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AN ANALYSIS OF SMALL NAVY TACTICS USING A MODIFIED HUGHES' SALVO MODEL

by

Yao Ming Tiah

March 2007

Thesis Advisor: Wayne P. Hughes Jr.
Second Reader: Thomas W. Lucas

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This thesis develops a modified version of Hughes' Salvo Model and employs it to analyze the tactical disposition (concentration or dispersion) of a small, but modern, navy whose adversary is numerically superior but technologically inferior. It also identifies tactical factors and develops insights that are critical to the success of small navies when fighting outnumbered.

Quantitative results indicate that the smaller navy must fight dispersed and win by outscouting the enemy and attacking him effectively first. This requires a superior scouting capability, effective command, control, and communications (C3), and the ability to deliver sufficient striking power. To ensure the delivery of sufficient striking power, a small navy must put greater emphasis on offensive firepower to compensate for small force size.

To be successful in battle, small navies must show initiative, and be willing to implement bold tactics. These attributes have been demonstrated by small, but successful, naval forces in the history of naval warfare. In addition, innovative tactical thinking can allow small navies to take advantage of useful tactical phenomenon like the "missile-sump effect" and to design the most appropriate type of combat craft for their respective operating environments.

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AN ANALYSIS OF SMALL NAVY TACTICS USING A MODIFIED HUGHES' SALVO MODEL

Yao Ming Tiah
Civilian, DSO National Laboratories, Singapore
B.App.Sci, Monash University, 2000

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requirements for the degree of

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NAVAL POSTGRADUATE SCHOOL
March 2007

Author: Yao Ming Tiah

Approved by: Wayne P. Hughes, Jr.
Thesis Advisor

Thomas W. Lucas
Second Reader

James N. Eagle
Chairman, Department of Operations Research

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TABLE OF CONTENTS

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LIST OF FIGURES

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LIST OF TABLES

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EXECUTIVE SUMMARY

Littoral navies have long been imbued with the tactical concept that force concentration universally favors the superior fleet and dispersal is the tactic of choice when outgunned or outnumbered. As a consequence, many small, littoral navies have adopted this concept as their fleet doctrine against numerically superior adversaries. However, with the advent of network centric warfare and the modernization of their fleets, many small navies are beginning to re-think their doctrines and tactics. One tactical question in particular that some of these navies are asking themselves is: how should the fleet's tactical disposition be modified to reflect its qualitative improvements (e.g., better scouting effectiveness)?

To answer the above question, the Modified Salvo Model, which extends Hughes' Salvo Model by accounting for the effect of anti-ship cruise missile (ASCM) leakers through a naval force's anti-ASCM defenses, was developed in this thesis to analyze the tactical disposition (concentration or dispersion) of a small, but modern, littoral navy (Blue Navy) whose adversary (Orange Navy) is numerically superior but technologically inferior. Tactical factors and insights crucial to the success of the Blue Navy, and small navies in general, were also identified and developed.

For the purpose of this thesis, the Blue Navy is assumed to consist of four missile frigates (FFGs) while the Orange Navy could deploy 12 missile corvettes. Although the Blue Navy is outnumbered three to one with respect to numbers of ships, the Blue FFGs are superior to the Orange corvettes in terms of striking power, defensive power, and staying power. Furthermore, the Blue Navy's maritime air surveillance assets provide it with a scouting effectiveness advantage.

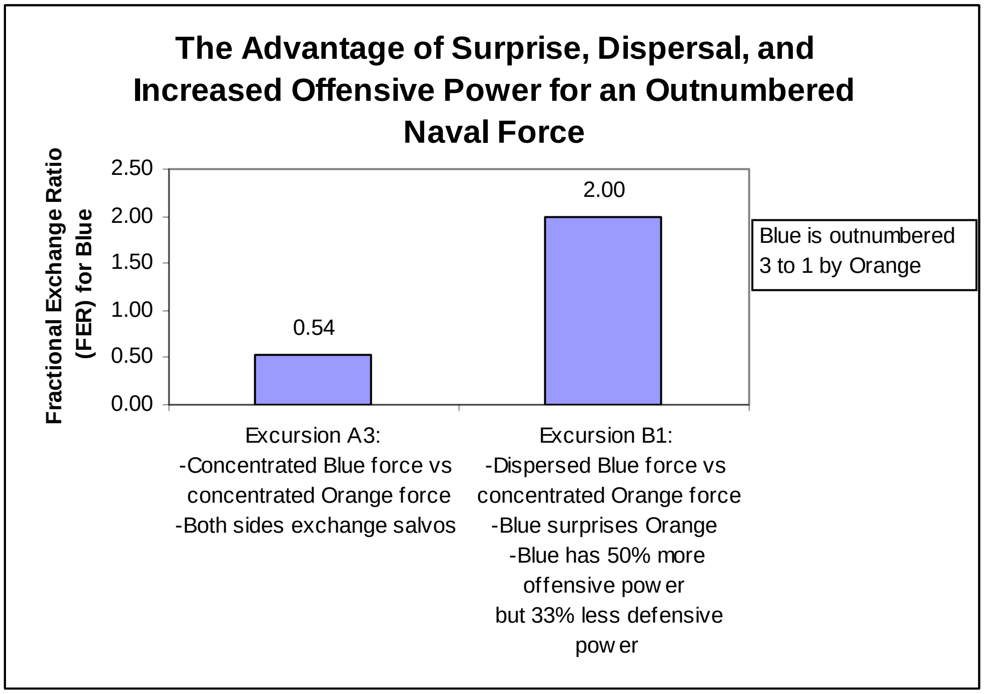
Results from the quantitative analysis using the Modified Salvo Model indicate that, in general, dispersal for stealthy surprise attack is the preferred tactic for Blue. The specific findings and insights are summarized in the following points:

- The critical factor for Blue's success against a numerically superior and concentrated Orange force is its ability to outscout Orange and deliver an effective pulse of offensive firepower onto the Orange combatants. The key to achieving this is through Blue's maritime air surveillance (MAS) assets which enable it to detect and effectively attack Orange before Orange can do the same to Blue.
- Insofar as the Orange Navy chooses to disperse its forces, Blue should do likewise so as to ensure at least a parity outcome in the event it fails to surprise Orange and both sides engage in an exchange of missile salvos.
- Blue's superior scouting capability makes it possible to simultaneously extend its information gathering network to detect all Orange forces, and allows dispersed Blue units to deliver a coordinated missile strike on Orange.
- A precondition for Blue to disperse its forces is the ability of its combatants to apply sufficient offensive pulsed power.

- An important prerequisite for a small navy or naval force to operate in a dispersed fashion is an effective command, control, and communications (C3) system. An effective C3 system allows a dispersed naval force to deliver a coordinated missile strike that is concentrated in both time and space.
- Blue’s numerical inferiority dictates that it should not engage in a force-on-force missile salvo exchange with Orange. Instead, Blue must put unstinting emphasis on superior scouting to achieve surprise and conduct an effective attack before Orange can do likewise.
- The consequence of being surprised is drastic for both Blue and Orange because either side has the potential to deliver offensive firepower in a sudden effective pulse.
- Blue’s small force size precludes a distribution of firepower amongst a large number of combatants. To deliver sufficient striking power for an effective attack, Blue must increase the offensive power of its combatants while still maintaining sufficient defensive capability. In other words, *offensive firepower must be emphasized to compensate for small force size.*

Figure 1 below amply sums up the key findings of this thesis by illustrating the advantage of surprise, dispersal, and increased offensive firepower for an outnumbered naval force.

Figure 1. The Advantage of Surprise, Dispersal, and Increased Offensive Firepower for an Outnumbered Naval Force



The results in Figure 1 are extracted from the quantitative analysis results presented in Chapter IV of this thesis. What Figure 1 shows is that if Blue concentrates its combatants into a single unit and engages in a missile salvo exchange with a massed Orange force, Blue will lose all (100%) of its combatants while putting only 54% of the Orange combatants out of action. On the other hand, if Blue possesses more offensive firepower, disperses its combatants, and uses its scouting advantage to achieve surprise, Blue can annihilate the entire Orange force while losing only half of its combatants. In short, surprise, dispersal, and increased offensive firepower allow Blue to increase its fractional exchange ratio (FER) almost four times.

In addition to the quantitative analysis, a review of historical naval battles shows that an outnumbered navy or naval force must try to exploit an opponent’s vulnerability by surprise. This requires a combination of initiative, willingness to act on an estimate of enemy intentions, and the ability to implement bold, innovative tactics. These attributes were demonstrated by the Imperial Japanese Navy in the World War II Battle of Savo Island as well as by the Israeli Navy during the naval missile battles of the 1973 Yom Kippur War.

Finally, innovative tactical thinking can allow small navies to take advantage of tactical phenomenon like the “missile-sump effect” to reduce a stronger adversary’s striking power or to design the most appropriate type of combat craft for their respective operating environments.

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I. INTRODUCTION

A. BACKGROUND

Many navies are beginning or have already begun the process of modernizing their fleets to keep up with the increasing demands of modern naval warfare. In particular, navies of many littoral states have been busily upgrading their fleets, especially in the areas of sensor and weapon technology. These littoral navies, especially those of the South East Asian states, have in the last thirty years or so, progressed from being purely coastal forces equipped predominantly with fast attack crafts (FACs) to being modern, well-rounded fleets with frigates and corvettes armed with long-range anti-ship cruise missiles. Some of these navies have even established an organic naval air arm composed of ship-borne helicopters and maritime patrol aircraft (MPA).

While it is a relatively easy process to upgrade a navy’s hardware or to procure new vessels and weapons, it is much harder to develop new doctrines and tactics that are able to exploit the vastly improved capabilities of a naval force. Littoral navies have long been imbued with the tactical concept that force concentration universally favors the superior fleet and dispersal for stealthy surprise attack is the tactic of choice when outgunned or outnumbered. As a consequence, many small, littoral navies have adopted this concept as their fleet doctrine when they were equipped mainly with FACs and were prepared (in the unfortunate event of war) to fight outnumbered and outgunned. However, with their modernization process completed or nearing completion, and especially with the advent of network centric warfare, many small navies are now beginning to re-think their doctrines and tactics. One tactical question in particular that some of these navies are now asking themselves is: should the fleet's tactical deployment be modified to reflect its qualitative improvements? If so, how should the fleet be tactically disposed in order to take advantage of its improved scouting effectiveness and longer sensor and weapon ranges?

The goal of this thesis is to address the above questions in the context of a small but technologically advanced navy. Specifically, this thesis seeks to address questions related to the tactical formation or disposition (force concentration or dispersion) of combatants (missile combatants in particular) of a littoral navy whose notional adversary is numerically superior but qualitatively inferior.

Given that the goal of this thesis is achieved, the contents of this thesis will aid in such decisions as determining tactical dispositions and selection of tactical doctrine for small navies.

B. THESIS OBJECTIVE

The specific objective of this thesis is to analyze tactical deployment alternatives for missile combatants of a small, but technologically advanced, littoral navy (herein referred to as the Blue Navy). The deployment alternatives will be analyzed in the context of a wartime scenario in which the Blue Navy is vying for sea control against an adversary navy (herein referred to as the Orange Navy) that is numerically superior but qualitatively inferior. The analysis will be conducted quantitatively using a modified version of Hughes' Salvo Model (herein referred to as the Modified Salvo Model). Detailed descriptions of both Hughes' Salvo Model and the Modified Salvo Model are provided in Chapter II of this thesis.

C. RESEARCH QUESTIONS

In the process of achieving the goal of this thesis, the following secondary but important questions must also be answered:

- How does improved scouting effectiveness for the Blue Navy, in the form of more and better maritime air surveillance assets, affect the tactical disposition of Blue missile combatants?
- How would the balance of firepower (offensive and defensive firepower) on board Blue missile combatants affect their tactical disposition?
- How should the tactical disposition of Blue missile combatants change in response to the tactical disposition adopted by the Orange Navy?

Addressing these secondary questions will help identify tactical factors that have a significant impact on the tactical disposition of Blue missile combatants.

D. SCOPE OF THESIS

The objective of this thesis will be achieved in three major stages.

First, the Modified Salvo Model will be used to analytically compute the results of force-on-force missile engagements between the Blue and Orange navies. These computations will be conducted for various combinations of Blue and Orange tactical dispositions.

Second, the effects of tactical factors that might affect the tactical disposition of Blue missile combatants will be investigated by varying relevant parameter values of the Modified Salvo Model.

Finally, the computed results from the first two stages will be analyzed to develop insights and identify significant tactical factors that will aid decisions on the tactical disposition of Blue missile combatants against the Orange Navy.

E. THESIS FLOW

Chapter II of this thesis provides a detailed description of Hughes' Salvo Model and proposes a modified version, the Modified Salvo Model. Both models' parameters and assumptions will be explained and a suitable measure of effectiveness (MOE) will also be provided.

Chapter III describes the background scenario that will be used as a framework for the computations in this thesis. Data sets to be used as inputs to the Modified Salvo Model as well as scenario variations will all be documented.

Chapter IV presents the results of all computations and provides a detailed discussion and analysis of the results.

Chapter V provides qualitative discussions of how small naval forces can fight and win.

Chapter VI consists of a summary of the work done as well as the conclusions developed from this thesis.

F. METHODOLOGY

Analytical computations using an Excel spreadsheet implementation of the Modified Salvo Model will be the main methodology for this thesis. Results of the computations will be presented, analyzed, and discussed.

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II. MODIFIED SALVO MODEL

A. INTRODUCTION

This chapter provides a description of Hughes' Salvo Model as developed by Captain USN(Retired) Wayne P. Hughes, Jr. [Ref. 1] and proposes a modified version of it, called the Modified Salvo Model. Hughes' Salvo Model represents missile combat between warships armed with conventional anti-ship cruise missiles (ASCMs) and surface-to-air missiles (SAMs). It was developed by Hughes to show the tactical consequences if a warship had the striking power to destroy one, or even more than one, similar warship with a single salvo.[1] The Modified Salvo Model extends Hughes' Salvo Model by accounting for the effect of ASCM leakers through a naval force's anti-ASCM defenses. Both models' equations, parameters, and assumptions are discussed in greater detail in the following sections.

B. HUGHES' SALVO MODEL EQUATIONS

The combat work achieved by a single ASCM salvo fired by a homogeneous force A is:

$$\Delta B = \frac{\sigma_A a_2 A - \tau_B b_3 B}{b_1} \tag{1}$$

and by a homogeneous force B:

$$\Delta A = \frac{\sigma_B b_2 B - \tau_A a_3 A}{a_1} \tag{2}$$

where in equation (1)

A = number of ships in force A

[1] A salvo is combat power which arrives at the target in a single, instantaneous pulse.

B = number of ships in force B

ΔB = number of ships in force B out of action from A's salvo

σ_A = scouting effectiveness of force A

a_2 = striking power of each ship in force A

τ_B = defensive readiness of force B

b_3 = defensive power of each ship in force B

b_1 = staying power of each ship in force B

The corresponding terms and terminology hold for equation (2).

The combat power of a salvo is measured in hits that damage the target force. The combat power per salvo of force A is the numerator of equation (1). Similarly, the numerator of equation (2) corresponds to force B's combat power per salvo. Combat power achieves combat work measured in hits. Dividing total salvo combat power by the number of hits a target can take before it is out of action (staying power), the result is the number of enemy ships out of action.[2]

C. DEFINITION OF HUGHES' SALVO MODEL PARAMETERS

This section provides definitions of the Hughes' Salvo Model parameters used in equations (1) and (2). The definitions are taken from Hughes' works [Refs. 1 and 2].

[2] A warship put out of action is rendered harmless with no combat power remaining. It is not necessarily sunk.

1. Striking Power (a2, b2)

In the context of modern naval ship-vs-ship missile warfare, the striking power of a warship is the number of *accurate* ASCMs fired by it per salvo. Striking power is, therefore, a function of actual salvo size, missile launch reliability, and missile hit probability. In mathematical terms,

Striking Power = (ASCM Salvo Size)(ASCM Launch Reliability)*(ASCM Hit Probability)* (3)

It must be noted that ASCM hit probability refers to the probability that an ASCM will hit a warship in the absence of anti-ASCM defenses.

2. Defensive Power (a_3, b_3)

Defensive power is the number of accurate ASCMs (within an ASCM salvo) that each defending warship can destroy or deflect when alert and ready to do so. The defensive power of a warship is therefore a function of the number of defensive fire control channels it has.

3. Staying Power (a_1, b_1)

The staying power of a warship is the number of nominal ASCM hits needed to put the warship out of action (OOA). Equivalently, it is the number of nominal ASCM hits that can be absorbed by a warship before its combat power is reduced to zero for the remainder of the engagement.

4. Scouting Effectiveness (σ_A, σ_B)

Scouting refers to the ability of a warship or naval force to collect all the essential and necessary information about the enemy required to effectively attack it.

In the context of Hughes' Salvo Model, scouting effectiveness is a multiplier applied to striking power and takes values between zero (or 0%) and one (or 100%). It measures the extent to which striking power is diminished due to less-than-perfect scouting and C2 (Command and Control) and hence, degraded targeting and distribution of fire against the opposing force. A scouting effectiveness value of zero means no information about the enemy and no ability to hit any targets. A value of one means all targets are within effective range and each is being tracked, so that every enemy ship may be fired at.

5. Defensive Readiness (τ_A, τ_B)

Defensive readiness is the extent to which a defending warship fails to take defensive actions up to its designed combat potential, due to a low level of alertness or inattention caused by faulty EMCON (Emissions Control). It is a multiplier of defensive power with values between zero (or 0%) and one (or 100%).

A good example of the effect of defensive readiness on a warship's defensive power was provided during the recent (Jul-Aug 2006) conflict in the Middle East between Israel and Hezbollah militants in Lebanon. The INS Hanit, an Israeli Navy Saar V missile corvette, was hit by a C-802 ASCM launched by a shore-based missile battery. The Hanit's defensive systems (consisting of an array of anti-ASCM missiles and ECM systems) were not activated because of an IFF (Identification Friend or Foe) conflict with Israeli Air Force (IAF) forces operating in the area. This effectively negated the Hanit's considerable defensive power and left it defenseless against the ASCM attack.[3]

D. HUGHES' SALVO MODEL ASSUMPTIONS

The essential assumptions inherent in Hughes' Salvo Model are listed below. These assumptions are extracted from Hughes' work [Ref. 1].

- Each of the two opposing naval forces consists of homogeneous warships equipped with identical weapons (ASCMs and SAMs).
- Accurate ASCM shots are spread equally over all targets. Although a uniform distribution is not necessarily the best distribution, it must be borne in mind that knowledge and control were never adequate in past naval battles when targets were in plain view, and it is less likely that optimal distribution of fire will be achieved in the future. Thus, this assumption is as good as any for exploratory analyses.
- Counterfire from the defensive systems of the targeted force (after taking into account defensive readiness) eliminates all accurate ASCM shots until the force's defenses are saturated, after which all accurate ASCM shots will hit. Thus, a subtractive process best describes the effect of defensive counterfire.
- A warship's staying power is the number of standard sized or nominal ASCM hits required to put it out of action, not to sink it. The tactical aim is to put

[3] The information pertaining to the INS Hanit incident was sourced from an article ("A Military Assessment of the Lebanon Conflict") written by a defense analyst named Ben Moores (ben.moores@btconnect.com) and circulated by Alidade Incorporated.

all enemy ships out of action so that none poses a threat, after which the helpless ships may be sunk without risk.

- Hits on a target force will diminish its whole fighting strength linearly and proportionate to the remaining hits the target force can take before it is completely out of action.
- Losses are measured in warships put out of action.

E. MODIFIED SALVO MODEL EQUATIONS AND ALGORITHM

The Modified Salvo Model attempts to inject more realism into Hughes' Salvo Model by accounting for the fact that anti-ASCM defenses are not perfect and a certain proportion of accurate ASCMs within a salvo will be able to "leak through" the anti-ASCM defenses of a naval force.

1. Equations for Striking Power

Equations (4) and (5) apply to an attacking naval force B.

$$b_2 = (ASCM\ Salvo\ Size) * (ASCM_{Rel}) * (ASCM\ P_{Hit}) \quad (4)$$

$$Strike_B = b_2 * B * \sigma_B \quad (5)$$

where

b_2 = striking power of each ship in force B

ASCM Salvo Size = ASCM salvo size of each ship

$ASCM_{Rel}$ = ASCM launch reliability

$ASCM\ P_{Hit}$ = ASCM hit probability in the absence of anti-ASCM defenses

$Strike_B$ = total striking power of force B

B = number of ships (missile combatants) in force B

σ_B = scouting effectiveness of force B

2. Equation for Defensive Power

Equation (6) applies to a defending naval force A.

$$Defense_A = a_3 * \tau_A * A \quad (6)$$

where

$Defense_A$ = total defensive power of force A

a_3 = defensive power of each ship in force A

τ_A = defensive readiness of force A

A = number of ships (missile combatants) in force A

3. Algorithm for Combat Power

The following algorithm computes the combat power per ASCM salvo of an attacking naval force B against a defending naval force A when ASCM “leakers” are accounted for.

IF $Strike_B > Defense_A$,

$Combat_B = (Strike_B - Defense_A) + (1 - ASCMD_A) * Defense_A$

ELSE IF $Strike_B <= Defense_A$,

$Combat_B = (1 - ASCMD_A) * Strike_B$

where

$Combat_B$ = force B’s combat power per ASCM salvo

$ASCMD_A$ = anti-ship cruise missile defense effectiveness of force A. This is the probability that the anti-ASCM defenses of force A will defeat a well-aimed ASCM when it is engaged.

4. Equation for Number of Ships Put Out of Action

The number of ships in force A put out of action by force B’s ASCM salvo is given by the following equation.

$$\Delta A = \frac{\text{Combat}_B}{a_1} \tag{7}$$

where

ΔA = number of ships in force A put out of action by force B’s ASCM salvo

a_1 = staying power of each ship in force A

The definitions and explanations of combat power, striking power, defensive power, staying power, scouting effectiveness, and defensive readiness are as stated in sections B and C of this chapter.

The calculation of ΔB is symmetrical with notation for sides A and B reversed. The Modified Salvo Model equations and algorithm documented in this section can therefore be applied to a missile salvo exchange between any two naval forces.

The assumptions inherent in the Modified Salvo Model are similar to those for Hughes’ Salvo Model stated in section D of this chapter. The major exception is that the Modified Salvo Model assumes that a certain proportion of accurate or well-aimed ASCMs within a salvo will always “leak through” a naval force’s anti-ASCM defenses.

F. MEASURE OF EFFECTIVENESS: FRACTIONAL EXCHANGE RATIO

A suitable measure of effectiveness (MOE) that can be computed using the Modified Salvo Model is the fractional exchange ratio (FER). The FER compares the fraction of two forces destroyed by each other under the supposition that they simultaneously exchange salvos. Using the same terms as used in the preceding section, the fraction of each force that can be put out of action by a salvo is given by the following equations:

$$\frac{\Delta A}{A} = \frac{Combat_B}{a_1 A} \tag{8}$$

$$\frac{\Delta B}{B} = \frac{Combat_A}{b_1 B} \tag{9}$$

Equation (9) is divided by equation (8) to obtain the FER. Mathematically, the FER is:

$$FER = \frac{\Delta B/B}{\Delta A/A} \tag{10}$$

When the FER is greater than one, force A has reduced force B by a greater fraction than force B has reduced force A and so if $\Delta A < A$ force A has won in the sense that it will have surviving warships when force B is eliminated (in subsequent simultaneous salvos). When the FER is less than one, force B has the advantage of the exchange. Parity is achieved when the FER is equal to one.

For this thesis, the FER is used as the MOE for force-on-force salvo exchange computations using the Modified Salvo Model as it provides a comparative effectiveness of two naval forces engaged in a missile salvo exchange.

G. MODEL IMPLEMENTATION

The equations and algorithm of the Modified Salvo Model are implemented as an Excel spreadsheet model. The model inputs are the Modified Salvo Model parameters as listed in section E of this chapter. The fraction of each force put out of action (expressed as a percentage) and the fractional exchange ratio (FER) are the main model outputs generated.

III. BACKGROUND SCENARIO, DATA SETS, AND SCENARIO VARIATIONS

This chapter provides a description of the background scenario used as a basis for the computations in this thesis. The data sets used as inputs to the Modified Salvo Model and the scenario variations are also presented.

A. BACKGROUND SCENARIO

The background scenario for this thesis is a maritime conflict in which a littoral state (Blue) is involved in a territorial dispute with its larger neighbor state (Orange) over a strategically located island accessible to maritime traffic from both states. The dispute has escalated into a shooting war between the two states and the Orange Navy has sortied its major naval combatants in an effort to acquire sea control over the sea lanes around the disputed island. The Blue Navy, being numerically inferior but technologically more advanced, has decided to challenge the Orange Navy and has also dispatched all its naval combatants to engage the Orange naval task force.

The Orange task force (TF) consists of 12 missile corvettes while the Blue TF is made up of four modern missile frigates. Although the Blue TF is outnumbered three to one with respect to numbers of ships, the Blue frigates are superior to the Orange corvettes in terms of striking power, defensive power, and staying power. Furthermore, the Blue Navy has invested heavily in maritime air surveillance assets and therefore has a scouting effectiveness advantage over the Orange Navy. The data pertaining to the attributes of the Blue and Orange combatants are presented in the next section.

The Orange TF commander (CTF) has the option of concentrating all his 12 corvettes in a single TF in the vicinity of the disputed island or splitting them into two dispersed task groups (TGs) of equal size to control both sea approaches to the disputed island. Similarly, the Blue CTF can choose to either concentrate or disperse his forces. The possible combinations of both forces' tactical dispositions are summarized in section C of this chapter.

B. DATA SETS

The attributes of the Blue and Orange combatants are summarized in Table 1 below. These attributes are used as model inputs for the Modified Salvo Model computations.

Table 1. Attributes of Naval Combatants

Attribute	**Blue Combatant**	**Orange Combatant**
Type of naval combatant	Guided missile frigate (FFG)	Guided missile corvette
ASCM salvo size (per combatant)	a) 8 b) 12	4
Defensive power (per combatant)	a) 6 b) 4	2
Staying power (per combatant)	1.5	1

It is assumed that the ASCM salvo size of each combatant is equivalent to the ASCM load carried since it is not unreasonable for a naval combatant to launch all its ASCMs in a salvo.

As stated in section C of Chapter II, the defensive power of a combatant is a function of the number of defensive fire control channels it has. The number of SAMs each combatant is capable of carrying is actually larger than its stated defensive power.

Blue FFGs are modular and can be equipped with either one of the following two offensive/defensive configurations displayed in Table 2.

Table 2. Blue FFG Offensive/Defensive Configurations

Configuration	ASCM Salvo Size	Defensive Power
a	8	6
b	12	4

1. Derivation of Staying Power

The respective staying powers (per combatant) of the Blue and Orange combatants displayed in Table 1 are derived from a relationship proposed by the Brookings Institution and re-stated in Ref. 2. The relationship proposed by the Brookings Institution asserts that the number of hits required to put a ship out of action can be related to the length of the ship. A similar relationship was reached by Beall [Ref. 3] when he concluded that ship vulnerability is proportional to the cube root of ship displacement. Since displacement is roughly proportional to the three dimensions of length, beam, and draft, the cube root reduces to the dominant dimension, which is the length [Ref. 2].

The Brookings study further concluded that a hit by one large warhead would incapacitate a modern warship up to 300 feet long, and another similar warhead is required for every additional 100 feet [Ref. 2].

Assuming that the length of each Blue FFG is approximately 350 feet (which is typical of modern FFGs used by many coastal navies) and each Orange missile corvette is approximately 300 feet long (again typical of the larger missile corvettes used by many coastal navies), and applying the conclusion of the Brookings study stated in the preceding paragraph, it can easily be seen that the staying power of each Blue and Orange combatant (with respect to the number of generic ASCM hits) are 1.5 and 1, respectively.

Using the relationship and conclusion from the Brookings study, it is also possible to develop a “back of the envelope” model for computing ship staying power with respect to the number of hits from an ASCM of a particular warhead weight. This work is presented in Appendix A.

2. Weapon Effectiveness

Generic weapon effectiveness data obtained from analyses of actual naval missile engagements [Ref. 2] are also used in the Modified Salvo Model computations. These data apply to both Blue and Orange combatants and are summarized in Table 3.

Table 3. Weapon Effectiveness Data

ASCM Launch Reliability	0.9
ASCM Hit Probability (no defense)	0.7
Anti-Ship Cruise Missile Defense (ASCMD) Effectiveness	0.68

ASCM launch reliability is the probability that an ASCM is successfully launched. The ASCM hit probability refers to the probability that an ASCM will hit a warship in the absence of anti-ASCM defenses and anti-ship cruise missile defense (ASCMD) effectiveness refers to defender effectiveness in defeating well-aimed ASCMs.

C. SCENARIO VARIATIONS

Four possible combinations of Blue and Orange tactical dispositions are considered in this thesis and each combination forms a scenario variation. These four scenario variations are summarized in Table 4 below.

Table 4. Scenario Variations

Scenario Variation	Blue Tactical Disposition	Orange Tactical Disposition
A	Concentration: all 4 FFGs in one Task Force (TF) for massed attack on Orange TF	Concentration: all 12 corvettes in one TF
B	Dispersion: 2 Task Groups (TGs) with 2 FFGs each for dispersed & simultaneous attack on Orange TF	Concentration: all 12 corvettes in one TF
C	Concentration: all 4 FFGs in one TF. Blue TF will attack Orange TGs sequentially.	Dispersion: 2 TGs with 6 corvettes each
D	Dispersion: 2 TGs with 2 FFGs each. Each Blue TG will attack 1 Orange TG.	Dispersion: 2 TGs with 6 corvettes each

Each scenario variation is explained in greater detail in Chapter IV together with the analytical process and computed results.

IV. RESULTS AND ANALYSIS

The aim of this chapter is to present the computed results and analysis for all scenario variations in Table 4. All results were computed using a spreadsheet implementation of the Modified Salvo Model.

A. ORGANIZATION OF RESULTS AND ANALYSIS

The following section provides an overview and discussion of the assumptions that are generic to all scenario variations. The scenario description, specific scenario assumptions, tables of numerical results (bar charts are presented in Appendix B), analysis, and key insights for each of the four scenario variations are presented in separate sections (sections C, D, E and F). Section G summarizes the important findings and highlights significant factors and insights derived from the analyses of the individual scenario variations.

B. GENERAL ASSUMPTIONS

A basic, but important, assumption for this thesis is that the Blue Navy, though numerically inferior, is technologically more advanced than the Orange Navy. The Blue Navy's technological superiority is manifested in its maritime air surveillance capabilities. In particular, the Blue Navy possesses long-range, long-endurance maritime patrol aircraft (MPA) operating from land bases as well as naval helicopters organic to the Blue FFGs. These maritime aircraft, though unarmed, provide the Blue Navy with a significant scouting and, therefore, targeting advantage over the Orange Navy. The Orange Navy, on the other hand, does not possess any maritime air surveillance assets and has to depend on its shipboard sensors for scouting and targeting. It is also assumed that the land-based strike aircraft of both sides’ air forces are not assigned to an anti-shipping role because the combat aircraft of both air forces are fully utilized in the ongoing air campaign.

On a one-to-one basis, each Blue FFG has greater striking power, defensive power, and staying power than an Orange missile corvette (refer to Table 1 for attributes of Blue and Orange naval combatants). It must be noted, however, that it is assumed that both Blue and Orange naval combatants employ the same types of offensive (ASCM) and defensive (ASCMD) weapons since both Blue and Orange navies acquire shipboard weapons from the same international supplier. As a result, both navies have similar weapons effectiveness (refer to Table 3 for weapon effectiveness data).

The assumptions stated in the preceding two paragraphs lead to the following important tactical assumptions:

- Blue has a significant sensor range advantage over Orange as a consequence of Blue’s possession of maritime air surveillance assets.
- Blue and Orange ASCM effective ranges are equivalent since they use the same type of ASCM.
- The sensor coverage provided by Blue maritime air surveillance assets exceeds Blue’s ASCM effective range. Hence, upon detection of Orange naval combatants by Blue air surveillance assets, Blue FFGs are required to close in to ASCM effective range in order to launch an effective attack.

An additional assumption is that the shipboard sensors on board Orange missile corvettes are able to detect Blue FFGs when they are within ASCM effective range. This implies that the Blue and Orange naval combatants are capable of engaging in an ASCM salvo exchange if the respective combatants are within ASCM effective range of each other. This assumption is necessary for carrying out the force-on-force engagement computations using the Modified Salvo Model.

All the above assumptions apply to all scenario variations.

C. SCENARIO VARIATION A

Scenario Variation A is a classic fleet versus fleet force-on-force engagement scenario. Both Blue and Orange navies concentrate their respective missile combatants into a single Task Force (TF) with the expectation of engaging the enemy in a head-to-head missile salvo exchange. This scenario variation is broken up into the following three excursions or sub-scenarios:

- <u>Excursion A1</u>: Blue manages to detect and target the Orange TF without itself being detected. Blue, in other words, manages to achieve tactical surprise over Orange. The Orange TF, on the other hand, is unable to launch a reply ASCM salvo since it has not detected the Blue TF and only manages to defend itself against the Blue ASCMs. This is the best-case scenario for Blue within the context of Scenario Variation A. The Modified Salvo Model parameter for Blue's scouting effectiveness is varied for each Blue offensive/defensive configuration and the resulting percentages of Orange combatants put out of action are computed. (In this case, since Orange is unable to launch a reply ASCM salvo, the percentage of Orange combatants put out of action by Blue's ASCM salvo is a more appropriate measure of effectiveness (MOE) than the Fractional Exchange Ratio (FER)). The defensive readiness parameter for Orange is fixed at 100% for all computations since it is assumed that the Orange TF's anti-ASCM defenses are up and ready all the time and, therefore, capable of detecting and countering the incoming Blue ASCMs.

- Excursion A2: This is similar to Excursion A1 except that the roles are reversed. In other words, Blue is now surprised by Orange. This is the worst-case scenario for Blue within the context of Scenario Variation A. The purpose of this excursion is to explore the possibility that despite Blue's superior maritime air surveillance capabilities, it could still be surprised by Orange. For example, the Orange missile corvettes could possibly delay or even avoid detection by Blue maritime surveillance aircraft by mingling with and 'hugging' merchant ships sailing along the sea lanes in the vicinity of the disputed island.

- Excursion A3: For this excursion, neither side achieves surprise and both sides exchange ASCM salvos. This is the case in which the Orange TF manages to detect the Blue TF and launches a reply ASCM salvo before the Blue ASCM salvo arrives at the Orange TF's location. The scouting effectiveness for

Orange is varied for each Blue offensive/defensive configuration and the FER for Blue computed. Blue’s scouting effectiveness and both sides’ defensive readiness are fixed at 100%.

1. Results for Excursion A1

Table 5. Excursion A1 Results

	MOE: % of Orange Ships OOA	
	Blue Offensive/Defensive Configuration	
Blue Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	5.38%	8.06%
20%	10.75%	16.13%
30%	16.13%	24.19%
40%	21.50%	32.26%
50%	26.88%	40.32%
60%	32.26%	48.38%
70%	37.63%	56.45%
80%	43.01%	65.60%
90%	48.38%	90.80%
100%	53.76%	100.00%

Blue’s scouting effectiveness is varied as a form of sensitivity analysis and to account for cases in which Blue’s striking power is diminished due to deficient targeting data (e.g., degradation of datalink between Blue maritime air surveillance aircraft and Blue FFGs).

With an offensive salvo size of eight ASCMs per FFG (Blue offensive/defensive configuration (a)), and with perfect scouting effectiveness, the Blue TF can at most put about 54% of the total of 12 Orange combatants out of action (OOA). An increase in ASCM salvo size for Blue from eight to twelve ASCMs per salvo per FFG will allow Blue to put all Orange combatants out of action if perfect scouting effectiveness can be achieved. In summary, for any level of Blue scouting effectiveness, the 50% increase in ASCM salvo size provided by offensive/defensive configuration (b) allows Blue, if it can achieve tactical surprise, to put a greater percentage of Orange combatants out of action. Blue’s defensive power does not play a role in this excursion since Orange is unable to apply its offensive firepower.

2. Results for Excursion A2

Table 6. Excursion A2 Results

	MOE: % of Blue Ships OOA	
	Blue Offensive/Defensive Configuration	
Orange Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	16.13%	16.13%
20%	32.26%	32.26%
30%	48.38%	48.38%
40%	64.51%	64.51%
50%	80.64%	80.64%
60%	96.77%	100.00%
70%	100.00%	100.00%
80%	100.00%	100.00%
90%	100.00%	100.00%
100%	100.00%	100.00%

If the Orange TF can achieve tactical surprise, it could suffer up to a 30% degradation in scouting effectiveness and still put the entire Blue TF out of action. This applies regardless of whether Blue adopts offensive/defensive configuration (a) or (b). The main reason for this is that the relatively large number of Orange combatants (12 missile corvettes) allows the Orange TF to apply sufficient striking power to overwhelm the Blue TF's anti-ASCM defenses and put every Blue FFG out of action. Blue must, therefore, use its superior maritime air surveillance capability to avoid a surprise attack by Orange.

3. Results for Excursion A3

Table 7. Excursion A3 Results

	MOE: FER for Blue Blue Offensive/Defensive Configuration	
Orange Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	3.33	6.20
20%	1.67	3.10
30%	1.11	2.07
40%	0.83	1.55
50%	0.67	1.24
60%	0.56	1.00
70%	0.54	1.00
80%	0.54	1.00
90%	0.54	1.00
100%	0.54	1.00

With an ASCM salvo size of eight ASCMs per FFG (offensive/defensive configuration (a)), Blue has to maintain at least a 70% scouting effectiveness advantage over Orange (100% Blue scouting effectiveness versus <=30% Orange scouting effectiveness) in order to win a missile salvo exchange (FER for Blue >1). Otherwise, Blue loses the salvo exchange (FER for Blue <1). Offensive/defensive configuration (a) allows Blue to put only about 54% of the 12 Orange combatants out of action (OOA). On the other hand, Orange is capable of putting all four Blue combatants OOA as long as it has a scouting effectiveness of at least 70%. This explains why the FER for Blue (with offensive/defensive configuration (a)) remains constant at 0.54 for levels of Orange scouting effectiveness >=70%.

If Blue adopts offensive/defensive configuration (b) and therefore increases its ASCM salvo size by 50%, it will either win the salvo exchange (FER for Blue >1) or achieve parity (FER for Blue = 1). This result holds as long as Blue has 100% scouting effectiveness while that for Orange is less than or equal to 100%. With this 50% increase in ASCM salvo size, Blue is capable of putting all Orange combatants OOA. Orange is capable of doing likewise to Blue if its scouting effectiveness is at least 60%. Hence, Blue (with offensive/defensive configuration (b)) achieves only parity (FER for Blue = 1) if its scouting effectiveness advantage over Orange does not exceed 40% (100% Blue scouting effectiveness versus >=60% Orange scouting effectiveness).

Given that Blue has perfect (100%) scouting effectiveness, the results indicate that it should achieve a significantly better FER for any level of Orange scouting effectiveness less than or equal to 100% if it has greater offensive firepower provided by offensive/defensive configuration (b). This implies that Blue should put greater emphasis on its offensive firepower and thus striking power in order to overcome its inferiority in number of combatants.

4. Key Insights from Results of Scenario Variation A

If both navies concentrate their respective missile combatants into a massed Task Force (TF), the Blue TF, though outnumbered three to one in number of combatants, can still defeat the Orange TF if it:

- Achieves tactical surprise, while at the same time avoiding a surprise attack, by using its superior scouting capability provided by its maritime air surveillance assets;
- Possesses sufficient striking power to overcome its numerical inferiority.

D. SCENARIO VARIATION B

In this scenario variation, the Orange tactical disposition is similar to that in Scenario Variation A in that all twelve Orange combatants are concentrated in a single Task Force (TF). Blue, on the other hand, has dispersed its TF into two separate Task Groups (TGs), with each TG consisting of two FFGs.

The two excursions of Scenario Variation B are discussed below.

- <u>Excursion B1</u>: The key assumption of this excursion is that Blue's superior maritime air surveillance capability allows it to detect the entire Orange TF and provide targeting data to the two Blue TGs (perfect or 100% Blue scouting effectiveness) before they can be detected by Orange. However, since it is assumed that both sides have equivalent ASCM effective ranges, it is still necessary for the Blue TGs to come within the Orange TF's ASCM effective range (and detection range) before they can effectively launch their attack. In order to prevent the Orange TF from being aware of the presence of both Blue TGs, only one Blue TG will radiate active sensors. This "active" Blue TG will be used as "bait" to draw the Orange TF's attention. The "silent" Blue TG, on the other hand, will use the targeting data provided by the Blue maritime surveillance aircraft to position itself for a surprise ASCM strike on the Orange TF. It will attempt to mingle with and "hug" any neutral vessels to further avoid detection by the Orange TF. In short, both Blue TGs will launch a simultaneous ASCM attack on the Orange TF while the Orange TF, being unaware of the "silent" Blue TG, can only engage the "active" Blue TG. The defensive readiness for both Blue and Orange are set to 100% since it is assumed that both sides' anti-ASCM defenses are alert and ready at all times. Orange's scouting effectiveness is varied for each Blue offensive/defensive configuration and the FER for Blue computed.

- <u>Excursion B2</u>: Excursion B2 serves to illustrate the importance of achieving tactical surprise for either side. For the purpose of illustration, it is assumed that Orange has superior scouting capabilities and manages to launch a pre-emptive strike against the "active" Blue TG which only manages to defend itself. The Orange TF is also aware of the position of the "silent" Blue TG and engages it simultaneously in a missile salvo exchange. In other words, the tables are now turned on Blue. The scouting effectiveness of the "silent" Blue TG and the Orange TF as well as both sides' defensive readiness are all set to 100%. The FER for Blue is computed for both Blue offensive/defensive configurations.

1. Results for Excursion B1

Table 8. Excursion B1 Results

	MOE: FER for Blue	
	Blue Offensive/Defensive Configuration	
Orange Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	3.33	6.20
20%	1.67	3.10
30%	1.11	2.00
40%	1.08	2.00
50%	1.08	2.00
60%	1.08	2.00
70%	1.08	2.00
80%	1.08	2.00
90%	1.08	2.00
100%	1.08	2.00

The Blue tactic in Excursion B1 allows the “silent” Blue TG (50% of the entire Blue force of four FFGs) to remain undetected by the Orange TF. This ensures that at least half of the Blue force will survive the engagement. Blue can effectively concentrate all its offensive firepower from both TGs on all combatants in the Orange TF, but Orange can only concentrate its firepower on 50% of the Blue force (the “active” Blue TG). Blue’s maritime air surveillance (MAS) capability plays a critical role since it allows Blue to detect all Orange combatants while Orange is denied this advantage due to its lack of MAS assets.

The effectiveness of Blue’s tactic can be clearly seen in the results displayed in Table 8 above. Blue always wins (FER for Blue >1) regardless of its offensive/defensive configuration and the level of Orange’s scouting effectiveness. It can again be seen that, in general, the greater amount of offensive firepower provided by offensive/defensive configuration (b) allows Blue to achieve a significantly better FER.

With offensive/defensive configuration (a), Blue achieves a FER of 1.08 for any level of Orange scouting effectiveness >=40%. This is because both Blue TGs (“active” and “silent”) can put about 54% of the Orange combatants out of action (OOA) while Orange, with a scouting effectiveness of between 40% and 100%, can only put the “active” Blue TG (50% of the total Blue force) OOA.

With the 50% increase in ASCM salvo size provided by offensive/defensive configuration (b), Blue can put the entire Orange TF OOA while Orange, with a scouting effectiveness of between 30% and 100%, can still put only the “active” Blue TG (50% of the entire Blue force) OOA.

This is why Blue (with offensive/defensive configuration (b)) achieves an FER of 2.00 for any level of Orange scouting effectiveness >=30%.

2. Results for Excursion B2

Table 9. Excursion B2 Results

	MOE: FER for Blue	
	Blue Offensive/Defensive Configuration	
	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
Blue Surprises Orange	1.08	2.00
Orange Surprises Blue	0.27	0.40

In Table 9 above, the results for “Blue Surprises Orange” were extracted from the last row of Table 8 (where Orange Scouting Effectiveness = 100%).

It is clear from Table 9 that if Blue loses the advantage of surprise to Orange its FER drops drastically to the extent that it loses the engagement (FER for Blue <1), regardless of its offensive/defensive configuration. This amply demonstrates the importance of achieving surprise, particularly for a numerically inferior force, in modern naval missile salvo warfare.

3. Key Insights from Results of Scenario Variation B

By means of superior scouting provided by its maritime air surveillance capability, and consequently its achievement of tactical surprise, the numerically inferior

Blue force is able to concentrate sufficient striking power from its two dispersed TGs to defeat the much larger massed Orange force. In summary, the following factors are critical for an outnumbered naval force to achieve success against its opponent:

- Superior scouting capability;
- Achieve tactical surprise and avoid being surprised;
- Possess sufficient striking power to offset own numerical inferiority as well as the ability to effectively concentrate striking power from dispersed forces if required;
- Use innovative tactics (Blue’s use of dispersed “active” and “silent” TGs in this case) and be willing to take risks (use of “active” Blue TG as “bait”).

E. SCENARIO VARIATION C

The tactical dispositions of both sides in Scenario Variation C are the reverse of that in Scenario Variation B. Hence, in Scenario Variation C Blue operates with all four FFGs concentrated in a single TF while the Orange combatants are dispersed into two TGs with six missile corvettes each. There are two excursions in this scenario variation and they are discussed below.

- Excursion C1: This excursion provides a worst-case scenario for Blue in the sense that its superior scouting advantage has been mitigated by Orange’s tactic of mingling its missile corvettes among merchant shipping traffic to delay detection by Blue maritime surveillance aircraft. As a consequence, Blue is unable to achieve surprise and has to contend with a missile salvo exchange with each of the two Orange TGs. Each of the two Orange TGs is operating along one of the sea approaches to the disputed island and their distance apart precludes them from mutually supporting each other. Blue’s course of action is to take advantage of this and engage the Orange TGs sequentially. However, Blue does not have ammunition replenishment ships to re-supply its FFGs with ASCMs. Neither can Blue sail back to its main naval base for reloading of expended ASCMs since this would leave the second Orange TG unchallenged for a significant amount of time. Hence, the main problem for Blue is whether it would have enough surviving FFGs and offensive firepower to take on the second Orange TG after its salvo exchange with the first Orange TG. The purpose of this excursion is, therefore, to compute the number of Blue FFGs that would be put out of action in a salvo exchange with the first Orange TG. The number of Blue ASCMs launched per FFG against the first Orange TG is varied for both Blue offensive/defensive configurations. Since both sides are fighting on an equal footing, the scouting effectiveness and defensive readiness for both sides are set to 100%. It will be determined from the computed results whether Blue has adequate surviving resources for a salvo exchange with the second Orange TG.

- Excursion C2: In this excursion, Blue is able to use its maritime air surveillance assets to help achieve surprise against the first Orange TG, which only manages to defend itself from Blue’s ASCMs. However, Blue still has to engage the second Orange TG in a missile salvo exchange since the second Orange TG has been informed by the first Orange TG of Blue’s presence and location. Furthermore, as in Excursion C1, Blue is still constrained by the lack of missile (ASCM) replenishment ships and is unable to sail back to base to reload with ASCMs. On the other hand, due to its ability to surprise the first Orange TG, the Blue TF should still be intact and possess sufficient offensive firepower to engage the second Orange TG. For this excursion, Blue’s scouting effectiveness and the defensive readiness for both sides are fixed at 100%. The scouting effectiveness of the second Orange TG is varied for both Blue offensive/defensive configurations and the FER for Blue (after engaging both Orange TGs) computed.

1. Results for Excursion C1

Table 10. Excursion C1 Results for Blue Offensive/Defensive Configuration (a)

# of Blue ASCMs Launched per FFG	# of Blue FFGs OOA	# of Orange Missile Corvettes OOA
1	3.23	0.81
2	3.23	1.61
3	3.23	2.42
4	3.23	3.23
5	3.23	4.44
6	3.23	6.00
7	3.23	6.00
8	3.23	6.00

Table 11. Excursion C1 Results for Blue Offensive/Defensive Configuration (b)

# of Blue ASCMs Launched per FFG	# of Blue FFGs OOA	# of Orange Missile Corvettes OOA
1	3.23	0.81
2	3.23	1.61
3	3.23	2.42
4	3.23	3.23
5	3.23	4.44
6	3.23	6.00
7	3.23	6.00
8	3.23	6.00
9	3.23	6.00
10	3.23	6.00
11	3.23	6.00
12	3.23	6.00

Tables 10 and 11 above show the results of the missile salvo exchange between the Blue TF and the first Orange TG for Blue offensive/defensive configurations (a) and (b), respectively. Clearly, from both tables, all six missile corvettes in the first Orange TG can be put out of action (OOA) if each of the four Blue FFGs launches a salvo of six ASCMs. Any more ASCMs launched by Blue would still result in six Orange missile corvettes OOA. Blue suffers a loss of 3.23 FFGs put OOA by the first Orange TG’s salvo.

To sum up, regardless of Blue’s offensive/defensive configuration, each Blue FFG has to launch six ASCMs to put all six missile corvettes in the first Orange TG OOA and only 0.77 Blue FFG would survive the salvo exchange. Hence, Blue would neither have adequate combatants nor offensive firepower for the subsequent salvo exchange with another six fully-armed missile corvettes in the second Orange TG. This implies that Blue cannot tolerate an exchange of missiles with both Orange TGs.

2. Results for Excursion C2

Table 12. Excursion C2 Results

	MOE: FER for Blue Blue Offensive/Defensive Configuration	
Orange Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	7.87	12.40
20%	3.93	6.20
30%	2.62	4.13
40%	1.97	3.10
50%	1.57	2.48
60%	1.31	2.07
70%	1.12	1.77
80%	0.98	1.55
90%	0.87	1.38
100%	0.79	1.24

The results of this excursion are generally more favorable to Blue, the reason being that Blue is able to surprise and put all six combatants in the first Orange TG out of action (OOA). In doing so, Blue expends six ASCMs per FFG and suffers no loss in combatants. However, only offensive/defensive configuration (b) provides Blue with sufficient remaining striking power for an effective missile salvo exchange with the second Orange TG. This can clearly be seen in the results: if Blue adopts offensive/defensive configuration (b), it always wins (FER for Blue >1), regardless of the level of Orange’s scouting effectiveness. On the other hand, if Blue adopts offensive/defensive configuration (a), it needs at least a 30% scouting effectiveness advantage in order to win. Furthermore, for any level of Orange scouting effectiveness, Blue would achieve a better FER if it adopts offensive/defensive configuration (b) instead of offensive/defensive configuration (a).

3. Key Insights from Results of Scenario Variation C

It is obviously unwise for the numerically inferior Blue force to engage the two dispersed Orange TGs in sequential head-to-head missile salvo exchanges. On the other hand, Blue could overcome the odds against it and win through a combination of surprise and sufficient striking power.

F. SCENARIO VARIATION D

In this final scenario variation, both Blue and Orange disperse their respective forces into two equal strength TGs. In other words, the Blue force is split into two dispersed TGs with two FFGs each, while each Orange TG consists of six missile corvettes. As in the preceding scenario variation, the two Orange TGs are dispersed such that they are unable to support each other. The following is a description of the two excursions considered in this scenario variation.

- Excursion D1: Each Blue TG is assigned to search for and engage one Orange TG. This implies that the Blue TGs are also unable to support each other due to the large distance between the Orange TGs. Furthermore, Orange merges its combatants amongst merchant shipping traffic so as to delay detection by Blue maritime surveillance aircraft and thus negate Blue’s superior scouting advantage (similar to Excursion C1). Hence, Blue is unable to use its air surveillance advantage to achieve surprise and, as a result, each Blue TG has to engage in a missile salvo exchange with an Orange TG. Both sides' defensive readiness as well as Blue's scouting effectiveness are fixed at 100%. The overall FER for Blue is then computed for both Blue offensive/defensive configurations and for various levels of Orange scouting effectiveness.

- Excursion D2: The main difference between Excursion D2 and D1 is that, in Excursion D2, Blue manages to achieve surprise against one Orange TG, which is only able to defend itself against Blue's ASCMs. This could be due to a lack of merchant shipping traffic for the combatants of the surprised Orange TG to hide amongst. The objective of this excursion is to investigate the effect on the battle outcome for Blue if it effectively surprises half (one TG) of the Orange force.

1. Results for Excursion D1

Table 13. Excursion D1 Results

	MOE: FER for Blue	
	Blue Offensive/Defensive Configuration	
Orange Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	3.33	6.20
20%	1.67	3.10
30%	1.11	2.07
40%	0.83	1.55
50%	0.67	1.24
60%	0.56	1.00
70%	0.54	1.00
80%	0.54	1.00
90%	0.54	1.00
100%	0.54	1.00

The results in Table 13 clearly indicate that the key factor that enables Blue to achieve parity (FER for Blue = 1) or win a salvo exchange (FER for Blue >1) is to possess sufficient offensive firepower provided by offensive/defensive configuration (b). If Blue has insufficient offensive firepower (as in offensive/defensive configuration (a)), it can win a salvo exchange only if Orange’s scouting effectiveness is somehow degraded by at least 70%.

With offensive/defensive configuration (a), Blue can put about 54% of the total Orange force out of action (OOA), but loses all four FFGs if Orange scouting effectiveness is >=70%. Therefore, Blue’s FER remains constant at 0.54 for levels of Orange scouting effectiveness >=70%.

With offensive/defensive configuration (b), Blue puts all 12 Orange combatants OOA but still loses all four FFGs if Orange scouting effectiveness is >=60%. This explains the parity result for Blue (FER for Blue = 1) if Orange scouting effectiveness is >=60%.

2. Results for Excursion D2

Table 14. Excursion D2 Results

	MOE: FER for Blue	
	Blue Offensive/Defensive Configuration	
Orange Scouting Effectiveness	Blue Config (a): ASCM Salvo Size = 8 Defensive Power = 6	Blue Config (b): ASCM Salvo Size = 12 Defensive Power = 4
10%	6.67	12.40
20%	3.33	6.20
30%	2.22	4.13
40%	1.67	3.10
50%	1.33	2.48
60%	1.11	2.00
70%	1.08	2.00
80%	1.08	2.00
90%	1.08	2.00
100%	1.08	2.00

With offensive/defensive configuration (a), Blue manages to put about 54% of the total of 12 Orange combatants out of action (OOA) and loses only two FFGs (50% of the total Blue force) when Orange scouting effectiveness is >=70%. The two surviving Blue FFGs are those that achieved surprise. Hence, Blue achieves an FER of 1.08 for Orange scouting effectiveness >=70%.

The 50% increase in ASCM salvo size provided by offensive/defensive configuration (b) allows Blue to put all 12 Orange combatants OOA. In this case, Blue loses only two FFGs (50% of the total Blue force) and achieves an FER of 2.00 when Orange scouting effectiveness is >=60%. The two surviving Blue FFGs are also those that achieved surprise.

A comparison of the results of excursions D1 and D2 shows the advantage of achieving surprise for the Blue force, even though surprise is achieved only against one of the two Orange TGs. If Blue manages to surprise just one Orange TG, it will win the battle (FER for Blue >1) regardless of its offensive/defensive configuration and the level of Orange's scouting effectiveness. In addition, having greater offensive firepower (offensive/defensive configuration (b)) and thus greater striking power will generally enable Blue to achieve a better FER.

3. Key Insights from Results of Scenario Variation D

As in Scenario Variation C, achieving surprise and possessing sufficient striking power for an effective attack are the two key factors for ensuring Blue's success against the numerically superior Orange force.

From the results in Tables 13 and 14, it can be seen that the FER for Blue is generally doubled if it is able to surprise one Orange TG. The significance of achieving surprise for Blue is shown in Table 15 below.

Table 15. The Significance of Achieving Surprise for Blue

	MOE: FER for Blue	
Orange Scouting Effectiveness	Blue Does Not Achieve Surprise	Blue Achieves Surprise on 1 Orange TG
10%	3.33	6.67
40%	0.83	1.67
70%	0.54	1.08
100%	0.54	1.08

The results in Table 15 are extracted from the results in Tables 13 and 14 pertaining to Blue offensive/defensive configuration (a). What Table 15 shows is that surprise could mean the difference between winning and losing for a numerically inferior force. Specifically, if Blue does not achieve surprise for levels of Orange scouting effectiveness above 40%, it loses the salvo exchange (FER for Blue <1). On the other hand, if Blue manages to surprise just one of the two Orange TGs, it is able to reverse the outcome and emerge as the victor (FER for Blue >1). The achievement of surprise must, therefore, be a key consideration in the tactical planning for a naval force expecting to fight outnumbered.

G. CHAPTER SUMMARY

The key findings and insights from the results and analyses presented in the preceding sections are summarized in the following points:

- The critical factor for Blue’s success against a concentrated Orange TF is not its tactical disposition but its ability to outscout the numerically superior Orange force and deliver an effective pulse of offensive firepower onto the Orange combatants. The key to achieving this is through Blue’s maritime air surveillance (MAS) assets which enable it to detect and effectively attack the Orange TF before Orange can do the same to Blue.

- If Orange disperses its forces into two non-supporting TGs, Blue should do likewise with each Blue TG engaging one Orange TG. Coupled with sufficient striking power provided by offensive/defensive configuration (b), this course of action allows Blue to achieve at least parity (FER for Blue >=1) in a missile salvo exchange if surprise cannot be achieved against Orange. On the other hand, if Blue operates with all four FFGs concentrated in one TF to engage the two Orange TGs sequentially, the Blue TF will be almost annihilated after the first salvo exchange if it fails to surprise any of the Orange TGs.
- In general, the numerically inferior Blue force can win the battle with superior scouting and sufficient offensive pulsed power. Superior scouting, provided by its MAS assets, enables Blue to achieve tactical surprise and deliver firepower in a sudden, effective pulse.
- To attack effectively first, the Blue force must be risk-prone and innovative in its tactical planning.

V. QUALITATIVE DISCUSSIONS

A. INTRODUCTION

The purpose of this chapter is to provide qualitative discussions pertaining to how small naval forces can fight and win.

This chapter is organized into the following sections:

B. The Battle of Savo Island: The Importance of Scouting and Surprise for an Outnumbered Naval Force

C. Tactics of the Naval Battles in the 1973 Yom Kippur War

D. Taking Advantage of the “Missile-Sump Effect”

E. Exploring Missile Torpedo Boats for Modern Coastal Navies

F. Chapter Summary

Section B is a brief qualitative description of the World War II Battle of Savo Island fought between Allied and Japanese naval forces. It describes how the outnumbered Japanese force used surprise, effective scouting, and offensive pulsed power to defeat the Allied force.

In section C, the significant factors that contributed to the Israeli naval victories during the Yom Kippur War are identified.

Section D discusses how a phenomenon in modern naval missile warfare known as the “missile-sump effect” can be taken advantage of by small navies to reduce an opponent’s offensive combat power.

The Missile Torpedo Boat or MTB can be a very effective littoral combat craft, especially when employed by small but competent coastal navies. This is explained and discussed in section E.

Section F summarizes the key points of this chapter and relates them to the findings and insights derived quantitatively in Chapter IV.

B. THE BATTLE OF SAVO ISLAND: THE IMPORTANCE OF SCOUTING AND SURPRISE FOR AN OUTNUMBERED NAVAL FORCE

The nighttime Battle of Savo Island (August 8-9 1942) was a naval battle in the Pacific Campaign of World War II fought between Imperial Japanese Navy (IJN) and Allied naval forces. The battle was the first major naval engagement during the campaign for Guadalcanal in the longer Solomon Islands campaign, which lasted until January 1943. [Ref. 4]

The mission of the Allied naval force was to protect the troop transports, supply ships, and American beachhead on Guadalcanal. To accomplish this, the Allied naval commander of the surface screening force divided his force into three groups. The “Southern Group” consisted of three cruisers and two destroyers; the “Northern Group” was also allocated three cruisers and two destroyers; while two cruisers and two destroyers made up the “Eastern Group”. In addition, two destroyers were deployed as pickets to provide early warning of any approaching Japanese ships. [Ref. 4]

The Japanese force was disposed in a single two-mile column and consisted of seven cruisers and a single destroyer [Ref. 4]. The aim of the Japanese force was to destroy Allied supply ships and troop transports at Guadalcanal, as well as any naval opposition encountered there [Ref. 3]. Thus, the Japanese force was superior to each Allied group even though the overall Allied force outnumbered the Japanese force [Ref. 3].

Both sides utilized scouting aircraft to reconnoiter enemy naval ship dispositions before the battle. The Japanese cruiser-launched scouting aircraft detected and reported the southern and northern Allied groups, providing ample time for the Japanese commander to formulate and communicate his battle plan to his warships. On the other hand, probably due to undeveloped and inadequate command, control, and communications (C3) between the Allied force components, scouting reports from Allied Hudson reconnaissance aircraft were not distributed to the relevant Allied warships until it was too late. [Ref. 4]

Thus, as a result of effective scouting and C3, the Japanese force was able to consecutively surprise both Allied southern and northern groups, initiate attacks with massed torpedo salvoes, and then mop up with gunfire [Ref. 3]. The battle outcome was four Allied cruisers sunk plus one cruiser and two destroyers damaged. The Japanese suffered only moderate damage to three cruisers. [Ref. 4]

Although many factors contributed to the Allies' defeat in this battle, such as the flawed tactical disposition of the Allied surface screening force and faulty tactical C3, this battle still provides a good example of how an outnumbered naval force (the Japanese force in this case) can use effective scouting and C3 to achieve tactical surprise and defeat its opponent with sufficient offensive pulsed power.

C. TACTICS OF THE NAVAL BATTLES IN THE 1973 YOM KIPPUR WAR[4]

The 1973 Yom Kippur War witnessed the first battles in the history of naval warfare involving ship-versus-ship missile engagements and the use of electronic countermeasures (ECM) against missiles. The two most significant force-on-force naval missile battles of this war were the Battle of Latakia and the Battle of Baltim. The first battle pitted the *Saar* missile boats of Israel against the Russian-made missile boats of Syria, while the latter battle involved Israeli *Saar* boats and Egyptian missile boats (also of Russian origin). The Israelis were the undisputed victors of both battles. They emerged from the battles without damage to any of their missile boats while managing to destroy eight Arab naval vessels (including six of the seven Arab missile boats involved in the two battles) [Ref. 5]. How was such a stunning victory achieved?

The Battle of Latakia (night of October 6-7 1973) was the first missile battle ever in naval warfare between naval vessels. The Israeli task force's objective in this battle was simple: draw Syrian warships out of Latakia, Syria's main harbor, and sink them. There were a total of five vessels in the Israeli task force and they were disposed in two parallel columns. The battle opened with the detection of a Syrian picket torpedo boat and ended with the destruction of five Syrian vessels (the torpedo boat, a minesweeper, and three missile boats) and no Israeli losses. [Ref. 5]

[4] The contents of this section were extracted from a research paper written by the author entitled "Naval Missile Battles of the 1973 Yom Kippur War," 22 October 2006.

The Israeli tactics against the Syrian missile boats in the Latakia battle were simple in concept but not easy to execute: charge towards the Syrian boats to induce them to fire their Styx missiles, then jam and decoy the Styx missiles using ECM and use the *Saar* boats' speed advantage to close within Gabriel (Israeli anti-ship cruise missile) range to engage and sink the Syrian missile boats (the Styx missile had an effective range of 24nm while the Gabriel missile's effective range was only 11nm). This tactic, though bold, worked perfectly. Key to its success was the effectiveness of the Israeli ECM systems, which worked flawlessly. All the Styx missiles fired at the Israeli boats were defeated by jamming or chaff and missed their targets. Another equally important contributor to the Israelis' success was the Gabriel missile. The Gabriel worked extremely well in its baptism of fire and was instrumental in the rapid destruction of three of the Syrian vessels (the other two vessels were destroyed by gunfire). [Ref. 5]

The Israelis repeated their tactics in the Battle of Baltim (night of October 8-9 1973) against the Egyptians. This time there were a total of six Israeli missile boats formed into three pairs moving in parallel lines across a broad front. Again it was a one-sided victory for the Israelis: three Egyptian *Osa* missile boats were sunk for no Israeli losses. Again, the Israeli ECM systems and the Gabriel missile performed successfully. An interesting feature of this battle was the Israelis' innovative use of long–range chaff decoys to draw fire from the Egyptian missile boats and thus positively identify them as hostile vessels. [Ref. 5]

In both battles a key factor that contributed to the Israelis' overwhelming success was the concentration of sufficient offensive firepower, and thus striking power, in their missile boats. The Israeli *Saar* boats involved in the Latakia battle were equipped with a total of 26 Gabriel missiles, compared to only eight Styx missiles for the Syrians [Ref. 5]. At Baltim, the Israelis had up to 34 Gabriels against 16 Egyptian Styxes [Ref. 5]. A plausible Israeli doctrine that could be deduced from this is to deploy and concentrate as much striking power as possible to overwhelm and destroy the enemy.

The Israelis were forced to use aggressive, innovative tactics. Being outranged, their tactic to charge and close the range to engage the Arab missile boats was a calculated gamble that paid off spectacularly.

The Israelis' effective tactical coordination and command and control (C2) system also played a major role in their victories. They had a well-practiced tactical command system in which the missile boat flotilla commander, embarked with his command staff on a designated missile boat, controlled and coordinated the actions of all missile boats involved in an operation [Ref. 5].

Although they did not have any maritime air surveillance available during the Yom Kippur War, the Israelis' missile boats expected this. They were equipped with passive electronic detection systems (Electronic Support Measures or ESM) that could reveal an enemy's radar without betraying their own presence as long as the Israeli boats maintained radar silence [Ref. 5]. This gave the Israelis a scouting advantage as the Arab missile boats were not equipped with ESM systems.

The Israelis, at both Latakia and Baltim, applied a sufficient pulse of striking power to defeat the enemy. This, in concert with effective tactical coordination and superior scouting, overwhelmed and thoroughly defeated the enemy. It is this decisive combination of offensive firepower, command and control, and scouting that modern navies must strive to achieve in order to have the best chance of winning any future naval battle, be it in the littorals or in the open oceans.

D. TAKING ADVANTAGE OF THE “MISSILE-SUMP EFFECT”[5]

First defined by LT Jeffrey Cares in his Naval Postgraduate School (NPS) Master’s thesis [Ref. 6], the “missile-sump effect” is a phenomenon in modern naval missile warfare in which some targets absorb proportionally more combat energy than other targets in the target environment. In other words, the “missile-sump effect” occurs when a target absorbs more than its share of hits when other targets are in the same environment. Cares, in his thesis [Ref. 6], used both simulation and analytical methods to demonstrate the tactical inefficiencies caused by the “missile-sump effect”.

As an illustrative example of the “missile-sump effect”, two radar-homing ASCMs fired at two target ships in close proximity (each target ship with a staying power of one ASCM hit per ship), with the intention of hitting each target ship with one ASCM, can inadvertently result in both ASCMs hitting the same ship. A possible cause for this is that the target ship that absorbed both ASCMs has, due

[5] The contents of this section were extracted from a research paper written by the author entitled “Taking Advantage of the Missile-Sump Effect,” 2 November 2006.

to poor stealth characteristics, a significantly larger radar cross section (RCS) for the ASCMs to home in on. In this case, the attacker would have “wasted” one ASCM, resulting in a target getting away without any damage whatsoever.

The example in the preceding paragraph, though fictional, shows that the “missile-sump effect” can be exploited to reduce an opponent’s striking power by causing the opponent to “waste” missile shots on less important or decoy targets. In this context, the decoy targets act as missile “absorbers” by “soaking up” a large number of incoming missiles, so that hits on high value units or major combatants are significantly reduced or even negated. This, however, is not a new tactical concept and has been employed in relatively recent naval battles. In the 1973 Yom Kippur War, the Syrians used neutral foreign merchant ships anchored outside their harbors as floating “sandbags” behind which the Syrian missile boats could take cover after firing their missiles at attacking Israeli missile boats [Ref. 5]. A Syrian boat could thus come out from behind a merchant ship, fire its missiles, and then rapidly dodge behind another merchantman. This tactic proved rather effective for the Syrians as the Israelis could not lock on to the Syrian boats long enough to fire their semi-active radar-homing Gabriel missiles effectively. In fact, the Israelis did not score any confirmed hits on Syrian boats employing this tactic, but ended up hitting and sinking some neutral freighters instead [Ref. 5].

Admiral Woodward, the British Battle Group Commander during the 1982 Falklands War, was in a way taking advantage of the “missile-sump effect” when he placed large cargo ships, such as the *Atlantic Conveyor,* on the threat axis between his aircraft carriers and his outer screen. In this case, the *Atlantic Conveyor* absorbed both Exocet ASCMs that could have hit the British aircraft carrier HMS *Hermes* had the *Atlantic Conveyor* not been acting as the carrier's de facto missile shield. Although the *Atlantic Conveyor* was lost, together with the important cargo on board, the loss of a British carrier (the British aircraft carriers were their center of gravity) was averted. [Refs. 2 and 7]

In the 1980-1988 Iran-Iraq War, both the Iranians and Iraqis used simple radar reflectors fixed on floating buoys as decoy targets to lure and absorb radar-homing ASCMs [Ref. 8]. It has been claimed that some of these floating decoys were hit repeatedly by ASCMs and 90% of the Exocets fired during the war hit buoys with radar reflectors on them instead of actual ships [Ref. 8]. This was possibly the most cost-effective method that has been used in actual combat to take advantage of the "missile-sump effect".

It is in the littoral environment, in particular, that the "missile-sump effect" can be put to good use by a defending navy. Small navies operating in narrow seas littered with numerous islands or islets (the Aegean Sea and the Malacca Straits are two good examples) can make full use of their geographical environment coupled with the "missile-sump effect" to counter an aggressor navy. Decommissioned naval vessels or old merchant ships can be stripped of their equipment and fitted with simple radar reflectors to act as cheap decoy targets and missile "absorbers". Decommissioned amphibious warfare ships, for example, can be used as they make good missile "absorbers" due to their large size. These decoys can be towed to strategic choke points among island groups where they can act as floating "sandbags". The defender's small fast attack missile craft can use these decoys as cover from which they can launch missile strikes at the attacker’s ships. There is a very good chance that any return missile salvo from the attacker will be attracted to the larger RCS of the floating decoys, with the result that the decoys absorb a large proportion of or hopefully all the missiles meant for the defender’s missile craft. This “missile-sump effect” “wastes” the attacker’s missiles and thus erodes the attacker’s striking power. From the defender’s perspective, this is a very cost-effective tactic since the decoys are cheap and expendable. A point to note is that this tactic works only if the attacker’s ships are armed predominantly with radar-homing missiles that can be “lured” by the larger RCS of the floating decoys. (Most modern ASCMs use radar seekers to home in on their targets so this is not yet a major concern.)

A possible variation of the above concept would be to employ remotely controlled decoy ships instead of static floating decoy ships. The decoy ships could be controlled by a master control ship or aircraft. Though slightly more expensive (due to the procurement and retrofitting of remote-control devices), this makes the decoy ships more “credible” in the sense that they will be actual moving ships. Fast attack missile craft could move together with such remote-control decoy ships, using them as mobile missile shields. Besides fitting the remote-control decoy ships with simple radar reflectors, an electronic warfare device called the traveling wave tube (TWT) could also be used. The TWT [Ref. 9] functions by amplifying received missile radar signals and transmitting them back to the missile. The re-transmitted signals appear very strong to the missile, thus simulating a much bigger target. This has the effect of further increasing the probability that an incoming ASCM is “absorbed” by the decoy ship. The idea of employing the TWT to decoy ASCMs was pioneered by the British during the Falklands War when TWT-equipped Royal Navy helicopters were used as mobile missile decoys [Ref. 8]. A similar idea was also used by Tom Clancy in his best-selling fictional military techno-thriller “Red Storm Rising” [Ref. 10].

The “missile-sump effect” can, therefore, be taken advantage of, especially by small navies operating in littoral environments, in innovative ways to reduce an opponent’s striking power by using decoys to “absorb” a large proportion (or even all) of his offensive missiles. The “missile-sump effect” can have a significant influence on modern naval missile warfare and it should be an important consideration in tactical planning and resource acquisition (e.g., acquisition of remote-control decoy ships). The historical examples cited in this section have amply demonstrated its tactical importance.

It would probably be appropriate to point out here, as a final note to this section, that the “missile-sump effect” is difficult to model using the Modified Salvo Model (or Hughes’ Salvo Model) due to its inherent assumption (for mathematical simplicity and analytical clarity) that incoming ASCMs are uniformly distributed over all targets. Although this will rarely happen in reality (even a random distribution of missile shots will lead to a

Gaussian distribution), the Modified Salvo Model suffices for the exploratory analyses conducted for the purposes of this thesis.[6]

E. EXPLORING MISSILE TORPEDO BOATS FOR MODERN COASTAL NAVIES[7]

After the German invasion of Norway (April 1940) during World War II, officers and men of the Royal Norwegian Navy became heavily involved in the activities of the Motor Torpedo Boats (MTB) of the Royal Navy's Coastal Forces. The Norwegians were, in fact, allocated their own MTB flotilla (based in the Shetland Islands in England) equipped with the British *Fairmile* D Class MTB (also called "Dog Boats"). The Norwegian MTB flotilla eventually consisted of 12 "Dog Boats". Taking advantage of their knowledge of the unique aspects of the Norwegian littoral environment (consisting of fjords and narrow inlets among numerous islands), the Norwegian "Dog Boats" were very effectively used against German coastal convoys in so-called "lurking operations". In such operations, the Norwegian "Dog Boats", after sailing to Norway from their operating base in England, would find a good position to stalk the enemy close to the shore or an island, so as to be in the shadow of the land. Once alongside, the "Dog Boats" were camouflaged and would lie in wait for an opportunity to ambush an enemy convoy. The effectiveness of

[6] It should be noted that in his Naval Postgraduate School Master's Thesis titled "Using Hughes' Salvo Model to Examine Ship Characteristics in Surface Warfare," September 2004, Kevin G. Haug used Hughes' Salvo Model, while assuming a Polya distribution of shots, to show that the bonus gained by attaining perfect information is a significant edge, and the hazard of failing to deny the enemy the same.

[7] The contents of this section were extracted from a research paper written by the author entitled "Missile Torpedo Boats for Modern Littoral Warfare," 21 November 2006.

this tactic was demonstrated by the fact that a total of 26 enemy vessels were definitely sunk and four enemy aircraft were shot down while no Norwegian “Dog Boat” was lost in actual combat. [Ref. 11]

At the end of World War II, the Norwegian “Dog Boats” returned to Norway to operate (in peacetime) for the next few years from their homeland [Ref. 11]. These boats were the nucleus of the post-war Norwegian Navy’s coastal combat force, which was to consist of successive classes of Norwegian-designed motor torpedo boats such as the *Rapp* [Ref. 12] and *Tjeld* [Ref. 13] classes. Subsequently during the Cold War, the Royal Norwegian Navy (as part of NATO) was optimized for sea denial in Norwegian coastal waters, in order to make an invasion from the sea as difficult and costly as possible [Ref. 14]. With that mission in mind, the Norwegian Navy was predominantly made up of fast attack craft armed with ASCMs, anti-ship torpedoes, and medium-caliber guns. These craft were classified by the Norwegians as Missile Torpedo Boats [Ref. 14] and thus shared the same acronym (MTB) as their predecessor, the World War II Motor Torpedo Boat. Even after the Cold War and until today the Norwegian Navy has retained the Missile Torpedo Boat within its surface combatant inventory [Ref. 14].

The Missile Torpedo Boat is certainly not obsolete in modern naval warfare and, in fact, might prove to be one of the most lethal combatants in modern littoral warfare. Although modern ASCMs, on the average, have significantly greater effective ranges than most anti-ship torpedoes, their effectiveness can be seriously reduced within littoral environments. The following three points highlight some shortcomings of many modern ASCMs when used in the littorals:

- Most modern ASCMs use active radar seekers to home in on their targets. However, the radar clutter caused by the coastline, islands and islets, and neutral shipping (features that are common in the littorals) would pose difficulties for the active radar seeker on an ASCM to home in on the correct target.
- ASCMs equipped with active radar seekers can be decoyed simply by mounting simple radar reflectors on large, decommissioned ships acting as decoy targets and missile “absorbers” (as discussed in the preceding section of this chapter).
- Ship-to-ship identification in littoral environments is usually accomplished through electro-optic sensors (infra-red sensors at night) or visually. Depending on the size of the target and environmental conditions, identification ranges in the littorals are usually relatively short, probably around 2-5nm for a fast attack craft or corvette-sized target or 7-8nm for a frigate-sized target. Although small ship-launched UAVs (Unmanned Aerial Vehicles) can be used to extend a warship’s identification range, weather conditions often preclude their employment. Most, if not all, ship-launched ASCMs have a minimum range within which they are ineffective. The minimum range for a ship-launched ASCM depends on the length of its boost phase after launch and generally varies from about 2nm to 5nm. Hence, there would be situations in which ASCMs, even those with electro-optic or infra-red seekers (which are arguably more effective than active radar seekers in littoral environments), are ineffective due

to short target identification ranges (especially at night or in bad weather conditions).

Anti-ship torpedoes, therefore, can be used to plug the gaps caused by the abovementioned shortcomings of ASCMs. Torpedoes are less constrained by minimum ranges and cannot be "fooled" by radar clutter or radar decoys. Furthermore, torpedoes are more destructive than ASCMs since they hit a ship below its waterline, in the screws, or under its keel, thus causing flooding, immobility, or most effective of all, breaking a ship's back.

Although it can be argued that acoustic-homing torpedoes might not be effective amidst the cacophony of background noises in the littoral underwater environment, this problem can be solved to a certain extent by using wire-guided torpedoes which can be guided by an operator all the way from the launch platform to the target. In fact, even unguided straight-running torpedoes can be employed since these torpedoes are not equipped with seekers and simply proceed on the course along which they are aimed. These straight-runners, therefore, cannot be countered by noise-makers or acoustic jammers. Though inherently less accurate than homing torpedoes, the short engagement ranges in the littorals and modern fire control systems can still ensure a high probability of hit for a salvo of straight-running torpedoes.

In conclusion, it must be emphasized that the purpose of this section is not to "promote" the use of ship-launched anti-ship torpedoes in littoral combat, but to make the point that naval combatants armed with complementary anti-ship pulse weapons (torpedoes and missiles) can be effectively used as littoral combat craft.

The Missile Torpedo Boat is a fine example of such a combatant. It is nimble and maneuverable, and its ASCMs can be used in longer-range engagements in which the target or targets can be clearly distinguished from the background clutter while its torpedoes can be employed in situations in which ASCMs are ineffective. Thus, the Missile Torpedo Boat is a viable platform option that can be considered by modern coastal navies.

F. CHAPTER SUMMARY

Sections B and C of this chapter provide historical examples of how outnumbered naval forces of a small navy have defeated their opponents through the use of superior and effective scouting and the application of sufficient offensive firepower. Section B demonstrates the importance of achieving surprise for a numerically inferior naval force. Section C shows how the small Israeli Navy used bold, innovative but risky tactics to overcome their tactical limitations and achieve victory. These examples qualitatively reinforce the key findings and insights in Chapter IV that were derived quantitatively using the Modified Salvo Model.

Section D discusses how modern coastal navies can innovatively take advantage of tactical phenomenon like the “missile-sump effect” to reduce an opponent’s striking power. Section E suggests that the Missile Torpedo Boat can play an effective role in modern littoral warfare, especially when employed by competent coastal navies. The key points are two: first, that modern small navies must strive to be innovative in tactical planning as well as in force structuring. Second, that the results of quantitative analysis must be combined with considerations no combat model can fully account for in order to construct the best combat doctrine.

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VI. SUMMARY AND CONCLUSIONS

A. SUMMARY

In this thesis, the Modified Salvo Model (a modified version of Hughes' Salvo Model) was developed to analyze quantitatively how the missile frigates of a small, but modern, littoral navy (Blue Navy) should be tactically disposed against its numerically superior but technologically inferior adversary (Orange Navy). Significant tactical factors and insights that are crucial to the success of small navies when fighting outnumbered were also identified in the analysis. Examples of past naval battles that illustrate the practical importance of the identified factors are then presented to qualitatively support the quantitative findings.

B. CONCLUSIONS

1. Tactical Dispositions

How the outnumbered Blue Navy should be tactically disposed depends, in part, on the tactical disposition adopted by its Orange Navy opponent. Insofar as the Orange Navy chooses to disperse its forces into two non-supporting task groups, the Blue Navy should do likewise so as to ensure at least a parity outcome (in terms of FER) in the event it cannot surprise Orange. A precondition for Blue to disperse its forces is the ability of its dispersed units to apply sufficient pulsed power. This implies that Blue must put greater emphasis on the amount of offensive firepower on board its missile frigates while still maintaining sufficient defensive capability.

If Orange favors concentration instead, Blue’s tactical disposition becomes secondary to its scouting advantage. It is more important that Blue deploys its maritime air surveillance assets wisely in order to detect the Orange force and deliver *sufficient* offensive power to attack it effectively before Orange can do likewise. The achievement of an *effective* first strike might be by outranging the enemy weapons, by concealment in coastal clutter, or by causing a mal-distribution of enemy ASCMs, but in every case first detection and targeting is key to battle victory.

The above findings lead to the general conclusion that dispersal for stealthy surprise attack is the preferred tactic for a numerically inferior naval force. The Blue Navy is better off dispersing its combatants in the face of Orange’s numerical superiority. Orange, therefore, has to detect and engage the dispersed Blue task groups individually, making simultaneous action against all of them difficult if not impossible. Blue’s superior scouting capability, on the other hand, makes it possible to simultaneously extend its information gathering network to detect all Orange forces, and allows the dispersed Blue units to deliver a coordinated missile strike on Orange.

Assuming Orange, knowing that its individual units are weak in defensive power, would most probably adopt the traditional tactic of concentrating or massing its forces to support one another defensively, the attainment of surprise and the delivery of overwhelming striking power become even more critical for Blue. To achieve surprise and attack effectively first, Blue must put unstinting emphasis on superior scouting, be risk-prone and be willing to use aggressive and innovative tactics.

2. Tactical Insights

The preceding sub-section presents conclusions pertaining to the tactical disposition of the Blue Navy. Equally important are the tactical insights inferred from the analysis conducted in this thesis. These are summed up below.

- Blue's numerical inferiority dictates that it should not engage in a force-on-force missile salvo exchange with Orange. Unless Orange suffers a severe degradation in targeting effectiveness or Blue increases its defensive power to a level significantly above that considered in this thesis, the Blue Navy in this thesis cannot prevail in an exchange of salvos.
- The consequence of being surprised is drastic for both Blue and Orange because either side has the potential to deliver offensive firepower in a sudden effective pulse. The possibility of surprise and swift destruction is even more likely to arise in littoral waters than in the open ocean.
- An important implication of the above conclusions is that the smaller Blue Navy must be able to detect, track, target, and attack effectively while avoiding similar tactical success by the Orange units. First detection, tracking, and targeting can be achieved by capable scouting platforms such as long-endurance maritime surveillance aircraft or UAVs (Unmanned Aerial Vehicles). An adequate number of such platforms must be provided to ensure continuous coverage of the area of operations. The delivery of an effective attack requires that the ASCM salvo

size of the small number of Blue combatants be large enough to produce a sufficient pulse of striking power. Given that the size of Blue's force is fixed, which precludes a distribution of firepower amongst more combatants, Blue can only overcome this limitation by increasing the ASCM load of its frigates to the maximum possible extent while still retaining adequate defensive power. To put it in another way, *offensive firepower must be emphasized to compensate for small force size.*

- An important prerequisite for a small navy or naval force to operate in a dispersed fashion is an effective command, control, and communications (C3) system. An effective C3 system allows a dispersed naval force to deliver a coordinated missile strike that is concentrated in both time and space.
- As important as superior scouting, effective C3, and sufficient striking power are, a small navy must also be able to catch its enemy with a temporary vulnerability and exploit it to achieve surprise. This requires some combination of initiative, willingness to act on an estimate of enemy intentions, and the ability to implement bold, innovative tactics. These attributes have all been demonstrated by small, but victorious, naval forces in the history of naval warfare. The World War II Battle of Savo Island and the naval missile battles during the Yom Kippur War provide two excellent examples.
- The "missile-sump effect" is an important tactical phenomenon in modern naval missile warfare and it

offers a cost-effective way for a small navy to even out the odds by reducing or “wasting” a stronger opponent’s striking power.

- Most small navies operate in the littorals and must possess combat craft that are well-equipped for the unique characteristics of their respective operating environments. The selection or design of the appropriate type of littoral combatant therefore requires innovative and unconventional thinking on the part of force planners.

C. ENDNOTE

This thesis ends with the following quotes from Captain USN(Retired) Wayne Hughes as written in his book *Fleet Tactics And Coastal Combat* [Ref. 2].

“First application of effective firepower is the foremost tactical aim.”

- Captain USN(Retired) Wayne Hughes

“To attack effectively first, an inferior force must overcome its limitations by some combination of initiative and surprise.”

- Captain USN(Retired) Wayne Hughes

“Applying sufficient pulsed power (single large salvoes), a considerably inferior force can win the battle with superior scouting or C2. The firepower of the inferior force must be sufficient.”

- Captain USN(Retired) Wayne Hughes

This thesis has shown, both analytically and through historical examples, the validity of these three statements that planners and tacticians of modern, small navies would do well to heed.

APPENDIX A: A PROPOSED STAYING POWER MODEL[8]

A. INTRODUCTION

A study by the Brookings Institution asserts that the number of hits required to put a ship out of action (OOA) can be related to the length of the ship. This study also concluded that a hit by one large warhead would incapacitate a modern warship up to 300 feet long, and another similar warhead is required for every additional 100 feet. [Ref. 2]

Using the findings from the Brookings study, this appendix proposes a simple "back of the envelope" deterministic staying power model for computing the number of anti-ship cruise missiles (ASCMs) of a given warhead weight required to put a warship of a given length OOA.

B. PROPOSED STAYING POWER MODEL

The proposed model is expressed in the form of an IF ELSE statement as presented below.

```
IF  L <= (z/w)*300
    N = 1;
ELSE
    N = 1 + {[L - (z/w)*300] / [(z/w)*100]};
```

where

[8] The contents of this appendix were extracted from a research paper written by the author entitled "A Proposed Model to Compute the Number of Anti-Ship Cruise Missiles Required to Put a Warship Out of Action," 1 November 2006.

L = length (in feet) of warship;

z = warhead weight (in pounds) of ASCM;

w = warhead weight (in pounds) of an ASCM such that a hit by such an ASCM would incapacitate a modern warship up to 300 feet long, and another similar ASCM is required for every additional 100 feet;

N = number of ASCMs required to put the given warship OOA.

Assuming that w = 363 pounds (warhead weight of an Exocet ASCM), computations using the above model show that 3 Exocets are required to put a warship 500 feet in length (approximate length of a Sovremenny class DDG) OOA while only 1.7 Harpoon ASCMs (Harpoon ASCM warhead weight = 488 pounds) are required to put the same warship OOA. This makes intuitive sense since the Harpoon ASCM has a significantly larger warhead weight compared to the Exocet and thus fewer Harpoons are required to put the same warship OOA.[9]

C. REMARKS

Although the above model can be used to compute a rough estimate of the staying power of a warship in terms of the number of hits from a particular type of ASCM, it is important to bear in mind that this model was not developed to draw any firm conclusions about warship staying power. Neither was this model developed to derive precise warship vulnerability figures for engineering purposes. Its main

[9] The Exocet ASCM and Harpoon ASCM warhead weights and the length of the Sovremenny class DDG were obtained from Jane's Fighting Ships.

purpose is simply to produce credible estimates of warship staying power that can be used as inputs for analytical combat models that are used to gain insights into naval warfare issues.

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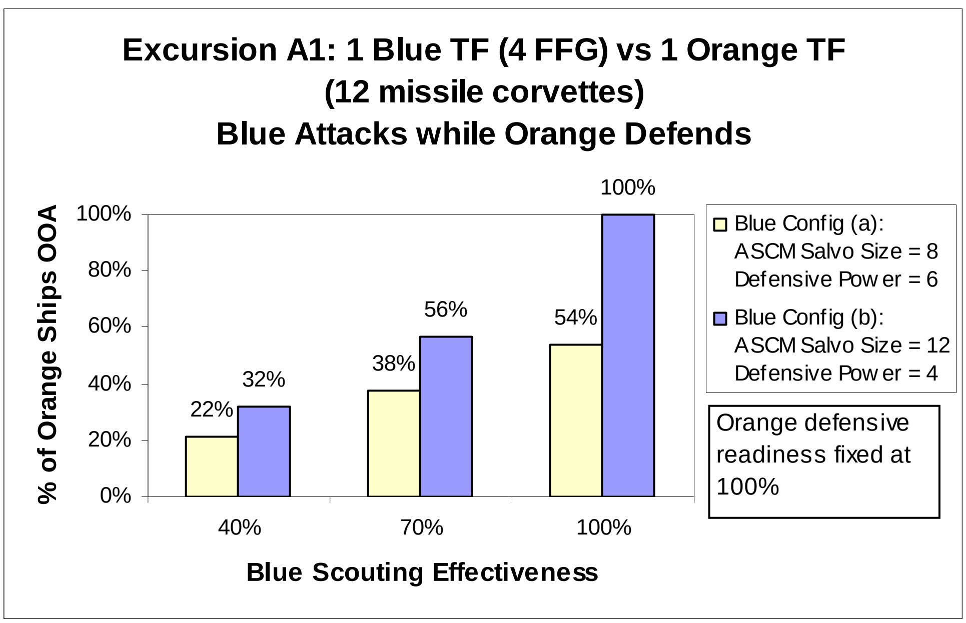
APPENDIX B: BAR CHARTS OF QUANTITATIVE RESULTS IN CHAPTER IV

This appendix provides bar charts of the quantitative results for all excursions presented in Chapter IV. For excursions in which the scouting effectiveness of either the Blue or Orange force is varied, only the bar charts for scouting effectiveness levels of 40%, 70%, and 100% are presented. This makes the charts less cluttered and more readable while still retaining the key information.

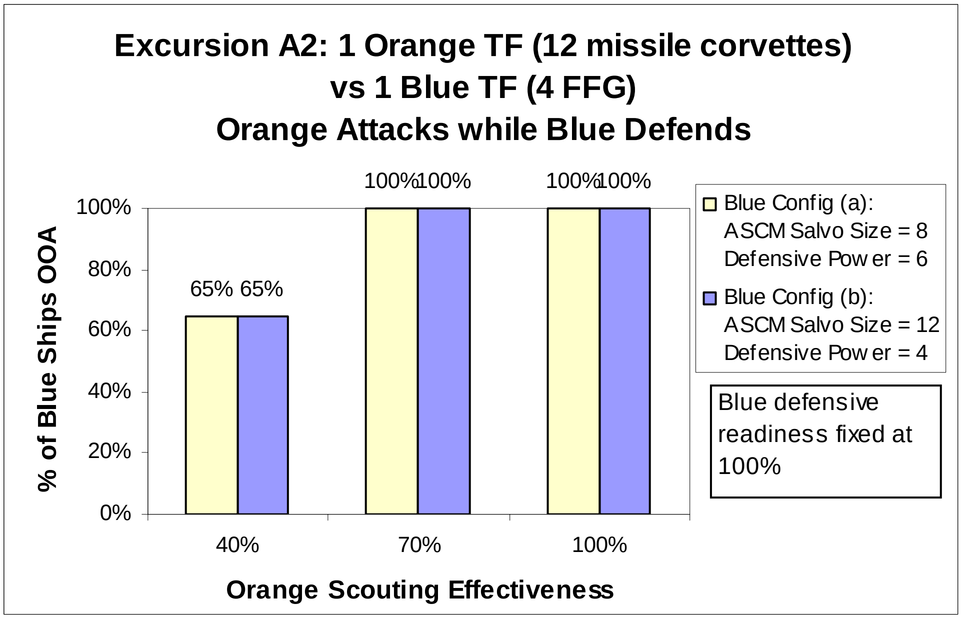
A. BAR CHARTS OF EXCURSION A RESULTS

Figure 2. Bar Chart of Excursion A1 Results



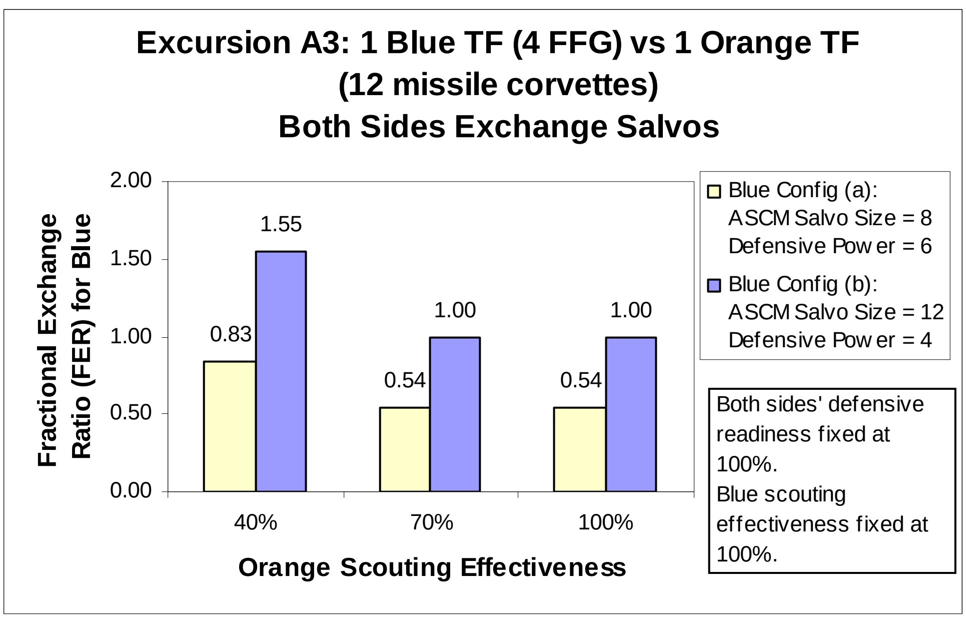
Values in bar chart are rounded to nearest percent.

Figure 3. Bar Chart of Excursion A2 Results



Values in bar chart are rounded to nearest percent.

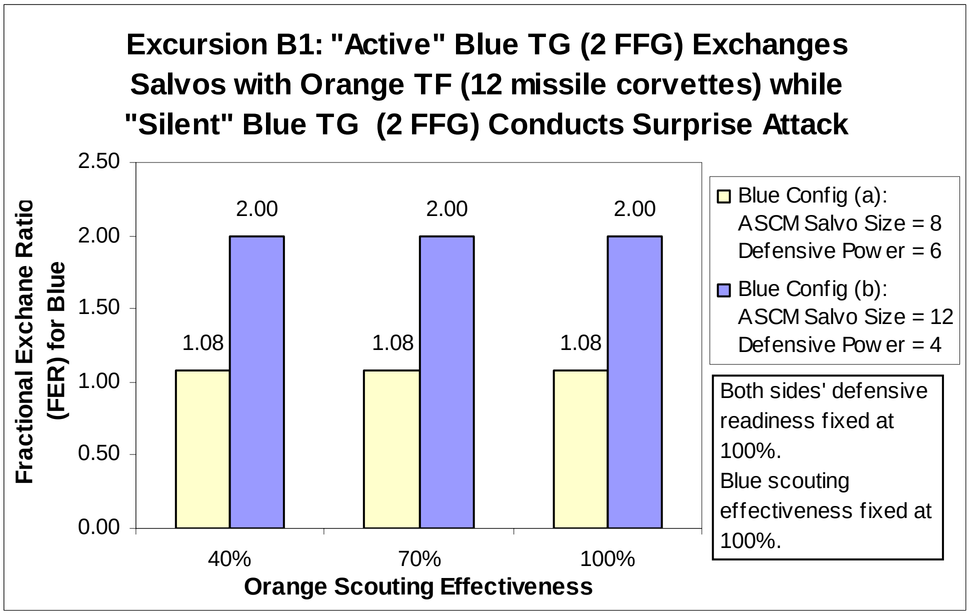
Figure 4. Bar Chart of Excursion A3 Results



Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

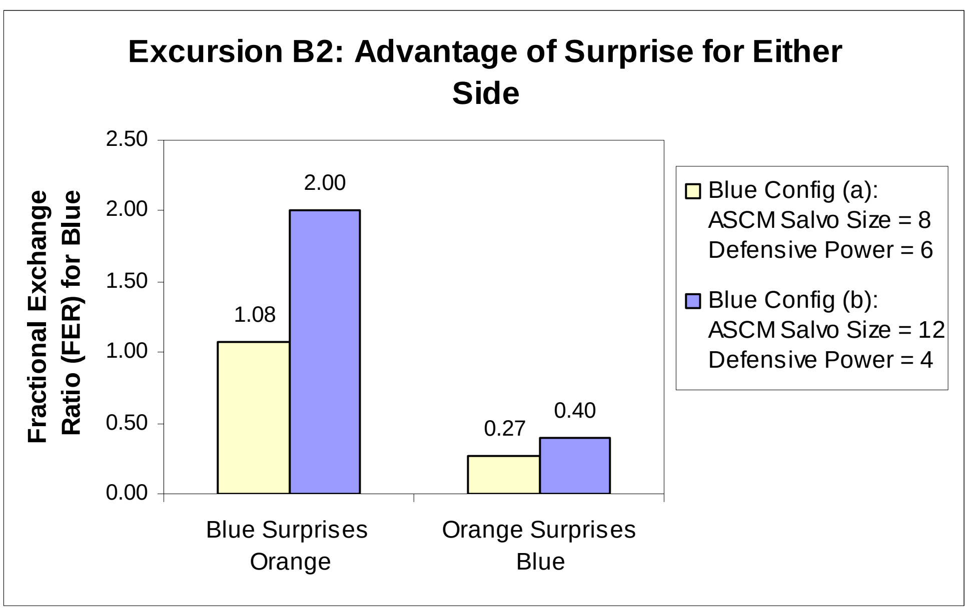
B. BAR CHARTS OF EXCURSION B RESULTS

Figure 5. Bar Chart of Excursion B1 Results



Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

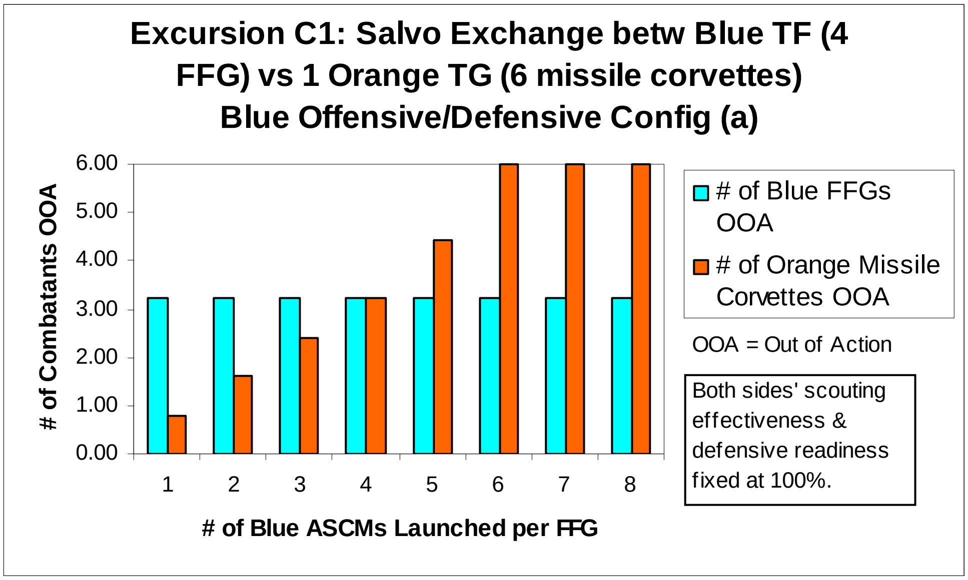
Figure 6. Bar Chart of Excursion B2 Results



Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

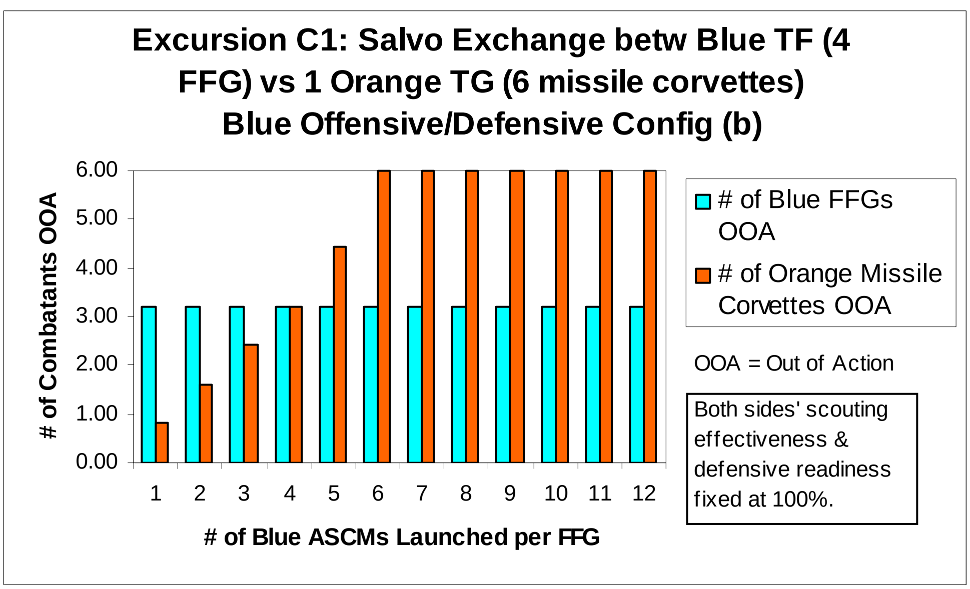
C. BAR CHARTS OF EXCURSION C RESULTS

Figure 7. Bar Chart of Excursion C1 Results for Blue Offensive/Defensive Configuration (a)



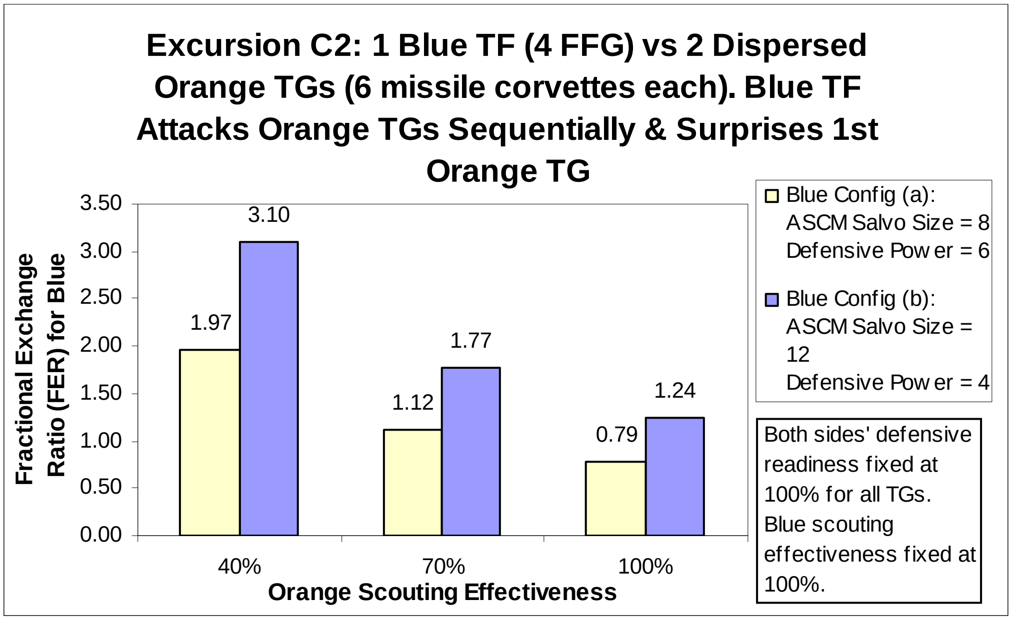
Blue Offensive/Defensive Configuration (a): ASCM Salvo Size = 8; Defensive Power = 6

Figure 8. Bar Chart of Excursion C1 Results for Blue Offensive/Defensive Configuration (b)



Blue Offensive/Defensive Configuration (b): ASCM Salvo Size = 12; Defensive Power = 4

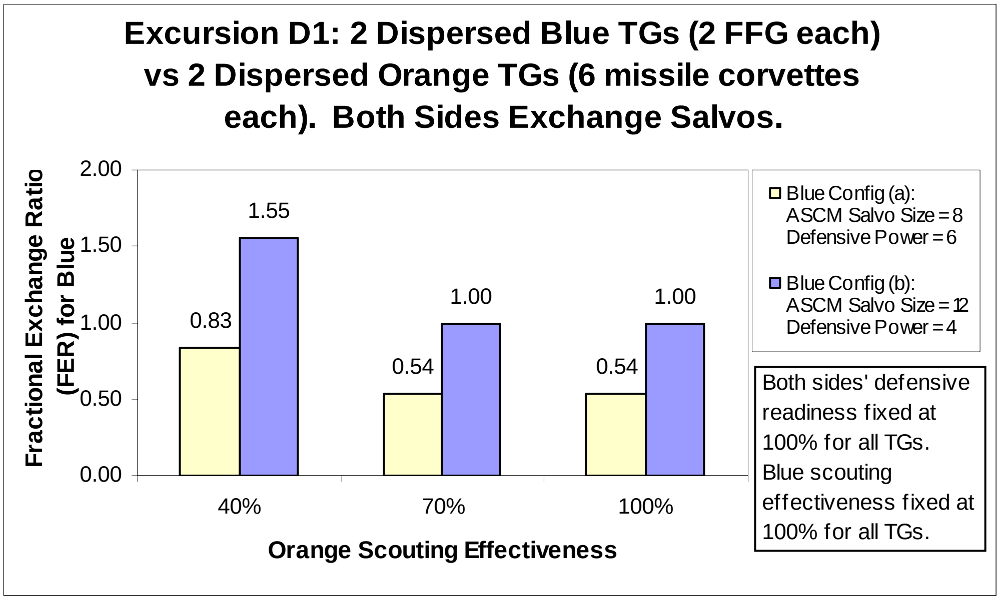
Figure 9. Bar Chart of Excursion C2 Results



Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

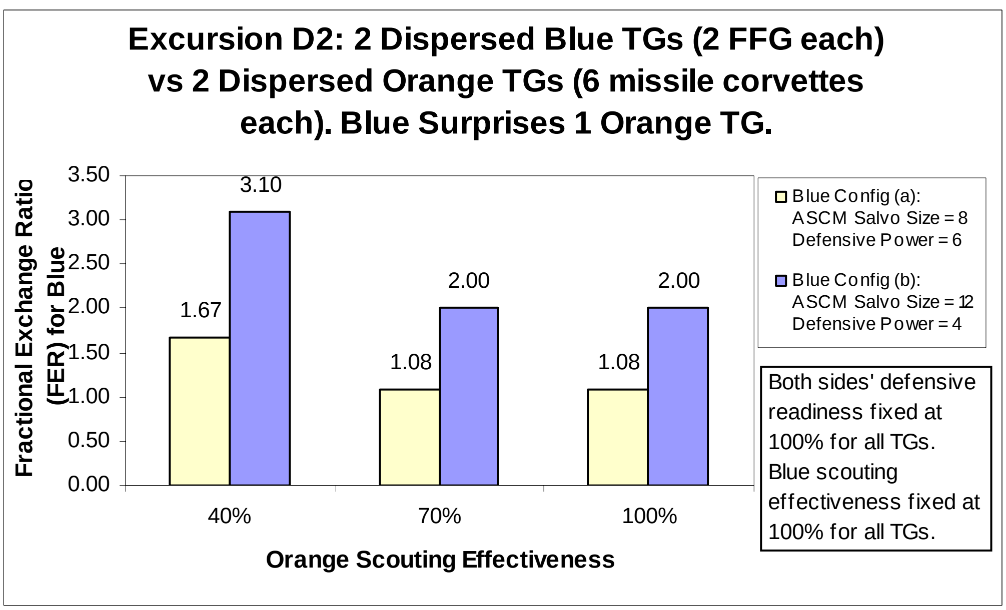
D BAR CHARTS OF EXCURSION D RESULTS

Figure 10. Bar Chart of Excursion D1 Results



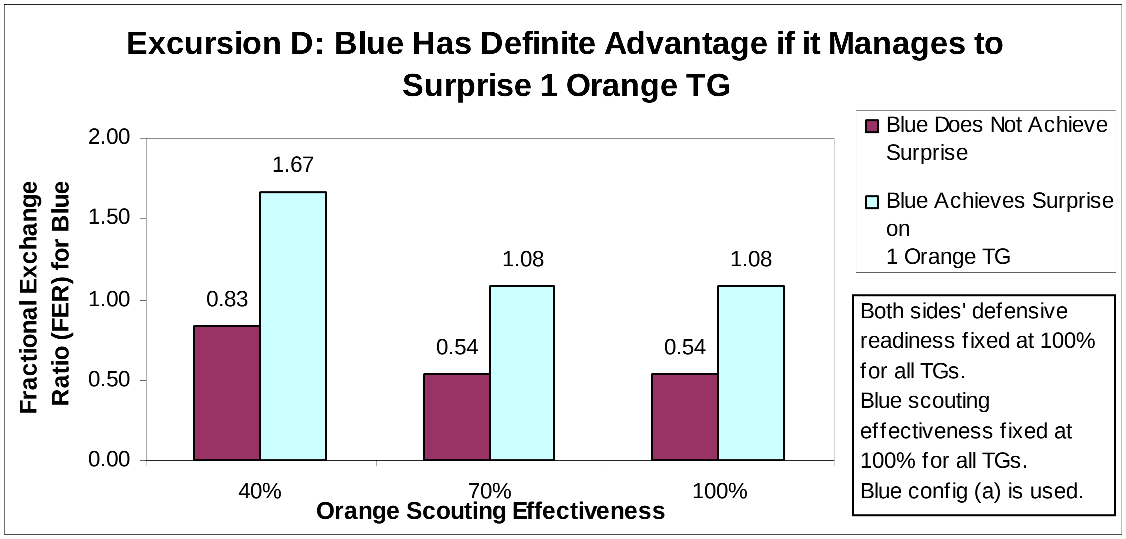
Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

Figure 11. Bar Chart of Excursion D2 Results



Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

Figure 12. Bar Chart to Show Advantage for Blue if it Manages to Surprise 1 Orange TG in Excursion D



Blue wins if FER>1 and achieves parity if FER=1, else Blue loses.

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