Principles of Modeling and Simulation

A Multidisciplinary Approach

Edited by

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This book is dedicated to

Marsha, Amy, and Whitney

—John A. Sokolowski

Benjamin M. Mercury

—Catherine M. Banks

Contents

Preface

The impetus for this study is the realization that no textbook exists that provides an introduction to modeling and simulation suitable for multiple disciplines, especially those that are outside the science and engineering fields.

Many universities are realizing that modeling and simulation is becoming an important tool in solving and understanding numerous and diverse problems. They have begun to offer introductory courses in this field to acquaint their students with the foundational concepts that will help them apply modeling and simulation in many areas of research. This text serves to provide an orientation to the theory and applications of modeling and simulation from a multidisciplinary perspective.

To students who will be reading this text we offer a concise look at the key concepts making up the field of modeling and simulation. While modeling and simulation necessarily entails mathematical representations and computer programs, students need only be familiar with math at the college algebra level and the use of spreadsheets to understand the modeling and simulation concepts covered in this book.

The text is divided into three parts with nine chapters. Part One, *Principles of Modeling and Simulation: A Multidisciplinary Approach* introduces modeling and simulation and its role. Chapter 1 answers the question, "What Is Modeling and Simulation?" The chapter provides a brief history of modeling and simulation, lists the many uses or applications of modeling and simulation, and speaks to the advantages and disadvantages of using models in problem solving. Chapter 2 focuses on "The Role of Modeling and Simulation." It covers the two main reasons to employ modeling and simulation: solving a specific problem, and using modeling and simulation to gain insight into complex concepts.

Part Two, *Theoretical Underpinnings*, examines the most fundamental aspects of modeling and simulation. Chapter 3, "Simulation: Models That Vary over Time," provides a definition for simulation and introduces the reader to two main simulation concepts: discrete event simulation and simulation of continuous systems. Chapter 4, "Queue Modeling and Simulation" examines queuing models, sequential simulation, and parallel simulation. Chapter 5, "Human Interaction with Simulations," explains the two primary methods in which humans interface with simulations: simulation and data dependency and visual representation. Chapter 6, "Verification and Validation," answers two fundamental questions: What is verification and validation? and Why is verification and validation important?

Part Three, *Practical Domains*, affords the student an opportunity to consider the many uses of modeling and simulation as a tool in workforce development. Students will also review case studies and research conducted in various disciplines emphasizing the notion that models serve as approximations of real-world events.

Chapter 7 addresses the "Uses of Simulation." These uses are found in training, analysis, decision support, and acquisition. Chapter 8, "Modeling and Simulation: Real-World Examples," delves into specific applications of modeling and simulation in the Transportation, Business, Medical, and Social Sciences domains. Chapter 9 addresses "The Future of Simulation" by providing a basis for accepting modeling and simulation as a discipline with its own body of knowledge, research methods, and curriculum of study. It provides answers to the questions: Is modeling and simulation a tool or discipline? How should education, research, and training be conducted to support workforce development?

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Part One

Principles of Modeling and Simulation: A Multidisciplinary Approach

Chapter 1

What Is Modeling and Simulation?

Catherine M. Banks

INTRODUCTION

Modeling and Simulation, or M&S as it is commonly referred, is becoming one of the academic programs of choice for students in all disciplines. M&S is a discipline with its own body of knowledge, theory, and research methodology. At the core of the discipline is the fundamental notion that *models are approximations for the real-world*. To engage M&S, students must first create a model approximating an event. The model is then followed by *simulation*, which allows for the repeated observation of the model. After one or many simulations of the model, a third step takes place and that is *analysis*. Analysis aids in the ability to draw conclusions, verify and validate the research, and make recommendations based on various iterations or simulations of the model. These basic precepts coupled with *visualization*, the ability to represent data as a way to interface with the model, make M&S a problem-based discipline that allows for repeated testing of a hypothesis. Teaching these precepts and providing research and development opportunities are core to M&S education. M&S also serves as a tool or application that expands the ability to analyze and communicate new research or findings.

There has been much attention paid to M&S by the National Science Foundation (NSF). In 1999, then Director Dr. Rita R. Colwell declared simulation as the *third branch* of science at the fall meeting of the American Geophysical Union [1]. In a more recent report entitled, "Simulation-based Engineering Science: Revolutionizing Engineering Science through Simulation," the NSF drew on the expertise of an esteemed cadre of scientists to discuss the challenges facing the United States as a technological world leader. The group made four recommendations that they

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believed would help restore the United States to its leadership role in this strategically critical technology (simulation). One recommendation went straight to the study of M&S:

> *"The Panel recommends that NSF underwrite an effort to explore the possibility of initiating a sweeping overhaul of our engineering educational system to reflect the multidisciplinary nature of modern engineering and to help students acquire the necessary modeling and simulation skills."* [2]
>
> Simulation-Based Engineering Science: Final Report, May 2006

The intent of this text is to introduce you to M&S education and research from a multidisciplinary approach so that you can acquire the skills necessary to this critical technology.

Fundamental to a formal engineering M&S program of study is its curriculum built upon four precepts—modeling, simulation, visualization, and analysis. Students study the basics of **modeling** as a way to understand the various modeling paradigms appropriate for conducting digital computer simulations. They must understand **simulation** and the methodology, development, verification and validation, and design of simulation experiments. Students who are able to engage **visualization** are able to provide an overview of interactive, real-time 3D computer graphics and visual simulations using high-level development tools. Important to any student research is the **analysis** of the findings; and included in any good analysis is an observation of the constraints and requirements of applying M&S. In other words, analysis also includes making known the limitations of the research.

It was political scientist Herbert A. Simon (1916–2001) who introduced the notion of *learning by doing* (also known as experiential learning).[1] M&S can be just that. It is the simulation of a model that allows for the imitation of the operation of a real-world process or system over time. To imitate an operation over time one must generate a history, real or artificial, to draw inferences concerning the operating characteristics of the real system that is represented [3]. The art and science of M&S has evolved very rapidly since the mid-1980s, so much so that it easily parallels the technological advances of mainframe and desktop computers and the ever-increasing emergence of the internet and World Wide Web (www).

[1] **Herbert A. Simon** was a political scientist who conducted research in a variety of disciplines including cognitive psychology, computer science, public administration, economics, management, and philosophy of science. Dr. Simon was among the founding fathers of several of today's most important scientific domains, including artificial intelligence, information processing, decision-making, problem-solving, attention economics, organization theory, complex systems, and computer simulation of scientific discovery. He was the first to analyze the architecture of complexity and to propose a preferential attachment mechanism to explain power law distributions. He introduced the notion of *experiential learning, bounded rationality*, and *satisficing*. Dr. Simon's research at Carnegie Mellon University resulted in numerous cited publications. He remains one of the most influential social scientists of the 20th century.

MODELS: APPROXIMATIONS OF REAL-WORLD EVENTS

A *model* is a representation of an event and/or things that is real (a case study) or contrived (a use-case). It can be a representation of an actual system. It can be something used in lieu of the real thing to better understand a certain aspect about that thing. To produce a model you must abstract from reality a description of a vibrant system. The model can depict the system at some point of abstraction or at multiple levels of the abstraction with the goal of representing the system in a mathematically reliable fashion. A *simulation* is an applied methodology that can describe the behavior of that system using either a mathematical model or a symbolic model [4]. Simply, simulation is the imitation of the operation of a real-world process or system over a period of time [3]. As you will see there are many uses of M&S. M&S can be used to determine the ordering policies of Wal-Mart's extensive inventory system, or it can be used to analyze the prospects and rate of rehabilitation of a patient who just underwent knee-replacement surgery, or it can be used to evaluate ocean currents and waves to better understand weather patterns.

M&S begins with 1) developing computer simulation or a design based on a model of an actual or theoretical physical system, then 2) executing that model on a digital computer, and 3) analyzing the output. Models and the ability to act out with those models is a credible way of understanding the complexity and particulars of a real entity [4]. From these three steps you can see that M&S facilitates the simulation of a system and then a testing of the hypothesis about that system. For example, if you wanted to determine how many cashiers are needed to process a certain number of customers during rush hour with the assurance that the store's high level of quality service was not compromised, you must first research the current system of processing customers.

You will no doubt review the work schedule and note that the manager has scheduled more cashiers during peak times. You will then assess how many customers are processed during peak times based on the cashier tapes. Also, you might want to see how long it takes to process a customer at slow periods and at heavy traffic periods—you might be surprised to find that customers are processed in shorter exchanges at busy times. Do the customers feel rushed? How many errors are made? Do the customer lines flow smoothly? Are the cash registers placed in good locations? All of this is part of the initial research you will do to develop your model. Once you have sufficient data you can create your model. It is important to note that *models are driven by data* and so your data collection must be done with great accuracy.

Once the model is created you can craft a fairly well-thought-out and credible hypothesis such as, *if the store manager does this, this will be his result*. But are you certain? There may be unexpected changes to the model—a cashier is out sick, a cash register breaks, the power goes out and stops all transactions. What can the manager do to accommodate these unforeseen occurrences? You can assist the manager by creating a number of simulations or iterations of the model to ascertain the "what if." Upon reviewing the output of your simulations, you can provide that data to the store manager so that he or she can make well-informed decisions about the scheduling of cashiers and distribution of registers to meet the goal of high-quality service. As you can see from the example, M&S gives you many opportunities to repeat a simulation of the hypothesis. In essence, you have the ability to repeat the testing of the hypothesis through various simulations. Let's take a closer look at simulation.

First, we must appreciate that defining simulation is not as clear-cut as defining model. Definitions of simulation range from:

- a method for implementing a model over time
- a technique for testing, analysis, or training in which real-world systems are used, or where real-world and conceptual systems are reproduced by a model
- an unobtrusive scientific method of inquiry involving experiments with a model rather than with the portion of reality that the model represents
- a methodology for extracting information from a model by observing the behavior of the model as it is executed
- a nontechnical term meaning not real, imitation (the correct word here is the adjective simulated)[2]

Simulation is used when the real system cannot be engaged. The real system may not be engaged because 1) it may not be accessible, 2) it may be dangerous to engage the system, 3) it may be unacceptable to engage the system, or 4) the system may simply not exist. So to counter these objections a computer will "imitate" operations of these various real-world facilities or processes. Modeling depends on computational science for the visualization and simulation of complex, large-scale phenomena. These models may be used to replicate complex systems that exhibit chaotic behavior and so simulation must be used to provide a more detailed view of the system. Simulation also allows for virtual reality research whereby the analyst is immersed within the simulated world through the use of devices such as head-mounted display, data gloves, freedom sensors, and forced-feedback elements [4]. *Artificial Life* and *Computer Animation* are offshoots of computational science that allow for additional variations in modeling.[3]

Now that we know what comprises a model and what constitutes a simulation, we then couple these steps with visualization. M&S coupled with visualization refers to the process of developing a model of a system, extracting information from the

[2] Additional information and definitions can be found at the U.S. Department of Defense, Defense Modeling and Simulation Office (DMSO) online glossary at http://www.dtic.mil/whs/directives/corres/pdf/500059m.pdf.

[3] *Artificial life* enables the analysts to challenge the experiment by allowing the computer program to simulate artificial life forms. *Computer animation* is emphasized within computer graphics and it allows the modeler to create a more cohesive model by basing the animation on more complex model types. With the increased use of system modeling there has been an increased use of computer animation, also called physically based modeling [4].

model (simulation), and using visualization to enhance our ability to understand or interpret that information. We have mentioned "system" a number of times. Let's take a look at what constitutes a system.

An accepted definition of "system" was developed by the International Council of Systems Engineering (INCOSE). A **system** is a *construct or collection of different elements that together produce results not obtainable by the elements alone*.[4] The elements can include people, hardware, software, facilities, policies, documents—all things required to produce system-level qualities, properties, characteristics, functions, behavior, and performance. Importantly, the value of the system as a whole is the relationship among the parts. There are two types of systems: 1) *discrete* in which the variables change instantaneously at separate points in time and, 2) *continuous* where the state variables change continuously with respect to time. There are a number of ways to study a system:

- the actual system versus a model of the system
- a physical versus mathematical representation
- analytical solution versus simulation solution (which exercises the simulation for inputs in question to see how they affect the output measures of performance) [5]

As you will learn, M&S holds a significant place in research and development due to its inherent properties of modeling, simulating, analyzing, and visualizing (communicating). It is becoming the training apparatus of choice. In fact, M&S is considered a new tool of choice in the fields of health services, education, social sciences, business and industry. Many folks in the M&S community (researchers, academicians, industry, and military) were introduced to M&S as a tool that evolved with the modern military of the 20th century. But its origins can be traced to an ancient military whose use of wargames made it one of the most efficient armies in military history.

A BRIEF HISTORY OF MODELING AND SIMULATION

The act of wargames and challenging or outwitting an opponent on the battlefield is centuries old. In ancient Rome, the then world's largest empire was secured by the world's largest military. The Roman Army conducted live training between two contingents of its military (red team versus blue team). Their training battlefield reflected an environment the troops would encounter somewhere within the expansive Roman Empire that spanned the Scottish border in northern Europe throughout North Africa into the Near East (Afghanistan). The Roman Army had to learn how to fight in unknown regions against armies with diverse warring techniques. Although their training exercises were not intended to draw blood, their training honed a mili-

[4] Additional information and definitions can be found at the INCOSE online glossary at http://www.incose.org/mediarelations/glossaryofseterms.aspx.

tary prowess that made the Roman Army the greatest military the world had known for centuries (circa 500 B.C.E.–1500 C.E.). Significant as they were with Rome's legions, models were not restricted to the art of wargames and military training.

During the age of the Renaissance (1200–1600 C.E), or rebirth of learning, artists and scientists were using models in their designs of statuary or edifices. These models were presented to the artist's patron or commissioner as a way of seeking approval of a design before beginning an expensive project such as a marble bust or sarcophagus. One of the most notable scientists of the time was Leonardo DaVinci. He is famous for his paintings, sculptures, building designs, and scientific experiments. His projects include the design of advanced weaponry (to include tanks and submarines), flying machines, municipal construction, canals, and ornamental architecture (churches and fortresses), as well as his famous anatomical studies. Among his many assignments Leonardo worked as a military engineer where he was called upon to design a bridge to span the Golden Horn (a freshwater waterway dividing the city) in Constantinople (modern day Istanbul). Leonardo was also commissioned to do a life-sized equestrian statue (which was later changed to be four times larger). To do this he studied the movement of horses, made countless sketches, and devised new casting techniques. He did not complete the project, but he had succeeded in making a 22-foot clay model.

Leonardo made repeated uses of modeling to test the design of many of his inventions and projects. He determined that by understanding how each separate machine part functioned, he could modify it and combine it with other parts in different ways to improve existing machines or create new machines. He provided one of the first systematic explanations of how machines work and how the elements of machines can be combined. Fortunately, his studies and sketches have been collected into various codices and manuscripts that are available for our review. Around this same time a new competition was introduced in Europe. It came in the form of a game that required intellect and prowess—chess.

The current game of chess, as most westerners know it, had its origins in southern Europe in the second half of the 15th century. That game was a derivation of a 7th century game of Indian origin. Included on the chessboard are the King, Queen, Bishop, Knight, Rook, and Pawn. The object of the game is to checkmate the opponent's King by first placing that King under immediate duress or "check" with such maneuvering that there is no way for your opponent to remove his King from attack. Think about what is created on the chessboard: a simulated battlefield with two armies who possess equal strength of force. It is now up to the human commander (the chess player) to conduct his simulations: what if I move this way? What will happen if I do this? How will my opponent respond? What is he planning? The ultimate "checkmate" is rewarded by winning the war (the game). But what if you are playing a computer? Can it outwit a human opponent? Yes, it can.

In 1997 an IBM chess playing computer named Deep Blue won a short six-game exhibition match (not a world title match) by two wins to one with three draws against the Russian world champion Garry Kasparov after he made a blunder in the opening of the last game. Kasparov accused Deep Blue—IBM—of cheating and demanded a rematch, but officials at IBM declined. His accusation stemmed from the fact that he saw deep intelligence and creativity in the machine's moves suggesting that during the second game human chess players, in violation of the rules, intervened. IBM's response was that the human intervention occurred only between games as the rules provided so the developers could modify the program between games. This gave IBM an opportunity to modify for weaknesses in the computer's play as it was displayed during the game. Doing these modifications precluded the computer from falling into previous traps set by Kasparov [6]. There are a number of theoreticians who have developed extensive chess strategy and tactics. Many who play the game cite chess as one of the first wargames. By the 18th century military modeling, simulation, and training took on a new perspective.

In the 1780s, with England at the height of its naval power, a Scotsman named John Clerk developed a method of using model ships to gain tactical insights. He used his ships to step through battles analyzing the influence that geometry of the combatants had on their combat power. While a military simulation, Mr. Clerk's work was not considered a wargame because it did not provide a way to measure or apply the effects of actions—the reward and risk from game theory [7]. On the European continent, however, wargames were being formally developed by the Prussians (modern-day northeastern Germany).

Prussia attained its greatest importance in the 18th and 19th centuries. In the 18th century during the reign of the Soldier King Frederick I (1713–1740), Prussia instituted a *standing army*, or an army composed of full-time professional soldiers who *stand over* and never disband, even during times of peace. As a result of this significant military capacity, Prussia became a great European power during the latter half of the century under the reign of Frederick II (1740–1786). The Prussians saw the advantages to playing wargames and by 1824 games were incorporated as part of the training throughout the Prussian army. It was during the 19th century that Prime Minister Otto von Bismarck pursued a policy of uniting the German principalities into a "Lesser Germany" that would exclude the Austrian Empire. This led to the unification of Germany in 1871. Wargaming no doubt contributed to the outstanding military capability of Prussia's standing army and its success on the battlefield during the 19th century.

In the United States, Major W. R. Livermore of the Army Corps of Engineers introduced modern wargaming to the American military [7]. In 1883 he translated the German rules to a wargame they had developed based on the American Civil War and Prussia's own wars of 1866 and 1870–1871. Livermore found that when he compared the German attrition tables to actual statistics errors were made. Livermore determined that the German attrition tables usually predicted lower casualties than the historical record indicated. He adjusted his tables accordingly. Upon improving the wargame with the historically accurate data, Livermore sought official acceptance of wargaming for the U.S. military. Much to his surprise he was blocked by General William T. Sherman who was serving as the U.S. Army's Chief-of-Staff. Sherman felt wargames depicted men as blocks of wood rather than human beings. He therefore refused the integration of wargames into military training. Four years after Sherman's refusal to use wargames, the Naval War College decided it would use Livermore's model. In 1887 the college introduced its first Army-Navy field exercise. By the turn of the 20th century wargames made their way into U.S. military exercises and training. These games, however, lacked the capability and the complexity to model an event with the accuracy we now see in military modeling, a change that came about with the introduction of technology.

M&S can trace its technical origins to the first flight simulator, the *Link Flight Simulator*, which was patented in 1929 by American Edward Link. The pilot trainer resembled a toy airplane from the outside with short wooden wings and fuselage mounted on a universal joint. Link used organ bellows driven by an electric pump to make the trainer pitch and roll as the pilot worked the controls. The *Link Flight Simulator* was used in both government and private sectors [8]. In 1931 *Link Flight Simulator* was fully instrumented and sold to the Navy. The Army took delivery of *Link* trainers three years later. And on the home-front, the *Link Flight Simulator* was used in amusement parks during the 1930s. This was no doubt great fun for those young at heart who enjoyed pretending to be a pilot. But importantly, the *Link Flight Simulator* was great economy for the military as vast sums of money and time were saved with the training of Navy and Army pilots in simulators replicating air flight. This is a good example of how using simulation allows the military or any other company or organization to test a system before investing in the full-scale model, or to train an individual in a less expensive environment.

In the post–World War I period the Navy and the Marine Corps both employed wargames as part of their training. This training proved useful with the coming of the Second World War. Under the leadership of General George C. Marshall live simulation was introduced into military training. As a result, military M&S was making quick inroads into training the military of a new world power and that was by no accident. With the end of two World Wars a new period of military engagement was beginning, one that brought with it weapons of mass destruction that required computer-assisted air defense systems to interfere with their delivery. This post–World War II period is called the *Cold War*. The Cold War took place between the two world powers: the United States and the Soviet Union, and it would last almost a half century (1945–1989) as a military competition between the two.

On 29 August 1949 the Soviet Union detonated an atomic device at the Semipalatinsk Test Site in Kazakhstan, making it the second nation in the world to detonate a nuclear mechanism. This action served as the impetus for the U.S. government to give grave consideration to the threat of another nation possessing nuclear military capability. As a result, the Department of Defense was given the approval to invest funds for research in air defense systems. By the winter of 1949 digital computers were engaged in creating simulated combat. Developed by the U.S. Air Force, a semi-automated ground environment—SAGE—simulated combat from the perspective of more than one combatant. This type of simulation provided military training that now incorporated an air-defense system.

By the 1950s computers were being used to generate model behavior followed by simulation programs. These computers were then required to process the results of the elements of the simulation-based problem solving environments [9]. Digital radar was now able to transmit from the newly developed Microwave Early Warning (MEW) radar. This innovative research was being conducted by engineers at the

Massachusetts Institute of Technology (MIT). Significant to the research was a transmission that tied together the MEW located at Hanscom Field to the digital computer named *Whirlwind* located at MIT. Also at this time a scaled-down version of SAGE was being developed. Dubbed the *Cape Cod System*, this simulator was introduced in 1953. It allowed radar operators and weapons controllers to react to simulated targets presented to them exactly as these targets would appear in an engagement. The country was becoming embroiled in a military contest that called for technology far beyond the imagination of the average citizen.

Interestingly, some of that same technology was making its way into the homes of so many families in everyday, ordinary appliances and communication devices that brought a new definition to the post-modern age. In essence, as the country was developing militarily, and so was every other aspect of technology—that is why the 1950s were so progressive. This was a unique time in the social history of the country. It was both an age of innocence and a post-modern world with technical advances that would send men into outer space. Ironically, it was the newly invented *RCA FlipTop* television and *Regency TR1* transistor radio that delivered fear and talk of war with the Soviets into the American family living room.

At the close of his two-term presidency (1953–1961), Dwight D. Eisenhower gave an address to the American people about the effects of the ongoing military competition with the Soviet Union. Eisenhower's Military-Industrial Complex Speech made Americans aware that *a vital element in keeping the peace is our military establishment*. The president emphasized that *U.S. arms must be mighty, ready for instant action, so that no potential aggressor may be tempted to risk his own destruction* [10]. To do this the federal government would support and fund research that would make the military state-of-the-art, always ahead of the opposition. The president's speech referred to the increasing military buildup in the United States throughout the 1950s. That build-up fueled the nation's growing economy and many were living quite comfortably during this time. Perhaps somewhat oblivious to what was truly happening, Eisenhower was compelled to explain to his fellow citizens the ramifications of coupling an immense military establishment with an expanding arms industry. This was a new concept for Americans. In fact, the **Military-Industrial Complex** was a new American experience with an economic and political influence that reverberated throughout the country. By 1960 the increased spending for this complex amounted to more than half of the U.S. federal expenditure. And, as the complex grew so did the workforce. From the close of World War II (1945) to the end of Eisenhower's second term (1961), an expansive workforce of civilian employees constituted much of the defense industry. Additionally, many universities thrived on the increased research opportunities.

Throughout the 1960s military wargames became much more sophisticated, moving from strictly tactical training to strategic commands. Games were now incorporating things like the political capacity of a state or leader. They also became technically mature. This became apparent with work done at the universities. In 1961 a student at MIT created an interactive computer game called *Spacewar* [11]. The game required the player to operate his spaceship during a conflict that was fought with the firing of torpedoes. Pilots of the spaceships scored points by launching missiles that inflicted damage on the opponent, avoiding direct hits by the opponent, and maneuvering the spaceship to avoid the gravitational pull of the sun. This computer game was one of the first *interactive* games in the country. The president and Congress were also pushing forward a research agenda at government institutions. Just over a decade after Spacewar, two engineers at the National Aeronautics and Space Administration (NASA) in Moffett Field, California, developed another computer game, one a bit more complex called *Mazewar* [12]. This game was networked and it introduced the concept of online players as **avatars** (a graphical image of a user or a graphical personification of a computer or a computer process) in the form of an eyeball chasing other players around a maze.[5] Mazewar's development in 1974 served as a catalyst for a number of versions on various programs.

The military was also making contributions to M&S by formalizing simulation as a training tool. In 1971 the Navy's *Top Gun* school opened to train fleet fighter pilots in air combat tactics. In 1975 the Tactical Advanced Combat Direction and Electronic Warfare (*TACDEW*) simulator was being used for team training. The simulator created 22 separate shipboard mock-ups with the ability to generate a virtual (also called synthetic) threat environment [13]. There was also work done with linking training simulators. Fighter plane cockpits like the B-52 (long-range, heavy bomber aircraft) were simulated so that they could operate with tanker (refueling aircraft) simulators to facilitate training plane/tanker rendezvous.

By 1983 simulator networking was advancing rapidly. The *Defense Advanced Research Projects Agency (DARPA)* had initiated simulator networking—*SIMNET*—with an emphasis on tactical team performance on the battlefield. The U.S. Army supported the idea of incorporating armor, mechanized infantry, helicopters, artillery, communications, and logistics into the model for a much more expansive simulated training experience. Combatants could now see each other and communicate over radios. The SIMNET simulator was introduced at the First-Platoon Level in 1986. By 1990 over 250 networked simulators at 11 different sites were delivered to the U.S. Army [14]. It wasn't long before the benefit of SIMNET training was realized.

On July 25, 1990, Saddam Hussein convened a meeting with U.S. Ambassador to Iraq April Glaspie expressing his contempt for two of his Persian Gulf neighbors, Kuwait and the United Arab Emirates. He specifically accused Kuwait of exceeding the Organization for Petroleum Exporting Countries (OPEC) production limits and thus driving down oil prices. This lowering of prices was having a negative affect on the Iraqi economy and he faulted the United States for encouraging this high level of production. Additionally, his aggressive behavior earlier in the year resulted in the cessation of American aid—no more American aid meant he would look elsewhere, and that elsewhere was Kuwait. Within two weeks of his meeting with Ambassador Glaspie, Saddam ordered his troops into Kuwait. Iraqi troops entered

[5] Please note the difference between a GAME and a SIMULATION. A game is more concerned with entertaining and there is much more player participation. A simulation is more focused on getting the details of the model and system correct. A simulation does not require a participant or player, but a game does.