3-2001

The Effects of Budgetary Constraints, Multiple Strategy Selection, and Rationality on Equilibrium Attainment in an Information Warfare Simulation

Steven W. Tait

THE EFFECTS OF BUDGETARY CONSTRAINTS, MULTIPLE STRATEGY SELECTION, AND RATIONALITY ON EQUILIBRIUM ATTAINMENT IN AN INFORMATION WARFARE SIMULATION

THESIS

Steven W. Tait, 1st Lieutenant, USAF

AFIT/GIR/ENV/01M-13

DEPARTMENT OF THE AIR FORCE
AIR UNIVERSITY

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

AFIT/GIR/ENV/01M-13

THE EFFECTS OF BUDGETARY CONSTRAINTS, MULTIPLE STRATEGY SELECTION, AND RATIONALITY ON EQUILIBRIUM ATTAINMENT IN AN INFORMATION WARFARE SIMULATION

THESIS

Presented to the Faculty of the

Department of Systems and Engineering Management

Graduate School of Engineering and Management

Air Force Institute of Technology

Air University

Air Education and Training Command

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Information Resource Management

Steven W. Tait, B.S.

1st Lieutenant, USAF

March 2001

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

AFIT/GIR/ENV/01M-13

THE EFFECTS OF BUDGETARY CONSTRAINTS, MULTIPLE STRATEGY SELECTION, AND RATIONALITY ON EQUILIBRIUM ATTAINMENT IN AN INFORMATION WARFARE SIMULATION

Steven W. Tait, B.S.
1st Lieutenant, USAF

Approved:

David P. Biros
Maj. David P. Biros (Chairman)

6 Mar 01
date

James M. Norris
Col. James M. Norris (Member)

6 Mar 01
date

Alan R. Heminger
Dr. Alan R. Heminger (Member)

6 Mar 01
date

Acknowledgments

I would like to express my sincere appreciation to all those who have supported me throughout this study, including my thesis committee members and my fellow classmates. In particular, I would like to thank my advisor, Major David P. Biros, who suggested the need for additional research on using game theory to model information warfare and who guided me through the thesis process. I would also like to express my profound gratitude to Captain David Burke, who created the information warfare model that I had the opportunity to expand on. In addition, I would like to thank Captain Burke for allowing me to alter and use the original software he developed to test the information warfare model.

Most of all I would like to thank my wife for her love and support. Throughout my studies, my career, and our lives together, she has continuously supported my efforts, whatever they be. Her belief in me has given me the inspiration to achieve ever-higher goals that I had previously thought to be beyond my reach.

Steven W. Tait

Table of Contents

Page

Page

List of Figures

List of Tables

AFIT/GIR/ENV/01M-13

Abstract

Information warfare (IW) has developed into a significant threat to the national security of the United States. Our critical infrastructures are linked together by information systems in a way that is unprecedented in time and is increasingly vulnerable to information attack. However, beneath all the technical means of instigating or defending against such an attack lies the individual decision-maker. This study seeks to understand sum of those factors which affect the ability of an individual to make accurate decisions in an information warfare environment.

The study used game theory to analyze the behavior of decision-makers within an IW simulation. The information warfare game model is based on a set of games known as infinitely repeated games of incomplete information. It uses the Bayesian Nash equilibrium concept to determine the strategy which a player should use repeatedly in order to maximize his or her payoff.

The results of the experiment show that when a person is faced with increasing numbers of potential strategies, he or she is less likely to make an accurate decision. The results also show that decision-makers that are faced with budgetary constraints and forced to pay for alternative strategies tend to pick those strategies which are most expensive. This is regardless of the actual utility of the strategy as long as it is within the decision-makers' allotted budget. Additionally, the study found that the rationality of the decisions made by an opponent did not significantly affect a player's ability to find the strategy that maximizes his or her own payoff.

THE EFFECTS OF BUDGETARY CONSTRAINTS, MULTIPLE STRATEGY SELECTION, AND RATIONALITY ON EQUILIBRIUM ATTAINMENT IN AN INFORMATION WARFARE SIMULATION

I. Introduction

Problem Statement

The United States and the U.S. military are highly dependent on their information systems. The President's Commission on Critical Infrastructure Protection (1997) found eight critical U.S. infrastructures which if attacked could result in serious harm to the United States. These infrastructures include telecommunications, transportation, electrical power systems, water supply systems, gas and oil storage and transportation, emergency services, banking and finance, and continuity of government services. Because of the interlinked nature of these information systems, they are increasingly vulnerable to information attack by malicious hackers, terrorist groups, rogue nations, and traditional adversaries (Robinson, 98).

The vulnerability of military information systems has been demonstrated on at least two separate occasions. The first occurred in 1997 when the National Security Agency (NSA) conducted a red team exercise called "Eligible Receiver" (Denning, 1999: 75). The NSA concluded that during the exercise, red team hackers were able to penetrate military information systems to a point where they could have disrupted and delayed troop movements. The second demonstration came in 1999 at the outbreak of

North Atlantic Treaty Organization (NATO) operations against Serbia. According to Rapaport (1999), Serbian hackers launched a cyber attack against a NATO web server which managed to paralyze one of NATO's Sun Sparc 20 servers. Though the attack was militarily insignificant, the Serbian attack as well as other incidents do underscore the need for a method to analyze information warfare (IW) attacks and the decisions made by those involved.

Theory

Burke (1999) proposed game theory as a means to model information warfare in order to analyze the most common strategies used in IW as well as the human behavior affecting those strategies. Burke created an information warfare game model based on the Nash and Bayesian equilibrium concepts to predict behavior and analyze the decisions made in conducting information warfare. The goal of those playing the game is to maximize their utility. A player achieves this by discovering and repeatedly playing the one strategy or combination of strategies that maximizes his or her expected payoff. The utility of the game theory model is based on the ability to measure the player's level of equilibrium attainment. If the game model is unable to measure the player's or the majority of the players' attainment of equilibrium, then the game model is of little use for predicting human behavior. This study seeks to further Burke's research with the goal of refining the equilibrium calculations in order to better predict human behavior. It also seeks to make enhancements to the game model to better reflect the environment in which information operations are conducted.

Research Questions

The objective of this study is to develop enhancements to the IW Game Model developed by Burke (1999) and thereby improve its ability to predict human behavior. This is accomplished by making four changes to the game model that not only enhance the model but also suggest new issues for study. The changes include: 1) adding budgetary constraints, 2) allowing multiple strategy selection, 3) adding rational vs. irrational opponent play, and 4) making changes to the equilibrium calculations.

Research Question 1: Do budgetary constraints placed on a player affect his or her ability to find and use an equilibrium strategy? Hardly any organization exists without budgetary constraints. This is true of any organization conducting information attack or defense, including the Department of Defense and its adversaries. Rarely does a decision-maker have all of the resources wanted or required to find and implement the ideal strategy as quickly as desired.

Research Question 2: Does the ability to implement more than one strategy at a time affect the player's ability to find and use an equilibrium strategy? In reality, many strategies are often studied for implementation. Often, one strategy alone is found to be lacking and consequently a combination of different strategies is implemented (Cohen, 1999). Furthermore, the implementation is usually parallel rather then sequential. For this reason, the game model should allow players to implement any combination of strategies at once instead of in sequential turns. Further, an additional strategy available to a player may be to choose to implement no strategy if he is low on funds.

Research Question 3: Is a player who faces a rational opponent more or less likely to discover and play the equilibrium strategy than a player who faces an irrational opponent? It is not guaranteed that all individuals or organizations wishing to conduct information warfare will act in a rational manner. In fact, it could be argued that terrorist organizations such as those that commit suicide bombings are irrational by nature. This study addresses this limitation by controlling the rationality of the subject's opponent.

Research Question 4: Does calculating equilibrium as a percentage of total game play provide a better measurement of equilibrium attainment than calculating the number of rounds to reach equilibrium (NORRE)? The original equilibrium calculation by Burke (1999) estimated a player's ability to find and play the equilibrium strategy by determining at which round of game play the decision-maker started to play only the equilibrium strategy. This provided the number of rounds to reach equilibrium and was the primary measurement for the model. The NORRE calculation will still be performed; however, it will only serve as additional information and comparison. It will not serve as the primary measure of equilibrium attainment.

Research Design

The research was conducted using a within-subjects and between-subjects analysis of variance (ANOVA) research design, which used a complete 2 x 2 x 2 factorial experiment. The experiment consisted of a pretest-posttest control group design (true experiment), as defined by Dooley (1999). It included 8 treatment groups comprising all the possible combinations of factors.

Assumptions and Limitations

Although the experiment controls the rationality of a player's opponent, this model assumes that all the subjects (defenders) in the experiment are rational. That is, they will act in a rational manner to maximize their expected payoff. This is also a possible limitation of the study because it does not guarantee that all subjects will play in a rational manner.

The maximization of expected payoffs is further complicated by the fact that not all payoffs are of a monetary nature as depicted in the model. Therefore, the model assumes that the monetary payoff includes any and all benefits a player receives for his actions. This includes but is not limited to actual monetary gains, political gains, and personal prestige and satisfaction.

Applicability

Warfare of any kind is ultimately a social endeavor. Though we spend billions of dollars building technological wonders, the decisions of which ones to build, as well as where, how and when to use them, rest with human beings. General George S. Patton knew that part of success in battle is dependent upon knowing your enemy and the reasons why he or she makes his or her decisions. This is why General Patton regularly studied the actions of great military leaders, including those of his enemy Field Marshal Erwin Rommel (Essame: 1974). By studying Rommel's book <u>Infantry Attacks</u>, General Patton could predict and account for the decisions that Rommel or any other skilled tactician would be likely to make (Allen: 1979). As in traditional battle, knowing how and why humans make the decisions they make is crucial to the information warrior.

This study furthers prior research in the field by showing yet another way which game theory can be used to study human behavior. It focuses on budgetary constraints, multiple strategy selection, and opponent rationality as they pertain to three specific strategies. This, however, is not the extent of applicability. The model can easily be adapted to a wide variety of strategies or levels of conflict. For example, instead of defending single organizational systems, the model could seek to study overall strategies taken by the United States to defend our national information infrastructure against other nation states or terrorist organizations by studying their possible strategies and predicted behaviors.

Preview

Chapter II presents a general description of both game theory, as applied to the IW game model, and strategies available to information warfare and their supporting literature. The section on game theory includes a detailed description of the formulas used to calculate success probabilities and expected payoffs in a multiple strategy selection environment. Chapter III describes the methodology used to conduct and analyze the experiment. Chapter IV provides the analysis of the experiment. Chapter V discusses the results as well as their significance and provides recommendations for future research. As a prelude to discussing the nature of game theory and the information warfare game model the next chapter starts with a brief introduction to relevant strategies within the information warfare field.

II. Literature Review

Introduction

This chapter is broken into four main sections. The first section provides a basic overview of information warfare strategies and operations. The second section provides an overview of game theory and how it has been used in the past to predict human behavior. The third section provides an explanation of the information warfare game model and basic game theory concepts as applied to the model. The final section describes enhancements to the game model and their associated hypotheses based on the research questions posed in Chapter I.

Information Warfare

As noted in Chapter I, the information warfare game model can be used to analyze a multitude of differing IW threats and strategies at differing levels. Various authors such as Denning (1999), White (1998), Schwartau (2000), and Cohen (2000) have described these threats in a multitude of ways. This section describes those threats as well as proposed counter strategies for the information security professional seeking to defend his or her system.

Denning (1999) describes IW threats in terms of operations, which affect the value of the resource attacked. After an attack is made, a resource has the possibility to either gain or lose value to the defender as well as the possibility to gain in value to the attacker. According to Denning, a number of different operations cause this change in value. Although presented below with their most likely outcome, it is important to note that the operations are not mutually exclusive. Each operation does have the potential to cause more than one outcome to occur dependent upon its application.

The first outcome possible is an increase in availability of the information resource to the offensive player. According to Denning (1999: 32-33), there are five different types of operations that attain this outcome including "espionage and intelligence operations", "information piracy", "penetration into physical premises and computer systems", "superimposition fraud", and "identity theft." In all cases, the attacker gains use of the defenders resources. However, this does not necessarily mean that the defender loses use of his or her resources, as is the case in the next scenario.

Denning's (1999: 34) second outcome of an information attack involves the decrease in availability of a resource to the defensive player. This type of attack is commonly known as a denial of service attack and takes the form of three types of operations, "physical theft, sabotage, and censorship." This type of attack may or may not result in the attacker gaining use of the resource.

The third type of possible outcome described by Denning results in a decrease in the integrity of the resource. This includes "tampering, penetration and fabrication" operations. The goal of this type of operation is to manipulate the information in the system without the knowledge of the user. This creates the possibility of the user making erroneous decisions based on bad information.

White (1998: 7-8) has a similar view on threats to information security, which can be closely matched to Denning's "outcomes". White characterizes IW threats in terms of objectives of the "cyber-terrorist". White's objectives include the "destruction, alteration, or acquisition and retransmission of data/commands." These objectives are attained by using a myriad of different electronic tools (virus, worm, logic bomb, bot), extortion, or social engineering. However, as shown by the next author these same tools can be used in information attacks at a number of different levels.

Schwartau (2000: 3) explains these levels in a slightly different view of the classification of IW threats. He breaks information operations and the threats that they present into three classes based on their intensity. Schwartau defines Class I as operations aimed at individuals, such as identity theft or blackmail. Class II is defined as industrial and economic espionage, which includes operations such as electronic eavesdropping, hacking, and sniffing. Class III is defined as operations conducted by nation states or against nation states. This would include attacks against our national information infrastructure by an individual hacker, a terrorist group, or a nation state.

In written testimony before the Joint Economic Committee of the U.S. Congress, Cohen (2000) stated that the risks to our information systems come from a "combination of threats, vulnerabilities, and consequences." Much like the "outcomes" of Denning (1999) and the "objectives" of White (1998), Cohen (2000) breaks IW threats into possible "consequences" of an information attack. These consequences include affecting the confidentiality, the availability, and the integrity of information systems.

Given that these three factors correspond well to those of Denning and White, they will serve as the basis for the information warfare game model. Therefore, attackers and defenders playing the IW game will be able to perform operations to affect the integrity, availability, or confidentiality of the information system and are defined as follows:

1. **Integrity Operations**: The goal of this strategy is often to effect the operations of the system without the knowledge of the user. This strategy involves operations that penetrate the information systems, tamper with the systems, and fabricate and / or modify data within the systems.

2. **Availability Operations:** This type of operation is commonly known as a denial of service attack. It differs from an integrity attack in that it overtly halts operations instead of controlling the output of operations (Cohen 2000). The attacker is not concerned with forcing the user to make erroneous decisions based on bad data but to ensure that the user get no use out of the system at all. It takes the form of three types of operations: physical theft of hardware, sabotage either physically or logically, and censorship.

3. **Confidentiality Operations**: The goal of a confidentiality operation is to gather sensitive information. Five different types of operations attain this outcome including: espionage and intelligence operations, information piracy, penetration into physical premises and computer systems, identity theft, and superimposition fraud (use of a stolen identity to charge goods or services).

Now that the strategies or courses of action are broken down into their basic parts and defined, they can flow directly into the information warfare game model. As shown in the following sections, game theory is a method of mathematically modeling complex social interactions. It allows a player to implement the strategies defined above in order to maximize his or her expected payoff and in so doing reveal the reasons surrounding their decision process.

Game Theory Overview

First developed by Von Neuman and Morgenstern (1944), game theory was originally designed to model economic activities. It involves two or more players determining courses of action based on a set of strategies, each with its own payoff function. Each player must base his decisions on his beliefs about the other player's intentions (Harsanyi, 1995). The overall goal of the game is for each player to choose strategies, which maximize his or her expected utility. That is to say, that each player wants to receive the most beneficial payoff at the end of each round that he or she can.

Since its inception, game theory has evolved beyond its original purpose of modeling economic situations. Now game theory involves modeling complex interactions in a number of different disciplines including the political and social sciences (Lichbach 1990). Over the years, game theory proved to be an effective way to analyze the decisions people make, and to determine the factors that influence those decisions.

There has been considerable work done using game theory to analyze complex negotiations. Aumann and Maschler (1995) showed how game theory was used to model nuclear disarmament negotiation between the United States and the Soviet Union. Like information warfare, the negotiations were games of incomplete information where one side never really new the underlying objectives of the other. Zeager and Bascom (1997) developed a game model to analyze the negotiations between the United Nations High Commission for Refugees and nation states for the repatriation of refugees to the countries of origin.

Game theory has also been used to analyze situations of conflict. Leathom (1971) used non-zero sum games to model air combat situations. In another study, Healy and Wantchekon (1999) created a two-sided incomplete information game to determine the factors that would lead a nation state to use torture as a method to extract information or to control the society. Most recently, however, and as described in the next section Burke (1999) showed that a number of factors within the realm of game theory lend themselves nicely to the modeling of information warfare.

Information Warfare Game Model

Now that a basic idea of game theory and its prior uses have been provided, this section describes how game theory is implemented within the information warfare game model. This research will not focus on an all-encompassing overview of game theory or proofs of its theorems. This has already been provided by a myriad of other authors such as Gibbons (1997), Aumann and Maschler (1995), and is beyond the scope of this study. Instead, this section will focus only on those aspects of game theory that apply specifically to this study's focus and as they pertain to the information warfare model.

Based on Nash and Bayesian equilibrium, the information warfare game model developed by Burke (1999) is part of a class of games known as infinitely repeated games of incomplete information. This type of game lends itself nicely to the study of information warfare for a number of reasons, which will become evident as the model is discussed throughout this chapter. At this point, however, the concepts of infinitely repeated games and incomplete information must be related to the study of IW.

"Infinitely repeated" refers to the fact that neither player knows when the game will end. Round after round is played with each player either winning or losing, and gaining his or her respective payoff. In this scenario, the player must make his or her decisions based on the strategy, which will provide the best average payoff over time. This is similar to information warfare where the defender cannot hope to successfully protect 100 percent of his information 100 percent of the time. The defender must choose a strategy, which best protects his or her information over time, dependent upon what kind of information is most important to the defender.

Repeat play allows a player to change strategies on subsequent moves based on the information he or she learned from the outcome of the previous move (Carlton and Perloff, 1999: 175). This is similar to any form of conflict and certainly of information warfare. As time goes by and actions are taken, a player will form perceptions about his opponent and his overall goals. As more information is gathered and processed, these perceptions could be refined and honed causing a change in strategy based on the new information.

Incomplete information refers to the fact that each player knows some or all of the information about himself but not his opponent. In the case of the IW game model, a player knows his or her own payoff value but not that of his or her opponent. This shows the asymmetric nature of information warfare in that we often know the defenses as well as the value of the information we are protecting. However, we rarely know all the strategies available to our opponent or the value of the information to him, which could be different than the value to ourselves (Denning: 1999, Schwartau 2000).

Bayesian Nash Equilibrium

The information warfare model relies on what is known as a Bayesian Nash equilibrium. The calculation for this equilibrium and thus the strategy the player should choose is shown in a later section. For now, it is enough to know that a Nash equilibrium exists if; holding all other strategies constant, no player can obtain a higher payoff (profit) by choosing a different strategy (Gibbons: 1997). This means that for every set of strategies, there is either a single strategy or a mix of strategies that the player should choose every time to maximize his or her payoff. This is known as the dominant strategy as opposed to the other, weaker strategies. The weaker strategies are said to be dominated by the dominant strategy.

A Bayesian Nash equilibrium is a pair of strategies such that each player's strategy is a best response to the other player's strategy. However, this is confounded by the Bayesian equilibrium concept if the player does not know the payoff function of his opponent. The Bayesian concept says that if a player is operating under incomplete information and does not know the payoff function of his or her opponent, then the player must rely on his or her beliefs about the type of opponent he or she is facing and on his associated payoff functions (Gibbons: 1997). These beliefs may or may not be true and have the possibility of changing over time.

The actual equilibrium strategy that a player should employ is based on a mathematical calculation. The calculation is based on a number of factors, which take into account concepts such as actual payoff, success probability, and expected payoff. All of these concepts, along with others, are explained in the next section on game elements.

Game Elements

The information warfare game model consists of four main elements, which include the players, the payoffs, information, and the strategies available to the players. Each of these elements was touched on above. This section, however, will seek to explain each in more detail as they apply to the model

Every game must have a set of players and the IW game model is no exception. The players represent the decision-makers of the game. In theory, an infinite number of players could participate in a game (Shubic, 1982: 26); however, most games have a specific set of players. In the case of the IW model, the set of players equals two and consists of the attacker and the defender. At each player's disposal there are a number of resources to draw upon (funds, strategies, manpower, etc.). Normally, the player is also assumed to be a rational player and will seek to maximize his or her expected payoff.

However, for the purposes of this study's research objectives, the attacker's rationality was controlled by the experimenter.

Strategies are courses of action or moves that are available to a player. The IW game model consists of three strategies available to the attacker. They include attacking the systems integrity, the systems confidentiality, and the systems availability. The defender has three strategies as well. They include actions to defend the systems integrity, the systems confidentiality, and the systems availability. The strategies themselves are symmetrical to the attacker strategies; however, the actions taken to implement the strategies can be quite different.

Von Neumann and Morgenstern (1944: 79) point out that a strategy is different from making a decision at every point in the game. A strategy exists when a player makes a decision beforehand about his or her actions given all possible contingencies. This does not mean that a player is confined to a single strategy, just that he has predetermined how his actions will change when given more information.

The normal form of the IW model is depicted by a 4 x 4 matrix of strategies. This includes the three basic attack and defend strategies as well as an option to not implement any strategy. Since this option is always present in any information warfare environment, it must by available to the players even if it is unlikely to be used. The matrix, therefore, produces 16 possible outcomes depending on the strategy selected by each player.

Based on Nash equilibrium, both the attacker and the defender have an optimum or dominant strategy (calculation shown later) to choose in order to maximize their expected payoffs. This can be a pure strategy where the player would choose one strategy every time or it could be a mixed strategy where the player picks between two or more strategies based on a probability distribution. For example, the attacker could choose to attack the system integrity 35% of the time and attack the system availability 65% of the time.

A player's payoff refers to the state of affairs after each player has chosen and implemented a strategy. The value of the payoff is indicated by the intersection of the strategy matrix (Shubik, 1982: 70). The payoff for each player in the IW game model is of a monetary nature and it is assumed that it represents all monetary or non-monetary gains or losses that a player receives for his or her actions. Table 1 shows an example payoff matrix for an IW game. The top values at each intersection represent the defender's payoff while the bottom value represents the attacker's payoff. The attacker values are shaded for clarity. Each value is the actual value a player receives on the completion of one turn. For the purpose of this study, the values represent millions of U.S. Dollars.

Table 1. Actual Player Payoff

		Defensive Strategies			
		Integrity	Availability	Confidentiality	None
Attacker Strategies	Integrity	-50	-50	-50	-50
		70	70	70	70
	Availability	-35	-35	-35	-35
		40	40	40	40
	Confidentiality	-75	-75	-75	-75
		50	50	50	50
	None	0	0	0	0
		0	0	0	0

In keeping with the asymmetrical nature of information warfare, the IW game model is a non-zero sum game. In other words, one player does not necessarily win the exact amount another player looses. For example, an organization (Player A) may have $50,000 worth of customer information stored in a database that is compromised by a hacker (Player B). Player B seeks no gain except the satisfaction of compromising the security. Player B's subsequent satisfaction and prestige may have a value of $500 while Player A's loss could be in the hundreds of thousands of dollars when news of the breach leaks and customers no longer trust the organization and go elsewhere.

Information is a key component of the IW game model. As stated earlier this is a game of incomplete information. Therefore, the player knows information about himself but only limited information about his opponent. This is the same as saying the player knows his type but not his opponent's. In a game of incomplete information, a player must rely on his or her beliefs about the type of player that he or she is opposing. This is the essence of Bayesian theory (Gibbons: 1997, Aumann and Maschler 1995).

In the IW game model, a player's type is defined by the value of pursuing a specific strategy to the player. For example, in the payoff matrix on the previous page, attacking the integrity of a system is of most value to the attacker, while defending the confidentiality of the system is of greatest value to the defender. Therefore, the attacker is of type "Integrity" while the defender is of type "Confidentiality". The importance of knowing ones type in an information warfare environment cannot be underestimated because knowing what is really important is key to being able to defend it.

It is important to note that at the beginning of a repeated game each player will know his or her own type but not the type of his opponent. This is the same as saying the player knows his own payoff function for a specific strategy but not his opponent's

(Gibbons, 1997: 136). However, as the game progresses each player will gather more information about his or her opponent and may deduce his or her type. Additionally, as shown in the next section, a player's type (e.g. integrity), although influential, does not automatically equate to being the player's equilibrium strategy.

Determining Expected Payoff

Until now the term payoff has been used rather generically. However, it is important to note the difference between a player's actual payoff and his expected payoff. Actual payoff refers to the actual gain or loss experienced by the player after the completion of one turn in a repeated game. One turn is defined as each player choosing and implementing a strategy simultaneously. Alternatively, a player's expected payoff in the IW game model takes into account the probability of a strategy succeeding (success probability) as well as the player's beliefs about the other player's type. The formulas used for calculating expected payoff are as follows:

Att. Expected Payoff = Success Probability * Actual Payoff

Def. Expected Payoff = [(Success Probability * Actual Loss) – Actual Loss * (-1)]

The defender's success probability is based on the percentage chance of his chosen strategy defending against the attacker's chosen strategy. The attacker's success probability is equal to 1 minus the defense success probability (see Table 2). Again, the defender's success probability is on top while the attackers is on the bottom.

Table 2. Success Probability Matrix

	Defender			
Attacker	Integrity	Availability	Confidentiality	None
Integrity	0.7	0.5	0.5	0.2
	0.3	0.5	0.5	0.8
Availability	0.5	0.6	0.5	0.2
	0.5	0.4	0.5	0.8
Confidentiality	0.5	0.5	0.7	0.2
	0.5	0.5	0.3	0.8
None	1	1	1	1
	0	0	0	0

Table 3 shows the expected payoff calculations based on the actual payoff and the success probability for Game II where each player is of type Integrity. The attacker's values are grayed for clarity. Note: the actual payoff, success probability, and expected

Table 3. Expected Payoff Table

	Defender											
Attacker	I			A			C			None		
	Success Prob.	Actual Payoff	Expect Payoff	Success Prob.	Actual Payoff	Expect Payoff	Success Prob.	Actual Payoff	Expect Payoff	Success Prob.	Actual Payoff	Expect Payoff
I	0.70	-70.00	-21.00	0.75	-70.00	-17.50	0.55	-70.00	-31.50	0.20	-70.00	-56.00
	0.30	70.00	21.00	0.25	70.00	17.50	0.45	70.00	31.50	0.80	70.00	56.00
A	0.50	-50.00	-25.00	0.40	-50.00	-30.00	0.60	-50.00	-20.00	0.20	-50.00	-40.00
	0.50	40.00	20.00	0.60	40.00	24.00	0.40	40.00	16.00	0.80	40.00	32.00
C	0.50	-25.00	-12.50	0.50	-25.00	-12.50	0.63	-25.00	-9.25	0.20	-25.00	-20.00
	0.50	55.00	27.50	0.50	55.00	27.50	0.37	55.00	20.35	0.80	55.00	44.00
None	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

payoff values used in this experiment for the basic game are the same as those developed and used by Burke for the sake of consistency and comparability. Later it is shown that the basic values can be extended to strategies for games in which players are allowed to select multiple strategies in a single turn. Now that the expected payoffs are known for each alternative outcome, it is possible to explain how expected payoffs are used to determine a player's equilibrium strategy.

Determining Equilibrium Strategy

A player's equilibrium strategy in any game of incomplete information is the strategy or set of strategies that is a best response to the opponent's strategy (Gibbons, 1997: 137). This, however, takes into account the player's beliefs about the other player's type. Determining each player's equilibrium is a two step process, which sets a probability distribution over the set of strategies. It is important to remember that determining the equilibrium strategy is based on the expected payoff instead of the actual payoff in order to account for the probability of the attack succeeding..

The first step to determine the equilibrium strategy is to eliminate dominated strategies from consideration. A dominated strategy is a strategy that is never a best response to any strategy played by the opponent. Because a dominated strategy has no chance of being played, it is given a value of zero in the probability distribution. This is not to say that a player can not choose the strategy but that he or she should not in order to maximize his or her utility.

Referring back to table 3 for Game II, the attacker's Availability strategy and the defender's Integrity strategy both have probability of zero because in each case it would be wiser to choose another strategy. For instance, if the attacker chose an Availability or Confidentiality strategy the defender loses less money based on expected payoff by using a Confidentiality strategy. If the attacker chooses an Integrity strategy the defender's best option is to choose an Availability strategy in order to lose the least amount if money. Likewise, it is never good for either player to choose no strategy so it is also given a value of zero.

The second step to determining the equilibrium strategy is to apply a probability distribution across the remaining strategies. This is done by solving the four equations below provided by Burke (1999: 32). In essence, what the equations does is set the sum probability of each player's remaining strategies equal to one. Then it determines how often each should be play based on the expected payoff of each strategy to both the attacker and the defender.

P(Att. I) + P(Att. C) = 1
P(Def. A) + P(Def. C) = 1
-17.5 * P(Att. I) – 12.5 * P(Att. C) = -31.5 *P(Att. I) – 9.25 * P(Att. C)
17.5 * P(Def. A) + 31.5 * P(Def. C) = -27.5 *P(Def. A) + 15.125 * P(Def. C)
Results:
Attacker: P(I) = 0.18, P(C) = 0.82
Defender: P(A) = 0.63, P(C) = 0.37

The preceding equations provide a mixed strategy profile where the attacker should choose an Integrity attack 18% of the time and a Confidentiality attack 82% of the time. The Defender, however, should choose an Availability defense 63% of the time while choosing a Confidentiality defense 37% of the time in order to maximize the expected payoff. Notice that even though both the defender and the attacker are of type Integrity, it is never beneficial for the defender to use integrity as a defense. The repeated nature of the game should allow a player to come to this realization over time.

Model Enhancements and Hypotheses

The preceding section described the basic elements of the IW game model, including the underlying game theoretic concepts. The following four sections describe enhancements made to the information warfare model. These enhancements fall directly out of the research questions discussed in Chapter I. They include: allowing a person to implement more the one strategy at a time, instituting budgetary constraints, controlling the rationality of the opposing player, and modifying the calculation to measure equilibrium attainment by the players. This section also states the hypotheses associated with the enhancements.

Multiple Strategy Selection

Decision-makers are rarely limited to implementing a single strategy. Often times, lack of complete information about threats can force a decision-maker to implement multiple strategies to ensure that all of his or her bases are covered. Even if complete information is known, a combination of strategies may be called for. Cohen (1999) views this approach as "combining the effectiveness of the different approaches to different degrees" so that a mix of strategies coexists over time. This can also be thought of as a layering of defensive strategies. In military terms, this is known as defense in depth or full dimensional protection (Turk and Hollingsworth: 1999; DOD: 2000).

At first glance, it may seem beneficial to always implement multiple strategies. This however, may not be the case for all situations. The benefits of selecting multiple strategies must always be weighed against loses that can occur by spreading resources to thinly. In trying to protect everything a player may leave his or her most valuable resources vulnerable degree that is unacceptable.

For the purposes of the IW game model, a combination of strategies can be thought of as a strategy in and of itself. In other words, each possible combination of the available strategies becomes its own strategy providing eight alternatives for the player to choose from. Previous studies have shown, that the number of alternatives available was significantly inversely related to the accuracy of decisions made (Malhotra: 1982, Best and Ursic:1987, Helgeson and Ursic: 1993). It is conceivable, therefore, that allowing a player to choose multiple strategies at one time will decrease that player's ability to identify and play the equilibrium strategy.

Hypothesis 1: Multiple strategy selection will decrease a player's ability to identify and play the equilibrium strategy and thus result in a lower equilibrium score.

The eight alternatives created by allowing multiple selection turn the original 4 x 4 matrix of strategy payoffs into a 8 x 8 matrix with 64 possible outcomes or strategy combinations as shown in Table 4. The payoffs for each combination of strategies are merely an average of the strategies utilized by the attacker. It must be remembered that the loss a defender realizes is dependent on the value of the information attacked by the attacker. If an attacker succeeds in a combination of Integrity and Availability attack, the defender loses the same amount whether he or she defends against that type of attack or chooses no strategy whatsoever.

Table 4. Actual Player Payoff for Multi-Strategy Game

	Defender							
Attacker	I	IA	IC	A	AC	C	IAC	None
I	-70.00 70.00	-70.00 70.00	-70.00 70.00	-70.00 70.00	-70.00 70.00	-70.00 70.00	-70.00 70.00	-70.00 70.00
IA	-60.00 55.00	-60.00 55.00	-60.00 55.00	-60.00 55.00	-60.00 55.00	-60.00 55.00	-60.00 55.00	-60.00 55.00
IC	-47.50 62.50	-47.50 62.50	-47.50 62.50	-47.50 62.50	-47.50 62.50	-47.50 62.50	-47.50 62.50	-47.50 62.50
A	-50.00 40.00	-50.00 40.00	-50.00 40.00	-50.00 40.00	-50.00 40.00	-50.00 40.00	-50.00 40.00	-50.00 40.00
AC	-37.50 47.50	-37.50 47.50	-37.50 47.50	-37.50 47.50	-37.50 47.50	-37.50 47.50	-37.50 47.50	-37.50 47.50
C	-25.00 55.00	-25.00 55.00	-25.00 55.00	-25.00 55.00	-25.00 55.00	-25.00 55.00	-25.00 55.00	-25.00 55.00
IAC	-48.33 55.00	-48.33 55.00	-48.33 55.00	-48.33 55.00	-48.33 55.00	-48.33 55.00	-48.33 55.00	-48.33 55.00
None	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00	0.00 0.00

Allowing a player to implement multiple strategies must also take into account the probability of success for using more than one strategy. The success probability of using two strategies is not necessarily the sum of the success probabilities of the individual strategies. As pointed out by Denning (1999: 37), strategies in information warfare are not "mutually exclusive" and many of the tools used fall into more than one category. This, however, does not mean that benefits to using more than one defensive strategy are non-existent. Indeed, many of the tools used could have a synergetic effect.

Table 5. Success Probability Matrix for Multi-Strategy Game

	Defender							
Attacker	I	IA	IC	A	AC	C	IAC	None
I	0.70	0.83	0.73	0.75	0.75	0.55	0.87	0.20
	0.30	0.18	0.28	0.25	0.25	0.45	0.13	0.80
IA	0.50	0.61	0.59	0.48	0.58	0.48	0.58	0.10
	0.50	0.39	0.41	0.53	0.43	0.53	0.42	0.90
IC	0.50	0.61	0.60	0.53	0.61	0.49	0.61	0.10
	0.50	0.39	0.41	0.48	0.39	0.51	0.40	0.90
A	0.50	0.55	0.65	0.40	0.60	0.60	0.70	0.20
	0.50	0.45	0.35	0.60	0.40	0.40	0.30	0.80
AC	0.40	0.48	0.56	0.35	0.53	0.52	0.52	0.10
	0.60	0.53	0.44	0.65	0.47	0.49	0.48	0.90
C	0.50	0.60	0.67	0.50	0.67	0.63	0.74	0.20
	0.50	0.40	0.34	0.50	0.34	0.37	0.26	0.80
IAC	0.37	0.46	0.48	0.35	0.47	0.39	0.57	0.10
	0.63	0.54	0.52	0.65	0.53	0.61	0.43	0.90
None	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

To account for synergistic effects of multiple strategies, when calculating the defender's success probability, the IW game model takes the average of the success probabilities for the chosen strategies and adds 10 percent for each additional strategy chosen above the number chosen by the attacker. Since the attacker's success probability is dependent on the defender, there is no change in the attacker's success probability formula. The success probability for the attacker remains one minus the success probability of the defender. The success probabilities for the multiple strategy selection version of Game II are shown in Table 5. It is important to note that combining strategies does not always insure a higher probability of success against any given attack.

Budgetary Constraints

Often times a decision-maker must take into account the monetary cost of differing strategies. Denning (1999: 37) points out that it is not always "cost effective – or even possible – to provide sufficient defenses to prevent all offensive operations and avoid all losses". A decision-maker, therefore, must decide where it is best to invest his or her limited resources.

Budget constraints have the potential to affect a decision-maker's choice, whether or not he or she has sufficient funds to cover all possibilities. For example, "you get what you pay for" is a term that is often associated with the linking of quality with price. It is feasible that a decision-maker could believe that a higher priced strategy will equate to a better defense or that a lower priced strategy will save the company money. Though this is possible, it is not necessarily the case. Either case could lead to a loss of value in the form of the value of stolen information or monetary costs.

Monetary constraints were operationalized in the IW model by providing the player with a monthly budget to be used on the purchase of IW strategies. Each strategy had a monetary cost associated with it, which was subtracted from the player's budget each time it was selected. For games in which multiple strategies could be selected on each turn, the cost was equal to the sum of the individual strategies. Though the player was working on a limited budget, care was taken to ensure that he or she had a sufficient amount to play the equilibrium strategy (i.e., Availability 63%, Confidentiality 37%). However, it is hypothesized that working on a budget will reduce a player's equilibrium attainment.

Hypothesis 2: Budgetary constraints will decrease a player's ability to identify and play the equilibrium strategy and thus result in a lower equilibrium score.

Opponent Rationality

Game theory generally assumes that all players will act rationally (Gibbons, Harsanyi, et al). That is to say that a player will always make decisions on the basis of maximizing his or her utility. Myerson (1992: 66) points out, however, that according to experimental evidence "axioms of consistency in decision making", which are the basis of rational utility maximization, are often violated in real life. In other words, this is not a perfect world and people do not always make decisions that maximize their utility.

The possibility of a player making decisions that are not of a rational nature poses an interesting question. How does facing an irrational or seemingly irrational opponent in the IW game model affect a player's ability to identify and play the equilibrium strategy? This situation can come up in one of two ways. Either the player's opponent is not of, what most people would call, a rational mind or the opponent's utility (or perceived utility) is so different from the player's that what is rational for the opponent is seemingly irrational to the player.

Hypothesis 3: Facing a seemingly irrational opponent will decrease a player's ability to identify and play the equilibrium strategy and thus result in a lower equilibrium score.

Information warfare is not devoid of these types of situations. Unlike traditional warfare, IW has the ability to totally mask the identity of the attacker and thus hamper the defender's ability to determine his or her overall objectives. Cronin contends that this "near unknowability of the attackers coupled with the nagging uncertainty as to his driving motivations" is one of the most critical aspects of information warfare (1999: 259). This view is seemingly supported by the former Commander of U.S. Space Command and current Vice Chairman of the Joint Chiefs of Staff, General Richard Myers. According to General Myers, one of the biggest problems facing the military when confronted with a cyber attack is determining the nature of the attacker. "Is it a nation-state? Is it a terrorist? Is it a hacker or someone out for a joyride on the Internet?" (Boyle, 2000) A rational decision for any one of these players may well be irrational for another as well as for the defender.

This study sought to account for the possibility of facing a seemingly irrational opponent by controlling his or her rationality. Unlike the original IW game model study, the subjects in this study played the computer, which acted as the opponent, instead of another subject. Half of the treatment groups played a rational opponent who played only equilibrium strategies based on their equilibrium percentage (i.e., Integrity attack 18% of the time and a Confidentiality attack 82%) while the other half played a seemingly irrational opponent who chose between all alternative strategies randomly.

Equilibrium Calculations

As pointed out by Burke (1999: 67), his original study was limited by the method used to calculate equilibrium play. This is because using the number of rounds to reach equilibrium (NORRE) calculation to measure equilibrium attainment among players has two inherent weaknesses. Those weaknesses along with a proposed solution is the focus of this section.

First, NORRE does not account for players who attain equilibrium play early on in the game but happen to play a non-equilibrium strategy late in the game in an attempt to throw off their opponent. For example, a player could realize the equilibrium strategy at Round 5 and play it until Round 35. At that point, he could decide to play a non-equilibrium strategy for a round or two in order to try to confuse his opponent. The formula would then determine that the player attained equilibrium at Round 35 instead of Round 5.

The second problem with the NORRE calculation is that the calculation does not account for differing levels of equilibrium strategies. For example, the equilibrium strategy may be to play strategy "A" 83 percent of the time and strategy "B" 17 percent of the time. The previous calculation only examines at which point the player stops playing anything but the equilibrium strategy. It does not take into consideration if the player played strategy "A" 40 percent of the time and strategy "B" 60 percent of the time.

This study proposes to calculate the equilibrium attainment measure by using a percentage instead of the raw number of rounds needed to reach equilibrium. In other words, equilibrium attainment will be measured as a percentage of total rounds played.

This can be calculated at any round of play or as a total for the entire game. The independent variables, therefore, can be measured by how close a player came to the ideal equilibrium percentages (e.g. strategy "A" 83%, Strategy "B" 17%). This change in calculation should create a more robust IW game model.

Hypothesis 4: Measuring equilibrium as a percentage of total rounds played (Percent Equilibrium Attainment) will result in a higher mean equilibrium score than calculating the number of rounds to reach equilibrium (NORRE).

Summary

This chapter sought to provide insight into the information warfare game model and the enhancements, which are the focus of this study. It provided a general overview of current strategies in IW as well as those used in the study. The chapter also provided an overview of game theory as it applies to the study. Finally, this chapter provided an explanation of the model enhancements as well as the stated hypotheses. The next chapter will explain the methodology used to test the stated hypotheses.

III. Methodology

Introduction

The preceding chapter explained the basic strategies within information warfare, described the information warfare game model, and provided model enhancements based on the stated research questions in Chapter I. This chapter will seek to explain the methodology used to test the hypotheses that were developed in Chapter II. It will do this by first describing the basic research design for the experiment. It will then show how and why subjects were selected for the experiment and placed in their treatment groups. Then the basic conduct of the experiment will be shown followed by a description of the experimental game software used. Finally, this chapter will end by presenting the statistical analysis that will be used to test the hypotheses in Chapter IV.

Research Design

As stated in Chapter I, this research was conducted using a within-subjects and between-subjects analysis of variance research design. The experiment consisted of a pretest-posttest control group design (true experiment) as defined by Dooley (1999) and included 8 treatment groups to form a complete 2 x 2 x 2 factorial experiment. The research design is depicted in figure 1 on the following page.

O X_1 O	Group 1
O X_2 O	Group 2
O X_3 O	Group 3
O X_4 O	Group 4
O X_5 O	Group 5
O X_6 O	Group 6
O X_7 O	Group 7
O X_8 O	Group 8

Figure 1. Research Design

The experiment involved two rounds of game play for each group. In the first round (pretest), all groups played without a budget, were limited to just one strategy per turn, and faced a rational opponent. This constitutes the baseline and is identical to treatment one in the posttest. The second round of play (posttest) consisted of each subject playing the game based on one of the eight treatments. The eight treatments are as follows with the control group being treatment number one.

Treatment 1: No Budget	Single Strategies	Rational Opponent
Treatment 2: No Budget	Single Strategies	Irrational Opponent
Treatment 3: No Budget	Multiple Strategies	Rational Opponent
Treatment 4: No Budget	Multiple Strategies	Irrational Opponent
Treatment 5: Budget	Single Strategies	Rational Opponent
Treatment 6: Budget	Single Strategies	Irrational Opponent

Treatment 7: Budget	Multiple Strategies	Rational Opponent
Treatment 8: Budget	Multiple Strategies	Irrational Opponent

Figure 2 provides a graphical depiction of the full model. The dependent variable in this experiment is the percentage of equilibrium attainment for a single player during a single game. The independent variables are whether a player has budgetary constraints, whether the player is allowed to play more than one strategy simultaneously, and whether the player is facing a rational opponent or an irrational opponent.

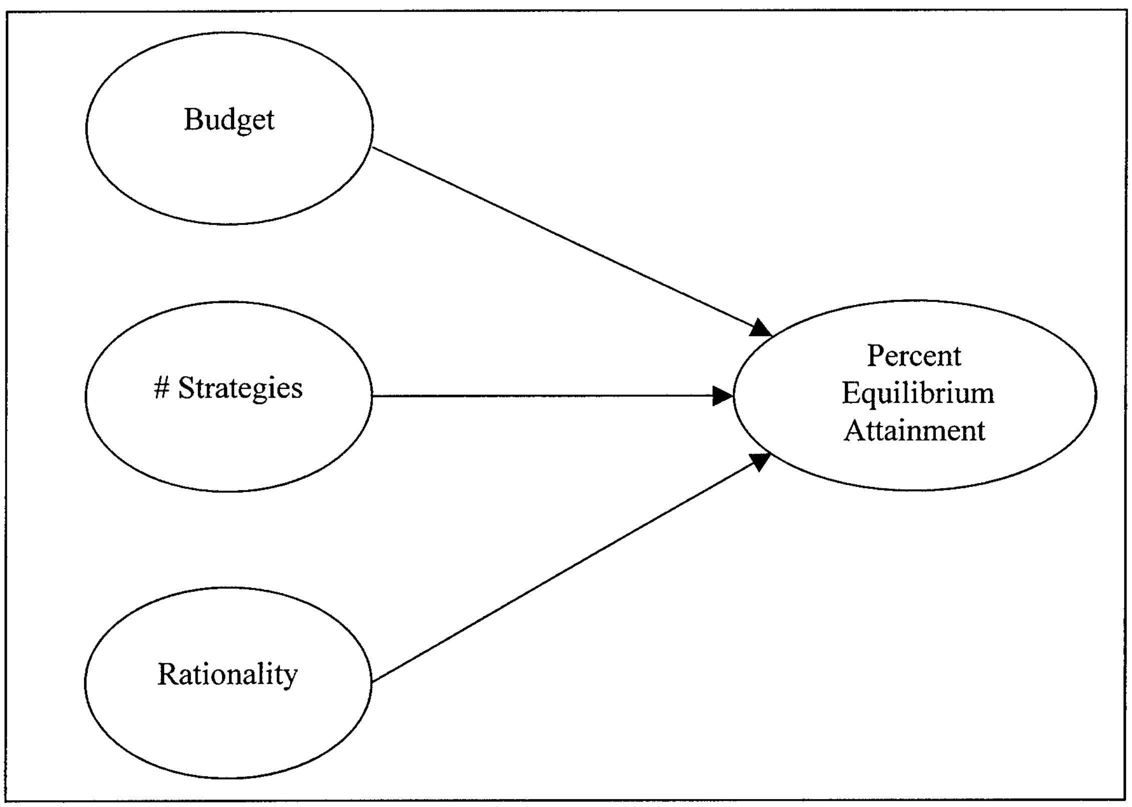


Figure 2. Effects of Independent Variables on Equilibrium Attainment

Subject Selection and Assignment

The population of interest for this experiment consisted of those individuals who currently are or that are likely in the future to make decisions regarding defensive information warfare policies. The sampling frame consisted of graduate students attending the Air Force Institute of Technology (AFIT). Results from the sampling frame can be generalized to the larger population due to two reasons. First, all the graduate students are professional military officers who have been in the field where they likely had to make similar decisions of utility maximization in the past. Second, graduate students at AFIT will return to operational and staff units where they will be expected to make or recommend such decisions.

The experiment was conducted During November and December of 2000. The sample size consisted of 80 volunteers from the sampling frame, playing two games each. The sampling size, which allowed for 10 people per treatment group, was based on recommendations for the design of controlled experiments by McClave, Benson, and Sincich (1998). The sampling size also allowed the experiment to achieve its desired power level of greater than 0.80.

Subjects were randomly assigned a subject number using the random numbers generator in Microsoft Excel. The subject number generated subsequently determined the treatment group in which the subject was placed. During each round of play, which is described in the next section, the subjects were assigned a role as a defender. The attacker in each round was played by the computer, allowing the experimenter to control the attacker's rationality.

The Experiment

The experiment consisted of two separate games being played. The first game (pretest) took place in early November 2000 and consisted of each subject playing the IW game with the same treatment (Treatment 1, control group treatment). The experiment was administered by e-mailing a link to the Information Warfare Game, which resided on a network drive at AFIT, to each of the subjects. The subjects were given simple instructions in the e-mail to click on the link and play the game.

To ensure uniformity among all players, the computer provided all game play instructions. To ensure that the subjects actually read and understood the instructions, each subject was given a short quiz before the start of play. A copy of the instructions provided to the players, the quiz and screen shots from the game can by found in appendixes A - E. Once a player reached the end of game play, the program thanked the subject for his or her efforts and automatically terminated.

The second game (post test) occurred approximately three weeks after the first round. This combined with the simplicity of the game should have been sufficient time to account for learning effects. The second round of game play was administered identical to the first. However, in this round each group played with the factors associated with their treatment groups. The control group (Treatment Group 1) played with the same factors as round one.

Both rounds consisted of playing a mixed strategy game. However, a different game was played in each round in an additional control for learning effects. Round one consisted of game II where both the attacker and the defender were of type Integrity. This equated to the equilibrium strategy for the attacker consisting of 18% Integrity and 82% Confidentiality. The defender's equilibrium strategy consisted of playing Availability 63% of the time and Confidentiality 37% of the time.

In round two, the subjects played game CI where the attacker was of type Integrity and the defender was of type Confidentiality. The equilibrium strategies for the attacker and defender varied depending on whether they could select multiple strategies or not. For single strategy selection games, the attacker's equilibrium strategy consisted of playing Integrity 58% of the time and Availability 42% of the time. The defender's equilibrium strategy included playing Integrity 86% of the time and Availability 14% of the time. In the multiple strategy games, the attacker's equilibrium strategy consisted of playing Integrity 19% of the time while playing a combination of Integrity, Availability, and Confidentiality 81% of the time. The defender should have played Integrity 52% of the time while playing a combination of Integrity, Availability, and Confidentiality 47% of the time.

The Game

The information warfare game software used for this experiment was the same created and used by Burke (1999) but re-coded with the enhancements discussed in Chapters I and II. The game is based on Microsoft ACCESS and Visual Basic code. Each player, both the attacker (computer automated) and the defender (the subject), had three information warfare strategies to choose from with the option of playing zero to all of them on each repetition. This, however, was limited by the amount of funds available or by the treatment assigned. A player knew if his or her strategy was successful by the payoff or loss that he or she received in monetary form at the end of each repetition (each player selecting a strategy).

The defenders were not told that they were playing a computer opponent. However, because of the nature of the game it is assumed that the subjects came to this realization. In any case, it should not have made a difference in game play. This is because a player's equilibrium strategy is always the best response to any strategy chosen by the computer. The player therefore should have still been able to determine the best strategy to play.

The goal of the player was to find the strategy or mix of strategies, which maximizes his or her payoff over the long run. This is consistent with the instructions that the player received by a pre written script on the computer. The only instructions given by the experimenter were to click on the game link and play the game. Each game consisted of fifty repetitions of each player (attacker and defender) choosing a strategy or strategies to play and then viewing his payoff or loss.

The game software recorded each move made by both the attacker and defender for every game. In addition, it recorded the amount of dollars spent on differing strategies at each round. It can be expected that at first a player's strategy or strategies will vary considerably. However, as each payoff or loss is observed, the player should be able to calculate the equilibrium strategy or combination of strategies, which provides the maximum gain over time. This of course works off the assumption that the subject will actually seek to maximize his or her payoff as they were told to do in the instructions. Since all of the subjects are graduate students at the Air Force Institute of Technology and are considered to have a high degree of professionalism and integrity, it is assumed that this will be the case.

Statistical Analysis

This study used three different methods to analyze the data and test the hypotheses. The overall difference in treatments was tested by using a one-way ANOVA and students t-test, while a regression analysis was used to gain a greater understanding of the differences in treatment factors and to test Hypothesis 1, Hypothesis 2, and Hypothesis 3. These tests were conducted using the results (PEA) from round two, which included all the treatment groups. Finally, a paired t-test was used to test Hypothesis 4 using the results from round one. Furthermore, the percent equilibrium attainment (PEA) was used as the primary means of measure in all tests.

Summary

This chapter outlined the basic research design of the study. It also provided a description of the IW Game and how it was used to gather the data necessary for the testing of the hypotheses. Finally, this chapter provided a brief preview of the various statistical methods that were used to test the hypotheses.

IV. Results and Analysis

Introduction

Chapter III depicted the methodology used to conduct the experiment and collect data to test the hypotheses for this study. This chapter is presented in two sections. First it will describe the statistical analysis used to test the hypotheses. Secondly it will report the results of the analysis.

Description of Statistical Analysis

Hypotheses 1 through 3 were tested by conducting an analysis of variance based on the mean percent equilibrium attainment scores. Since the only controlled independent variables in the experiment are whether there are budgetary constraints, whether multi-strategy selection is possible, and whether the opponent is rational or irrational, this is a so-called three-factor experiment (McClave, Benson, Sincich, 1999). The full factorial design produces eight factor-level combinations (treatments). The dependant variable was the subject's percentage of equilibrium attainment and ranged between 0.0 and 1.0 for a single game. The experimental unit (EU) for this experiment is one individual playing one game. The observational unit (OU) is also one individual playing one game.

The analysis of variance was carried out by using two separate methods of analysis. Each method was conducted utilizing a significance level of $\alpha = 0.05$. Alpha represents the chance of committing a Type I error or incorrectly rejecting the null hypothesis (H_o = status quo). In other words, there is a five percent chance of accidentally accepting the alternative hypothesis (H_a = research hypothesis) when in fact there is no significant difference in the treatment groups. All tests were also based on the assumptions of independence, constant variance, and normality.

The experiment also had to take into account the chance of producing a Type II error, which is defined as the probability of concluding that the null hypothesis is true when it is in fact false. The probability of committing a Type II error is equal to β. The power of the experiment, which is defined as the probability of the test correctly leading to the rejection of the null hypothesis for a particular value of μ in the alternative hypothesis is equal to $1 - \beta$. Therefore, any increase in the power of the test leads to an equal decrease in β, or the probability of committing a Type II error. For this experiment, power was calculated to be 0.80 as determined by a combination of effect size, standard deviation of error (sigma), the significance level (alpha), and sample size (Sall and Lehman, 1996: 163).

The first method consisted of a one-way analysis of variance using the Student's t. This test compares the means of each treatment group to determine if there is a significant statistical difference in their value. This is done by fitting the Y variable (Percent Equilibrium Attainment) to the X variable (Treatment Group). The Y variable is continuous and can take on a value between 0.0 and 1.0. The X variable is categorical and can take on a value of Treatment 1 through Treatment 8. The ratio of variation between each treatment group was measured by using the F-statistic. The F-statistic was considered significant (i.e. that there was a significant statistical difference between the treatment groups) at an $\alpha < 0.05$.

The second method of analysis consisted of generating a multiple linear regression model using the least squares approach. This was conducted to determine the significant of each of the independent variables (budget, multiple strategies, opponent Rationality) in relation to the dependent variable (Percent Equilibrium Attainment). Each of the independent variables were coded as either 1 or 0, which represents their two possible states of existence. A rejection of the null hypothesis (indicating an effect on the dependent variable) should generate negative coefficients for the independent variables. In other words, the presence of any of the above independent variables should cause a lower percentage of equilibrium attainment on the part of the subject.

In addition to the above dependant variables that are of interest to this study, the regression model will include pre-test (Game 1) equilibrium scores and information warfare (IW) experience as covariates. This is in keeping with the original IW Game study conducted by Burke (1999). The original study attempted to use a pure strategy game average score to account for a player's innate game theoretic rationality in a mixed strategy game. This study will attempt to account for innate ability by using the pre-test equilibrium scores as a covariate in the regression analysis. The IW experience covariate accounts for a player's prior experience in information warfare and should produce a positive coefficient.

The overall significance of the model in each analysis method was assessed using R^2 as the multiple coefficient of determination. R^2 measures how well the model fits the data, and therefore, provides a measure of the overall usefulness of the model. Additionally, R^2 measures the explanatory power of all the terms included in the model assuming that all of the terms are present. The closer R^2 comes to 1.0 the more explanatory power of the model.

Hypothesis 4 was tested by conducting a paired t-test on the equilibrium results from game 1. The paired t-test tests to see if the means of two variables are the same at a 0.05 significance level. For this test, the variables consisted of the Percent Equilibrium Attainment score (described earlier) and the NORRE score (as developed by Burke) for the first game. However, in order for the two measures to be directly comparable, the NORRE score had to be converted into a percentage. This was done by using the equation (50 – NORRE)/50 where 50 equals the total rounds in the game.

Analysis Results

One-way ANOVA – Student's-t

Figure 3 on the following page provides a graphical representation of the Y response variable (percent equilibrium attainment) plotted against the treatment groups for round two. The graphic clearly shows a decreasing trend in equilibrium attainment as the different constraints are added. Treatment Group 1, which acted as the control group had a mean equilibrium attainment of 67 percent while Treatment Group 8 had a mean equilibrium attainment of only 38 percent. The means for all treatment groups along with the standard error calculated in the analysis of variance can be found in Table 6. Note, a one-way ANOVA was also conducted using round one (Pre-Test) results and found no statistical difference between the treatment groups.

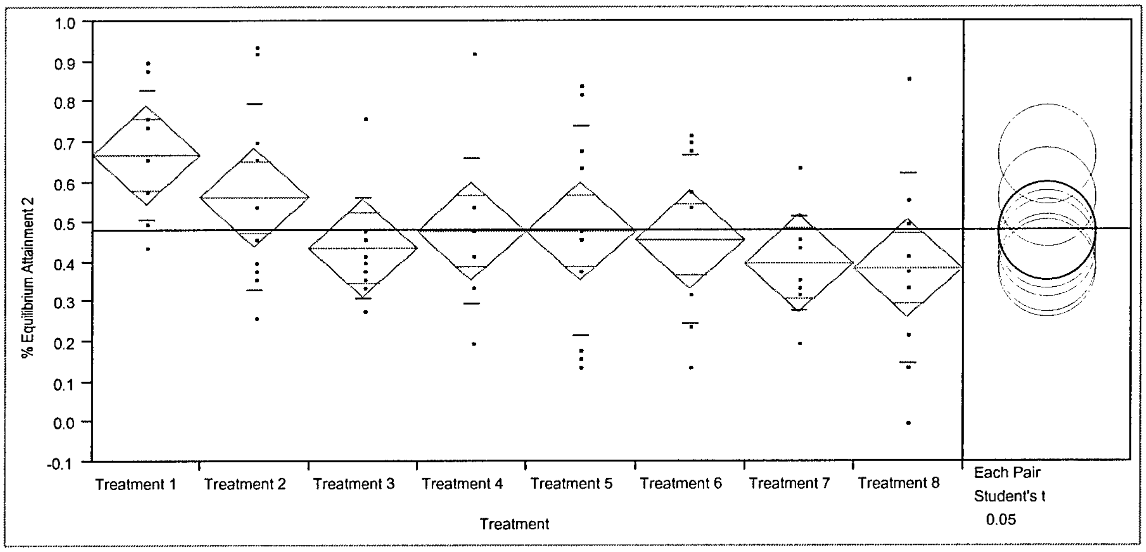


Figure 3. Equilibrium Attainment vs Treatment Group

The one way analysis of variance and students t-test show that there is a significant difference between the mean equilibrium attainment of Treatment Group 1 (the control group) with that of Treatment Groups 3,4,5,6,7, and 8) at $\alpha < 0.05$. This seems to suggest that budget constraints and / or multiple strategy selection significantly affect a player's ability to identify and play the equilibrium strategy. There was, however, no significant difference between Treatment Groups 1 and 2. This suggests that an opponent's rationality had no effect on a player's ability to find and play the equilibrium strategy. To find out exactly how and to what degree budgetary constraints and multiple selection effect equilibrium attainment, a regression analysis had to be performed.

Table 6. Equilibrium Attainment Means per Treatment Group

Level	Mean	Std. Error
Treatment 1	0.670	0.6311
Treatment 2	0.562	0.6311
Treatment 3	0.436	0.6311
Treatment 4	0.476	0.6311
Treatment 5	0.478	0.6311
Treatment 6	0.456	0.6311
Treatment 7	0.398	0.6311
Treatment 8	0.384	0.6311
Standard Error uses a pooled estimate of error variance		

Multiple Regression Analysis

This section presents the results of the regression analysis and serves as the primary basis for support or rejection of the Hypotheses 1, 2, and 3. The full model includes both the IW experience and game one equilibrium attainment covariates along with the three primary treatment factors and their interactions. The 23 percent of the variation in equilibrium attainment accounted for by the model should be sufficient for assessing the stated hypotheses. The beta coefficient for each variant along with its associated significance level is presented in Table 7 on the following page.

Table 7. Regression Analysis

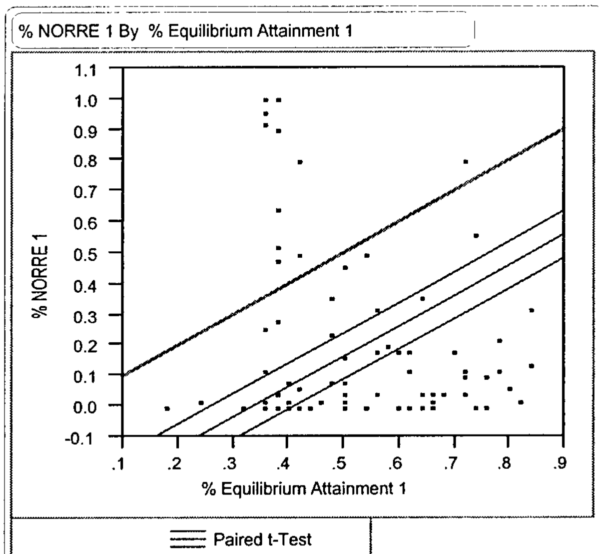
Independent Variables	Beta Coefficient	Significance Level
IW Experience.	0.078	0.149
Percent Equilibrium Attainment (PEA) 1	-0.260	0.083
Rationality	-0.133	0.134
Budget	-0.220	0.017
Multiple	-0.251	0.005
Rational * Budget	0.143	0.259
Rational * Multiple	0.168	0.180
Budget * Multiple	0.162	0.194
Rationality * Budget * Multiple	-0.179	0.310

Though not a primary focus of this study, the significance of the two covariates will be discussed first. A review of the regression results shows that prior experience with information warfare did not have a significant impact on equilibrium attainment at $\alpha < 0.05$. This differs from the results reported by Burke (1999) who did find a significant increase in equilibrium attainment due to prior information warfare experience. The data does show moderate support for the second covariate, which sought to account for innate game theoretic ability of the players.

A cursory look at the regression table shows that all three treatment factors (Rationality, Budget, Multiple) had negative effects on the attainment of equilibrium. This is evident by the negative signs of their beta coefficients. Budgetary constraints and multiple strategy selection both had particularly strong effects with significance values less than 0.05. Therefore, the evidence supports rejecting the null hypotheses for both Hypothesis 1 and Hypothesis 2 at $\alpha < 0.05$. However, there is only weak support that opponent rationality had any effect on equilibrium attainment. Therefore, the null hypothesis for Hypothesis 3 cannot be rejected at $\alpha < 0.05$. Interactions between the treatment factors were also tested but none showed significance.

Paired t-Test

Hypothesis 4 was tested using a Paired t-Test to determine if there was a significant difference in the mean level of equilibrium attainment dependent on the type of calculation used. The results of the test, along with a graphical representation are depicted in Figure 4. Specifically the results show that the null hypothesis (i.e., that there is no significant difference in the means) can be rejected at $\alpha < 0.05$.



Paired t-Test

% Equilibrium Attainment 1 - % NORRE 1

Mean Difference	0.34125	Prob > |t|	<.0001
Std Error	0.037951	Prob > t	<.0001
t-Ratio	8.991801	Prob < t	1.0000
DF	79		

Figure 4. Paired-t Test

The bold line on top shows the points where the two variables are equal. The set of thin lines below show the 95 percent confidence interval of the mean difference. If the bold line was inside of the confidence interval, it would indicate that there was no difference in the means. However, in light of the apparent mean difference of 0.34, the null hypothesis is rejected and Hypothesis 4 is supported.

Summary

This chapter described the statistical analysis used to test the hypotheses. It the reported the results of the analysis conducted on the experimental data. The analysis found strong support for Hypotheses 1, 2, and 4 but could only find weak support for Hypothesis 3. The implications for these results will be explored in the next chapter.

V. Discussion

Introduction

The last chapter reported the results of this study's experiment as they related to the stated hypotheses. This section will look at the implications of those results in further detail. Additionally, some of the limitations of this study and recommendations for future research are discussed. Finally, concluding remarks are given to close out the study.

Hypothesis 1 – Multiple Strategy Selection

The results reported in Chapter IV show strong support for Hypothesis 1. That is, the ability of a player to choose multiple strategies at once tended to have a negative effect on a player's ability to find and play the equilibrium strategy (see Figure 5). This is consistent with the work of Malhotra (1982), Best and Ursic (1987), and Helgeson and Ursic (1993), who all found that the number of alternatives available had a negative effect on the accuracy of decision-making. This inability to make accurate decisions when faced with a growing number of alternatives could have an impact on the effectiveness of strategies chosen by IT professionals seeking to protect our nation's critical information systems.

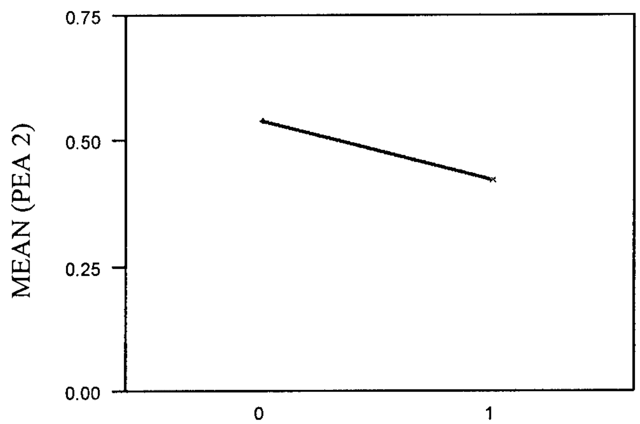


Figure 5. Multiple Strategies vs. PEA Game 2

Support for Hypothesis 1 indicates that a decision maker's effort of trying to protect everything may have the reverse effect of not protecting anything to the desired degree. This suggests that it may be best to determine what type of information is most important and to concentrate our defensive strategies on it. Of course, this will be dependent upon the specific system being protected and shows that a cookie cutter strategy of protecting everything regardless of "type" will not work. For example, if a system has top secret information on it that could cause grave and serious harm to the national security of the United States, then it may by better to concentrate on the confidentiality of the system instead of its availability. Trying to ensure that the system is available 100 percent of the time and easily accessible to its users could compromise the confidentiality of the system and subsequently cost American lives.

Hypothesis 2 – Budgetary Constraints

The results also found strong support for Hypothesis 2, that budgetary constraints placed on a player had a negative effect on his or her ability to find and play the equilibrium strategy (see Figure 6). It is important to remind the reader that each player had more than sufficient funds to consistently play the equilibrium strategy. Interestingly, it was most often best for the player to choose the least expensive strategy available to him or her. This provides some interesting insight into how differing strategies are judged based on price.

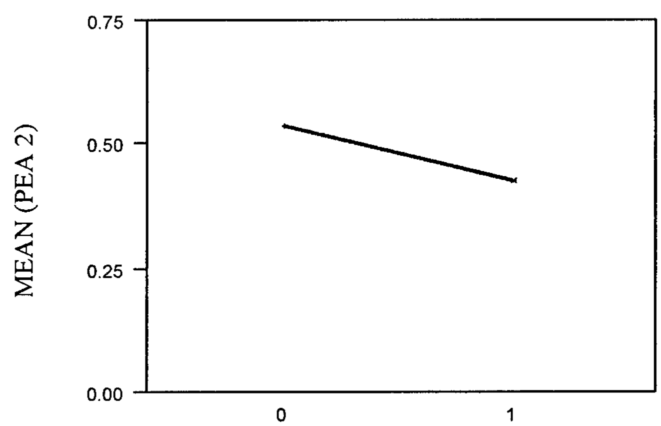


Figure 6. Budgetary Constraints vs. PEA Game 2

Consistently throughout the course of play, subjects who had to purchase strategies tended to choose more expensive strategies than were needed. This suggests that players believed that the more expensive strategies were somehow better than the less expensive strategies. However, this assumption on the part of the players had no basis in fact. Repeated losses should have helped the player to eventually come to this realization; however, it may have taken more time than the 50 turns allotted.

Throughout the Department of Defense and other agencies of the federal government, strategies are almost never considered without some emphasis on their cost. The results of this study show that the human mind may tend to automatically equate more expensive with more effective. That is, if the most expensive strategy is chosen, the most effective results will be obtained. However, this is not always the case, and the study's results suggest that when evaluating differing strategies, information technology professionals may want to first look at the merits of each strategy without regard to cost. Nothing here suggests that cost should not be considered, only that measures of effectiveness must be looked at first. This way, a strategy may be chosen which best protects our systems within the budgetary constraints imposed.

Hypothesis 3 – Opponent Rationality

The data collected for this study does not support the hypothesis that opponent rationality has a significant effect on a person's ability to find and play the equilibrium strategy at $\alpha < 0.05$. However, as depicted in Figure 7, the rationality of an opponent

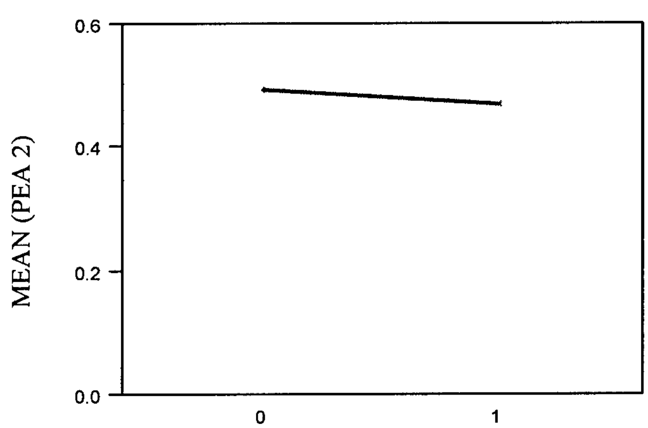


Figure 7. Opponent Rationality vs. PEA Game 2

does have a slightly negative effect if a player is facing someone that is making seemingly irrational decisions at $\alpha < 0.15$. Although this study found no significant effect at the desired $\alpha < 0.05$, the outcome does provide some impetus for further research in the area.

If further studies also find no significant effect, it could mean that the human mind does not generally have a problem devising rational solutions in response to irrational behavior. Taken another way, it is possible for us to develop logical defenses for our information systems even though we do not know who is attacking them or for what purpose. We do not need to develop an irrational response by hampering the free flow of unclassified information or completely tightening the security to our systems to a point that it denies access to legitimate users. This would be consistent with our experience in dealing with international and domestic terrorism, which provides a good example for this scenario.

Most people would associate fundamentalist terrorism with irrational behavior. This is because the perpetrators generally have little regard for human life including their own. Additionally, those trying to defend against it, never really know when or why the perpetrators will strike next. Therefore, even if the terrorist' s actions seem and are rational to them, to us they seem irrational. Nevertheless, the U.S. manages to devise rational methods to defend against terrorism using sound practices of security and law enforcement.

Unfortunately, our defenses are not always 100 percent effective, but in the long run we maximize payoffs to society by ensuring the relative safety of our citizens while maintaining an open society. This is in contrast to an irrational response such as declaring a police state and indefinitely suspending individual rights in order to completely eradicate the threat. The irrational response may have short run benefits in the fight against terrorism but in the long run it would be devastating to our way of life and the fundamentals of democracy.

Hypothesis 4 – Equilibrium Calculations

Hypothesis 4 looked at the calculation used as the main instrument of measure in the information warfare model. Specifically, it asked whether calculating equilibrium attainment as a percentage of total rounds played (PEA) accounts for more equilibrium attainment (by a player) then counting the number of rounds to reach equilibrium (NORRE) as performed in the original study by Burke (1999). The analysis found strong support for this hypothesis, concluding that a mean difference of 0.34 exists between the equilibrium accounted for using the PEA than the NORRE. Therefore, it is recommended that any future study use the PEA method of calculation. This allows the experimenter to calculate exactly how close a subject came to the playing the equilibrium strategy even in a mixed strategy game.

Study Limitations

Throughout the course of this study, a few limitations became apparent. The first limitation comes in the assumption that there are only two players (attacker and defender) in any given game. The second limitation is based in the way monetary constraints were integrated into the game. The third limitation is inherent to game theory itself.

In regards to the first limitation, the assumption of only two players probably is not always the case in real life. Specifically, for any given defender in information warfare, there could be multiple attackers using different methods. Furthermore, each of these attackers could have differing objectives, which could affect their utility maximization. For instance, the United States military information systems face threats from a myriad of vastly different types of attackers at any point in time. Telling the difference between the types and reacting appropriately is a significant obstacle. One type of attacker may be a foreign espionage agency trying to steal secrets. Another attacker at the same point in time could be a teenage hacker that just wants to overcome a challenge. Not knowing which type of attacker it is may hamper the development of an appropriate response.

As for the second limitation, it became apparent that the players might have disassociated to a degree the purchasing of strategies and the loss of information during an attack. This is probably because the payoff a defender received (lost) when a defensive strategy failed was dependent entirely on the strategy chosen by the attacker. Even though the defender spent money out of the IW budget on purchasing defensive strategies, he or she did not see it translate directly into the payoff.

The third limitation of this study involves the assumption of a Nash equilibrium in information warfare. Remember, that an equilibrium strategy is one that the player should use every time in order to maximize his or her payoffs. Though this was the case for the payoffs in this study, it may not be the case in all situations involving information warfare.

Recommendations for Further Research

Recommendations for further research stem directly from the limitations discussed previously. Specifically, any future research should include a closer integration of strategy cost with the actual payoff received by a player. In other words, any payoff received by the player should be reduced by the cost of the chosen strategy. This could also be done prior to the calculation of expected payoff so that it is linked to the equilibrium strategy as well.

A future study could also integrate multiple players into the IW game model. Although most game theoretic models use only two players, theoretically a game model could have an infinite amount of players. Zagare (1984: 64) points out, however, that games of this type are both "quantitatively and qualitatively different from two person games". He points specifically to the fact that once more than two players are involved in a game, the possibility of a coalition arises. This possibility also seems to be evident in information warfare where, for example, an international criminal organization could find common ground with a rogue nation opposed to the United States.

Conclusion

This study has provided significant enhancements to the information warfare game model to more accurately represent the realities of information warfare. In addition, it has provided further confirmation that the model is a useful method of analyzing human behavior and the decisions of those engaged in strategy formulation for information warfare. It has shown that both, the ability to choose multiple strategies and the existence of budgetary constraints have a significant negative effect on a person's ability to make accurate decisions about information warfare strategies. It has also provided hope that we can develop rational responses to what looks like irrational attacks against our systems. Finally, it has provided a more robust method of measuring a subject's attainment of equilibrium thus allowing for more accurate results in the analysis of the data.

There is still much work to be done in this field and in the development of the IW model. It is hoped that others will carry on this work and develop more enhancements to the model which will further our understanding of information warfare and human nature

Appendix A: Experiment Instructions

Instructions

Thank you for participating in this experiment. This experiment involves playing a simple Information Warfare (IW) based game. Please do not use writing materials, calculators, or other external devices while playing the game. Also, please do not have any other software applications open on your computer during the experiment. Please do not speak to other subjects during or after the experiment (in particular, do not reveal your strategies or winnings/losses). Finally, please read all instructions, scenario, and the help page completely. After you have read all the pages you will be asked to answer a few simple questions to ensure your comprehension of the experiment. Thank you for your cooperation.

If you encounter a software error that stops you from proceeding during the experiment, please close the software and notify the experimenter at steven.tait@afit.af.mil **. Likewise, if you have any questions please notify the experimenter.**

The purpose of this experiment is to test and validate a game theory model with various aspects of information warfare. Game theory is a technique frequently used in economics and other social sciences to model social behavior. The primary motivation for developing a game theory model is to simplify complex situations. The simplified model can then allow better understanding of people's actions and the reason(s) for their actions.

Your goal is to maximize your payoff while minimizing your losses – REGARDLES OF WHAT PREVIOUS IW EXPERIENCE MAY INDICATE.

Each of you will have three strategies available. These strategies will be explained on the following Scenario Page. Your overall goal is to determine and employ the combination of strategies that yields you the best **long-term** payoff. Under some conditions, it may be advantageous to use a combination of two or all three strategies in response to your opponent' s strategies. At other times, it may be better to use only one strategy. During the first few turns you should complete the following actions:

1) Determine your best strategy(s), i.e. those that seem to succeed most often **and** that yield the best **long-term** payoff.

2) If no single strategy seems best, determine the combination of strategies that yields higher **long-term** payoffs.

3) Attempt to determine the preferred strategy(s) of your opponent and alter your strategy accordingly.

4) When you believe you have found the best strategy or combination of strategies, continue using it unless your overall payoffs seriously decline.

Appendix B: Basic Scenario

Scenario

You are the Chief Information Officer (CIO) for the United States Air Force. From your latest meeting with senior intelligence advisors and the FBI, you learned that Air Force information systems are being targeted by a foreign adversary. Their goal is to use information operations to counter the military advantage held by the United States.

You have since learned that there are three potential strategies available to your adversary. The opposing states will either try to attack the integrity of Air Force information systems, to affect the availability of Air Force information systems or they will try to attack the confidentiality of Air Force information systems. Each of these are strategies and the operations to achieve them are explained below. Each month your adversary will devote all of its resources to one or none of these strategies.

1. Integrity Attack: The goal of this strategy is often to affect the operations of the system without the knowledge of the user. This strategy involves operations that penetrate the information systems, tamper with the systems, and fabricate data within the systems.

2. Availability Attack: This type of attack is commonly known as a denial of service attack. It differs from an integrity attack in that it overtly halts operations instead of controlling the output of operations. It takes the form of three types of operations: physical theft of hardware, sabotage either physically or logically, and censorship.

3. Confidentiality Attack: The goal of a confidentiality attack is to gather sensitive information. Five different types of operations attain this outcome: espionage and intelligence operations, information piracy, penetration into physical premises and computer systems, superimposition fraud, and identity theft.

Your Information Security department has developed defensive strategies to counter each of the above attacks. Each month, you will select one or none of these strategies to employ. Although each defense strategy counters a specific attack, they also have limited effectiveness against the other attack strategies. Your defense strategies are not cumulative. Thus, you will begin anew each month. At the end of each month, you will receive a report indicating the costs of any information resources that were compromised.

Appendix C: Help Screen

DEFENDER GAME HELP

PAYOFF MATRIX

The Payoff Matrix indicates the costs of compromised information resources when a particular Defense Strategy ***fails***. The actual cost depends upon the Defense Strategy chosen ***and*** the Attacker's Strategy. The sample payoff matrix below shows that you will lose $70Million if your Integrity Defense Strategy ***fails*** against a Integrity Attack. However, if your Integrity Defense succeeds, you lose nothing. Two important items should be noted here. First, when your Defense strategy succeeds, the Attacker gains nothing. However, when your Defense Strategy fails, the Attacker may or may not gain the same amount that you have lost (i.e. this is not a zero-sum game). In the below example, if your Integrity Defense strategy fails and you lose $70Million, the Attacker may only realize a gain of $50Million. Indeed, the Attacker's payoff matrix may look much different than yours. ***Thus, you should not immediately assume that the Attacker values their strategies in the same way that you do.***

	Integrity Defense	**Availability Defense**	**Confidentiality Defense**
Integrity Attack	-70	-70	-70
Availability Attack	-50	-50	-50
Confidentiality Attack	-25	-25	-25

Notice that if your defense strategy does fail, you will be able to determine the strategy that the Attacker used by noticing how much money you lost. In the above example you would be able to determine that your opponent used an Integrity Attack.

STRATEGY SUCCESS

Although you cannot directly select your own payoff, you will quickly notice which of your strategies are more effective (***i.e. those that succeed more often***). Additionally, your Defense Strategies are more effective against some attacks than they are against others. Thus, your Integrity Defense may be very effective against a Integrity Attack, but only moderately effective against a Availability Attack.

The "Approximate Chance of Success" area of your Game screen shows the ***averaged, approximate*** chance of success for each of your strategies. ***THESE VALUES ARE ONLY A GUIDE TO HELP GET YOU STARTED***. You will notice that Defense Strategies are more effective against particular types of Attacks. Additionally, you should notice that a Defense Strategy with a low overall chance of success may be very effective against one type of attack. For instance, the Confidentiality Defense may be very effective against the Confidentiality Attack (60% or better) but ineffective against other attacks (25% or worse).

A KEY FACTOR IN SELECTING THE BEST STRATEGY IS DETERMINING WHEN YOUR DEFENSE STRATEGIES ARE MOST EFFECTIVE.

TOOLS HELP

Average Payoff boxes, one for each move, have been place on the upper, right-hand side of the Game Form. These boxes show the average payoff for each move, averaged over the number of turns that you have played the move. Each box's average is updated after you use that move. The example below shows how this works:

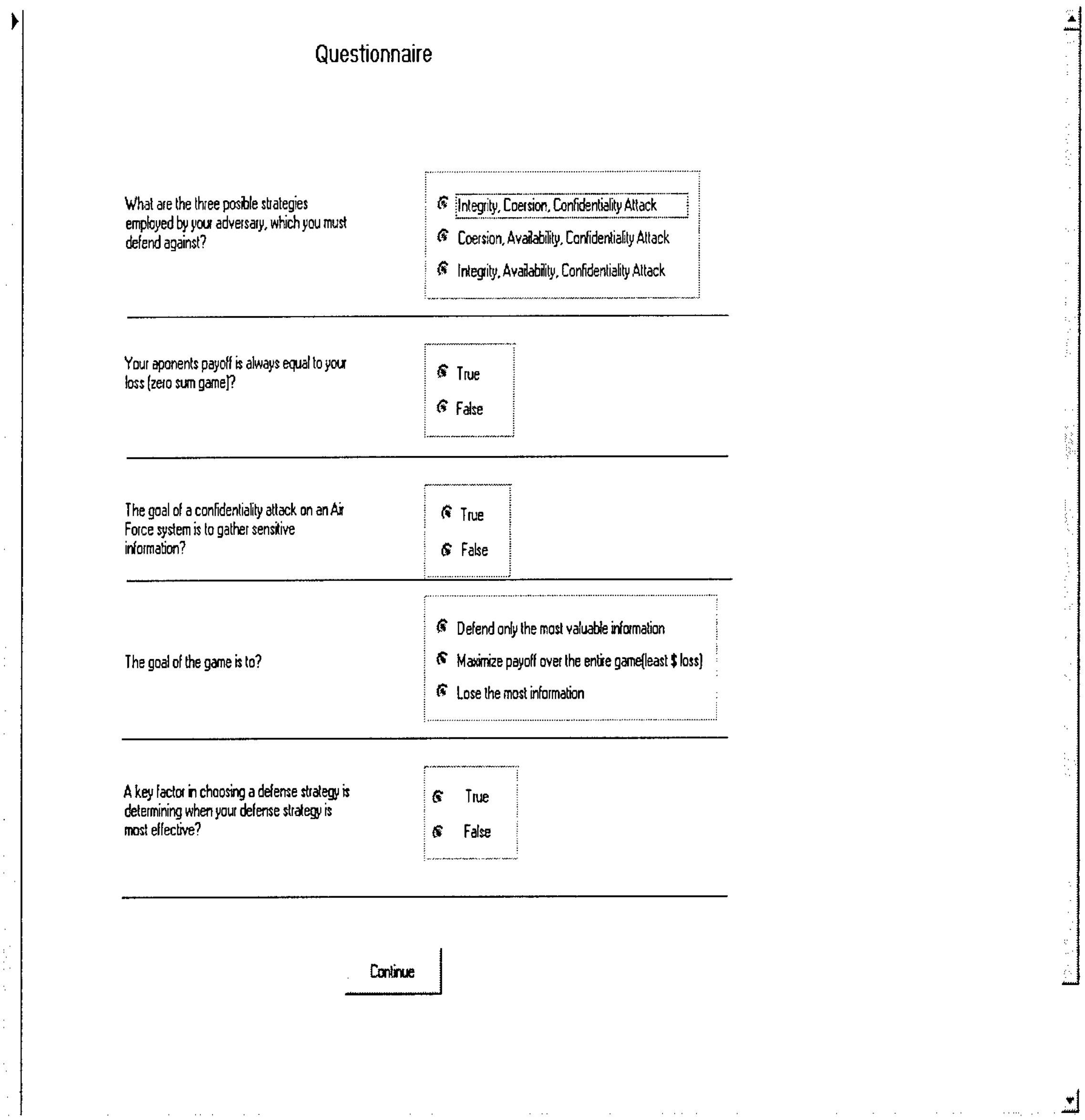
Suppose that you have played 5 turns so far, as shown in the table below: (NOTE: All strategies will be shown on the game form)

TURN	MOVE	PAYOFF RECEIVED	AVERAGE PAYOFFS	
1	Availability Def.	0	Availability Def. = 0	Integrity Def. = 0
2	Integrity Def.	-75	Availability Def. = 0	Integrity Def. = -75
3	Availability Def.	-25	Availability Def. = -12.5	Integrity Def. = -75
4	Integrity Def.	0	Availability Def. = -12.5	Integrity Def. = -37.5
5	Integrity Def.	-50	Availability Def. = -12.5	Integrity Def. = -41.67

Since your goal is to lose as little as possible, you should favor strategies that have an Average Payoff close to zero. *Keep in mind that the Average Payoff will become more accurate as more turns are played.*

Below the Average Payoff boxes is a scroll-box that shows the moves and payoffs for each turn of the game. This box allows you to see what moves you have made previously and what payoff you received for those moves.

Appendix D: Questionnaire



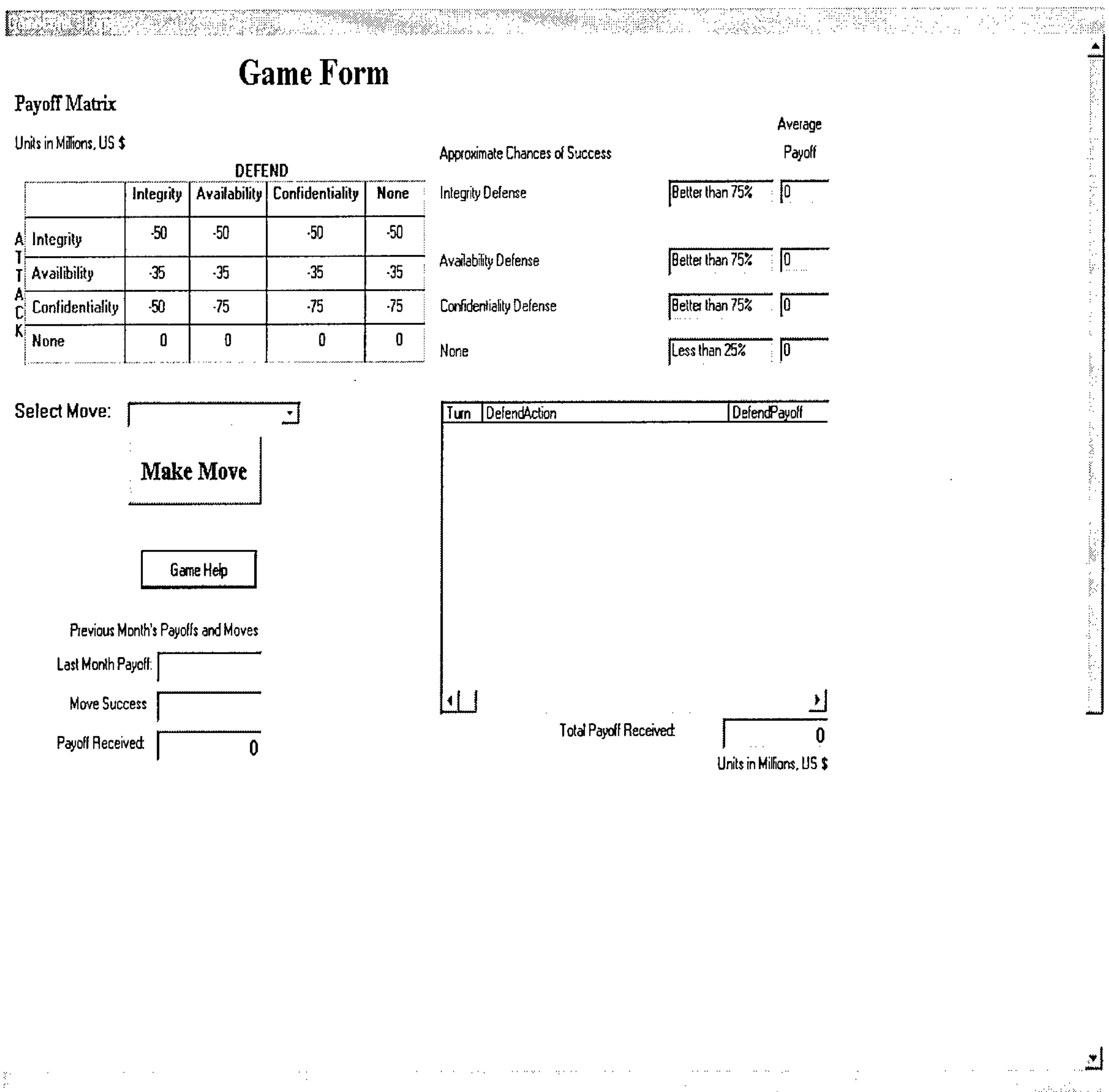
Questionnaire

What are the three posible strategies employed by your adversary, which you must defend against?	Integrity, Coersion, Confidentiality Attack Coersion, Availability, Confidentiality Attack Integrity, Availability, Confidentiality Attack
Your aponents payoff is always equal to your loss (zero sum game)?	True False
The goal of a confidentiality attack on an Air Force system is to gather sensitive information?	True False
The goal of the game is to?	Defend only the most valuable information Maximize payoff over the entire game(least $ loss) Lose the most information
A key factor in choosing a defense strategy is determining when your defense strategy is most effective?	True False

Continue

Appendix E: Game Forms

Basic



Game Form

Payoff Matrix

Units in Millions, US $

		DEFEND			
		Integrity	Availability	Confidentiality	None
ATTACK	Integrity	-50	-50	-50	-50
	Availibility	-35	-35	-35	-35
	Confidentiality	-50	-75	-75	-75
	None	0	0	0	0

Approximate Chances of Success		Average Payoff
Integrity Defense	Better than 75%	0
Availability Defense	Better than 75%	0
Confidentiality Defense	Better than 75%	0
None	Less than 25%	0

Select Move:

Make Move

Game Help

Turn	DefendAction	DefendPayoff

Previous Month's Payoffs and Moves

Last Month Payoff:

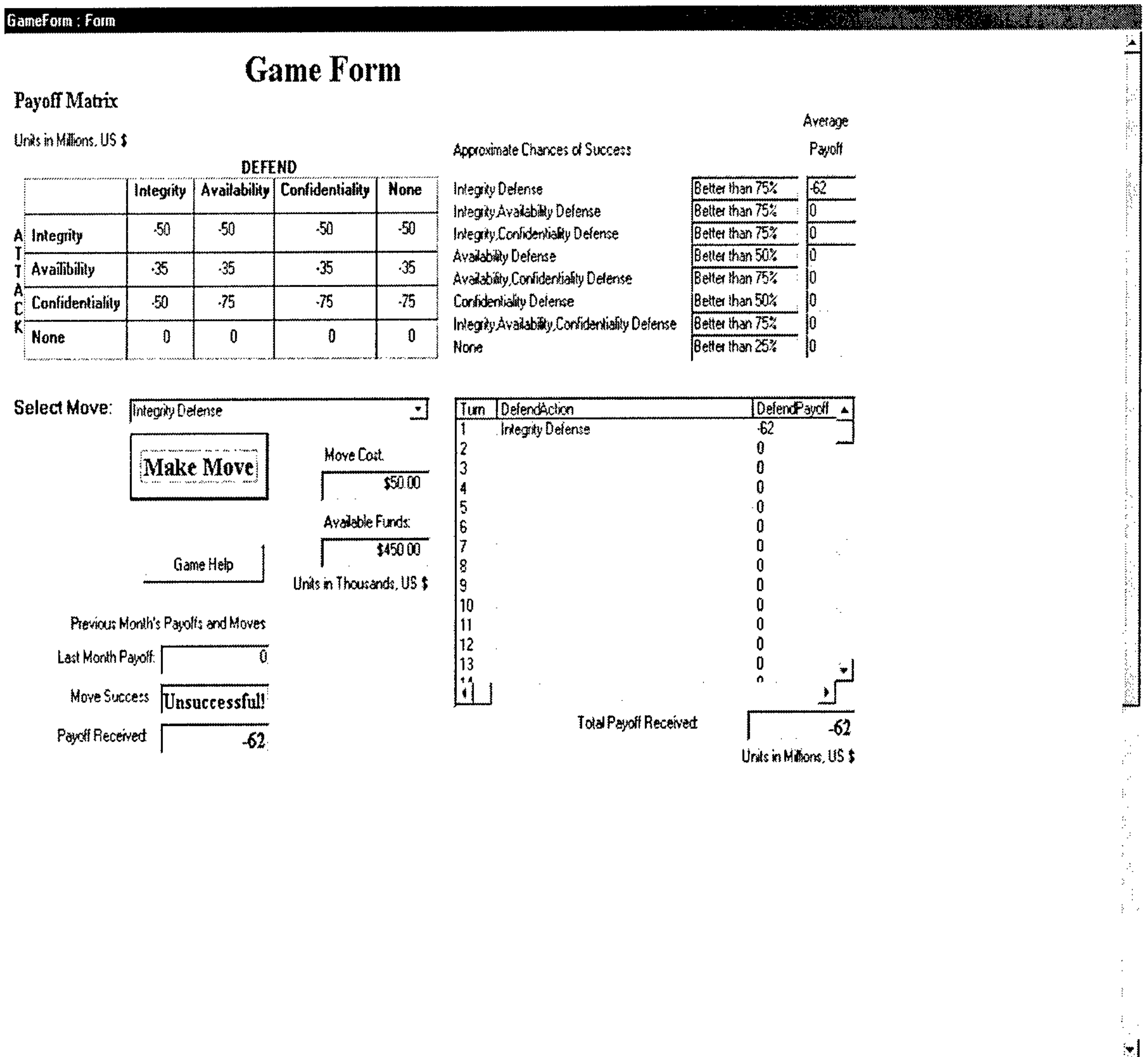
Move Success

Payoff Received: 0

Total Payoff Received: 0

Units in Millions, US $

Full


GameForm : Form
Game Form
Payoff Matrix
Units in Millions, US $
DEFEND
ATTACK

	Integrity	Availability	Confidentiality	None
Integrity	-50	-50	-50	-50
Availibility	-35	-35	-35	-35
Confidentiality	-50	-75	-75	-75
None	0	0	0	0

Approximate Chances of Success		Average Payoff
Integrity Defense	Better than 75%	-62
Integrity,Availability Defense	Better than 75%	0
Integrity,Confidentiality Defense	Better than 75%	0
Availability Defense	Better than 50%	0
Availability,Confidentiality Defense	Better than 75%	0
Confidentiality Defense	Better than 50%	0
Integrity,Availability,Confidentiality Defense	Better than 75%	0
None	Better than 25%	0

Select Move: Integrity Defense
Make Move
Move Cost: $50.00
Available Funds: $450.00
Units in Thousands, US $
Game Help
Previous Month's Payoffs and Moves
Last Month Payoff: 0
Move Success: Unsuccessful!
Payoff Received: -62

Turn	DefendAction	DefendPayoff
1	Integrity Defense	-62
2		0
3		0
4		0
5		0
6		0
7		0
8		0
9		0
10		0
11		0
12		0
13		0

Total Payoff Received: -62
Units in Millions, US $

Appendix F: Visual Basic Code

```
Option Compare Database
Option Explicit

Private Sub Continue_Click()
Dim FindSubject As QueryDef
Dim SubjectRecord As Recordset, ErrorRecord As Recordset
Dim Query As String
Dim Subject As Integer, Counter As Integer

On Error GoTo ErrorHandler

Begin:


If IsNull(SubjectNumber) Then
  MsgBox "Please Select Your Name"
Else
  Subject = SubjectNumber

  Query = "SELECT * FROM Subjects WHERE SubjectID =" & Subject
  Set FindSubject = CurrentDb.CreateQueryDef("FindSubject" & Subject, Query)
  Set SubjectRecord = FindSubject.OpenRecordset
  SubjectRecord.MoveFirst
  DefenderBox = SubjectRecord("Defender")
  RationalBox = SubjectRecord("Rational")
  BudgetBox = SubjectRecord("Budget")
  MultiBox = SubjectRecord("Multi")
  SubjectRecord.Edit
    SubjectRecord("IWExperience") = IWExperience
    SubjectRecord("GameExperience") = GameExperience
    'SubjectRecord("LastName") = LastNameBox
    'SubjectRecord("FirstName") = FirstNameBox
  SubjectRecord.Update
  CurrentDb.QueryDefs.Delete "FindSubject" & Subject
  CurrentDb.QueryDefs.Refresh

  DoCmd.OpenForm "GameForm"
  DoCmd.OpenForm "Quiz"
  DoCmd.OpenForm "DefenderHelp"

  If MultiBox = True Then
    If BudgetBox = True Then
      DoCmd.OpenForm "MultiBudgetScenario"
    Else
      DoCmd.OpenForm "MultiScenario"
    End If

  ElseIf BudgetBox = True Then
```

```
      DoCmd.OpenForm "BudgetScenario"

    Else
      DoCmd.OpenForm "DefenderScenario"
    End If

    DoCmd.OpenForm "Instructions"
    DoCmd.Maximize
    Forms!Quiz!SubjectBox = Subject
    DoCmd.Close acForm, "SubjectIdentification"
End If
GoTo Out

ErrorHandler:
    Set ErrorRecord = CurrentDb.OpenRecordset("Errors", DB_OPEN_DYNASET)
    With ErrorRecord
      .AddNew
      !BlownUpCount = -1 ' Indicates that Error Occurred on Subject ID Form
      !ErrorDesc = Err.Description
      !ErrorNumber = Err.Number
      .Update
    End With
    For Counter = 1 To 1000
      Next Counter
    Resume Begin

Out:
End Sub

Private Sub Form_Open(Cancel As Integer)
DoCmd.Maximize


End Sub



Private Sub FeaturesHelpButton_Click()


      DoCmd.OpenForm "DefendToolsHelp"

End Sub

Private Sub DmoveBox_Change()
If DMoveBox = "Integrity Defense" Then
    MoveCost = Strategy1CostBox
ElseIf DMoveBox = "Availability Defense" Then
    MoveCost = Strategy2CostBox
ElseIf DMoveBox = "Confidentiality Defense" Then
    MoveCost = Strategy3CostBox
ElseIf DMoveBox = "Integrity,Availability Defense" Then
    MoveCost = Strategy1CostBox + Strategy2CostBox
```

```
ElseIf DMoveBox = "Integrity,Confidentiality Defense" Then
   MoveCost = Strategy1CostBox + Strategy3CostBox
ElseIf DMoveBox = "Availability,Confidentiality Defense" Then
   MoveCost = Strategy2CostBox + Strategy3CostBox
ElseIf DMoveBox = "Integrity,Availability,Confidentiality Defense" Then
   MoveCost = Strategy1CostBox + Strategy2CostBox + Strategy3CostBox
Else: MoveCost = 0

End If
End Sub

Private Sub Form_Open(Cancel As Integer)
   Dim Payoff As Integer
   Dim i As Integer
   Dim Subject As Integer
   Dim Match As Integer
   Dim Game As Integer, BlownUp As Integer
   Dim Defender As Boolean, TableExists As Boolean, Rational As Boolean, Multi As Boolean, Budget As
Boolean
   Dim Move1Sum As Single, Move2Sum As Single, Move3Sum As Single, Move4Sum As Single,
Move5Sum As Single, Move6Sum As Single, Move7Sum As Single, Move8Sum As Single
   Dim Query As String

   Dim PayoffRecord, MatchRecord, SuccessRecord, TurnRecord, HistoryRecord As Recordset
   Dim ErrorRecord As Recordset
   Dim FindPayoff, FindMatch, FindSuccess As QueryDef
   Dim MatchTable As TableDef
   Dim MatchField As Field

On Error GoTo Common_Error
BlownUp = 0

Begin:
DoCmd.Maximize
Defender = Forms!SubjectIdentification!DefenderBox
Rational = Forms!SubjectIdentification!RationalBox
Multi = Forms!SubjectIdentification!MultiBox
Budget = Forms!SubjectIdentification!BudgetBox
Subject = Forms!SubjectIdentification!SubjectNumber
Forms!GameForm!DefenderBox = Defender
Forms!GameForm!RationalBox = Rational
Forms!GameForm!MultipleBox = Multi
Forms!GameForm!BudgetaryBox = Budget
Forms!GameForm!SubjectBox = Subject
TurnBox = 1


   Move1Label.Caption = "Integrity Defense"
   Move2Label.Caption = "Integrity,Availability Defense"
   Move3Label.Caption = "Integrity,Confidentiality Defense"
   Move4Label.Caption = "Availability Defense"
   Move5Label.Caption = "Availability,Confidentiality Defense"
   Move6Label.Caption = "Confidentiality Defense"
```

```
    Move7Label.Caption = "Integrity,Availability,Confidentiality Defense"
    Move8Label.Caption = "None"
      'Set text color to Blue
    Move1Label.ForeColor = 16711680
    Move2Label.ForeColor = 16711680
    Move3Label.ForeColor = 16711680
    Move4Label.ForeColor = 16711680
    Move5Label.ForeColor = 16711680
    Move6Label.ForeColor = 16711680
    Move7Label.ForeColor = 16711680
    Move8Label.ForeColor = 16711680

    Query = "SELECT * FROM Matches WHERE Defender =" & Subject
    DefendHistory.Visible = True
    DefendHistory.Enabled = True



If Multi = False Then
    Move2Label.Visible = False
    Move3Label.Visible = False
    Move5Label.Visible = False
    Move7Label.Visible = False

    Move2Success.Visible = False
    Move3Success.Visible = False
    Move5Success.Visible = False
    Move7Success.Visible = False

    Move2Average.Visible = False
    Move3Average.Visible = False
    Move5Average.Visible = False
    Move7Average.Visible = False


    SingleMoveBox.Visible = True
    SingleMoveBox.Enabled = True
    SingleMoveBox.TabStop = True


ElseIf Multi = True Then


    MultiMoveBox.Visible = True
    MultiMoveBox.Enabled = True
    MultiMoveBox.TabStop = True


End If
Set FindMatch = CurrentDb.CreateQueryDef("FindMatch" & Subject, Query)
Set MatchRecord = FindMatch.OpenRecordset
MatchRecord.MoveFirst
Game = MatchRecord("GameID")
```

```
Match = MatchRecord("MatchID")
GameBox = Game
MatchBox = Match
CurrentDb.QueryDefs.Delete "FindMatch" & Subject
CurrentDb.QueryDefs.Refresh
Query = "SELECT * FROM Payoffs WHERE GameID =" & Game
Set FindPayoff = CurrentDb.CreateQueryDef("FindPayoff" & Subject, Query)
Set PayoffRecord = FindPayoff.OpenRecordset
PayoffRecord.FindFirst "[Defender] = " & Defender
A1D1Payoff = Str$(PayoffRecord("A1D1"))
A1D2Payoff = Str$(PayoffRecord("A1D2"))
A1D3Payoff = Str$(PayoffRecord("A1D3"))
A1D4Payoff = Str$(PayoffRecord("A1D4"))
A1D5Payoff = Str$(PayoffRecord("A1D5"))
A1D6Payoff = Str$(PayoffRecord("A1D6"))
A1D7Payoff = Str$(PayoffRecord("A1D7"))
A1D8Payoff = Str$(PayoffRecord("A1D8"))
A2D1Payoff = Str$(PayoffRecord("A2D1"))
A2D2Payoff = Str$(PayoffRecord("A2D2"))
A2D3Payoff = Str$(PayoffRecord("A2D3"))
A2D4Payoff = Str$(PayoffRecord("A2D4"))
A2D5Payoff = Str$(PayoffRecord("A2D5"))
A2D6Payoff = Str$(PayoffRecord("A2D6"))
A2D7Payoff = Str$(PayoffRecord("A2D7"))
A2D8Payoff = Str$(PayoffRecord("A2D8"))
A3D1Payoff = Str$(PayoffRecord("A3D1"))
A3D2Payoff = Str$(PayoffRecord("A3D2"))
A3D3Payoff = Str$(PayoffRecord("A3D3"))
A3D4Payoff = Str$(PayoffRecord("A3D4"))
A3D5Payoff = Str$(PayoffRecord("A3D5"))
A3D6Payoff = Str$(PayoffRecord("A3D6"))
A3D7Payoff = Str$(PayoffRecord("A3D7"))
A3D8Payoff = Str$(PayoffRecord("A3D8"))
A4D1Payoff = Str$(PayoffRecord("A4D1"))
A4D2Payoff = Str$(PayoffRecord("A4D2"))
A4D3Payoff = Str$(PayoffRecord("A4D3"))
A4D4Payoff = Str$(PayoffRecord("A4D4"))
A4D5Payoff = Str$(PayoffRecord("A4D5"))
A4D6Payoff = Str$(PayoffRecord("A4D6"))
A4D7Payoff = Str$(PayoffRecord("A4D7"))
A4D8Payoff = Str$(PayoffRecord("A4D8"))
A5D1Payoff = Str$(PayoffRecord("A5D1"))
A5D2Payoff = Str$(PayoffRecord("A5D2"))
A5D3Payoff = Str$(PayoffRecord("A5D3"))
A5D4Payoff = Str$(PayoffRecord("A5D4"))
A5D5Payoff = Str$(PayoffRecord("A5D5"))
A5D6Payoff = Str$(PayoffRecord("A5D6"))
A5D7Payoff = Str$(PayoffRecord("A5D7"))
A5D8Payoff = Str$(PayoffRecord("A5D8"))
A6D1Payoff = Str$(PayoffRecord("A6D1"))
A6D2Payoff = Str$(PayoffRecord("A6D2"))
A6D3Payoff = Str$(PayoffRecord("A6D3"))
A6D4Payoff = Str$(PayoffRecord("A6D4"))
```

```
A6D5Payoff = Str$(PayoffRecord("A6D5"))
A6D6Payoff = Str$(PayoffRecord("A6D6"))
A6D7Payoff = Str$(PayoffRecord("A6D7"))
A6D8Payoff = Str$(PayoffRecord("A6D8"))
A7D1Payoff = Str$(PayoffRecord("A7D1"))
A7D2Payoff = Str$(PayoffRecord("A7D2"))
A7D3Payoff = Str$(PayoffRecord("A7D3"))
A7D4Payoff = Str$(PayoffRecord("A7D4"))
A7D5Payoff = Str$(PayoffRecord("A7D5"))
A7D6Payoff = Str$(PayoffRecord("A7D6"))
A7D7Payoff = Str$(PayoffRecord("A7D7"))
A7D8Payoff = Str$(PayoffRecord("A7D8"))
A8D1Payoff = Str$(PayoffRecord("A8D1"))
A8D2Payoff = Str$(PayoffRecord("A8D2"))
A8D3Payoff = Str$(PayoffRecord("A8D3"))
A8D4Payoff = Str$(PayoffRecord("A8D4"))
A8D5Payoff = Str$(PayoffRecord("A8D5"))
A8D6Payoff = Str$(PayoffRecord("A8D6"))
A8D7Payoff = Str$(PayoffRecord("A8D7"))
A8D8Payoff = Str$(PayoffRecord("A8D8"))

CurrentDb.QueryDefs.Delete "FindPayoff" & Subject
CurrentDb.QueryDefs.Refresh
Query = "SELECT * FROM Success WHERE GameID =" & Game
Set FindSuccess = CurrentDb.CreateQueryDef("FindSuccess" & Subject, Query)
Set SuccessRecord = FindSuccess.OpenRecordset
SuccessRecord.FindFirst "[Defender] = " & Defender
A1D1Success = Str$(SuccessRecord("A1D1"))
A1D2Success = Str$(SuccessRecord("A1D2"))
A1D3Success = Str$(SuccessRecord("A1D3"))
A1D4Success = Str$(SuccessRecord("A1D4"))
A1D5Success = Str$(SuccessRecord("A1D5"))
A1D6Success = Str$(SuccessRecord("A1D6"))
A1D7Success = Str$(SuccessRecord("A1D7"))
A1D8Success = Str$(SuccessRecord("A1D8"))
A2D1Success = Str$(SuccessRecord("A2D1"))
A2D2Success = Str$(SuccessRecord("A2D2"))
A2D3Success = Str$(SuccessRecord("A2D3"))
A2D4Success = Str$(SuccessRecord("A2D4"))
A2D5Success = Str$(SuccessRecord("A2D5"))
A2D6Success = Str$(SuccessRecord("A2D6"))
A2D7Success = Str$(SuccessRecord("A2D7"))
A2D8Success = Str$(SuccessRecord("A2D8"))
A3D1Success = Str$(SuccessRecord("A3D1"))
A3D2Success = Str$(SuccessRecord("A3D2"))
A3D3Success = Str$(SuccessRecord("A3D3"))
A3D4Success = Str$(SuccessRecord("A3D4"))
A3D5Success = Str$(SuccessRecord("A3D5"))
A3D6Success = Str$(SuccessRecord("A3D6"))
A3D7Success = Str$(SuccessRecord("A3D7"))
A3D8Success = Str$(SuccessRecord("A3D8"))
A4D1Success = Str$(SuccessRecord("A4D1"))
A4D2Success = Str$(SuccessRecord("A4D2"))
```

```
A4D3Success = Str$(SuccessRecord("A4D3"))
A4D4Success = Str$(SuccessRecord("A4D4"))
A4D5Success = Str$(SuccessRecord("A4D5"))
A4D6Success = Str$(SuccessRecord("A4D6"))
A4D7Success = Str$(SuccessRecord("A4D7"))
A4D8Success = Str$(SuccessRecord("A4D8"))
A5D1Success = Str$(SuccessRecord("A5D1"))
A5D2Success = Str$(SuccessRecord("A5D2"))
A5D3Success = Str$(SuccessRecord("A5D3"))
A5D4Success = Str$(SuccessRecord("A5D4"))
A5D5Success = Str$(SuccessRecord("A5D5"))
A5D6Success = Str$(SuccessRecord("A5D6"))
A5D7Success = Str$(SuccessRecord("A5D7"))
A5D8Success = Str$(SuccessRecord("A5D8"))
A6D1Success = Str$(SuccessRecord("A6D1"))
A6D2Success = Str$(SuccessRecord("A6D2"))
A6D3Success = Str$(SuccessRecord("A6D3"))
A6D4Success = Str$(SuccessRecord("A6D4"))
A6D5Success = Str$(SuccessRecord("A6D5"))
A6D6Success = Str$(SuccessRecord("A6D6"))
A6D7Success = Str$(SuccessRecord("A6D7"))
A6D8Success = Str$(SuccessRecord("A6D8"))
A7D1Success = Str$(SuccessRecord("A7D1"))
A7D2Success = Str$(SuccessRecord("A7D2"))
A7D3Success = Str$(SuccessRecord("A7D3"))
A7D4Success = Str$(SuccessRecord("A7D4"))
A7D5Success = Str$(SuccessRecord("A7D5"))
A7D6Success = Str$(SuccessRecord("A7D6"))
A7D7Success = Str$(SuccessRecord("A7D7"))
A7D8Success = Str$(SuccessRecord("A7D8"))
A8D1Success = Str$(SuccessRecord("A8D1"))
A8D2Success = Str$(SuccessRecord("A8D2"))
A8D3Success = Str$(SuccessRecord("A8D3"))
A8D4Success = Str$(SuccessRecord("A8D4"))
A8D5Success = Str$(SuccessRecord("A8D5"))
A8D6Success = Str$(SuccessRecord("A8D6"))
A8D7Success = Str$(SuccessRecord("A8D7"))
A8D8Success = Str$(SuccessRecord("A8D8"))


If Multi = True Then

Move1Sum = SuccessRecord("A1D1") + SuccessRecord("A2D1") + SuccessRecord("A3D1") +
SuccessRecord("A4D1") + SuccessRecord("A5D1") + SuccessRecord("A6D1") + SuccessRecord("A7D1")
+ SuccessRecord("A8D1")
Move2Sum = SuccessRecord("A1D2") + SuccessRecord("A2D2") + SuccessRecord("A3D2") +
SuccessRecord("A4D2") + SuccessRecord("A5D2") + SuccessRecord("A6D2") + SuccessRecord("A7D2")
+ SuccessRecord("A8D2")
Move3Sum = SuccessRecord("A1D3") + SuccessRecord("A2D3") + SuccessRecord("A3D3") +
SuccessRecord("A4D3") + SuccessRecord("A5D3") + SuccessRecord("A6D3") + SuccessRecord("A7D3")
+ SuccessRecord("A8D3")
```

```
Move4Sum = SuccessRecord("A1D4") + SuccessRecord("A2D4") + SuccessRecord("A3D4") +
SuccessRecord("A4D4") + SuccessRecord("A5D4") + SuccessRecord("A6D4") + SuccessRecord("A7D4")
+ SuccessRecord("A8D4")
Move5Sum = SuccessRecord("A1D5") + SuccessRecord("A2D5") + SuccessRecord("A3D5") +
SuccessRecord("A4D5") + SuccessRecord("A5D5") + SuccessRecord("A6D5") + SuccessRecord("A7D5")
+ SuccessRecord("A8D5")
Move6Sum = SuccessRecord("A1D6") + SuccessRecord("A2D6") + SuccessRecord("A3D6") +
SuccessRecord("A4D6") + SuccessRecord("A5D6") + SuccessRecord("A6D6") + SuccessRecord("A7D6")
+ SuccessRecord("A8D6")
Move7Sum = SuccessRecord("A1D7") + SuccessRecord("A2D7") + SuccessRecord("A3D7") +
SuccessRecord("A4D7") + SuccessRecord("A5D7") + SuccessRecord("A6D7") + SuccessRecord("A7D7")
+ SuccessRecord("A8D7")
Move8Sum = SuccessRecord("A1D8") + SuccessRecord("A2D8") + SuccessRecord("A3D8") +
SuccessRecord("A4D8") + SuccessRecord("A5D8") + SuccessRecord("A6D8") + SuccessRecord("A7D8")
+ SuccessRecord("A8D8")

Else
Move1Sum = SuccessRecord("A1D1") + SuccessRecord("A4D1") + SuccessRecord("A6D1") +
SuccessRecord("A8D1")
Move4Sum = SuccessRecord("A1D4") + SuccessRecord("A4D4") + SuccessRecord("A6D4") +
SuccessRecord("A8D4")
Move6Sum = SuccessRecord("A1D6") + SuccessRecord("A4D6") + SuccessRecord("A6D6") +
SuccessRecord("A8D6")
Move8Sum = SuccessRecord("A1D8") + SuccessRecord("A4D8") + SuccessRecord("A6D8") +
SuccessRecord("A8D8")

End If



CurrentDb.QueryDefs.Delete "FindSuccess" & Subject
CurrentDb.QueryDefs.Refresh
Query = "SELECT * FROM Games WHERE GameID =" & Game
Set FindGames = CurrentDb.CreateQueryDef("FindGames" & Subject, Query)
Set GamesRecord = FindGames.OpenRecordset

Percent1 = Str$(GamesRecord("APercent1"))
Percent2 = Str$(GamesRecord("APercent2"))
Strategy1 = GamesRecord!AStrategy1
Strategy2 = GamesRecord!AStrategy2
Strategy3 = GamesRecord!AStrategy3
If Budget = True Then
IncomeBox = GamesRecord!Income
Strategy1CostBox = GamesRecord!Strategy1Cost
Strategy2CostBox = GamesRecord!Strategy2Cost
Strategy3CostBox = GamesRecord!Strategy3Cost
BudgetBox = IncomeBox
BudgetBox.Visible = True
Label252.Visible = True
Label122.Visible = True
Label247.Visible = True
MoveCost.Visible = True
```

```
End If

CurrentDb.QueryDefs.Delete "FindGames" & Subject
CurrentDb.QueryDefs.Refresh

If Multi = True Then
If Move1Sum >= 5 Then
   Move1Success = "Better than 75%"
ElseIf Move1Sum >= 4 Then
   Move1Success = "Better than 50%"
ElseIf Move1Sum >= 2 Then
   Move1Success = "Better than 25%"
Else
   Move1Success = "Less than 25%"
End If
If Move2Sum >= 5 Then
   Move2Success = "Better than 75%"
ElseIf Move2Sum >= 4 Then
   Move2Success = "Better than 50%"
ElseIf Move2Sum >= 2 Then
   Move2Success = "Better than 25%"
Else
   Move2Success = "Less than 25%"
End If
If Move3Sum >= 5 Then
   Move3Success = "Better than 75%"
ElseIf Move3Sum >= 4 Then
   Move3Success = "Better than 50%"
ElseIf Move3Sum >= 2 Then
   Move3Success = "Better than 25%"
Else
   Move3Success = "Less than 25%"
End If
If Move4Sum >= 5 Then
   Move4Success = "Better than 75%"
ElseIf Move4Sum >= 4 Then
   Move4Success = "Better than 50%"
ElseIf Move4Sum >= 2 Then
   Move4Success = "Better than 25%"
Else
   Move4Success = "Less than 25%"
End If
If Move5Sum >= 5 Then
   Move5Success = "Better than 75%"
ElseIf Move5Sum >= 4 Then
   Move5Success = "Better than 50%"
ElseIf Move5Sum >= 2 Then
   Move5Success = "Better than 25%"
Else
   Move5Success = "Less than 25%"
End If
If Move6Sum >= 5 Then
```

```
  Move6Success = "Better than 75%"
ElseIf Move6Sum >= 4 Then
  Move6Success = "Better than 50%"
ElseIf Move6Sum >= 2 Then
  Move6Success = "Better than 25%"
Else
  Move6Success = "Less than 25%"
End If
If Move7Sum >= 5 Then
  Move7Success = "Better than 75%"
ElseIf Move7Sum >= 4 Then
  Move7Success = "Better than 50%"
ElseIf Move7Sum >= 2 Then
  Move7Success = "Better than 25%"
Else
  Move7Success = "Less than 25%"
End If
If Move8Sum >= 5 Then
  Move8Success = "Better than 75%"
ElseIf Move8Sum >= 4 Then
  Move8Success = "Better than 50%"
ElseIf Move8Sum >= 2 Then
  Move8Success = "Better than 25%"
Else
  Move8Success = "Less than 25%"
End If


Else
If Move1Sum >= 2.75 Then
  Move1Success = "Better than 75%"
ElseIf Move1Sum >= 2.5 Then
  Move1Success = "Better than 50%"
ElseIf Move1Sum >= 2 Then
  Move1Success = "Better than 25%"
Else
  Move1Success = "Less than 25%"
End If
If Move4Sum >= 2.75 Then
  Move4Success = "Better than 75%"
ElseIf Move4Sum >= 2.5 Then
  Move4Success = "Better than 50%"
ElseIf Move4Sum >= 2 Then
  Move4Success = "Better than 25%"
Else
  Move4Success = "Less than 25%"
End If
If Move6Sum >= 2.75 Then
  Move6Success = "Better than 75%"
ElseIf Move6Sum >= 2.5 Then
  Move6Success = "Better than 50%"
ElseIf Move6Sum >= 2 Then
  Move6Success = "Better than 25%"
```

```
Else
  Move6Success = "Less than 25%"
End If

If Move8Sum >= 2.75 Then
  Move8Success = "Better than 75%"
ElseIf Move8Sum >= 2.5 Then
  Move8Success = "Better than 50%"
ElseIf Move8Sum >= 2 Then
  Move8Success = "Better than 25%"
Else
  Move8Success = "Less than 25%"
End If

End If


'Set up match payoff table for defender - attacker will simply link to it
If Defender = True Then
  'Check if Match Table already exists
  TableExists = False
  For Each MatchTable In CurrentDb.TableDefs
    If MatchTable.Name = "Match" & Match Then
      TableExists = True
    End If
  Next
  If TableExists = False Then
    Set MatchTable = CurrentDb.CreateTableDef("Match" & Match)
    Set MatchField = MatchTable.CreateField("Turn")
    MatchField.Type = DB_INTEGER
    MatchTable.Fields.Append MatchField
    Set MatchField = MatchTable.CreateField("SuccessNumber")
    MatchField.Type = DB_SINGLE
    MatchTable.Fields.Append MatchField
    Set MatchField = MatchTable.CreateField("DefenderMoved")
    MatchField.Type = DB_BOOLEAN
    MatchField.DefaultValue = False
    MatchTable.Fields.Append MatchField
    Set MatchField = MatchTable.CreateField("DefenseSuccess")
    MatchField.Type = DB_BOOLEAN
    MatchField.DefaultValue = False
    MatchTable.Fields.Append MatchField
    Set MatchField = MatchTable.CreateField("AMove")
    MatchField.Type = DB_TEXT
    MatchField.AllowZeroLength = True
    MatchTable.Fields.Append MatchField
    Set MatchField = MatchTable.CreateField("DMove")
    MatchField.Type = DB_TEXT
    MatchField.AllowZeroLength = True
    MatchTable.Fields.Append MatchField
    CurrentDb.TableDefs.Append MatchTable
    CurrentDb.TableDefs.Refresh
    Set TurnRecord = CurrentDb.OpenRecordset("Match" & Match)
```

```
      Set HistoryRecord = CurrentDb.OpenRecordset("History")
      For i = 1 To 50
         'Now create turn Entries
         TurnRecord.AddNew
         TurnRecord("Turn") = i
         TurnRecord("AMove") = ""
         TurnRecord("DMove") = ""
         TurnRecord.Update
          'Setup History Table Records
         HistoryRecord.AddNew
         HistoryRecord("MatchID") = Match
         HistoryRecord("Turn") = i
         HistoryRecord.Update
      Next
   End If
End If
GoTo Out ' skip error handling

'Labels Section

Common_Error:
   If BlownUp > 50 Then
      Resume Fatal
   ElseIf Err.Number = 3012 Then
      If StrComp(Query, "SELECT * FROM Matches WHERE Defender =" & Subject) = 0 Then
         CurrentDb.QueryDefs.Delete "FindMatch" & Subject
         CurrentDb.QueryDefs.Refresh
      ElseIf StrComp(Query, "SELECT * FROM Matches WHERE Attacker =" & Subject) = 0 Then
         CurrentDb.QueryDefs.Delete "FindMatch" & Subject
         CurrentDb.QueryDefs.Refresh
      ElseIf StrComp(Query, "SELECT * FROM Payoffs WHERE GameID =" & Game) = 0 Then
         CurrentDb.QueryDefs.Delete "FindPayoff" & Subject
         CurrentDb.QueryDefs.Refresh
      ElseIf StrComp(Query, "SELECT * FROM Success WHERE GameID =" & Game) = 0 Then
         CurrentDb.QueryDefs.Delete "FindSuccess" & Subject
         CurrentDb.QueryDefs.Refresh
      End If
      Resume Begin
   Else
      BlownUp = BlownUp + 1
      Set ErrorRecord = CurrentDb.OpenRecordset("Errors", DB_OPEN_DYNASET)
      With ErrorRecord
         .AddNew
         !BlownUpCount = BlownUp
         !ErrorDesc = Err.Description
         !ErrorNumber = Err.Number
         .Update
      End With
      Resume Begin
   End If

Fatal:
   MsgBox "An Error has Occurred in Form_GameForm:Class Module Load_Form. Notify Experimenter"
```

```
   GoTo Out

Out:

End Sub

Private Sub GameHelpButton_Click()


      DoCmd.OpenForm "DefenderHelp"


End Sub

Public Sub MakeMove_Click()
   Dim MatchReady As Boolean
   Dim Defender As Boolean, Rational As Boolean, Multi As Boolean, Budget As Boolean
   Dim AttackerMove As String, DefenderMove As String, MoveString As String
   Dim InitPayoff As Integer, i As Integer, MsgResponse As Integer, BlownUp As Integer, WaitCount As
Integer
   Dim Turn As Integer, Match As Integer, Game As Integer
   Dim AttackerPayoff As Single, DefenderPayoff As Single, SuccessProb As Single
   Dim RandomNumber As Single
   Dim TurnRecord As Recordset, ErrorRecord As Recordset
   Dim MatchTable As TableDef
   Dim AttackValue As Single



On Error GoTo ErrorHandler


Begin:
BlownUp = 0
Defender = Forms!GameForm!DefenderBox
Rational = Forms!GameForm!RationalBox
Multi = Forms!GameForm!MultipleBox
Budget = Forms!GameForm!BudgetaryBox
Turn = Forms!GameForm!TurnBox
Match = Forms!GameForm!MatchBox
Game = Forms!GameForm!GameBox

 If Multi = True Then
  DMoveBox = MultiMoveBox
  Else
  DMoveBox = SingleMoveBox
 End If

 If IsNull(DMoveBox) Then
     GoTo No_Move
 ElseIf Budget = True Then
     test = CalcBudget(DMoveBox, Multi)
     If test = False Then
```

```
      GoTo Out
    End If
  End If

  If Rational = True Then
    Randomize
    AttackValue = Rnd
    AttackValuebox = AttackValue

    If AttackValue <= Forms!GameForm!Percent1 Then
      AttackerMove = Forms!GameForm!Strategy1

    ElseIf AttackValue <= Forms!GameForm!Percent2 Then
      AttackerMove = Forms!GameForm!Strategy2

    Else
      AttackerMove = Forms!GameForm!Strategy3
    End If
  Else

  Randomize
  AttackValue = Int((8 * Rnd) + 1)
  If AttackValue = "1" Then
      AttackerMove = "A1"
    ElseIf AttackValue = "2" Then
      AttackerMove = "A2"
    ElseIf AttackValue = "3" Then
      AttackerMove = "A3"
    ElseIf AttackValue = "4" Then
      AttackerMove = "A4"
    ElseIf AttackValue = "5" Then
      AttackerMove = "A5"
    ElseIf AttackValue = "6" Then
      AttackerMove = "A6"
    ElseIf AttackValue = "7" Then
      AttackerMove = "A7"
    Else
      AttackerMove = "A8"
    End If
  End If

  attackbox = AttackerMove
  DefenderMove = ConvertMove(DMoveBox, True)
  defendbox = DefenderMove
  Set TurnRecord = CurrentDb.OpenRecordset("Match" & Match, DB_OPEN_DYNASET)
  TurnRecord.FindFirst "[Turn] = " & Turn
  WaitCount = 0
  While TurnRecord.EditMode = dbEditInProgress
    If WaitCount > 40000 Then
      MsgResponse = MsgBox("Move processing may be taking too long.  Notify the Experimenter.
Continue Waiting?", vbYesNo)
      If MsgResponse = vbYes Then
        WaitCount = 0
```

```
        Else
          GoTo Out
        End If
      End If
      WaitCount = WaitCount + 1
    Wend
    TurnRecord.Edit
    TurnRecord("DMove") = DefenderMove
    TurnRecord("AMove") = AttackerMove
    TurnRecord.Update
    DoCmd.Hourglass True
    WaitCount = 0


    DoCmd.Hourglass False
    'Get Initial Payoff
    MoveString = AttackerMove & DefenderMove
    InitPayoff = FindPayoff(MoveString)
    SuccessProb = FindSuccess(MoveString)
    WaitCount = 0
    While TurnRecord.EditMode = dbEditInProgress
    If WaitCount > 40000 Then
        MsgResponse = MsgBox("Move processing may be taking too long.  Notify the Experimenter.
Continue Waiting?", vbYesNo)
        If MsgResponse = vbYes Then
          WaitCount = 0
        Else
          GoTo Out
        End If
      End If
      WaitCount = WaitCount + 1
    Wend
    TurnRecord.Edit
    Randomize
    TurnRecord("SuccessNumber") = Rnd()
    If TurnRecord("SuccessNumber") < SuccessProb Then
      DefenderPayoff = 0
      TurnRecord("DefenseSuccess") = True
      MoveSuccessBox = "Successful!"
    Else
      DefenderPayoff = InitPayoff
      TurnRecord("DefenseSuccess") = False
      MoveSuccessBox = "Unsuccessful!"
    End If
    TurnRecord("DefenderMoved") = True
    TurnRecord.Update
    TurnRecord.Close
    LastPayoffBox = PayoffBox
    PayoffBox = DefenderPayoff
    TotalPayoffBox = TotalPayoffBox + DefenderPayoff
    Call UpdateHistory(AttackerMove, DefenderPayoff, DefenderMove, Match, Turn)
    Beep
```

```
'Check if 50 turns completed
If Turn = 50 Then
   MsgBox "You Have Completed The Experiment. Please Close the Program.  Thanks for Your
Participation"
   Application.Quit acPrompt
   GoTo Out
End If

'Normal End of Turn Processing
Turn = Turn + 1
Forms!GameForm!TurnBox = Turn
GoTo Out

'LABELS SECTION

No_Move:
   MsgBox "Please Select a Move!"
   If Multi = True Then
      MultiMoveBox.SetFocus
   Else
      SingleMoveBox.SetFocus
   End If
   GoTo Out

ErrorHandler:


   Resume Begin
   'BlownUp = BlownUp + 1
   'Set ErrorRecord = CurrentDb.OpenRecordset("Errors", DB_OPEN_DYNASET)
  ' With ErrorRecord
  '    .AddNew
   '   !BlownUpCount = BlownUp
    '  !ErrorDesc = Err.Description
     ' !ErrorNumber = Err.Number
   '   .Update
   'End With
  ' Resume


Abort:
   MsgBox "Experiment Terminated!"
   DoCmd.Hourglass False
   DoCmd.Close acForm, "GameForm"

Out:
End Sub

Public Function FindPayoff(Move As String) As Integer

   If Move = "A1D1" Then
      FindPayoff = Int(Forms!GameForm!A1D1Payoff)
   ElseIf Move = "A1D2" Then
```

```
    FindPayoff = Int(Forms!GameForm!A1D2Payoff)
  ElseIf Move = "A1D3" Then
    FindPayoff = Int(Forms!GameForm!A1D3Payoff)
  ElseIf Move = "A1D4" Then
    FindPayoff = Int(Forms!GameForm!A1D4Payoff)
  ElseIf Move = "A1D5" Then
    FindPayoff = Int(Forms!GameForm!A1D5Payoff)
  ElseIf Move = "A1D6" Then
    FindPayoff = Int(Forms!GameForm!A1D6Payoff)
  ElseIf Move = "A1D7" Then
    FindPayoff = Int(Forms!GameForm!A1D7Payoff)
  ElseIf Move = "A1D8" Then
    FindPayoff = Int(Forms!GameForm!A1D8Payoff)
  ElseIf Move = "A2D1" Then
    FindPayoff = Int(Forms!GameForm!A2D1Payoff)
  ElseIf Move = "A2D2" Then
    FindPayoff = Int(Forms!GameForm!A2D2Payoff)
  ElseIf Move = "A2D3" Then
    FindPayoff = Int(Forms!GameForm!A2D3Payoff)
  ElseIf Move = "A2D4" Then
    FindPayoff = Int(Forms!GameForm!A2D4Payoff)
  ElseIf Move = "A2D5" Then
    FindPayoff = Int(Forms!GameForm!A2D5Payoff)
  ElseIf Move = "A2D6" Then
    FindPayoff = Int(Forms!GameForm!A2D6Payoff)
  ElseIf Move = "A2D7" Then
    FindPayoff = Int(Forms!GameForm!A2D7Payoff)
  ElseIf Move = "A2D8" Then
    FindPayoff = Int(Forms!GameForm!A2D8Payoff)
  ElseIf Move = "A3D1" Then
    FindPayoff = Int(Forms!GameForm!A3D1Payoff)
  ElseIf Move = "A3D2" Then
    FindPayoff = Int(Forms!GameForm!A3D2Payoff)
  ElseIf Move = "A3D3" Then
    FindPayoff = Int(Forms!GameForm!A3D3Payoff)
  ElseIf Move = "A3D4" Then
    FindPayoff = Int(Forms!GameForm!A3D4Payoff)
  ElseIf Move = "A3D5" Then
    FindPayoff = Int(Forms!GameForm!A3D5Payoff)
  ElseIf Move = "A3D6" Then
    FindPayoff = Int(Forms!GameForm!A3D6Payoff)
  ElseIf Move = "A3D7" Then
    FindPayoff = Int(Forms!GameForm!A3D7Payoff)
  ElseIf Move = "A3D8" Then
    FindPayoff = Int(Forms!GameForm!A3D8Payoff)
  ElseIf Move = "A4D1" Then
    FindPayoff = Int(Forms!GameForm!A4D1Payoff)
  ElseIf Move = "A4D2" Then
    FindPayoff = Int(Forms!GameForm!A4D2Payoff)
  ElseIf Move = "A4D3" Then
    FindPayoff = Int(Forms!GameForm!A4D3Payoff)
  ElseIf Move = "A4D4" Then
    FindPayoff = Int(Forms!GameForm!A4D4Payoff)
```

```
ElseIf Move = "A4D5" Then
  FindPayoff = Int(Forms!GameForm!A4D5Payoff)
ElseIf Move = "A4D6" Then
  FindPayoff = Int(Forms!GameForm!A4D6Payoff)
ElseIf Move = "A4D7" Then
  FindPayoff = Int(Forms!GameForm!A4D7Payoff)
ElseIf Move = "A4D8" Then
  FindPayoff = Int(Forms!GameForm!A4D8Payoff)
ElseIf Move = "A5D1" Then
  FindPayoff = Int(Forms!GameForm!A5D1Payoff)
ElseIf Move = "A5D2" Then
  FindPayoff = Int(Forms!GameForm!A5D2Payoff)
ElseIf Move = "A5D3" Then
  FindPayoff = Int(Forms!GameForm!A5D3Payoff)
ElseIf Move = "A5D4" Then
  FindPayoff = Int(Forms!GameForm!A5D4Payoff)
ElseIf Move = "A5D5" Then
  FindPayoff = Int(Forms!GameForm!A5D5Payoff)
ElseIf Move = "A5D6" Then
  FindPayoff = Int(Forms!GameForm!A5D6Payoff)
ElseIf Move = "A5D7" Then
  FindPayoff = Int(Forms!GameForm!A5D7Payoff)
ElseIf Move = "A5D8" Then
  FindPayoff = Int(Forms!GameForm!A5D8Payoff)
ElseIf Move = "A6D1" Then
  FindPayoff = Int(Forms!GameForm!A6D1Payoff)
ElseIf Move = "A6D2" Then
  FindPayoff = Int(Forms!GameForm!A6D2Payoff)
ElseIf Move = "A6D3" Then
  FindPayoff = Int(Forms!GameForm!A6D3Payoff)
ElseIf Move = "A6D4" Then
  FindPayoff = Int(Forms!GameForm!A6D4Payoff)
ElseIf Move = "A6D5" Then
  FindPayoff = Int(Forms!GameForm!A6D5Payoff)
ElseIf Move = "A6D6" Then
  FindPayoff = Int(Forms!GameForm!A6D6Payoff)
ElseIf Move = "A6D7" Then
  FindPayoff = Int(Forms!GameForm!A6D7Payoff)
ElseIf Move = "A6D8" Then
  FindPayoff = Int(Forms!GameForm!A6D8Payoff)
ElseIf Move = "A7D1" Then
  FindPayoff = Int(Forms!GameForm!A7D1Payoff)
ElseIf Move = "A7D2" Then
  FindPayoff = Int(Forms!GameForm!A7D2Payoff)
ElseIf Move = "A7D3" Then
  FindPayoff = Int(Forms!GameForm!A7D3Payoff)
ElseIf Move = "A7D4" Then
  FindPayoff = Int(Forms!GameForm!A7D4Payoff)
ElseIf Move = "A7D5" Then
  FindPayoff = Int(Forms!GameForm!A7D5Payoff)
ElseIf Move = "A7D6" Then
  FindPayoff = Int(Forms!GameForm!A7D6Payoff)
ElseIf Move = "A7D7" Then
```

```
    FindPayoff = Int(Forms!GameForm!A7D7Payoff)
  ElseIf Move = "A7D8" Then
    FindPayoff = Int(Forms!GameForm!A7D8Payoff)
  ElseIf Move = "A8D1" Then
    FindPayoff = Int(Forms!GameForm!A8D1Payoff)
  ElseIf Move = "A8D2" Then
    FindPayoff = Int(Forms!GameForm!A8D2Payoff)
  ElseIf Move = "A8D3" Then
    FindPayoff = Int(Forms!GameForm!A8D3Payoff)
  ElseIf Move = "A8D4" Then
    FindPayoff = Int(Forms!GameForm!A8D4Payoff)
  ElseIf Move = "A8D5" Then
    FindPayoff = Int(Forms!GameForm!A8D5Payoff)
  ElseIf Move = "A8D6" Then
    FindPayoff = Int(Forms!GameForm!A8D6Payoff)
  ElseIf Move = "A8D7" Then
    FindPayoff = Int(Forms!GameForm!A8D7Payoff)
  ElseIf Move = "A8D8" Then
    FindPayoff = Int(Forms!GameForm!A8D8Payoff)
  End If

End Function

Public Function FindSuccess(Move As String) As Single

  If Move = "A1D1" Then
    FindSuccess = Forms!GameForm!A1D1Success
  ElseIf Move = "A1D2" Then
    FindSuccess = Forms!GameForm!A1D2Success
  ElseIf Move = "A1D3" Then
    FindSuccess = Forms!GameForm!A1D3Success
  ElseIf Move = "A1D4" Then
    FindSuccess = Forms!GameForm!A1D4Success
  ElseIf Move = "A1D5" Then
    FindSuccess = Forms!GameForm!A1D5Success
  ElseIf Move = "A1D6" Then
    FindSuccess = Forms!GameForm!A1D6Success
  ElseIf Move = "A1D7" Then
    FindSuccess = Forms!GameForm!A1D7Success
  ElseIf Move = "A1D8" Then
    FindSuccess = Forms!GameForm!A1D8Success
  ElseIf Move = "A2D1" Then
    FindSuccess = Forms!GameForm!A2D1Success
  ElseIf Move = "A2D2" Then
    FindSuccess = Forms!GameForm!A2D2Success
  ElseIf Move = "A2D3" Then
    FindSuccess = Forms!GameForm!A2D3Success
  ElseIf Move = "A2D4" Then
    FindSuccess = Forms!GameForm!A2D4Success
  ElseIf Move = "A2D5" Then
    FindSuccess = Forms!GameForm!A2D5Success
  ElseIf Move = "A2D6" Then
    FindSuccess = Forms!GameForm!A2D6Success
```

```
ElseIf Move = "A2D7" Then
  FindSuccess = Forms!GameForm!A2D7Success
ElseIf Move = "A2D8" Then
  FindSuccess = Forms!GameForm!A2D8Success
ElseIf Move = "A3D1" Then
  FindSuccess = Forms!GameForm!A3D1Success
ElseIf Move = "A3D2" Then
  FindSuccess = Forms!GameForm!A3D2Success
ElseIf Move = "A3D3" Then
  FindSuccess = Forms!GameForm!A3D3Success
ElseIf Move = "A3D4" Then
  FindSuccess = Forms!GameForm!A3D4Success
ElseIf Move = "A3D5" Then
  FindSuccess = Forms!GameForm!A3D5Success
ElseIf Move = "A3D6" Then
  FindSuccess = Forms!GameForm!A3D6Success
ElseIf Move = "A3D7" Then
  FindSuccess = Forms!GameForm!A3D7Success
ElseIf Move = "A3D8" Then
  FindSuccess = Forms!GameForm!A3D8Success
ElseIf Move = "A4D1" Then
  FindSuccess = Forms!GameForm!A4D1Success
ElseIf Move = "A4D2" Then
  FindSuccess = Forms!GameForm!A4D2Success
ElseIf Move = "A4D3" Then
  FindSuccess = Forms!GameForm!A4D3Success
ElseIf Move = "A4D4" Then
  FindSuccess = Forms!GameForm!A4D4Success
ElseIf Move = "A4D5" Then
  FindSuccess = Forms!GameForm!A4D5Success
ElseIf Move = "A4D6" Then
  FindSuccess = Forms!GameForm!A4D6Success
ElseIf Move = "A4D7" Then
  FindSuccess = Forms!GameForm!A4D7Success
ElseIf Move = "A4D8" Then
  FindSuccess = Forms!GameForm!A4D8Success
ElseIf Move = "A5D1" Then
  FindSuccess = Forms!GameForm!A5D1Success
ElseIf Move = "A5D2" Then
  FindSuccess = Forms!GameForm!A5D2Success
ElseIf Move = "A5D3" Then
  FindSuccess = Forms!GameForm!A5D3Success
ElseIf Move = "A5D4" Then
  FindSuccess = Forms!GameForm!A5D4Success
ElseIf Move = "A5D5" Then
  FindSuccess = Forms!GameForm!A5D5Success
ElseIf Move = "A5D6" Then
  FindSuccess = Forms!GameForm!A5D6Success
ElseIf Move = "A5D7" Then
  FindSuccess = Forms!GameForm!A5D7Success
ElseIf Move = "A5D8" Then
  FindSuccess = Forms!GameForm!A5D8Success
ElseIf Move = "A6D1" Then
```

```
    FindSuccess = Forms!GameForm!A6D1Success
  ElseIf Move = "A6D2" Then
    FindSuccess = Forms!GameForm!A6D2Success
  ElseIf Move = "A6D3" Then
    FindSuccess = Forms!GameForm!A6D3Success
  ElseIf Move = "A6D4" Then
    FindSuccess = Forms!GameForm!A6D4Success
  ElseIf Move = "A6D5" Then
    FindSuccess = Forms!GameForm!A6D5Success
  ElseIf Move = "A6D6" Then
    FindSuccess = Forms!GameForm!A6D6Success
  ElseIf Move = "A6D7" Then
    FindSuccess = Forms!GameForm!A6D7Success
  ElseIf Move = "A6D8" Then
    FindSuccess = Forms!GameForm!A6D8Success
  ElseIf Move = "A7D1" Then
    FindSuccess = Forms!GameForm!A7D1Success
  ElseIf Move = "A7D2" Then
    FindSuccess = Forms!GameForm!A7D2Success
  ElseIf Move = "A7D3" Then
    FindSuccess = Forms!GameForm!A7D3Success
  ElseIf Move = "A7D4" Then
    FindSuccess = Forms!GameForm!A7D4Success
  ElseIf Move = "A7D5" Then
    FindSuccess = Forms!GameForm!A7D5Success
  ElseIf Move = "A7D6" Then
    FindSuccess = Forms!GameForm!A7D6Success
  ElseIf Move = "A7D7" Then
    FindSuccess = Forms!GameForm!A7D7Success
  ElseIf Move = "A7D8" Then
    FindSuccess = Forms!GameForm!A7D8Success
  ElseIf Move = "A8D1" Then
    FindSuccess = Forms!GameForm!A8D1Success
  ElseIf Move = "A8D2" Then
    FindSuccess = Forms!GameForm!A8D2Success
  ElseIf Move = "A8D3" Then
    FindSuccess = Forms!GameForm!A8D3Success
  ElseIf Move = "A8D4" Then
    FindSuccess = Forms!GameForm!A8D4Success
  ElseIf Move = "A8D5" Then
    FindSuccess = Forms!GameForm!A8D5Success
  ElseIf Move = "A8D6" Then
    FindSuccess = Forms!GameForm!A8D6Success
  ElseIf Move = "A8D7" Then
    FindSuccess = Forms!GameForm!A8D7Success
  ElseIf Move = "A8D8" Then
    FindSuccess = Forms!GameForm!A8D8Success
  End If

End Function

Public Sub UpdateHistory(AttMove As String, DPayoff As Single, DefMove As String, Match As Integer,
Turn As Integer)
```

```
   Dim HistoryQuery As QueryDef
   Dim HistoryRecord As Recordset, ErrorRecord As Recordset
   Dim Query As String
   Dim BlownUp As Integer

   On Error GoTo Error_Handler
   BlownUp = 0

Begin:
   If AttMove = "A1" Then
      AttMoveH = "Integrity Attack"
   ElseIf AttMove = "A2" Then
      AttMoveH = "Integrity,Availability Attack"
   ElseIf AttMove = "A3" Then
      AttMoveH = "Integrity,Confidentiality Attack"
   ElseIf AttMove = "A4" Then
      AttMoveH = "Availability Attack"
   ElseIf AttMove = "A5" Then
      AttMoveH = "Availability,Confidentiality Attack"
   ElseIf AttMove = "A6" Then
      AttMoveH = "Confidentiality Attack"
   ElseIf AttMove = "A7" Then
      AttMoveH = "Integrity,Availability,Confidentiality Attack"
   ElseIf AttMove = "A8" Then
      AttMoveH = "None"

   End If

   If DefMove = "D1" Then
      DefMoveH = "Integrity Defense"
      Forms!GameForm!Move1Turns = Forms!GameForm!Move1Turns + 1
      Forms!GameForm!Move1Payoffs = Forms!GameForm!Move1Payoffs + DPayoff
      Forms!GameForm!Move1Average = Forms!GameForm!Move1Payoffs /
Forms!GameForm!Move1Turns
   ElseIf DefMove = "D2" Then
      DefMoveH = "Integrity,Availability Defense"
      Forms!GameForm!Move2Turns = Forms!GameForm!Move2Turns + 1
      Forms!GameForm!Move2Payoffs = Forms!GameForm!Move2Payoffs + DPayoff
      Forms!GameForm!Move2Average = Forms!GameForm!Move2Payoffs /
Forms!GameForm!Move2Turns
   ElseIf DefMove = "D3" Then
      DefMoveH = "Integrity,Confidentiality Defense"
      Forms!GameForm!Move3Turns = Forms!GameForm!Move3Turns + 1
      Forms!GameForm!Move3Payoffs = Forms!GameForm!Move3Payoffs + DPayoff
      Forms!GameForm!Move3Average = Forms!GameForm!Move3Payoffs /
Forms!GameForm!Move3Turns
   ElseIf DefMove = "D4" Then
      DefMoveH = "Availability Defense"
      Forms!GameForm!Move4Turns = Forms!GameForm!Move4Turns + 1
      Forms!GameForm!Move4Payoffs = Forms!GameForm!Move4Payoffs + DPayoff
      Forms!GameForm!Move4Average = Forms!GameForm!Move4Payoffs /
Forms!GameForm!Move4Turns
```

```
  ElseIf DefMove = "D5" Then
    DefMoveH = "Availability,Confidentiality Defence"
    Forms!GameForm!Move5Turns = Forms!GameForm!Move5Turns + 1
    Forms!GameForm!Move5Payoffs = Forms!GameForm!Move5Payoffs + DPayoff
    Forms!GameForm!Move5Average = Forms!GameForm!Move5Payoffs /
Forms!GameForm!Move5Turns
  ElseIf DefMove = "D6" Then
    DefMoveH = "Confidentiality Defense"
    Forms!GameForm!Move6Turns = Forms!GameForm!Move6Turns + 1
    Forms!GameForm!Move6Payoffs = Forms!GameForm!Move6Payoffs + DPayoff
    Forms!GameForm!Move6Average = Forms!GameForm!Move6Payoffs /
Forms!GameForm!Move6Turns
  ElseIf DefMove = "D7" Then
    DefMoveH = "Integrity,Availability,Confidentiality Defense"
    Forms!GameForm!Move7Turns = Forms!GameForm!Move7Turns + 1
    Forms!GameForm!Move7Payoffs = Forms!GameForm!Move7Payoffs + DPayoff
    Forms!GameForm!Move7Average = Forms!GameForm!Move7Payoffs /
Forms!GameForm!Move7Turns
  ElseIf DefMove = "D8" Then
    DefMoveH = "None"
    Forms!GameForm!Move8Turns = Forms!GameForm!Move8Turns + 1
    Forms!GameForm!Move8Payoffs = Forms!GameForm!Move8Payoffs + DPayoff
    Forms!GameForm!Move8Average = Forms!GameForm!Move8Payoffs /
Forms!GameForm!Move8Turns
  End If
  Query = "SELECT * FROM History WHERE MatchID = " & Match
  Set HistoryQuery = CurrentDb.CreateQueryDef("FindHistory" & SubjectBox, Query)
  Set HistoryRecord = HistoryQuery.OpenRecordset
  HistoryRecord.FindFirst "[Turn] = " & Turn

    While HistoryRecord.EditMode = dbEditInProgress
      Wend
    HistoryRecord.Edit
      HistoryRecord("DefendAction") = DefMoveH
      HistoryRecord("DefendPayoff") = DPayoff
      HistoryRecord("AttackAction") = AttMoveH
    HistoryRecord.Update
    HistoryRecord.Close
    DefendHistory.Requery

Delete_Query:
  CurrentDb.QueryDefs.Delete "FindHistory" & SubjectBox
  CurrentDb.QueryDefs.Refresh
  GoTo Out

Error_Handler:
  If Err.Number = 3167 Then
    Resume Delete_Query
  ElseIf Err.Number = 3012 Then
    CurrentDb.QueryDefs.Delete "FindHistory" & SubjectBox
    CurrentDb.QueryDefs.Refresh
    Resume Begin
  Else
```

```
        BlownUp = BlownUp + 1
        Set ErrorRecord = CurrentDb.OpenRecordset("Errors", DB_OPEN_DYNASET)
        With ErrorRecord
          .AddNew
          !BlownUpCount = BlownUp
          !ErrorDesc = Err.Description
          !ErrorNumber = Err.Number
          .Update
        End With
        Resume Begin
      End If

Out:

End Sub

Public Function ConvertMove(Move As String, Defender As Boolean) As String
'Converts Move from User's Name to A1/D1 Notation


        If Move = "Integrity Defense" Then
          ConvertMove = "D1"
        ElseIf Move = "Integrity,Availability Defense" Then
          ConvertMove = "D2"
        ElseIf Move = "Integrity,Confidentiality Defense" Then
          ConvertMove = "D3"
        ElseIf Move = "Availability Defense" Then
          ConvertMove = "D4"
        ElseIf Move = "Availability,Confidentiality Defense" Then
          ConvertMove = "D5"
        ElseIf Move = "Confidentiality Defense" Then
          ConvertMove = "D6"
        ElseIf Move = "Integrity,Availability,Confidentiality Defense" Then
          ConvertMove = "D7"
        Else
          ConvertMove = "D8"
        End If


End Function


Public Function CalcBudget(Move As String, Multi As Boolean) As Currency
'Calculates available budget based on strategy cost and new income
Dim Income As Currency, Cost As Currency

Begin:
Income = IncomeBox
CalcBudget = True


        If Move = "Integrity Defense" Then
          Cost = Strategy1CostBox
```

```
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  ElseIf Move = "Integrity,Availability Defense" Then
    Cost = Strategy1CostBox + Strategy2CostBox
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  ElseIf Move = "Integrity,Confidentiality Defense" Then
    Cost = Strategy1CostBox + Strategy3CostBox
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  ElseIf Move = "Availability Defense" Then
    Cost = Strategy2CostBox
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  ElseIf Move = "Availability,Confidentiality Defense" Then
    Cost = Strategy2CostBox + Strategy3CostBox
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  ElseIf Move = "Confidentiality Defense" Then
    Cost = Strategy3CostBox
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  ElseIf Move = "Integrity,Availability,Confidentiality Defense" Then
    Cost = Strategy1CostBox + Strategy2CostBox + Strategy3CostBox
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
    End If
  Else
    Cost = 0
    If Cost <= BudgetBox Then
      BudgetBox = BudgetBox + Income - Cost
    Else
      GoTo No_Funds
```

```
        End If
      End If

GoTo Out

No_Funds:
   MsgBox "Insuficiant Funds; Please Select Diferent Move!"
   CalcBudget = False
   If Multi = True Then
      MultiMoveBox.SetFocus

   Else
      SingleMoveBox.SetFocus

   End If
   GoTo Out
Out:
End Function

Private Sub MultiMoveBox_Change()
If MultiMoveBox = "Integrity Defense" Then
   MoveCost = Strategy1CostBox
ElseIf MultiMoveBox = "Availability Defense" Then
   MoveCost = Strategy2CostBox
ElseIf MultiMoveBox = "Confidentiality Defense" Then
   MoveCost = Strategy3CostBox
ElseIf MultiMoveBox = "Integrity,Availability Defense" Then
   MoveCost = Strategy1CostBox + Strategy2CostBox
ElseIf MultiMoveBox = "Integrity,Confidentiality Defense" Then
   MoveCost = Strategy1CostBox + Strategy3CostBox
ElseIf MultiMoveBox = "Availability,Confidentiality Defense" Then
   MoveCost = Strategy2CostBox + Strategy3CostBox
ElseIf MultiMoveBox = "Integrity,Availability,Confidentiality Defense" Then
   MoveCost = Strategy1CostBox + Strategy2CostBox + Strategy3CostBox
Else: MoveCost = 0
End If
End Sub

Private Sub SingleMoveBox_Change()
If SingleMoveBox = "Integrity Defense" Then
   MoveCost = Strategy1CostBox
ElseIf SingleMoveBox = "Availability Defense" Then
   MoveCost = Strategy2CostBox
ElseIf SingleMoveBox = "Confidentiality Defense" Then
   MoveCost = Strategy3CostBox
Else: MoveCost = 0
End If

End Sub
```

Bibliography

Allen, Lee, trans. Attacks by Erwin Rommel. Atlona Press: 1979.

Aumann, Robert J. and Michael B. Maschler. Repeated Games with Incomplete Information. Campbridge, MA: MIT Press, 1995

Best, Roger J. and Michael L. Ursic. "The Impact of Information Load and Variability on Choice Accuracy" In Advances in Consumer Research, 14: Eds. Melanie Wallendorf and Paul Anderson. Provo, UT: Association for Consumer Research 106-108 (1987)

Boyle, Mary. "Military Faces High-Tech Security Shortage" Colorado Springs Gazette (15 February 2000).

Burke, David A. Towards a Game Theory Model of Information Warfare. MS thesis, AFIT/GSS/LAL/99D-1. School of Engineering and Management, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, November 1999.

Carlton, Dennis W. and Perloff, Jeffrey M. Modern Industrial Organization. Addison Wesley Longman, 2000.

Cohen, Fred. "Managing Network Security Attack and Defense Strategies" http://all.net/journal/netsec/index.html (July 1999).

Cronin, Crawford Blaise. "Information Warfare: Its Applications in Military and Civilian Contexts" Information Society, 15:4: 257 – 264 (Oct-Dec 1999).

Denning, Dorothy E. Information Warfare and Security. ACM Press, 1999.

Department of Defense. Joint Vision 2020. Joint Chiefs of Staff Publication. Washingtion: GPO June 2000.

Dooley, David. Social Research Methods. New Jersey: Prentice Hall, 1999.

Essame, H. Patton: Study in Command. New York: Charles Scribner's Sons 1974

Gibbons, Robert. "An Introduction to Applicable Game Theory" Journal of Economic Perspectives, 11:1: 127 – 150 (Winter 1997).

Harsanyi, John C. "In Defense of Game Theory" Rationality & Society, 4:1: 51 – 62 (January 1992).

Harsanyi, John C. "Games With Incomplete Information" American Economic Review, 85:3: 289 – 304 (June 1995).

Heal, Andrew and Leonard Wantchekon. "The Game of Torture" Journal of Economic Conflict. (October 1999)

Helgeson, James G and Michael L. Ursic. "Information Load, Cost/Benefit Assessment and Decision Strategy Variability" Journal of the Academy of Marketing Science, 21: 13-20 (Winter 1993).

Joint Economic Committee. Cyber Threats and the U.S. Economy. United States Congress, 2000. Washington DC.

Leatham, Anthony L. Some Theoretical Aspects of Non Zero Sum Differential Games and Applications to Combat Problems. Air Force Institute Of Technology (AU), Wright-Patterson AFB OH, June 1971

Lichbach, Mark Irving. "When is an Arms Rivalry a Prisoner's Dilemma? Richardson's Models and 2 x2 Games" Journal of Conflict and Resolution, 34:1: 29 - 54 (March 90)

Malhotra, Naresh. "Information Load and Consumer Decision-Making" Journal of Consumer Research, 9: 436 – 440 (1982)

McClave, James T. and Others. Statistics For Business and Economics. New Jersey: Prentice Hall, 1998.

Myerson, Roger B. "On the Value of Game Theory in Social Science" Rationality & Society, 4: 1: 62 – 74 (January 1992).

President's Commission on Critical Infrastructure Protection. "Critical Foundations; Protecting America's Infrastructures. Part One, The Case for Action," The Report of the President's Commission on Critical Infrustructure Protection (October 1997).

Rapaport, Richard. "The Feds Strike Back" Forbes, 164: 4: 120 – 127 (23 August 1999).

Robinson, Paul C. "Critical Infrastructure: Interlinked and Vulnerable" Issues In Science & Technology, 15: 1: 61 – 68 (Fall 1998)

Sall, John, and Ann Lehman SAS Institute Inc. JMP® Start Statistics. Belmont: Duxbury Press, 1996.

Schwartau, Winn. "Asymmetrical Adversaries" Orbis, 44: 197-206 (Spring 2000).

Shubik, Martin. Game Theory in the Social Sciences – Concepts and Solutions, Cambridge: MIT Press, 1982.

Turk, Robert and Shawn Hollingsworth. "Information Assurance: The Army Prepares for the Next Generation of Warfare" Ianewsletter, 3: 15-17 (Fall 1999)

Von Neumann J. and Oskar Morgenstern. Theory of Games and Economic Behavior, Princeton University Press, 1944.

White, Kenneth C. Cyber-Terrorism: Modem Mayhem U.S. Army War College, Carlisle Barracks, Pennsylvania, April 1998 (AD-A345705).

Zagare, Franke C. "Game Theory: Concepts and Applications" Sage University Paper series on Quantitative Applications in the Social Sciences, 07-041: Newbury Park: Sage Publications, 1984.

Zeager, Lester. and Johnathan B. Bascom. "Strategic Behavior in Refugee Repatriation" Journal of Economic Conflict. (September1997)

Vita

1st. Lieutenant Steven W. Tait was born and raised in Southern California. He began his military career when he enlisted in the U.S. Army as an Infantryman in May of 1987. After completion of basic training at Ft. Benning, Georgia, he was assigned to the 2nd Battalion 41st Infantry Regiment at Ft. Hood Texas as a Bradley Fighting Vehicle Driver. In November of 1988, he was reassigned to the 1nd of the 30th Infantry Regiment (re-designated 2nd of the 15th), Schweinfurt, Germany. While stationed there he served as a Bradley Gunner, Bradley Commander, and Dismounted Squad Leader. During this time, he met and married his wife. In September of 1993, he was reassigned to the 3rd Training Brigade at Ft. Leonard Wood, Missouri.

In January of 1995 he left the Army to finish his undergraduate degree at Columbia College, Missouri, where he graduated with a Bachelor of Science in Computer Information Systems and Business Administration in 1997. He was commissioned through the Detachment 442 AFROTC at the University of Missouri Rolla where he was recognized as a distinguished graduate.

His first Air Force Assignment was at the 77th Communications Squadron, McClellan AFB, California, in November 1997. While there, he served as Chief of Base Systems and as the Deputy Commander, Information Systems Flight. In August of 1999, he entered the Graduate School of Engineering and Management, Air Force Institute of Technology, Wright-Patterson AFB, Ohio. Upon graduation, he will be assigned to the Air Force Communications Agency, Scott AFB, Illinois.

REPORT DOCUMENTATION PAGE			*Form Approved* *OMB No. 074-0188*

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From – To)*
20-03-2001	Master's Thesis	Aug 1999 – Mar 2001

4. TITLE AND SUBTITLE	**5a. CONTRACT NUMBER**
THE EFFECTS OF BUDGETARY CONSTRAINTS, MULTIPLE STRATEGY SELECTION, AND RATIONALITY ON EQUILIBRIUM ATTAINMENT IN AN INFORMATION WARFARE SIMULATION	**5b. GRANT NUMBER**
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	**5d. PROJECT NUMBER**
Tait, Steven, W., 1st Lieutenant, USAF	**5e. TASK NUMBER**
	5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(S)	**8. PERFORMING ORGANIZATION REPORT NUMBER**
Air Force Institute of Technology Graduate School of Engineering and Management (AFIT/EN) 2950 P Street, Building 640 WPAFB OH 45433-7765	AFIT/GIR/ENV/01M-13
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSOR/MONITOR'S ACRONYM(S)**
N/A	**11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION/AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Information warfare (IW) has developed into a significant threat to the national security of the United States. Our critical infrastructures, linked together by information systems, are increasingly vulnerable to information attack. This study seeks to understand some of those factors which affect the ability of an individual to make accurate decisions in an IW environment.
The study used game theory to analyze the behavior of decision-makers within an IW simulation. The IW game model is based on a set of games known as infinitely repeated games of incomplete information. It uses the Bayesian Nash equilibrium concept to determine the strategy which a player should use repeatedly in order to maximize his or her payoff.
The results of the experiment show that a person faced with increasing numbers of potential strategies, is less likely to make accurate decisions. The results also show that decision-makers faced with budgetary constraints tend to pick those strategies which are most expensive. This is regardless of the actual utility of the strategy as long as it is within the decision-makers' budget. Additionally, the study found that the rationality of decisions made by an opponent did not affect a player's ability to find the payoff maximizing strategy.

15. SUBJECT TERMS

Game Theory, Equilibrium Attainment, Nash Equilibrium, Bayesian Equilibrium, Information Warfare, Information Operations, Information Systems, Critical Infrastructure, Rationality, Strategies

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Major David P. Biros, ENV
U	U	U	UU	108	**19b. TELEPHONE NUMBER** *(Include area code)* (937) 255-3636, ext 4826

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39-18

	Form Approved *OMB No. 074-0188*