force, from action reports of Jap ships HARUNA, and KONGO, 24-26 Oct 1944 and 22 - 28 Oct 1944

15. CARDIV 4, FIRST STRIKING FORCE - Operations of First Striking Force. Contains translated extracts from action reports of Jap ships ATAGO, TAKAO and MAYA, 22 - 26 Oct 19444. Includes charts

16. CRUDIV 7, FIRST STRIKING FORCE - Contains translated extracts from action reports of CRUDIV 7 and Jap ships SUZUYA and TONE, Oct 1944. Also includes tables of ships movements, CRUDIV 7.

17. DESRON 2, FIRST STRIKING FORCE - Contains translated extracts from DESDIV 31 war diary and action report, 1-31 Oct 1944. Also from action reports of Jap ships AKISHIMO, ATAGO, MAYA, OKINAMI, NOSHIRO and TAKAO, Oct 1944

18. DESRON 10, FIRST STRIKING FORCE - Contains translated extracts from DESRON 10 war diaries, action reports and communication logs, Oct 1944; DESDIV 17 action reports, Oct 1944, and action reports of Jap ships YAHAGI and KIYOSHIMA, Oct 1944

19. SERVICE FORCE (FIRST STRIKING FORCE - Translated extracts from war diary of NICHIEI MARU and First Escort Force, 1-31 Oct 1944

20. 2nd STRIKING FORCE - Translated extracts from DESRON 1, 2nd Striking Force war diary, message logs and action reports, etc of various ships of DESRON 1, 2nd Striking Force, Oct 1944

21. CRUDIV 16 (1st Leyte Troop Trans Force) - Translated extracts from CRUDIV 16 action reports, war dairies, message logs, etc., Oct 1944. Also includes extracts from action reports of Jap ships AOBA, KINU and URANAMI, Oct 1944

22. NISHIMURA FORCE - Translated extracts from action reports on SURIGAO Strait operation. Includes Jap ships ASAGUMO, MICHISHIO, SHIGURE and MOGAMI, Oct 1944

23. SUBMARINE OPERATIONS - Merit Rating Reports for Naval Ship Units, Oct 1944, Sixth Fleet, VADM Shigeyoshi Miwa Commander,

24. NON PARTICIPATING CARRIERS - Extracts from war diaries, tabular records, etc., concerning carrier movements of Japanese ships, Oct 1944

25. AIR ORGANIZATION - Translated extracts from war dairies, organization tables, and orders, concerning operational aircraft strength

26. MISCELLANEOUS AIR ORDERS - Contains Index of translated operations orders; translated excerpts from war diaries, etc., of 23rd Air Flot and various Air Groups, Oct 1944

27. SIXTH BASE AIR FORCE - Translated extracts from diaries, memoranda, notes, deployment tables, operation orders, etc., concerning SHO Operations, Sep - Oct 1944

28. Twenty Fifth Air Flotilla - Translated extracts from war diaries, action reports, etc., concerning Air Operations, Okinawa, Taiwan, Ryukyus and Japanese Air Patrols from Southern Kyushu and Northern Formosa, Oct 1944

29. FIFTY FIRST AIR FLOTILLA - Translated extracts from war diaries, plans, action summaries, etc of Groups and Units of the 51st Air Flotilla, Oct 1944. Includes 701st Air Group Organization of Kamikaze Units

30. ONE HUNDRED FIRST AIR FLOTILLA - Translated extract from 101st Air Flot war diary, 1-31 Oct 1944

31. CARRIER AIR - Contains translated extracts from war dairies, action reports, etc., of Unit of the 653rd Air Group. Oct 1944

32. SIX HUNDRED FIRST AIR GROUP - Translated extract from war diary of 601st Air Group, ZUIKAKU Detachment, 18 - 25 Oct 1944

33. Air Group 901, 931 and 933 - Translated extracts of war diaries, action reports, search reports, etc., of AirGGroups 901, 931 and 933, Oct 1944

34. MISCELLANEOUS AIR UNITS - Translated excerpts from orders, war diaries, and action reports of Various Air Groups and Units, Oct 1944

35. ARMY AIR - Contains translated excerpts from Plan of General Offensive, LEYTE Washi Force, 22 Oct 1944; Outline of operations and Lessons of the LEYTE Campaign, Army Section, 26 Feb 1945; Fourth Air Army Plans for Sho 1 Operation, Lt Katsuo Sato, Staff Officer, 4th Air Army; and Plan for Operations for Philippines Decisive Battle, 4th Air Army, Oct 1944

36. TWENTY THIRD AIR FLOTILLA - Translations of excerpts from war diary of 23rd Air Flot, Sep 1944

37. BATDIV 1 - Translated extracts from action reports and war diaries of Battleship Division 1, 1-31 Oct 1944

38. CRUDIV 5 - Translated extracts from action reports, war diaries, etc., concerning operations and movements of CRUDIV 5 Units, Ships, etc., contains charts, Oct 1944

39. CRUDIV 7 - Translated extracts from war diaries, action reports, communications logs, etc., concerning operation and movements of ships and units of CRUDIV 7, Oct 1944.

40. CRUDIV 16 - Translated extracts from message log, war diaries, action reports, etc., of CRUDIV 16, Oct - Nov 1944

41. DESRON 1 - Translations from war diaries, message log and action reports of DESRON 1, Oct 1944

42. DESDIV 2 - Extract from war diary of DESDIV 2, Oct 1944

43. DESDIV 7 - Translations from war diary of DESDIV 7. Concerns operations of USHIO, Oct 1944

44. DESDIV 17 - Translated excerpts from action reports of DESDIV 17, Oct 1944

45. DESDIV 18 - Excerpts from DESDIV 18 action report, Surigao Straits action, Second Striking Force, 24-25 Oct 1944

46. DESDIV 21 - Translated excerpts from action report of DESDIV 21, South of MINDORO, Oct 1944

47. SIXTH BASE AIR FORCE (6FGB) - Translated memoranda notes of CAPT BUNZO SHIBATA, Staff Officer, Second Air Fleet, concerning SHO Operations, 10-23 Oct 1944. Also war diaries; deployment tables; file of orders kept by CAPT Bunzo Shibata; and supplementary material, Sep-Oct 1944

48. 221st AIR GROUP - Operation Orders, Staff Messages, (principally of 6th Base Air Force) concerning Taiwan and Philippine Air Operations, from message logs, war dairies, action reports, etc. Oct 1944

FOLDER 27 FOREIGN NAVAL CASUALTIES, WW II

FOLDER 28 ALPHABETICAL LISTING OF SHIPS WITH CONVOY NUMBER AND STATUS

FOLDER 29 CNA TAPE ASSIGNMENTS; OEG 1892-58 dated 29 July 1958; WORLDWIDE ATTACKS ON U/BOATS

FOLDER 30 WORLDWIDE ATTACKS ON U/BOATS, ATTACKS BY SURFACE CRAFT

Roll 1740

FOLDER 31 WORLDWIDE ATTACKS ON U/BOATS; ATTACKS BY SURFACE CRAFT; ATTACKS BY AIR CRAFT

FOLDER 32 WORLDWIDE ATTACTS ON U/BOATS

FOLDER 33 ATTACKS BY AIR CRAFT

FOLDER 37 WW II CASUALTIES - US NAVAL SUICIDE PLANE ACTION IN PACIFIC AREA BY DATE

FOLDER 38 CASUALTIES, WW II FOREIGN NAVAL: MED SEA, BY FLAG

FOLDER 39 (UNMATCHED) SURFACE CRAFT BY INCIDENT, NO. WITHIN DATE

FOLDER 40 WW II CASUALTIES - FOREIGN MERCHANT

FOLDER 41 NAVAL CASUALTIES WW II: AIRCRAFT BOMBING, EUROPEAN SEA AREAS, (BY DATE)

FOLDER 42 ATTACKS ON U/BOATS

FOLDER 43 WW II CASUALTIES - US NAVAL SUICIDE PLANE ACTION

FOLDER 44 ATTACKS ON U/BOATS

FOLDER 45 MINED, COLLISION, MARINE CASUALTY, SCRAPPED, CAPTURED, SCUTTLED AND SURRENDERED FILE

FOLDER 46 UNMATCHED AIRCRAFT

FOLDER 47 U/BOAT ATTACKS

FOLDER 48 U/BOAT ATTACKS

49. 331st AIR GROUP - Air Operations, Philippines, 20-26 Oct 1944. Extracts from 253rd Attack Unit (331st Air Group) action report. Also includes extract from 851st Fighter Unit action report, Oct 1944

50. 752nd AIR GROUP - Translated excerpts from action reports, war diaries, combat reports, etc., of groups and units of Seven Hundred Fifty Second Air Group, Oct 1944

51. 762nd Air Group - Translated excerpts from detailed patrol and action reports of 708th Attack Unit, 762nd Air Group, concerning air patrols from Northern Formosa and Southern Kyushu, 4-17 Oct 1944

52. 703rd Attack Unit -- Translated portions of air action off TAIWAN, 13 Oct 1944

53. 709th ATTACK UNIT - Translated extracts from detailed action reports of air operations off TAIWAN, 13, 14 and 18 Oct 1944. Includes charts

54. JAPANESE REINFORCEMENT OF LEYTE, Oct - Dec 1944 - Gives estimated Japanese strength for Leyte operation

55. JAPANESE PLANS, LEYTE OPERATION - Includes translation from a brief general summary of Mobile Force, Main Body operations plan contained in OYODO action report SHO No. 1 Operation, 20-28 Oct 1944

56. COMMAND & OB, LEYTE OPERATION - Translated extracts from plans, orders, action reports, organization material, etc. May - Dec 1944

57. DESDIV 30 - Translated summary of operations taken from war diary of DESDIV 30, Oct 1944

58. 11th RECCE UNIT - Translations from action report of the 11th RECCE Unit, concerning searches east and southeast of TAIWAN, 13, 17, 18 and 26 Oct 1944.

59. 12TH RECCE UNIT - Translated extracts from war diary of 12th RECCE Unit, KANOYA Detachment. Concerns searches from KANOYA, 12-15 Oct 1944

60. INTELLIGENCE - Translated extracts from Imperial General Headquarters Navy Section reports, directives, monographs, memoranda, records, etc., concerning high level planning for the SHO operations

61. ABUKUMA - Translations taken from action reports, war diaries, etc., of CL ABUKUMA (DESRON 1) concerning Suriago Strait action. Oct 1944. Includes extract from action report of (KASUMI) DESDIV 18, 24-25 Oct 1944

62. AKISHIMO - Translated extracts from action report and war diary of AKISHIMO (DESDIV 2), Oct 1944

63. AOBA - Translation from AOBA detailed action report, 23 Oct - 30 Nov 1944. Concerns action west of the Philippines

64. ASAGUMO - Translation from Composite report of Suriago Strait action, Commander, DD ASAGUMO

65. CHITOSE - Translated extracts from wary diary and action report of CHITOSE, 1-25 Oct and 20-25 Oct 1944

66. HAGURO - Track and plane movement charts of HAGURO, Oct 1944

67. HARUNA - Track chart of BB HARUNA, 22 - 28 Oct 1944

68. HYUGA - Translated extracts and war diary of HYUGA, 20-31 Oct 1944

69. ISE - Translated supplement to message log of ISE. Lists important dispatches, etc., not indicated in previous translation

70. ISUZU - Translated extracts from action reports, war diaries, etc., of ISUZU, 1-31 Oct 1944. Includes track chart

71. KINU - Translated extracts (pencilled) from KINU action report, Oct 1944

72. KONGO - Translated extracts from action report and message log of KONGO, concerning operations of First Striking Force, 17 - 28 Oct 1944. Includes charts

73. KUWA - Translations from action reports and message log of KUWA, concerns operations of Mobile Force, Main Body, off the Philippines, 20-26 Oct 1944

74. MAYA - Translated extracts from MAYA action report. Concerns operations of First Striking Force off the Philippines, 22-26 Oct 1944

75. MOGAMI - Translation from action report of MOGAMI. Concerns Surigao Strait Action, 18-25 Oct 1944

76. NAGATO: Translation from NAGATO action report. Concerns Operation of First Striking Force AA and surface actions, 24-26 Oct 1944. Includes charts

77. NICHIEI MARU - Translations from NICHIEI MARU war diary, 1-31 Oct 1944

78. SHIGURE - Translated extracts from action report of DD SHIGURE, Battle of Leyte Gulf, 23 - 27 Oct 1944

79. FLEET DISPOSITIONS - Translations from Japanese war diaries, etc., concerning fleet dispositions, carrier movements, etc.

80. SHIMOTSUKI - Translated extract from DD SHIMOTSUKI action report of Battle off the Philippines, 25 Oct 1944

81. TAKAO - Translation from TAKAO action report, Anti-Submarine Action, 23-25 Oct 1944. Concerns operations of First Striking Force

9/a. UGAKI, Matome: Personal Diary. Oct 1944.

82. URANAMI - Translations from URANAMI action report concerning operations of Second Striking Force (Guard Force) SHO Operation, Oct 1944

83. USHIO - Translated extracts from war diary of DESDIV 7 (USHIO), Oct 1944

84. YAHAGI - Translated extracts from MAHAGI action report. Concerns First Striking Force (Main Strength) Operations, Leyte Gulf Battle, Oct 1944

85. YAMATO - Translated extracts from YAMATO action reports, logs, etc., Oct 1944. Includes charts

86. ZUIHO - Translations from ZUIHO war diary concerning ships movements and operations

87. ZUIKAKU - Translated supplement to message log, ZUIKAKU action report, 17 - 27 Oct 1944

88. FOURTH AIR ARMY - Translated extracts from operation plans and orders of WASHI; Files of Fourth Air Army; etc., concerning Leyte Operations, Oct 1944. Includes charts

89. OPERATION ORDERS - Translated extracts from orders, plans dispatches, etc., concerning Battle of the Philippines, July - Oct 1944

90. MORISON DISPATCHES ON LEYTE - Translated Japanese messages and dispatches concerning Leyte Gulf operations. Contains battle information; position of own and enemy forces; casualties; losses; disposition of forces, etc., from various commands. Dates include 10 Aug - 31 Oct 1944

91. BATDIV 1, 1ST STRIKING FORCE - Translations from action reports, war diaries and communication logs concerning units of this Command. October 1944.

92. 1ST ESCORT FORCE - Translations from war diary, October 1944. Includes composition of Escort Squadron 31 (1st Escort Force). 1944

Appendix C

COMPUTER RECORDS OF NAVAL ANALYSES

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50	WW II CASUALTIES - US NAVAL SUICIDE PLANE ACTION IN THE PACIFIC AREA
51	JAPANESE LIST OF SHIP LOSSES DUE TO SUBMARINE ACTION, CORRELATION WITH ATTACKS BY US SUBMARINES
52	NON-TORPEDO ATTACKS
53	LIST OF 336 CASUALTIES
	ENEMY VESSELS ATTACKED BY SUBMARINE UNDER US OPERATIONAL CONTROL
54	NO TITLE PAGE
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57	UNMATCHED - BY INCIDENT WITHIN DATE
58	US MERCHANT VESSELS SUNK DURING WW II
59	1943 BY AREA (ASW WW II AHD)
60	1944 AREA BREAKDOWN/1945 AREA BREAKDOWN
61	GERMAN U-BOATS
62	SORG LISTS
63	SORG - ASSUMED 80-80 LIST K CARDS
64	SORG - TONNAGES SUNK BY AREA
65	NO TITLE PAGE
66	NO TITLE PAGE
67	GERMAN SALVO
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69	SHIP LOSSES (INFERRED FROM PRINTOUT - NO TITLE PAGE)
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71	ASSUMED - US NAVAL SHIP DAMAGE
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76	ALL CASUALTIES & ATTACKS BY ENEMY ON ALLIED M/V AND A/S VESSELS 7 DEC 41 TO 14 AUG 45
77	WORLDWIDE ATTACKS ON U-BOATS - ATTACKS BY AIRCRAFT
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79	U-BOAT ATTACKS
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81	GERMAN SALVO
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86 GERMAN TORPEDO SALVO
87 GERMAN TORPEDO SALVO
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89 GERMAN SALVO
91 GERMAN SALVO & JANAC TONNAGES
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144 MATERIAL USED TO ANSWER THE MINE DEFENSE LABS REQUEST OF 14 JUL 58 - WW II SHIP CASUALTIES
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149 UNMATCHED GERMAN SALVO
150 GERMAN SALVO - KEY TO GERMAN NAVAL GRID
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153 LITERATURE SURVEY - WW II AIR & SURFACE ANTISUBMARINE ATTACK STATISTICS
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FOLDER 14 US MERCHANT VESSEL CASUALTIES

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FOLDER 1 US NAVY VESSEL CASUALTIES

FOLDER 2 WW II CASUALTIES BY LATITUDE WITHIN SEA FRONTIER

FOLDER 3 WW II CASUALTIES BY LONGITUDE WITHIN SEA FRONTIER

FOLDER 4 US NAVAL CASUALTIES

FOLDER 5 FOREIGN NAVAL CASUALTIES

FOLDER 7 FOREIGN NAVAL CASUALTIES BY FLAG

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FOLDER 25 US MERCHANTS CASUALTIES, WW II

FOLDER 26 FOREIGN MERCHANTS CASUALTIES, WW II