9

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
under Contract No.
DNA001-81-C-0283

August 1982

HISTORICAL EVALUATION AND RESEARCH ORGANIZATION (HERO)
A Division of T.N. Dupuy Associates, Inc.
2301 Gallows Road, P.O. Box 15
Dunn Loring, Virginia 22027
(703) 560-6127

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS
BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
Conventional Attrition and Battle Termination Criteria; Feasibility of a Naval QJM Methodology

5. TYPE OF REPORT & PERIOD COVERED

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)

8. CONTRACT OR GRANT NUMBER(s)
DNA001-81-C-0283

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Historical Evaluation and Research Org.
P.O. Box 157
Dunn Loring, Virginia 22027

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Defense Nuclear Ageny
Washington, D.C. 20350

12. REPORT DATE
August 1982

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Naval QJM, OLI, Jutland, Environmental Factors, Operational Factors, naval warfare, combat power

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

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.

FEASIBILITY OF A NAVAL QJM METHODOLOGY
(CASE STUDY: THE BATTLE OF JUTLAND)

Draft Final Report

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

August, 1982

HISTORICAL EVALUATION AND RESEARCH ORGANIZATION (HERO)
Dunn Loring, Virginia, 22027

Reproduced by

THE DUPUY INSTITUTE
1497 Chain Bridge Road, Suite 100
McLean, Virginia 22101
Tel: 703-356-1151; Fax: 703-356-1152

March, 1995

TABLE OF CONTENTS

List of Figures

List of Tables

Appendices

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.

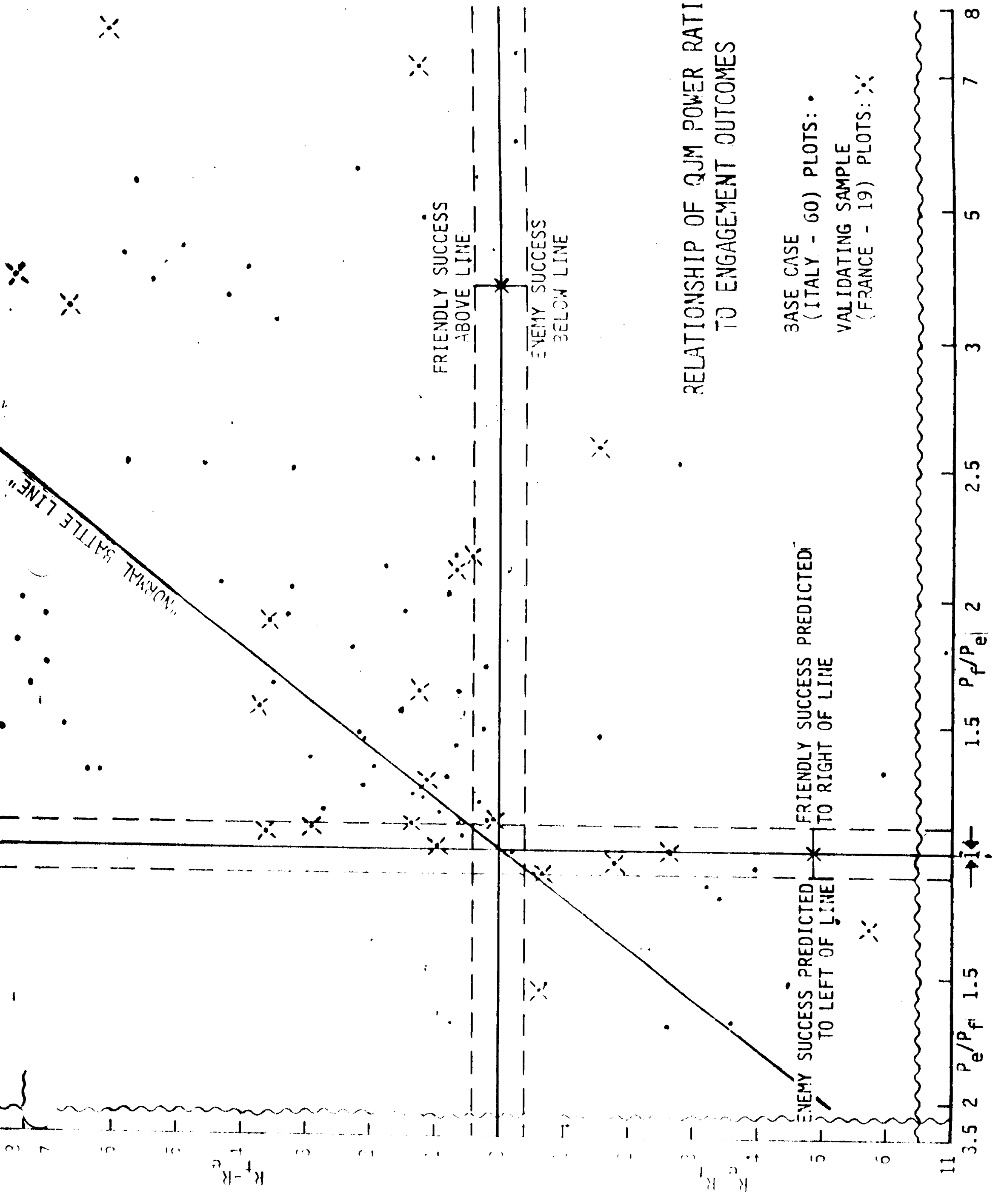
b. Spatial Effectiveness (Eff_{se}). This is calculated from an empirically-derived formula designed to reflect the ground-holding and/or ground-gaining capability of the opponents.

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 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 OLI 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).

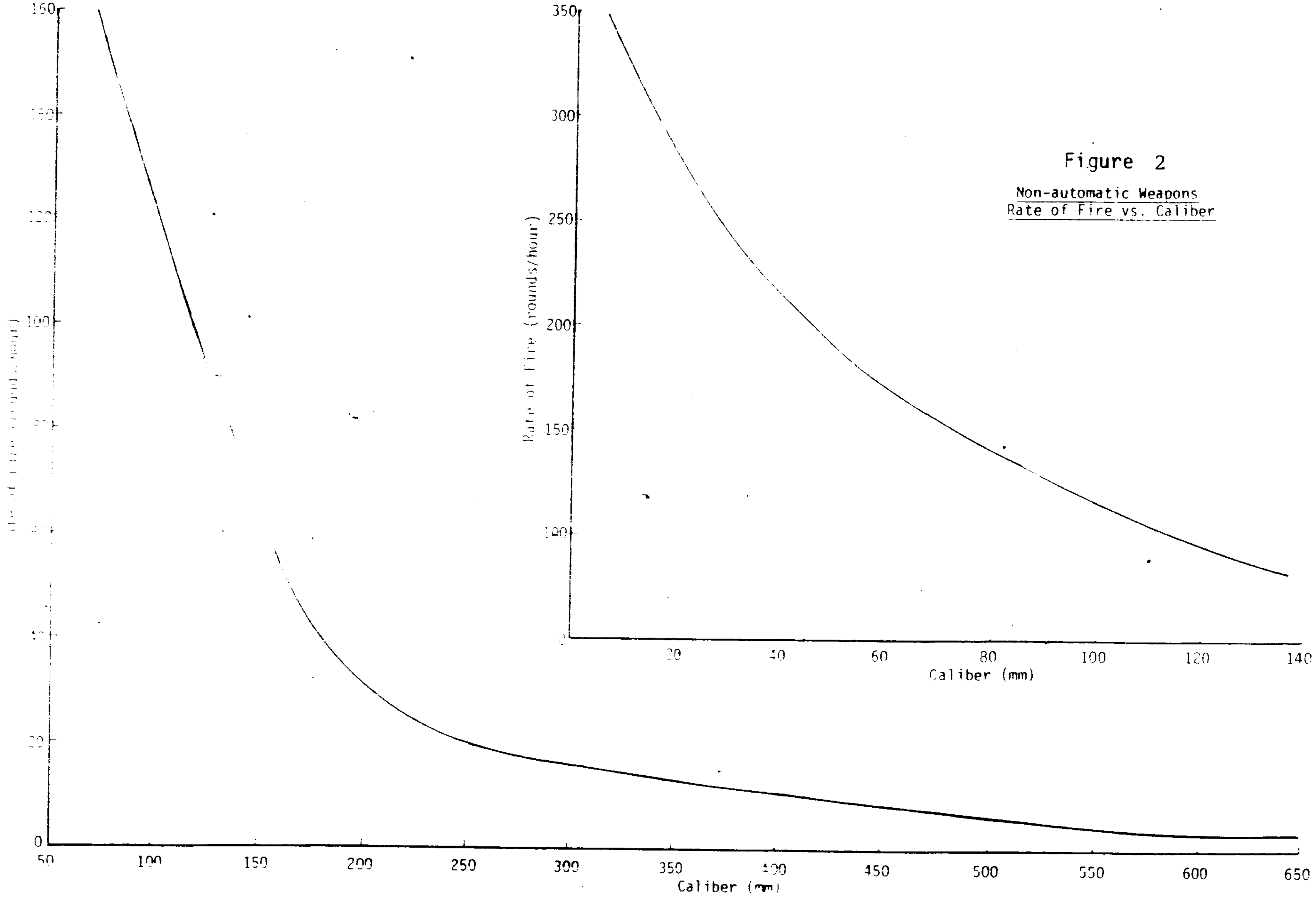


Figure 2

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 QJM.

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 <u>Jane's Fighting Ships</u>.

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.