A FRAMEWORK FOR THE COMPARISON OF FOUR MILITARY STRATEGIC SIMULATION MODELS

THESIS

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(14) AFIT/GOR/SM/78D-5

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THESIS (9) Master's thesis,

Presented to the Faculty of the School of Engineering
of the Air Force Institute of Technology
Air Training Command
in Partial Fulfillment of the
Requirements for the Degree of
Master of Science (12) 164 p.

by

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Graduate Operations Research

(11) December 1978

Preface

This thesis compares four military strategic simulation models, each of which is used by four different organizations within the Department of Defense. As a result of the model comparisons, and other factors, a generic framework for the comparison of models was also developed. This framework was developed to provide a common means within which any strategic simulation model can be viewed. Hopefully, the results of the study will be of value to the academic community as well as the simulation community.

To assist the reader in understanding the intended meaning of certain acronyms, a list of acronyms has been incorporated into the prefatory material. The terms in this section were included because of their unique nature or specific connotations. It is advised that this section be read before the text.

I would like to express my appreciation to Dr. Edward J. Dunne whose unending support and encouragement were a hallmark of this study, and to Lieutenant Colonel Edward T. Akerlund who provided most of the simulation expertise that I lacked. This gratitude also extends to the many individuals that took time from their busy schedules to participate in the interviews and the discussions for this thesis. And finally I would like to express my appreciation to my wife, Kathy, and my son, Brian, who spent many lonely hours patiently waiting for the completion of

this study.

Thomas E. Denesia

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List of Acronyms

1. AAA: Anti-Aircraft Artillery
2. ABMS: Anti-Ballistic Missile System.
3. ADDC: Air Defense Direction Center.
4. AEM: Arsenal Exchange Model. This is a strategic simulation model which is currently being used by Headquarters Air Force, Deputy Chief of Staff for Programs and Analysis, Directorate of Concepts and Analyses.
5. AF/PAC: Headquarters Air Force, Deputy Chief of Staff for Programs and Analysis, Directorate of Concepts and Analyses. This agency provides analysis support to Headquarters Air Force.
6. AGZ: Actual Ground Zero. This term refers to the actual point (as defined in some coordinate system) where a nuclear weapon detonated.
7. ALCM: Air Launched Cruise Missile.
8. ASM: Air to Surface Missile.
9. AWACS: Airborne Warning and Control System.
10. CAP Activity: Combat Air Patrol. This term refers to the protective covering that fighters or interceptors can provide for a missile site or airfield.
11. CEP: Circular Error of Probability. This term refers to the radius of a circle within which 50% of the bombs or missiles are estimated to impact.
12. CPU time: Central Processing Unit time. This term refers to the amount of time taken by a computer to process the data.
13. CRT: Cathode Ray Tube. This term refers to one of the means of displaying computer information.
14. DCAPS: Dual Criteria Aim Point Selection. This term refers to one of the programs used in

the SWADE simulation model. SWADE is one of the models that has been developed by Strategic Air Command, Deputy of Plans and Simulation at Offutt AFB, Nebraska.

15. DGZ: Desired Ground Zero. This term refers to the desired point (as defined in some coordinate system) where a nuclear weapon is supposed to detonate.

16. ECI: Earth Centered Inertial. This term refers to a type of coordinate system.

17. ECM: Electronic Countermeasures.

18. ECR: Earth Centered Rotational. This term refers to a type of coordinate system.

19. FOBS: Fractional Orbit Bombardment System.

20. GCI: Ground Control Intercept.

21. JCS: Joint Chiefs of Staff.

22. JSTPS: Joint Strategic Target Planning Staff. This organization is located at Offutt AFB, Nebraska.

23. LP: Linear Program. This term refers to a numerical technique used for analysis purposes.

24. MIRV: Multiple Independently targetable Re-entry Vehicle.

25. MRV: Multiple Re-entry Vehicle.

26. NTUPLE: Nine Tuple. This term refers to one of the programs used in the SWADE simulation model. SWADE is one of the models that has been developed by Strategic Air Command, Deputy of Plans and Simulation at Offutt AFB, Nebraska.

27. OASIS: Operational Analysis Strategic Interactions Simulation. This is a strategic simulation model which is used by the Joint Strategic Target Planning Staff at Offutt AFB, Nebraska.

28. PACCS: Post Attack Command and Control System.

29. PD: The Probability of Damage.

30. POL: Petroleum, Oil, and Lubricants.

31. QUICK: The Quick-Reacting General War Gaming System. This is a strategic simulation model which is used by the Joint Chiefs of Staff, Studies, Analysis and Gaming Agency at the Pentagon.

32. RISOP: Red Integrated Strategic Offensive Plan. This is a strategic war plan that represents the offensive intentions of an enemy country.

33. RV: Re-entry Vehicle.

34. SAC/XPS: The Strategic Air Command Deputy of Plans and Simulation.

35. SAGA: Studies, Analysis and Gaming Agency. This organization is part of the Joint Chiefs of Staff.

36. SAM: Surface to Air Missile.

37. SIOP: Single Integrated Operational Plan. This is the strategic war plan for the United States.

38. SRAM: Short Range Attack Missile.

39. SUDS: Single Uniform Data System. This term refers to one of the programs used in the SWADE simulation model. SWADE is one of the models that has been developed by Strategic Air Command, Deputy of Plans and Simulation at Offutt AFB, Nebraska.

40. SWADE: Strategic Weapon Allocation Damage Expectation Model. This is a strategic simulation model which is used by the Strategic Air Command Deputy of Plans and Simulation at Offutt AFB, Nebraska.

41. TDY: Temporary Duty Assignment.

42. TREE: Transient Radiation Effects on Electronics.

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Abstract

This study goes beyond the comparison of four strategic simulation models and attempts to develop a generic framework within which any strategic simulation model can be compared. The framework itself evolved with several iterations of changes. The first set of characteristics for the framework was developed with the help of an expert in the simulation community. This list was then added to or deleted from as various discussions and interviews proceeded with the operators and users of the four models specifically addressed in this study. Following this, a review of the overall philosophy of the framework was made, and a final form of the generic framework was established. After the framework had taken its final form, a comparison of the four strategic simulation models was made. Thus, within this standard basis for comparison (the generic framework), one can more easily see what specific characteristics a model possesses and what specific characteristics it does not.

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I. The Research Problem

Introduction

Several different organizations within the Department of Defense use strategic simulation models to examine the effectiveness of the United States strategic weapon systems against potential enemy forces. Even though the general subject matter appears to be the same, the models differ from one another. These differences can be a result of the level of detail or the types of vehicles considered. Thus, it is the difference in the models that is the subject matter of this study.

This chapter discusses various aspects of the research problem with which this study is concerned. The first item is the statement of the problem. This is followed by the background of the problem which develops the essential issues associated with the study. The importance and the objectives of the study are discussed next. The chapter concludes with the limitations and the methodology of the study.

Statement of the Problem

The organizations that perform strategic simulations seem to have approaches that differ slightly from each other.

Most of these differences can be attributed to the way in which certain strategic issues are addressed. For example: should the model consider a detailed treatment of both missiles and aircraft, or should the detail be focused in only one area? Should the model be designed to explore present force structures or future force structures? Should the model consider first strike capabilities or should it consider only retaliatory strike capabilities? The way in which an organization answers these questions can lead to vast differences in how a model is designed. But, despite these varying approaches to modeling, there do exist some basic underlying concepts which all models seem to follow.

Background of the Problem

Importance of Simulation. Simulation techniques have been used to construct models of certain portions of the real world. These models were then used to test certain hypotheses that were made about a real world situation. For example, models of newly designed machines are built by engineers to investigate situations where problems may occur. Also, aircraft simulators are built to provide several hours of experience for the novice pilot. In both situations the simulation is used to save time and money. If there were some serious error in the design of the machine, the engineer could redesign it before millions of dollars were committed to producing the first design. If the pilot had made some serious errors in his technique, he would be able to learn how to correct them before flying the actual aircraft. Thus, simulation can be extremely important in saving money, time, and even human lives.

The same reasoning can be used to support the existence of strategic simulation models. For example, it could cost billions of dollars, start World War III, and cost millions of lives if the United States actually tried to find out how many ICBMs could penetrate Soviet defenses. Thus, small-scale tests are performed to obtain base-line data points in lieu of the large-scale tests which cannot feasibly be performed. As a result, strategic simulation models have been developed to give us an idea of what would happen in a strategic exchange. The models also allow us to perform sensitivity analyses in one form or another to ascertain what parameters may be critical.

Concepts of Simulation. Strategic simulation modeling is big business. For example, a single simulation program may have 250,000 statements and over 100 subroutines. It may require a full time staff of ten people just to maintain its operational capability. Its simulation time is spoken of in terms of hours and days, not seconds, and presimulation and postsimulation programs may have to be executed just to manipulate the data for interpretation. Thus, when an organization operates many models, the size of its staff may indeed be large.

A closer look into modeling would show that models with long simulation times are those which deal in minute details, while those which deal with less detail have much faster simulation times. For example, the CPU time for the QUICK model is ten hours, while the CPU time for the AEM model is one to ten minutes. The reason for the difference is that the AEM model aggregates some areas that are considered with more detail in the QUICK model (Ref 24:2,184). Thus, there exists some tradeoff between time and the detail of the study.

Another point to be made is that the less detailed, fast running, models sometimes lend themselves more appropriately to the simulation of future forces. Future force postures are known with less accuracy than present force postures; therefore, there may be no need for the time consuming detailed simulations. However, even though this is generally true, future force structures are investigated with both long-detailed, and short-general models.

Finally, the documentation issue must be addressed. Many models have vast amounts of documentation, while others may have relatively small amounts. These documents may include many volumes of users manuals, analytical manuals, and maintenance manuals. Many of the models, which lack documentation, are new and just being developed or their funding has been cut short for some reason. A good source for finding the amount of documentation is the War Gaming Catalog (Ref 24). Then, if the documentation exists for a strategic simulation model, the documents can usually be located in the Defense Documentation Center.

Due to the need for this study to address detailed questions, a concerted effort was made to select models with adequate documentation. However, the SWADE simulation model has less written documentation than the other models because it is a new model and full documentation on it has not been completed.

<u>Agencies Involved</u>. The Joint Chiefs of Staff have an organization called the Studies, Analysis and Gaming Agency (SAGA) which develops strategic simulation models and analyzes the implications of the results. As a by-product from efforts to quantify enemy capabilities and tactics, SAGA provides the computerized form of these capabilities and tactics to the Navy and the Joint Strategic Target Planning Staff (JSTPS). As a result, the Navy, JSTPS, and SAGA sometimes use the same data base for scenarios which they model. These scenarios may include air, sea, land, and space forces, or any combination of them.

Other agencies develop their own data bases. However, these data bases are all developed from information obtained from the intelligence community and are usually quite similar (Ref 2). Located at Headquarters Air Force, the Directorate of Concepts and Analyses (AF/PAC), is a large organization which studies various aspects of present and future force structures. This study will involve a model which AF/PAC developed to simulate in detail the aircraft portion of the conflict.

The fourth organization which is viewed in this study is the Strategic Air Command Deputy of Plans and Simulation

(SAC/XPS). SAC/XPS is an organization which primarily models the future force structure required to counter the expected future threat. The model which will be studied from this organization projects capabilities approximately ten years into the future and simulates all aspects of the conflict.

Importance of the Study

The organizations which develop strategic simulation models have their own perspectives, which leads to variations in the size of the model, the specific objectives of the model, and the areas of complexity of the model. These variations result from the different objectives of each agency. For example, some groups are responsible for the engineering design of specific missile systems to accomplish well-defined strategic roles. Others are responsible for structuring the strategic force components of a service in accordance with its roles and missions. Some are responsible for formulating doctrines for employment of strategic weapons, and others are responsible for the determination of general characteristics of strategic forces which seem best suited for a particular set of strategic policies (Ref 3:1). However, all the models have some common elements which can be used when performing a comparison. Therefore, the primary thrust behind this study is to develop a generic framework for comparison of strategic simulation models within which any specific model can be viewed.

With a framework of comparison available, much time and money could be saved. A standard could then be developed within which all models could be easily compared and studied. Agencies could then interpret with ease what has been done by other agencies and use this information to improve their own models. This could lead to more precise and accurate models which in turn could help our leaders make more effective decisions. Thus, the development of a generic framework for comparison of strategic simulation models could be one key to more effective cooperation on a national level and perhaps to greater understanding of negotiation on an international level.

It should be noted that efforts along these lines have been taking place. Although a general generic framework has not been developed, the Studies, Analysis and Gaming Agency (SAGA) has been publishing an annual war gaming catalog which lists various models available with a brief description and a point of contact. The catalog does not compare the models with each other, it just lists the models with various cross references (Ref 24). Also, the Joint War Games Agency, which is another organization within the Joint Chiefs of Staff, publishes the Joint War Gaming Manual. The manual discusses general concepts and strategies of war gaming and traces the history of war gaming from the 16th century to the present (Ref 16). Finally, Science Applications Incorporated (SAI) has done some work in the review of strategic simulation models. SAI used a set of 24 general characteristics with which they compared 30 strategic simulation models (Ref 4). But, due to the general nature of the characteristics used by SAI, very few of the characteristics applied directly to this study. Thus, the SAI report served as one of the starting points for this study.

Specific Objectives of the Study

The overall objective was to compare and contrast several strategic simulation models used in the Department of Defense. The proposed method of performing the comparison will involve reviewing a model from SAGA, JSTPS, AF/PAC, and SAC/XPS. The decision of which model to choose in each agency was made after several detailed discussions with Lieutenant Colonel Edward T. Akerlund who has worked for the JSTPS (Ref 2). The models which were selected are as follows: the Quick-Reaction General War Gaming System (QUICK) by SAGA, the Operational Analysis Strategic Interactions Simulation (OASIS) by JSTPS, the Arsenal Exchange Model (AEM) by AF/PAC, and the Strategic Weapon Allocation Damage Expectation Model (SWADE) by SAC/XPS. The specific objectives of the research were as follows:

1. To develop a concise description of the methodology of operation of each simulation model and examples of its use.

2. To identify and analyze the key similarities of the models.

3. To identify and analyze the major areas of difference among the models.

4. To develop a generic description of strategic simulation models in general.

5. To identify and compare possible decision situations for which each model can be usefully employed.

Limitations of the Study

The limitations of the study are as follows:

1. This study will deal with one model from each of the major organizations which develop strategic simulation models. These models may or may not represent the types of modeling that the organization performs.

2. Only well-documented models are discussed and compared. More valuable models may have been overlooked because of the lack of documentation, or the nonavailability of documentation.

3. The study will be limited to the information found in analytic manuals, users manuals, executive overviews, and personal interviews.

4. The study deals only with unclassified strategic simulation models. Although it is usually only the output of a model that is classified, in some cases, the actual program is classified.

Methodology

The general approach taken while performing the research focused on three main questions:

- What are some general characteristics which are common to most strategic simulation models?
- How do various models compare when viewed from a common point of reference?
- To what decision situations do the various models lend themselves?

These questions provided the primary thrust for this study. Another driving factor was the amount and accessibility of the documentation on a particular simulation model. Without documentation, the ability to critically review a model is greatly degraded. Thus, to contribute to the success of this study, all of the models that were scrutinized had adequate documentation.

To accomplish the objectives, personal contact was made with the users of each of the simulation models. For the OASIS and SWADE models, contact was made with the JSTPS and SAC/XPS organizations at Offutt AFB, Nebraska. For the QUICK and AEM models, contact was made with the SAGA and AF/PAC organizations at the Pentagon, Washington, D.C. Documentation was obtained from these contacts and telephone interviews were conducted to clarify issues which were in question. The generic framework developed from the fourth objective was used as a guideline to obtain information about each model.

The development of the generic framework was the first objective to be accomplished. While thorough research of the documentation greatly aided this study, it was the expert assistance of Lieutenant Colonel Edward T. Akerlund that provided the cornerstone of the generic framework. His note pad, which was not only drawn up from his experiences, but also from the experiences of many of his co-workers, provided the primary basis of the generic framework. It was from this foundation that other characteristics were added or deleted based on information taken from other studies, users manuals, and the four models themselves.

Following the development of the generic framework, the accomplishment of the first three objectives was finalized. Thus, the framework was used as the basis for comparing the similarities and differences between the models.

The accomplishment of the fifth objective was based upon telephone interviews as well as personal interviews. Each user was asked about strategic issues which are addressed within their models and situations for which their models are currently being used. A sample of the issues which were addressed is as follows: what are the advantages and disadvantages of a model which can simulate both sides of a conflict? How does the model handle the allocation of weapons to targets? How is the model currently being used? Does the model have any error checking routines? A discussion of these issues and the development of specific situations in which the models can be used is summarized in Chapter IV.

II. The Model Descriptions

Introduction

In general terms, a strategic simulation model is a computerized analogy of a nuclear conflict between two or more countries. The simulation involves the construction of a working mathematical or physical model presenting similarity of properties or relationships with the natural or technological system under study. It is an approximation of a real life war or battle and it provides a means of gaining experience in problem solving without paying real world penalties. The models also offer opportunities to test proposed concepts; to study present and proposed military organizations; to probe past, present, and future force structures; to simulate nuclear wars which are difficult or impossible to investigate in a real world environment; to validate operational plans; and to serve as an educational tool for professional military commanders and staffs.

As man's knowledge has grown, so has the complexity of his strategies and the complexity of his simulation models. Before the advent of the computer, the simulation models were small and they were operated with hand calculations. But, as computers came into use, more sophistication was introduced into the models. Thus, high speed computations allowed a whole war to be fought in hours or minutes. And, due to this high speed, highly sophisticated fields of applied mathematics which include numerical analysis, probability theory, stochastic processes, linear equations, optimization, and statistics, have come into common use.

Typically, strategic simulation models deal with the strategic forces which one country might use against another in a conflict. The scenario can vary from a small skirmish with nuclear weapons, to a one-sided exchange of the weapons, to an all out nuclear war. There are two primary delivery systems that are almost always addressed (depending on the model) with a third system just coming into the picture. The first two delivery systems are the aircraft and the missile (which can be launched from land or water). The third system is that of the satellite for use as a delivery system. With the advent of the computer, the simulation can determine which missiles were successfully launched by statistical means. The computer can work so fast that it can look at each missile or aircraft individually and draw a random number to determine if it was launched successfully. In a like manner, it can look at each weapon to see if it penetrated defenses successfully, and if it detonated successfully.

So, of what use is a strategic simulation model? Strategic simulation models can be useful in simulating new tactics and concepts as well as revealing flaws in existing plans and concepts. A model can provide experimentation without the risk and cost involved in dealing with the real situation. It can permit evaluation of systems that cannot be adequately tested otherwise. It can be considerably faster than a comparable operational test. It can provide indications of variables that are of particular importance, and may reveal difficulties which were unforeseen. Finally, simulation models may be useful in answering questions other than the ones for which the model was originally designed, since this information may be analyzed and reassembled in a variety of ways.

Even though simulation models have become highly sophisticated, little effort has been expended toward developing a framework with which to compare models. This paper was designed to fill that void. Thus, in Chapter III a framework is developed in which hundreds of specific characteristics are described in detail. But, in order to gain an insight into the general structure of this way of describing strategic simulation models, a brief overview of the framework was deemed to be appropriate. The framework consists of six areas which are listed as follows:

1. General Features: This area consists of five categories which are called Simulation Design Type, Simulation Method, Simulation Content, Simulation Flexibility, and Output Information.

2. Targeting Methods and Weapon Effects: This area consists of four categories which are called Target Values, Weapon Allocation, Fallout Considerations, and Damage Analysis.

3. Error and Security Checks: This area has no categories.

4. Offensive Systems: This area consists of four categories which are called Aircraft, Missiles, Satellites, and Other Offensive Systems.

5. Defensive Systems: This area consists of five categories which are called ABM Sites, SAM Sites,

AAA Sites, Fighters, and Radars.

6. Offensive/Defensive Interactions: This area consists of two categories which are called Aircraft Penetration and Missile Penetration.

An important point to make is that as technology changes, various weapons systems may be added or deleted from arsenals and consequently the characteristics may be added or deleted. Thus, the framework developed in this study is merely a tool to use, a tool which may need to be revised and changed from time to time to stay current with technology. However, its development may help others to more critically review particular strategic simulation models.

As a prelude to the actual characteristics, this chapter describes the four models which were used as a partial input for the development of the generic framework and which were then compared using the framework. A brief description of how each model operates and the uses of the models are given. The reader should bear in mind that an exhaustive description of the models cannot be presented due to the fact that most of the models have many volumes of documentation. If an in-depth look at the function of any of the models is desired, the bibliography provides a list of reference documents.

The Quick-Reacting General War Gaming System (QUICK)

The Model Operation. QUICK was developed by an organization under the Joint Chiefs of Staff called the Studies, Analysis, and Gaming Agency. It is a tool for examining various facets of possible general wars under a variety of conditions of force posture, strategies, and starting conditions. The model considers bombers, manned interceptors, and ICBMs with MIRV capability, as well as ABMs and SAMs. Based upon suitable input data, QUICK has the capability to automatically generate global strategic nuclear war plans, simulate the planned events, and provide statistical output summaries (Ref 18).

The QUICK model is composed of five major subsystems: Data Assembly, Weapon/Target Identification, Weapon Allocation, Sortie Generation, and Simulation. A simplified block diagram of the model is shown in Figure 1 on the next page. The Data Assembly subsystem assembles and reformats the target data required for a particular plan or simulation. The Weapon/Target Identification subsystem selects and identifies which Red and/or Blue targets will be used for a particular plan or simulation. The Weapon Allocation subsystem allocates offensive weapons to these selected targets. Next, specific routes to each target are identified and evaluated by the Sortie Generation subsystem. Finally, the Simulation subsystem models and evaluates the significant interactions of opposing war plans developed by earlier runs of the QUICK model, and prepares summaries and other output data which reflect the results of the simulation.

The whole process is started by inputting parameters which describe potential targets. The Data Assembly subsystem reformats this data consistent with QUICK and/or

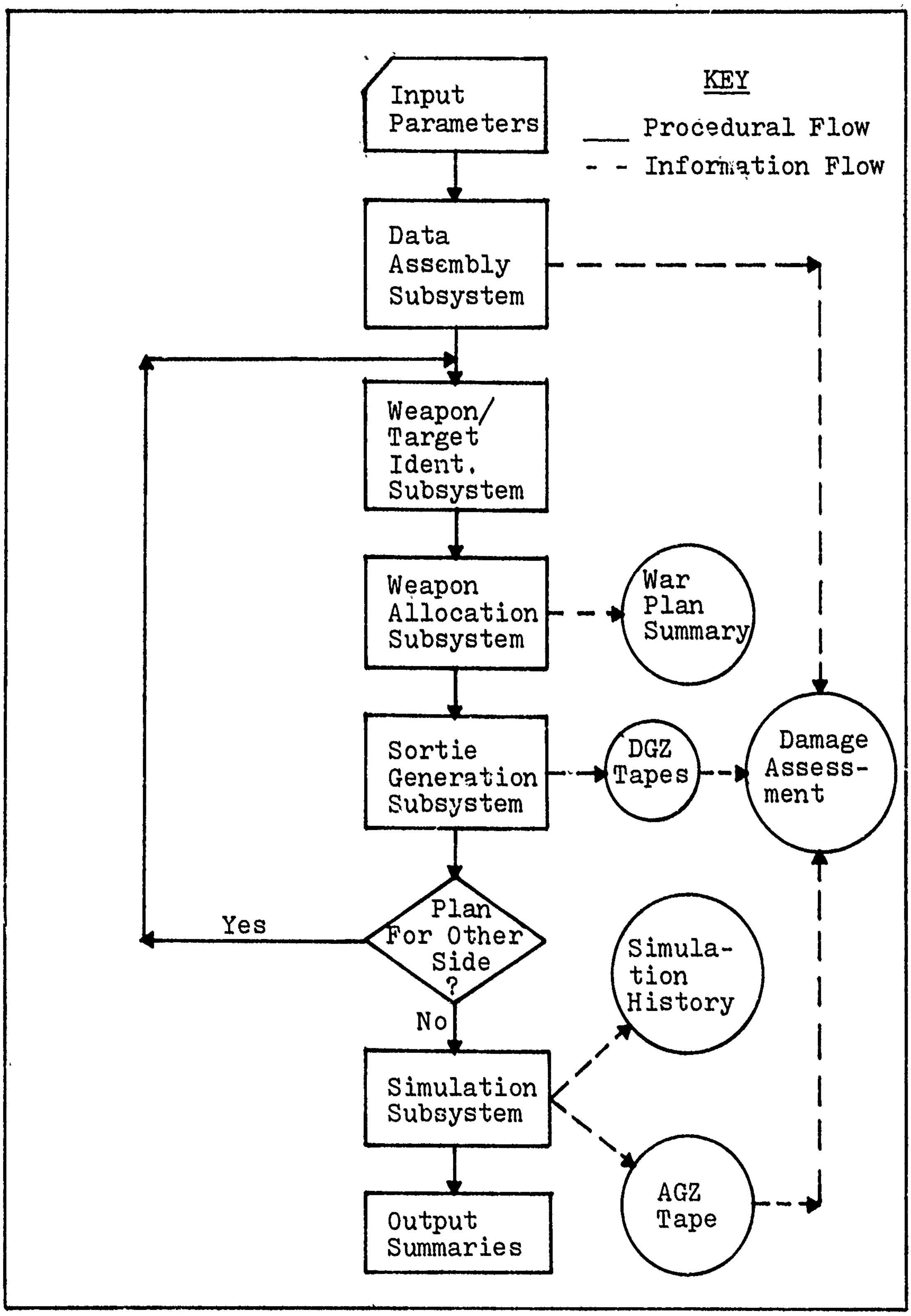

Figure 1. A Flow Diagram of the QUICK Model

external simulation specifications. Another means for obtaining this data is from the QUICK Data Base which can be stored on permanent file and can be updated. Following this, specified Red and/or Blue forces are extracted from the QUICK Data Base and processed by the Weapon/Target Identification subsystem, resulting in a Game Data Base which reflects the selected forces and targets.

The next step of the process is the development of the attack plan for the Red and Blue forces. This consists of a force allocation by the Weapon Allocation subsystem, and a detailed set of attack plans prepared by the Sortie Generation subsystem. A single run of each of the subsystems produces a plan for only one side. Thus, the process must be cycled through again to develop the attack plan for the opposing side (Ref 18:2).

In order for the attack plan to be developed as described above, two bodies of information are required. The first is the Game Data Base which is prepared by the Data Assembly and Weapon/Target Identification subsystems. The second is a set of parameters which relate to the strategy associated with the plan which is to be developed. These parameters are specified by the analyst and reflect his views of the objectives on both sides. They consist of which force will initiate the attack, the targeting constraints and doctrine to be used, and the relative values of each of the targets.

To reiterate, after a value for each target has been established, the plan generation phase allocates the weapons and prepares detailed missile and bomber attack plans for both the Red and Blue sides. These plans may be printed out for inspection and changed by changing the attack objectives. Next, a series of Red missile and bomber events corresponding to the sortie plan is prepared in a form suitable for input to the Simulator. A war plan summary is provided as a user option which includes an expected-value estimate of the results of the attack. Additionally, the Desired Ground Zero (DGZ) for each planned weapon can be output for subsequent evaluation utilizing an external damage assessment system. Then the Blue war plan is prepared in the same manner and the system is ready to proceed with the simulation (Ref 18:5).

The conditions of the simulation, such as the starting time for each side, and defensive capabilities, are read in from cards or a remote terminal. The events on the tapes are then processed in the Simulator along with any new events that are generated. For each event, a record on a history tape or permanent file is made.

When the last event in the game has been simulated, the history tape or file is processed by the Simulation subsystem to prepare the Actual Ground Zero (AGZ) tape which reflects such information as the latitude, longitude, and yield of all successful weapons. The AGZ tape is subsequently processed by a damage assessment system to produce detailed damage assessments. The formatted history is processed by the QUICK Simulation subsystem to provide two outputs: a standard summary of the game, and the results of any special requests for information concerning what transpired during the game (Ref 18:5).

The system can proceed automatically through all of these steps, but it has enough flexibility that it can be halted at the end of each of the five subsystems. Thus, the available output can be inspected for correctness and for adequacy. Also, an interactive capability permits the user to selectively scan the output of individual programs.

The Model Uses. There are two primary areas of application for the QUICK model. The first is in general war plan evaluation and the second is in future force posture studies. In addition, excursions into small segments of the war can be looked at with the QUICK model. Some possible excursions are: the effect of changes in targeting criteria; variations and uncertainties in basic parameters for friendly and opposing forces; and the effect of different levels of ballistic missile defense, deployment of defense, and allotments of penetration aids among the attack force.

One of the major uses of the QUICK system is to generate the hypothetical Red Integrated Strategic Offensive Plan (RISOP). Once this RISOP has been developed by QUICK, then it can be used to evaluate other plans for general war, such as the Single Integrated Operational Plan (SIOP). This evaluation can be carried out using existing systems, such as the Joint Strategic Target Planning Staff's Event Sequence Program (ESP). The principal advantage of the use of QUICK for SIOP generation is that the shorter development time permits testing the SIOP under a variety of enemy plans. This sensitivity analysis makes it possible to determine if there are likely conditions under which the SIOP is unsatisfactory and/or can be improved (Ref 18:35).

QUICK can also be used for the study of future force postures. For example, it could study the various number of minuteman missiles needed to wage war and how variations in the quantity of them would change the capability of the U.S. to wage a strategic nuclear war. Sensitivity of these results can also be investigated with respect to various assumptions. Another type of force posture study is the evaluation of a new weapon system. The QUICK system is flexible enough to accommodate the introduction of some new weapon systems by the appropriate choice of parameters and characteristics. However, new event routines would have to be added to the Simulator and the Plan Generator modified accordingly.

It should be noted that QUICK is not intended to be used to study limited wars. It is intended solely for modeling a general war.

The Operational Analysis Strategic Interaction Simulator (OASIS)

The Model Operation. The OASIS model has gone through many development stages over a number of years. The model that will be described here is used at Headquarters SAC, Offutt AFB, Nebraska, and is designated as OASIS-IIF. The OASIS-IIF program is a computer model which simulates strategic nuclear engagements involving ballistic missiles. It models ICBM, ABM, and RV trajectories and includes a wide spectrum of nuclear weapon effects. The program can handle continent-wide engagements with both exatmospheric (above 300,000 feet) and endoatmospheric (below 300,000 feet) ABM employment, but the endoatmospheric nuclear effects are confined to a local target or ICBM wing (Ref 8).

The OASIS-IIF model is composed of four major subsystems. They consist of two preprocessor programs followed by the main simulation program and ending with a postprocessor program. A simplified block diagram of the OASIS model is shown in Figure 2 on the next page. The first preprocessor program accepts system description data and environmental data and writes a tape or file describing the systems to be studied for that particular run. This tape normally requires infrequent updating. The second preprocessor program prepares a tape or file containing the RV attack and ICBM flyout schedules. Such an engagement tape is usually made for each run. The attack structure contained on the tape may be the result of sophisticated allocation program runs using other models, or it may be simply constructed to explore a particular weapon effect or system sensitivity (Ref 8:2).

Utilizing the two tape inputs described above, the

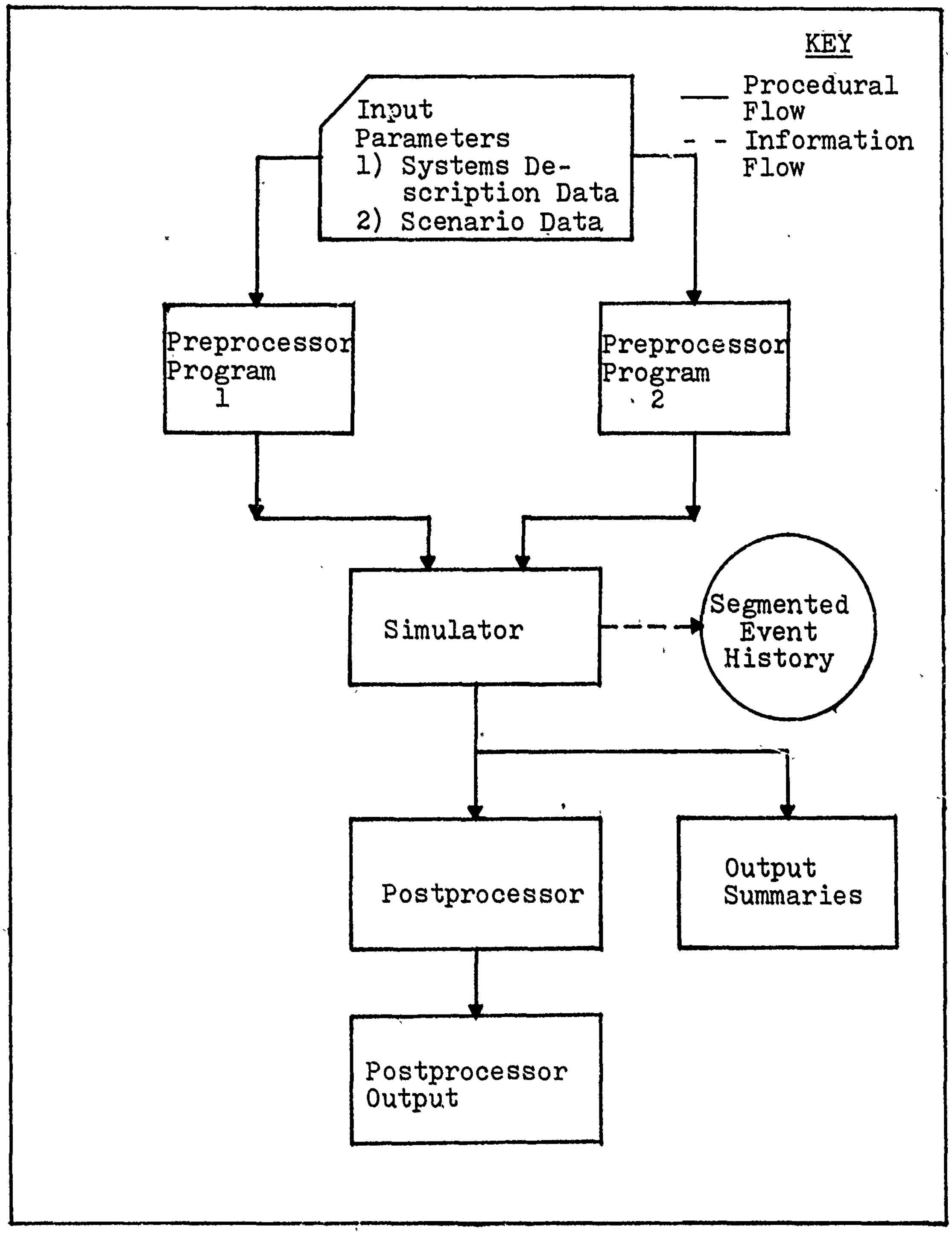

Figure 2. A Flow Diagram of the OASIS Model

simulation program processes the attack and the defensive response to produce an engagement history. This printout contains information on each significant event during the engagement. These events may consist of the following: RV detonations, ICBM launches, and vehicle and ground facility kills. At the completion of the simulation program a short summary is printed out, giving the silo and vehicle statistics.

The postprocessor program can be a useful tool, when doing analysis work with the OASIS model, due to the large volume of output which is generated. The postprocessor can be tailored to the particular study being undertaken by putting the information together into a useful format. Thus, the user can select which combination of the three possible reports is desired as well as the extent of each report chosen (Ref 8:17).

The first report is a segmented event history which is a subset of the normal output. The user may elect to reprint the entire history printout or a selected segment. The user may pick the start time and stop time for the segment printed, and may also identify those events to be printed from the specified time span.

The other reports print timelines for individual RVs and ICBMs. For each vehicle selected, all information pertaining to that vehicle is gathered and printed sequentially. The individual report allows the user to follow the activity of each vehicle without having to sort through the entire history printout (Ref 8:17).

In general, OASIS is a time-sequenced program. Each time the internal clock of the game is moved ahead one time cycle, the events which occurred during that time step are identified and processed in their proper temporal order.

OASIS incorporates a spherical rotating earth model in which several coordinate systems are used to describe the vehicles and events. These coordinate systems include the following: orbital plane parameters; earth-centered inertial (ECI) and earth-centered rotational (ECR) cartesian systems; latitude, longitude, and altitude polar coordinates; and a local flat-earth cartesian system centered at a target complex being studied. The nuclear environments which are considered by the program include: blast; thermal radiation; X-ray, gamma-ray, and neutron radiation; nuclear cloud interactions; and a number of others. The persistent endoatmospheric effects, which include blast, thermal radiation, and nuclear clouds, are used in the simulation until they become ineffective at damaging vehicles. It should be noted that in all phases of the model, emphasis has been placed on achieving a high degree of accurate nuclear effects modeling (Ref 8:4).

The engagement simulation within OASIS centers around strategic targets which are being attacked by enemy RVs. Usually, these targets are ICBM silos. These targets and the vehicles in the local complex are located in flat-earth cartesian coordinates. An engagement generally consists of

RVs attacking the various target points in the complex, with ICBMs being launched during the attack in the midst of nuclear detonations. During each time cycle, the flight of the RVs and ICBMs is followed and their positions are updated along each trajectory. Both RVs and ICBMs enter the game on a prescheduled basis.

The program computes the interaction of the radiation emitted by a nuclear burst with all vehicles and targets within the vicinity. Each detonation also serves as the origin of a shock front, a thermal pulse, and a nuclear cloud. These persistent environments are updated each time-cycle, and their interaction with the vehicles in flight is continuously computed. Those vehicles and targets which receive stresses or doses in excess of any specified degree, prompt or cumulative, are considered killed and are removed from the game (Ref 8:5).

The impact point of an RV attacking a silo or ground installation is determined by sampling a target-centered normal distribution. Each RV trajectory has an associated downrange variance and crossrange variance which is combined with the normal distribution to determine the location of impact. When detonation occurs the radiation dose, overburden, and blast overpressure at the target are computed as a function of the miss distance and are compared with the respective vulnerability thresholds to see if the target was killed.

The geometry of a typical target consists of a ceiling of 300,000 feet and a surface area of a square with a 100 mile length on each side, which is the approximate size of an ICBM wing. Outside of this volume of space, there is no need for vehicles in flight to be updated every time-cycle unless a detonation or other special event occurs. The vehicles are located in one of the global coordinate systems previously mentioned (i.e., orbital, ECI, ECR, latitude-longitude-altitude coordinates). Numbered targets which exist anywhere outside the local target complex are specified by latitude and longitude. RV attacks against these targets are processed in the same manner as those in the local target complex, but the blast, thermal radiation, and nuclear cloud environments are not generated. The radiation effects (X-ray, gamma-ray, and neutrons) on adjacent vehicles are computed for every detonation in the program, regardless of locations (Ref 8:6).

There are 250 numbered target locations available in OASIS-IIF, both local and nonlocal. RVs may be directed toward any target specified by latitude, longitude, and altitude. Also, ICBMs or SLBMs can be launched from any point specified in like manner. The number of vehicles in flight at any one time is predefined, but the total number of vehicles in the engagement is essentially unlimited. It should be noted that with program modification, the number of vehicles in flight at one time can be increased (Ref 8:6).

To reiterate, an engagement history is printed at each time step where significant events occur. At the completion of the run a summary is printed out, giving the silo and vehicle kill statistics.

The Model Uses. The OASIS program is structured to simulate ballistic missile engagements of virtually any size, including full scale nuclear war on a continent-wide scale. The vast amount of data that would be generated if all vehicles in a continent-wide engagement were to be moved every time-cycle through a complete environment, including the three persistent endoatmospheric phenomena (nuclear cloud, thermal, and blast front intersections), would seldom merit the large computer storage and run-times that would be required. OASIS handles the desired compromise between accuracy and computer requirements by providing a local complex in flat-earth coordinates where the total environment can be studied in great detail while permitting a continent-wide analysis in every respect except nuclear cloud, thermal, and blast front intercept (Ref 8:17-18).

With the use of additional subroutines, the model is also capable of simulating the effects of water and ice on the trajectories of re-entry vehicles. It can also determine the erosion effects of specific heat shields due to certain atmospheric and cloud parameters (Ref 8).

The Arsenal Exchange Model (AEM)

The Model Operation. The Arsenal Exchange Model was developed at Martin-Marietta Corporation during the mid 1960's. Although it is used by many government agencies, this study will address its use by Headquarters Air Force, Deputy Chief of Staff for Programs and Analysis, the Directorate of Concepts and Analyses (AF/PAC). The AEM is formulated around a mapping of two world powers into two components, namely, forces and homogeneously valued nonmilitary resources. The strategic forces considered are ICBMs, SLBMs, and bombers. Resources are singularly valued, (e.g., "population, manufacturing floor space, or GNP added") and are referred to as value targets. Area and terminal defenses may be possessed by either or both opponents (Ref 5:1.3).

An exchange may be initiated by either side. The AEM allows only for sequential attacks by alternating sides with provisions for up to three strikes. The relative importance of military targets ("damage limiting") and nonmilitary targets ("assured destruction") may be controlled by inputs if desired. Therefore, several types and levels of exchange may be analyzed under a variety of objectives (Ref 5:1.3).

The techniques employed by the AEM produce the marginal utility of all force components, both offense and defense, used during the exchange. This utility function is based on optimal allocations against both target types and is, therefore, a function of the forces and estimated target characteristics. However, it is also a function of the exchange type and the objective of the attackers (Ref 5:1.3).

Force target values are computed to answer the question, "What is the net value returned to me if this force target is deleted on this type of exchange where my objective and all resources in the game (offense, defense, and nonmilitary on both sides) are as stated?" The concepts of marginal return and force target values to produce optimal allocations are fundamental to exchange analysis with the AEM (Ref 5:1.3). A discussion of some possible strike scenarios follows.

In a one-strike scenario, the initiator allocates his arsenal against the opponent's value targets and nonretaliatory military targets. There is no retaliation. This scenario is generally used to determine the maximum nonforce target damage the initiator can achieve. A variation of this could be the counterforce strike in which the initiator attempts to maximize his advantage in force capability, by allocating his arsenal against the opponent's force targets.

The two-strike scenario is composed of both a counterforce and countervalue strike by the initiator with a retaliatory strike against the initiator's other military targets and value force targets. Force target values must be computed for the first strike. This scenario allows the initiator to maximize his value returned since his arsenal is not attacked while his opponent's forces may be. This scenario is used to gage the retaliator's capabilities in terms of expected "assured" destruction. A variation of this could be a sequence of two single-strike, limited, counterforce exchanges in which both sides try to maximize their advantage in force capability (Ref 5:1.5).

The third scenario is called the three-strike optimum reserve force scenario. It consists of a counterforce first strike, followed by both a counterforce and countervalue retaliation, with the initiator's countervalue strike last. Force target values must be computed for the first and second strikes as well as the optimum reserve force mixture. This mixture is sensitive to the survivability of the various weapon types. This scenario attempts to simulate a damage limiting first strike, with a reserve force holding the retaliator at risk. Such a plan could possibly preclude the second and third strike in a real war if the retaliator's price is sufficiently high. Also, the other military targets are attacked in the counterforce first strike. A variation of this scenario could be used to investigate a strategic limited war.

The structure of the AEM is shown in Figure 3 on the following page. A case is complete when the answer to the question, "is another strike necessary?" is no. A major iteration is complete on a return to the block called "Prepare to conduct current strike." A minor iteration is complete on a return to the block called "Choose potential strategies."

A major iteration is a strike allocation (that is, the first strike or second strike). Since the program executes those strikes repeatedly to obtain force target values, the word "cycle" is sometimes used instead of strike. For each strike, there is a brief summary printed to provide the analyst a road map of how convergence progressed. For a three-strike game, the force target values represented on

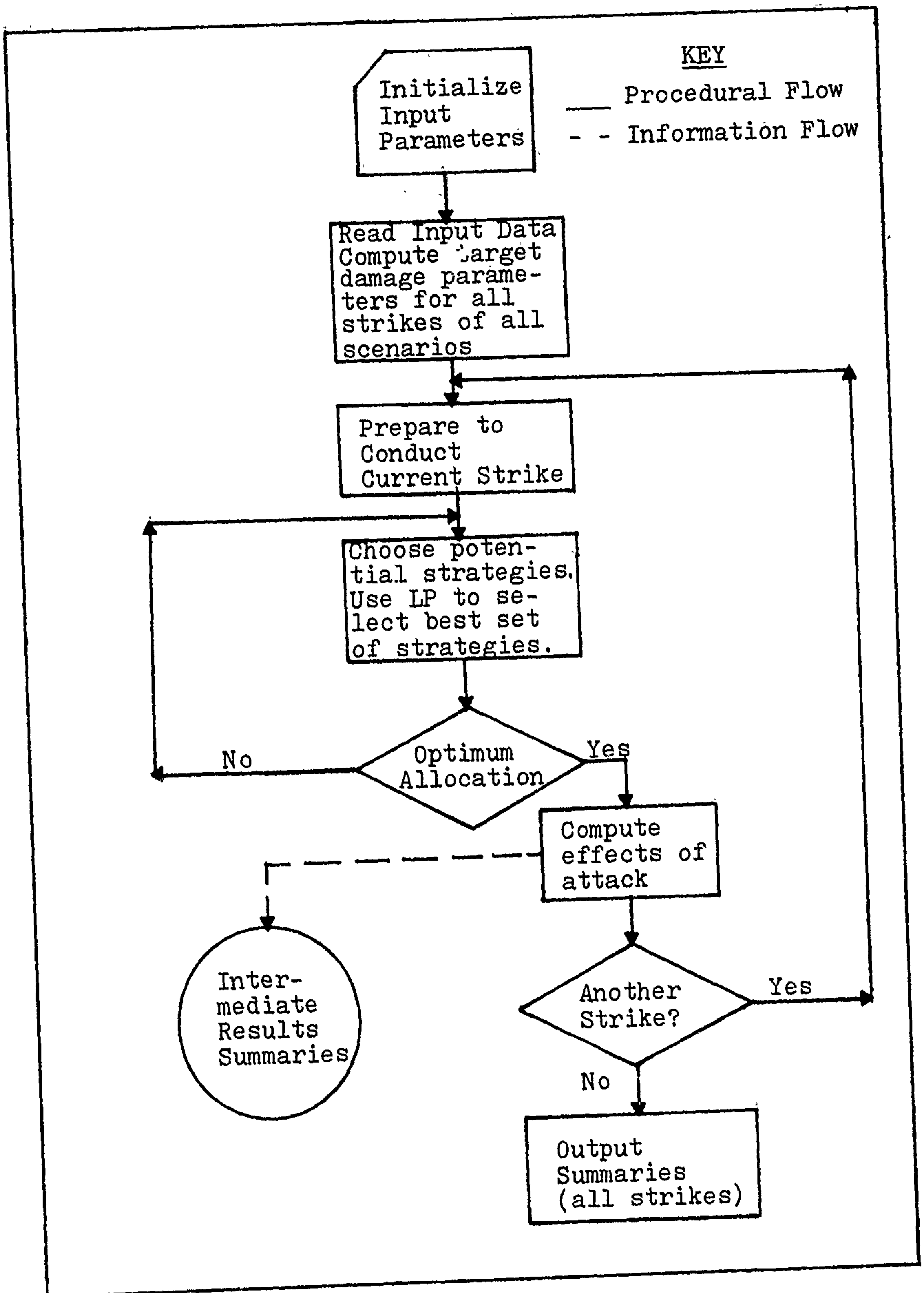

Figure 3. A Flow Diagram of the AEM Model

the second strike must be resolved prior to determining force target value on strike one. The force survivors from the first strike determine in part the force survivors from the second strike, thus the value of third-strike weapons. Therefore, after the first strike is performed, a sequence of strike two, strike three, strike two, etc., is performed until the proper weapon target values for the second strike are found, or until the maximum number of these inner, minor iterations have been performed. The outer, major iteration (return to strike one) is then started again with newly computed force target values. The process stops when there is convergence on a set of force target values which produce optimal allocation, or when the maximum number of outer, major iterations has been attempted. The number of outer, major iterations required for convergence depends on the particular case being run (Ref 5:2.1).

A minor iteration is performed to determine the optimum strategies which result in optimal value returned, for those target values being considered. The process is to choose strategies for each target class by the Lagrangian technique and input these strategies into the linear program which selects the optimum set of those strategies presented (Ref 5:21).

The Model Uses. The AEM model can be used for analysis prior to the employment of more detailed models. In this case the objective of the AEM-assisted investigations is normally to determine either candidate missions for specific weapons systems, or, conversely, candidate attackers for specific target types. This information is then used to restrict the range of investigations for simulations and/or engineering design models. In other cases the objective of AEM-assisted analysis could be to parametrically investigate the relative effects of one or more weapons systems, target, or force objective parameters, to find critical regions which can be subjected to more detailed quantitative or qualitative introspection. The reasons for this type of analysis could range from pure sensitivity analysis to determining the stability of results generated using best estimate potential threats, to the generation of quantitative arguments regarding the roles, missions, and characteristics of foreign forces.

Other areas for the use of the AEM model include screening of a large number of prespecified force alternatives with respect to one or more measures of effectiveness, so as to identify a few for further scrunity. Another use suggested by J. A. Battilega could be the education of strategic analysts involved in particular or specific studies. It could be used in this role to serve as a convenient way to obtain a "feel" for the dominant relationships and effects in a given strategic problem. It could be used to help the analyst understand the issues better, to sort the "issues" from the "nonissues," and to help give the analyst increased confidence that the conclusions he has reached are the correct ones (Ref 3:15-16).

The Strategic Weapon Allocation Damage Expectation (SWADE) Model

The Model Description. The SWADE model was developed as an "in house" project by Headquarters SAC/XPS in the mid 1970's. It is a model that is designed to have a fast run time. Consequently, it aggregates and clusters much of the targeting data so that data manipulation is kept at a minimum. Despite the clustering, SWADE considers bombers and missiles with single RVs as well as with MIRVs. The model itself is divided into three major areas which are called the Data Preparation Phase, the Allocation Phase, and the Assessment Phase. A block diagram of the SWADE model is shown in Figure 4 on the following page.

Before the Data Preparation Phase, estimates are made of the present world military, economic, and social complexes by the Defense Intelligence Agency. This information is transformed into a list of installations which then serves as the SWADE data base. In the Data Preparation Phase of SWADE, this basic data is altered to consider the growth of existing systems, the deletion of existing systems, or the development of new systems, or any combination of these. The next step is to input this installation list into a presimulation program called the Dual Criteria Aim Point Selection (DCAPS). The output of the DCAPS program is a list of Desired Ground Zeros (DGZs) which have been selected based on a prespecified criteria. Each DGZ represents the point where one weapon will detonate, and the area

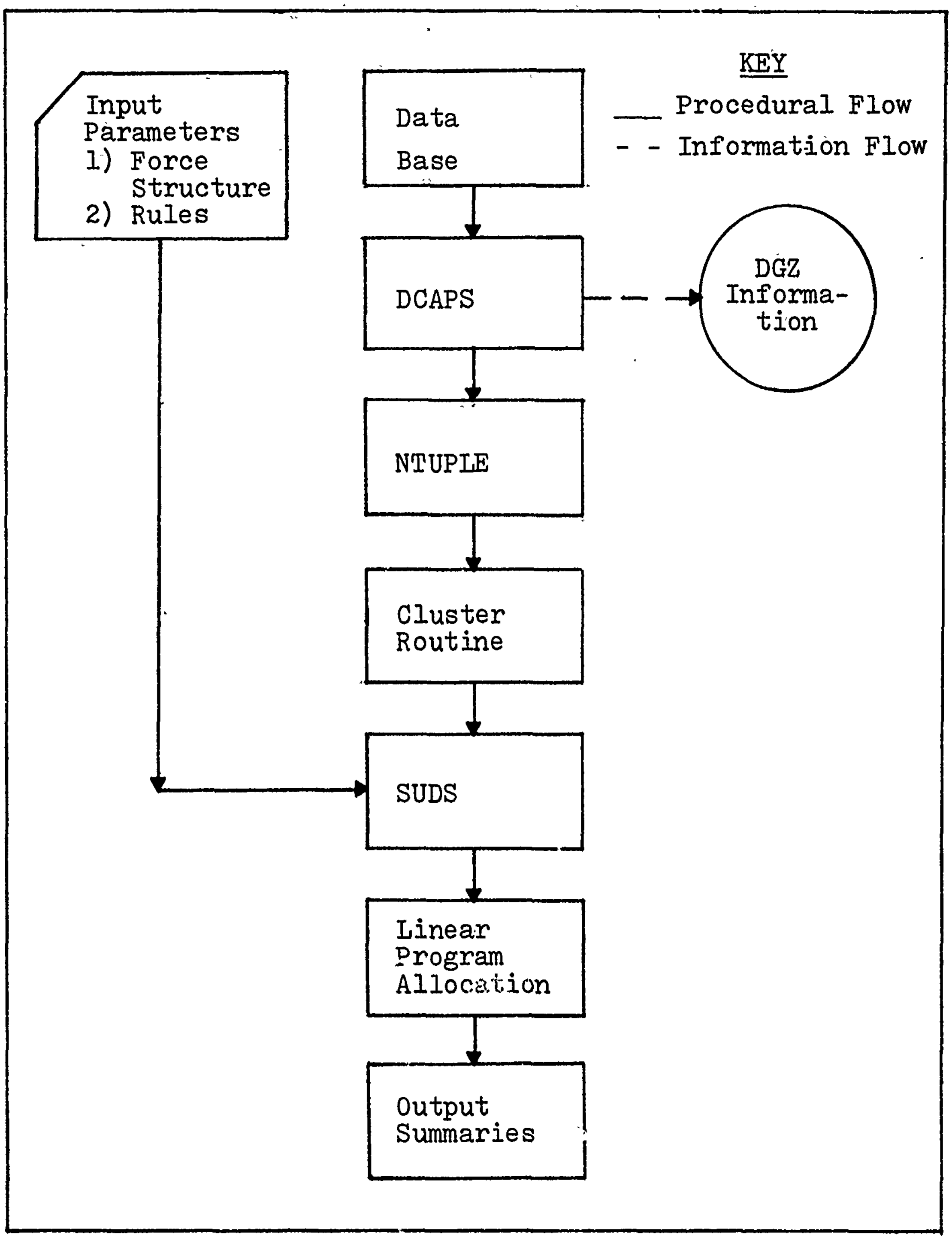

Figure 4. A Flow Diagram of the SWADE Model

around this point can encompass multiple enemy installations or targets. Also, along with each DGZ is listed all of the enemy installations which define that particular DGZ. The criteria, in general, prioritizes the targets according to what damage level is needed to destroy the installation and how much it will cost to inflict this damage. As installations receive the specified level of damage, they are taken out of the list and the next priority item is addressed.

Each DGZ that is output from the DCAPS model is processed by the nine-tuple routine (called NTUPLE) to give a spectrum of probability of damage (PD) values. For each DGZ, a small, medium, and large weapon yield is considered in combination with a small, medium, and large CEP. Thus, each DGZ has nine specific PDs associated with it. As noted above, the DGZ usually represents multiple enemy installations or targets. When this is the case, each of the nine specific PDs represents an average over all of the installations or targets associated with the DGZ. For example, suppose there are three enemy targets associated with DGZ #1. The first PD combination of small yield-small CEP is computed for each of the three targets and then averaged to obtain one PD for the small yield-small CEP combination. The second PD combination of small yield-medium CEP is computed for each of the three targets and then averaged to obtain one PD for the small yield-medium CEP combination. This process continues through the ninth combination (large yield-large CEP). The result is that DGZ #1 has nine PDs associated with it which represent the nine combinations of yield and CEP.

When this is completed, SWADE goes through another process of combining the data in order to reduce the computer storage required. This is performed by comparing each of the DGZs with their nine PDs to a template. There are a small number of templates, each of which has nine PDs associated with it, and a pseudovulnerability number associated with these nine PDs. The template that most closely matches its nine PDs to the nine PDs of the DGZ is chosen to represent that DGZ. Then, the single pseudovulnerability number associated with the particular template is used to describe the DGZ instead of the nine PDs. Thus, less information is needed for storage in the computer.

The final portion of the Data Preparation Phase is the clustering of the DGZs. Basic cluster groups are defined just prior to the clustering process. The basic groups may include such items as all of the airfields, all of the SAM sites, or all of the ICBM silos. For each pass of the cluster routine, the number of clusters within each of the basic groups decreases. Due to machine limitations, not model limitations, the SWADE model presently uses 40 cluster groups. Thus, the clustering is repeated until there are only 40 groups left. Following this, the Single Uniform Data System (SUDS) routine is applied. SUDS takes all of the prespecified force structures and rules, and the clustered DGZs, and converts them into a form which is capable of being used in the Allocation Phase.

The next step in the SWADE model is the Allocation Phase. This phase involves searching for an optimal solution with a linear programing (LP) algorithm. This LP process allocates specific weapons to specific DGZs. The final step is called the Assessment Phase. In this step, an assessment is made of the economic damage to the community and of the military damage expectancy. For instance, the damage inflicted by any single leg of the triad can be viewed as well as the damage inflicted by any combination of the legs of the triad (Ref 6).

<u>The Model Uses</u>. The SWADE model is primarily used to explore proposed future force structures. It can be used to evaluate the effectiveness of our new weapon systems against possible future systems developed by our enemies. It can be used to explore the effects of the Air Launched Cruise Missile, or the effects of new and improved radar systems, or the effects of the addition and deletion of missiles from our arsenal.

In addition, the SWADE model can be used to study the effects of deleting one leg of the triad or deleting two legs of the triad. It can also be used to perform sensitivity investigations on the composition of the triad. However, it should be noted that SWADE is a quick-running model because it aggregates much of the information. Although its output closely resembles the summary reports of much more detailed models, it should be remembered that SWADE was designed to provide quick answers to complex problems (Ref 6).

Now that the operation of each model has been discussed, the study moves into a more detailed examination of the similarities and differences between the four models. Chapter III presents the generic framework and compares the models in a step-by-step process through each characteristic.

III. The Generic Framework

Introduction

One of the specific objectives of this study is to develop a generic framework within which a strategic model can be analyzed. It should be noted that this lattice reflects a grouping of characteristics that are not found in any single source document. Even though strategic simulations have been around for a long time, no one has formally developed a comprehensive framework within which to analyze models in general. However, while this framework is by no means an exhaustive listing of all possible characteristics, it is an attempt to provide a consistent, traceable path of characteristics which anyone can follow.

The characteristics were developed from several sources. The most obvious sources were the four models themselves along with the many volumes of users manuals and analytic manuals. Other contributions came from the operators of these elaborate models, who spent many hours discussing the validity of some of the characteristics. Still other characteristics, in fact, the majority of the characteristics, came from the note pad of an expert in the simulation community. His note pad, which contained many inputs from previous co-workers, provided the primary source of information.

As shown in Figure 5, on the next page, the framework consists of six major areas. These areas are: General

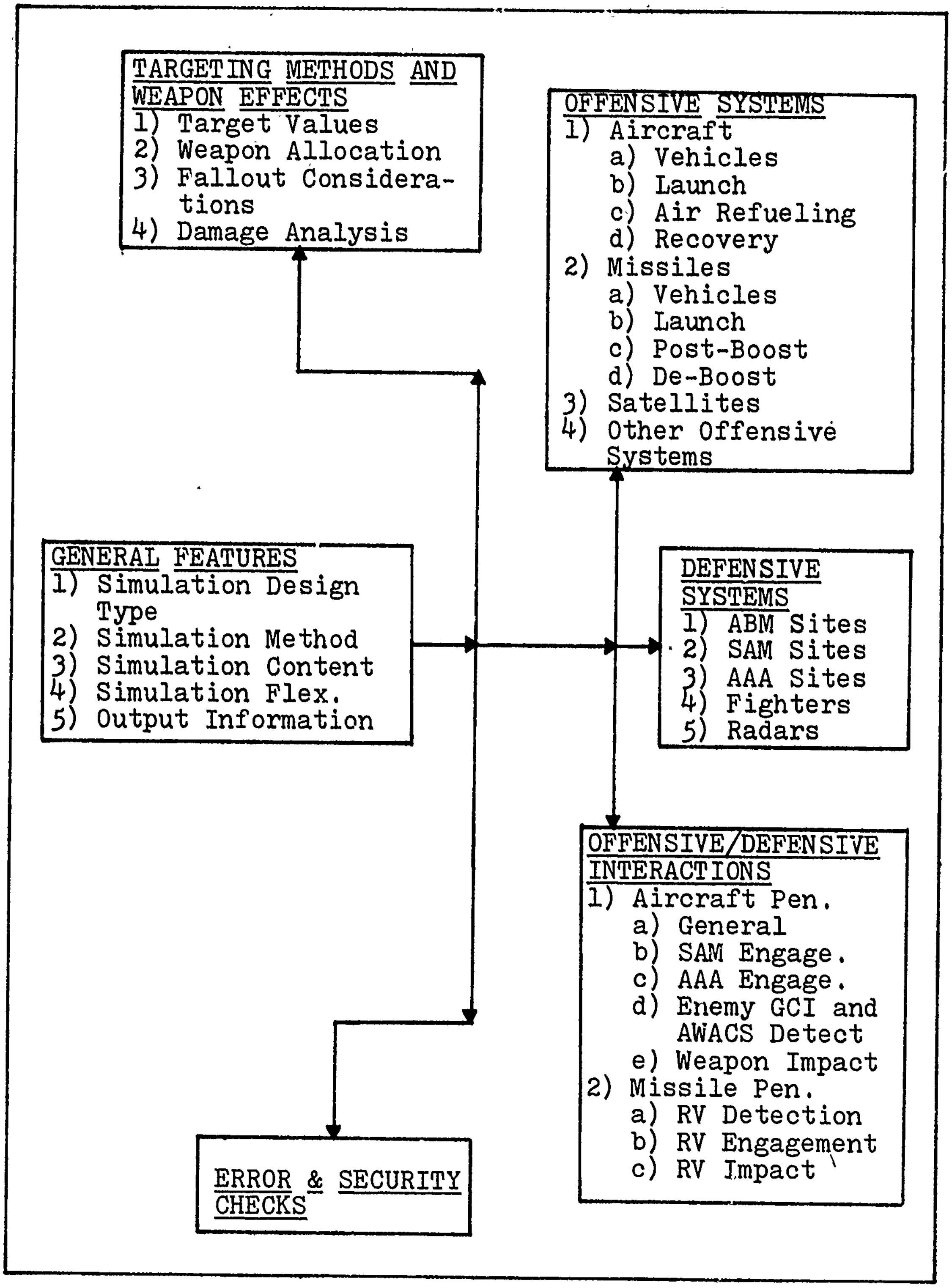

Figure 5. The Generic Framework

Features, Targeting Methods and Weapon Effects, Error and Security Checks, Offensive Systems, Defensive Systems, and Offensive/Defensive Interactions. Within each area there are various categories, except the Error and Security Checks area which has no categories. Each category is considered as an independent unit with the exception of the Offensive Systems and Offensive/Defensive Interactions areas which must be broken down further into subcategories. These subcategories are also considered as independent units. Thus, in this chapter, for each category and subcategory (i.e., each independent unit), there is an explanation of the characteristics, a discussion of how the models interface with the characteristics, and a table showing which models possess which characteristics. To aid the flow of the text, each table is arranged in numeric sequence at the end of this chapter beginning on page 89. If a model possesses the characteristic, an "X" is placed in the space provided, otherwise, a "dash" is placed in the space provided. Finally, any inconsistencies are labeled as footnotes.

An additional comment needs to be made about some characteristics that appear to overlap in content. Although very few characteristics overlap, it was felt that some of this was necessary. Thus, if an individual uses this study to focus on only one particular set of characteristics, the individual is assured of having a complete set of characteristics for the particular category he is viewing.

General Features

This area focuses on the basics of a simulation model. For example, is the model an event sequence or a fixed time increment simulation? Does the model consider aircraft, missile, and satellite events? These and other characteristics are discussed in the five categories. The category titles are: Simulation Design Type, Simulation Method, Simulation Content, Simulation Flexibility, and Output Information.

Simulation Design Type. This category involves some of the fundamental characteristics that most models use. For example, a model will either be one-sided, two-sided, or more than two-sided. All strategic simulation models will fit into one of the three categories. Thus, this category describes the overall design philosophy of the model. A description of the eleven characteristics follows.

1. Event Sequence Simulation: The simulation is advanced by stepping from one event to the next, irrespective of time.

2. Fixed Time Increment Simulation: The simulation is advanced by a predetermined time increment.

3. Dynamic Event Store: The simulation can dynamically change the timing of events.

4. Event Sequence and Dynamic Event Store: The user can specify which events are dynamic in the sense that their timing can be changed.

5. Dual Event Store: The simulation can store the results of the Event Sequence and the Dynamic Event Store, and it can compare the results.

6. Regenerative Simulation: The program will flag events specified by the user. For example, the program would output a message when 50% of the communications network had been destroyed.

7. One-Sided Exchange: The simulation models only one country involved in the war (either offensively or defensively).

8. Two-Sided Exchange: The simulation models a two country conflict where both countries have offensive and defensive capabilities.

9. More Than Two-Sided Exchange: The simulation models a conflict where there are more than two countries involved and each country has offensive as well as defensive capabilities.

10. Time in Minutes: The event sequence time is in minutes.

11. Time in Seconds: The event sequence time is in seconds.

As can be seen in Table I, the QUICK and SWADE models are event sequence models, while the OASIS and AEM models are designed to run on fixed time increments. It is also shown that the QUICK and AEM models can be run as two-sided simulations, while the other two models can only be used for one-sided exchanges.

Simulation Method. This category reflects the methodology used by particular models. For instance: is attrition handled probabilistically or dynamically? Is the model capable of multiplay, multicase, or multiplan operations? The specific meaning of these terms and a discussion of each of the 14 characteristics follows.

1. Probabilistic Attrition (Aircraft): The attrition of aircraft is determined by making a random number draw to see if the aircraft was destroyed or not. None of the events (i.e., launch, detection, penetration, weapon release, and recovery) are considered independently like they are in the dynamic attrition case.

2. Probabilistic Attrition (Missiles): The same definition applies from Number 1 (above), but missiles are used instead of aircraft.

3. Dynamic Attrition (Aircraft): Each event (i.e., detect, track, ABM launch, etc.) is examined and at each step a random number draw is made to determine its success or lack of success.

4. Dynamic Attrition (Missiles): Again the same definition is used as in Number 3, except that it applies to missiles.

5. Dynamic Degredation (Offensive): A continuously updated record is made of the offensive sites that were or were not destroyed.

6. Dynamic Degredation (Defensive): A continuously updated record is made of the defensive sites that were or were not destroyed.

7. Dynamic Damage Assessment: The program determines the percent damage to nontargeted structures that resulted from blast, fallout, etc.

8. One Step Inspection Model: The simulation can be stopped at any step and the parameters changed.

9. Multiprogram Single Operation Model: The user is able to interactively select the sophistication level at which the program can be operated.

10. Complete Single Operation Model: A complete software package which includes Items 8 and 9 as well as programmed instruction capability for beginners.

11. Multiplay Operation Model: Once the data base has been built, multiple plays of the game can be made with statistics computed over the multiple plays.

12. Multicase Operation Model: The data base remains the same, but the timing of events can be changed for subsequent plays of the game.

13. Multiplan Operation Model: Both the data base and the timing of events can be changed for subsequent plays of the game.

14. Statistical Weighing of the Results: Multiple simulation runs are made with the results of each being statistically combined into one report.

The tabular representation of these characteristics is found in Table II. As shown by the table, the QUICK and SWADE models use probabilistic attrition for both aircraft and missiles, while the AEM model uses probabilistic attrition for aircraft and dynamic attrition for missiles. The OASIS model looks at only missiles and, as shown in the table, addresses attrition dynamically. Finally, it can be seen that the QUICK model is somewhat more powerful in that it can operate in the multicase and multiplan mode.

Simulation Content. This category identifies specific items which a strategic simulation model might consider. For example: does the model consider aircraft events, as well as missile and satellite events? Does the model consider the population and damage levels? Again, although this category represents a fairly comprehensive listing, it is not exhaustive. A listing and discussion of each of the 20 characteristics follow.

1. Aircraft Events: The simulation models aircraft events.

2. Missile Events: The simulation models missile events.

3. Satellite Events: The simulation models satellite events.

4. Mobile Targets: The program has the capability for moveable targets.

5. Port Ties: The program considers the higher vulnerability of naval vessels at or within a certain radius of the port.

6. Vehicle Hardness: The program considers the susceptibility to blast overpressure (hardness) of all the vehicles (i.e., aircraft, missiles, satellites).

7. POL Storage: The program considers the locations and sizes of the petroleum, oil, and lubricant storage areas.

8. Damage Levels: The program differentiates between the different levels of destruction on items such as buildings, silos, vehicles, etc.

9. Industrial Growth Industrial Worth (IGIW): After the simulation, the potential for future industrial growth and the present industrial worth is computed.

10. Population Considerations: Some assessment of the effects of the war on the population is made.

11. Launch and/or Recovery Bases: The effects of weapons on the launch and recovery bases is made.

12. Alive/Dead Status: The program establishes if an item is alive or dead and if it is dead, the program will discontinue processing further events of that item.

13. Number of Alert and Nonalert Vehicles: For other than first strike scenarios, the simulation considers nonalert vehicles for possible use in second strike scenarios.

14. Launch Tactics: (a) Dynamic, (b) SIOP/RISOP Only: In the dynamic case (a), the timing of a sequence of events can be altered. For example, if the missile launch is successful, then the simulation will schedule the next in flight event. With the SIOP/RISOP only case (b), all the events (launch, post-boost, de-boost, etc.) have been prescheduled. Then, if the missile launch is unsuccessful, the program must delete all the rest of the events for that missile.

15. Command and Control Timing: The program considers the time delay encountered when delivering and receiving information.

16. Command and Control Probabilities: The computed probability of the status (alive, dead, or under repair) of the command and control network is considered.

17. Communication Damage Assessment: After the simulation, the output shows the level of damage at each communication site.

18. Simulation From the Real Time Situation: The parameters used by the model reflect the parameters of the current state of the world.

19. Recovery Base Saturation: The program considers some airfields, where aircraft are to be recovered, are full and cannot physically accomodate any more aircraft.

20. Coordinate Systems: (a) Earth Centered Inertial (ECI), (b) Earth Centered Rotational (ECR), (c) Longitude, Latitude, Altitude, (d) Flat Earth, (e) Range, Altitude, Azimuth from a Point: The program considers coordinate systems for locations of missile and/or space vehicles. The ECI (a) and ECR (b) are three dimensional systems in which the axis remains fixed in space (ECI) or the axis rotates with the earth (ECR). The longitude, latitude, altitude system (c) is used primarily for user convenience on the output. The flat earth system (d) is similar to a tangent plane system and is used when less detailed calculations are desired. The range, altitude, and azimuth system (e) is used for ease of manipulation within a computer system.

Table III lists these characteristics. As shown in the table, all of the models consider missile events and all but the OASIS model considers aircraft events. But, the OASIS model is the only one which considers satellite events. Finally, it can be seen that industrial growth, industrial worth, and population are considered by all of the models except OASIS.

Simulation Flexibility. This category investigates the degree to which an operator can interact with the model before and during the simulation run. For example, can the operator make changes just prior to the simulation run or can he make them during the simulation run? The listing and discussion of the 11 characteristics follows.

1. Control Card Changes Prior to Simulation: The program has the ability to make control card changes after the data base is built, but before the simulation has run.

2. Control Card Changes During the Simulation: The program has the capability to make control card changes during the simulation run.

3. Last Minute Add or Delete: The program has the ability to add or delete data after the data base is built, and before or during the simulation.

4. Print of All Preset Variables: (a) Presimulation, (b) Postsimulation: A summary of all of the variables is printed out prior to the simulation run (a), and/or after the simulation run (b).

5. Man Intervention Simulation: The user can intervene before the simulation run has been completed.

6. Man Observation Simulation: The user can look at various portions of the simulation as it progresses.

7. Tactic Decision Simulation (Offensive and Defensive): A tactic or tactics can be changed after a certain event or sequence of events have occurred.

8. Add or Delete Before the Simulation: (a) Vehicles, (b) Units, (c) Events: The items listed can be added or deleted just prior to the simulation run.

9. Add or Delete Interactively During the Simulation: (a) Vehicles, (b) Units, (c) Events: The items listed can be added or deleted interactively during the simulation.

10. Delay or Speed Up Time For: (a) An Event, (b) All Events, (c) Units: The timing for the events listed can be advanced or retarded.

11. Pseudoimpacts: The simulation allows some targets to be preselected as destroyed before the simulation starts.

The tabular representation of these characteristics can be found in Table IV. As shown in the table, all of the models except OASIS are flexible enough to allow control card changes just prior to the simulation run. Also, of the two time increment models (OASIS and AEM), only the OASIS model is flexible enough to allow a change in timing its on events. Finally, all of the models except QUICK allow for addition and deletion of vehicles, units, and events.

Output Information. This category addresses the various ways and possible situations in which output can be obtained. For example, output could automatically be generated during the simulation if a certain critical event occurs. A discussion of the five characteristics follows.

1. Fractional Play Summaries: The simulation can randomly look at different time slices of the game.

2. Situation Initiated Summaries: When a certain specified set of conditions occur within the simulation, a summary is printed out of the results of the game to that point.

3. Immediate Summaries: The user can interactively look at the game as it has occurred thus far, then let the game continue.

4. Detailed Summaries Following the Simulation: A summary of all facets of the simulation is automatically printed out at the end of the simulation run.

5. Summary Information Obtainable on: (a) Hard Copy, (b) CRT, (c) Magnetic Tape, (d) DISC File: The program has the capability to obtain output on the aforementioned devices.

These characteristics are listed in Table V. As is shown in the table, all of the models have detailed summaries following the simulation, but only the OASIS model has the capability of immediate summaries. Also, each of the four models can obtain output in any of the four forms listed.

Targeting Methods and Weapon Effects

This area addresses four categories of effectiveness.

The categories are as follows: Target Values, Weapon Allocation, Fallout Considerations, and Damage Analysis. Some of the issues which are examined are whether the targets are valued or not, and whether the allocation process is designated prior to the game or computed as the first step in the game. A discussion of each of these areas follows.

Target Values. This category addresses the issue of whether the targets are valued or not and if valued whether the value is precomputed or computed during the game. The three characteristics are defined as follows:

1. Value is Precomputed: The targets are valued and assigned a precomputed value before the simulation is run.

2. Value is Computed During Game: The targets are valued and their value is computed during the simulation run.

3. Not Valued: The targets are not valued.

The tabular comparison of the target value characteristics is shown in Table VI. It is readily apparent that all of the models except OASIS value their targets. Also, it should be pointed out that both QUICK and SWADE use precomputed values.

Weapon Allocation. This category investigates various methods within which the allocation process can be viewed. For example: is allocation permitted with cross targeting? Is the allocation based on time dependent targets? A discussion of the seven characteristics is as follows:

1. Allocation Designated Prior to Game: The weapon allocation scheme is designated prior to the running of the game.

2. Allocation Computed Prior to Game: The weapon allocation scheme is computed prior to the running of the game.

3. Allocation is the First Step of Game: The allocation scheme is computed by the program as the initial step of the game.

4. Allocation with Cross Targeting: More than one type of weapon can be allocated against a target.

5. Allocation - Mission Purity: The program considers that all of the RVs from an ICBM will go to the same geographic area or a specific set of targets.

6. Allocation - Target Island Information: The program considers the lethal radius of the weapon detonation.

7. Allocation - Time Dependent Targets: The program considers certain targets which must be destroyed within a specified length of time (for example, ICBMs).

The tabular comparison of the weapon allocation characteristics is found in Table VII. From the table, it can be seen that only the OASIS model allocates weapons to targets prior to the game. The other three models allocate weapons as the first step of the game. Also, it should be pointed out that only the QUICK and AEM models consider lethal radius (target island information).

Fallout Considerations. This category examines some of the more common characteristics associated with fallout. Other items could be added, but these are the ones which are most commonly considered. For example: is the fallout analysis performed with static or dynamic winds? A listing and discussion of all seven characteristics follows.

1. Fallout Levels: The program considers the effects of fallout on various items.

2. Fallout Analysis with Static Winds: The program considers fallout with certain constant winds.

3. Fallout Analysis with Dynamic Winds: The program considers fallout with changing wind patterns.

4. Shielding Factors: The program considers shielding factors (such as concrete buildings) when calculating damage.

5. Casualties: The program considers the fatality count.

6. Unlimited Monitoring Points for Fallout: The program considers the measurement of fallout throughout the entire country, and the effects it has with respect to time.

7. Limited Monitoring Points for Fallout: The program considers the measurement of fallout only at specific locations in a country, and does not consider the effects with respect to time.

Table VIII shows the fallout consideration characteristics for each of the four models. As shown in the table, OASIS and AEM are the only models which even consider fallout analysis. Additionally, AEM and SWADE are the only models which consider the casualties.

Damage Analysis. This category investigates characteristics which involve damage that results from nuclear effects. For example: does the model consider blast, heat, and radiation effects? The eleven characteristics are listed and discussed as follows.

1. Blast Effects: The program simulates the effects due to overpressure levels generated by weapon detonation.

2. Heat Effects (Thermal Radiation): The program simulates the effects of thermal output from a nuclear burst.

3. Radiation Effects (Nuclear Radiation): The program simulates the effects of nuclear radiation after a weapon detonation.

4. Blackout Effects: The program considers the loss of utilization of radar and communication equipment due to blackout.

5. Electromagnetic Pulse (EMP): The program considers the effects of the electromagnetic field generated by weapon detonation. The EMP is a function of weapon yield, height of burst, and the relative distance between the observer and the burst.

6. Dust: The program considers the effects of nuclear and nonnuclear particle clouds formed by the burst.

7. Compound Damage: The program considers the multiple damage resulting from more than one blast on a target.

8. Transient Radiation Effects on Electronics (TREE): The program considers the effects of transient radiation on various electronic systems.

9. Fission Product Cloud Dose: The program considers the effects on vehicles passing near nuclear fireballs or nuclear clouds. The effects are the result of being exposed to radiation emitted by the weapon fission fragment debris.

10. Cratering and Overburden: The program considers crater size and the debris that is deposited in the area.

11. Nuclear Winds: The program considers the strong nuclear wind which is generated at the center of the nuclear cloud.

The characteristics are listed and compared in Table IX. As shown in the table, the only model which considers all of the characteristics is OASIS. Although both the AEM and SWADE models consider the blast and radiation effects, the OASIS model is by far the most detailed in this category.

<u>Error and Security Checks</u>

This area focuses on methods which a simulation can attempt to check for errors and notify the user. For example: will the simulation halt when the number of error records exceeds a certain level? Are error records allowed if ample messages are sent to the operator? Because this is a small area, there are no separate category breakouts. Thus, the ten characteristics are listed and discussed as follows:

1. A Data Record Check Subroutine to Halt the Process: The program includes a subroutine which checks the data records as they are passed from one program to the next. This subroutine will halt the process if records are created or destroyed inadvertently.

2. An Error Check to Insure All Data Which Needs Multiple File Cross-Reference is Correct: In a typical program, this means that the targets from the target file are matched to the offensive missiles from the missile file. If any errors are made in the allocation process (i.e., sending all the missiles to one target), the errors can then be investigated before running the simulation.

3. Each Program that Uses Data, Error Checks the Data: All programs which add, delete, and/or change the data in the gaming files, will check the data.

4. Simulation Halts when Errors Exceed a Limit or Number of Errors Change Between Successive Plays: The simulation can be halted when the errors exceed a specified limit, or the number of errors reported after each play differs by a specified amount.

5. Error Recovery Attempts by Simulation: The simulation notifies the user of errors and halts processing for a specified time while the user attempts to correct the error.

6. Error Records Allowed with Ample Messages to User: The simulation will pass messages to the user and will continue processing.

7. Use of Minimax Values for Testing Errors in Data: Each parameter is bracketed with a minimum and maximum value in which it is considered not to be in error. When a parameter falls outside the bracket, an error message is output.

8. Use of CRT for Checking Input Control Cards and Correcting Errors in Data: The capability exists for checking input control cards and correcting the errors with a CRT.

9. Two Step Error Correction Process: Errors are corrected by one individual and those corrections are rechecked by a second individual.

10. Boundary Controls on All Probability Calculations: All calculated probabilities are bracketed by upper and lower limits.

A tabular comparison of the models with the error and security check characteristics is in Table X. As shown in the table, only the OASIS model attempts to recover from errors. Additionally, only the SWADE model places boundary controls on its probability calculations.

Offensive Systems

This fourth area focuses mainly on offensive characteristics of aircraft and missiles. Although there are a third and fourth category, Satellites and Other Offensive Systems, the first two categories of Aircraft and Missiles contain nearly all of the characteristics. These first two categories contain so many characteristics that each one contains four subcategories.

Aircraft. This first category contains four subcategories. The subcategories are titled: Vehicles, Launch, Air Refueling, and Recovery. These categories address the various events that an aircraft can encounter on a mission with the exception of penetration. The penetration events can be found in the Offensive/Defensive Interactions area.

Vehicles. This first subcategory addresses the various types of vehicles that can be used in a strategic role. A discussion of the nine characteristics follows.

1. Bombers With Gravity Weapon: The program considers bombers carrying gravity weapons.

2. Bombers With Missile Weapons: The program considers bombers carrying missiles.

3. Bombers With Gravity and Missile Weapons: The program considers bombers which carry both gravity and missile weapons.

4. Missiles Considered: (a) Air Launched Cruise Missiles (ALCM), (b) Short Range Attack Missiles (SRAM), (c) Air to Surface Missiles (ASM), (d) Decoys: The program considers the missiles carried by the bomber to be either ALCMs, SRAMs, ASMs, or Decoys.

5. Airborne Warning and Control System (AWACS): The program considers AWACS aircraft. These aircraft are used to detect enemy vehicles flying at low levels and to direct aircraft into target areas.

6. Tankers: The program considers tanker aircraft.

7. Post Attack Command and Control System (PACCS): The program considers the effects of a PACCS.

8. Minuteman Alternate Launch Control (ALC) Aircraft: The program considers the effects of a minuteman ALC aircraft when a particular underground launch control center has been destroyed.

9. Airborne Anti-Ballistic Missile (AABMIS): The program considers ballistic missile systems that can be carried on aircraft.

The tabular representation comparing the four models with the Aircraft (Vehicles) characteristics is found in Table XI. As is readily apparent all of the models except OASIS consider bombers. Also, it can be seen that only the QUICK model considers tankers.

<u>Launch</u>. This second subcategory investigates the various characteristics that can be considered when

aircraft are launched. A listing and discussion of the 23 characteristics follows.

1. Monte Carlo Prelaunch Survivability: In general, a monte carlo technique involves assigning a probability of an event successfully occurring. Then, a random number is drawn for that event and if it is less than or equal to the preassigned probability, the event was successful. If the random number was greater than the preassigned probability, then the event was not successful. In this case, for each aircraft in prelaunch status, a random number is drawn to determine whether the aircraft survived the launch.

2. Dynamic Destruction of Prelaunch Survivability: The destruction of aircraft in prelaunch status is not determined by a random number draw. Destruction is determined by previously timed events, such as the detonation of a warhead near the airfield. The method requires the inclusion of previous events, whereas the monte carlo technique does not.

3. Monte Carlo the Launch Abort: Whether an aircraft aborts its launch or not is determined by the selection of a random number using the monte carlo technique as explained above.

4. Monte Carlo Command and Control Survivability: Again, the monte carlo technique is used and a random number is selected to determine the survivability of the command and control system.

5. Dynamic Destruction of Command and Control Capability: The destruction of the command and control capability is determined by previous events, such as the detonation of a warhead.

6. Launch on Schedule: The program considers that the aircraft are launched at exact times according to a preplanned schedule.

7. Launch on Schedule Modified by Input Distribution of the Launch Deviations: A probability density function is established for the launch schedule. Thus, launch time is spoken of in the context of a confidence interval.

8. Launch Adjusted to Situation: Launch time can be altered to avoid certain events, such as postponing launch to ride out the missile attack.

9. Satellite Basing of Bombers: The bomber force is spread out over many bases to increase survivability.

10. Airborne Alert Bombers: The program simulates that some bombers are continuously kept in the air to prevent their destruction on the ground.

11. Airborne Sortie Replacement: The program considers that the aircraft which failed to launch are replaced by substitute aircraft.

12. Abort Sortie Regeneration: The program considers that the aircraft which failed to launch are taken out of the launch schedule.

13. Monte Carlo Tanker Launch: The success of each tanker is determined by selecting a random number and using the monte carlo technique (as described in Offensive Systems-Aircraft (Launch), number 1).

14. Tanker Abort Replacement: The program considers that the tankers which failed to launch are replaced by substitute tankers.

15. Tanker Abort Regeneration: The program considers that the tankers which failed to launch are taken out of the launch schedule.

16. Aircraft Damage Assessed After Enemy Impact: The program makes an assessment of the damage to aircraft after the impact of enemy weapons.

17. Launch and Loiter of Nonalert Sorties: In addition to the alert aircraft being launched, the program also considers the launching of nonalert aircraft.

18. In Flight Abort Played Immediately After Launch: When the abort is played in this manner, the aborted aircraft cannot be replaced.

19. In Flight Abort Played Prior to Weapons Release: When the abort is played in this manner, the aborted aircraft cannot be replaced.

20. PACCS Events: The program considers post-attack command and control system events.

21. AWACS Events: The simulation considers airborne warning and control system events that occur during launch.

22. Fighter Deployment for Incoming Bombers: The program considers the deployment of fighters against incoming enemy bombers.

23. Fighter Launch for Loiter: The program considers the launch of fighters for loiter to increase their rate of survivability.

The tabular representation comparing the four models with the Aircraft (Launch) characteristics is found in Table XII. The table shows that QUICK is the only model that considers any of the launch characteristics with one exception. The exception is that the AEM model considers in flight abort.

Air Refueling. The third subcategory addresses some of the characteristics involved in the refueling process. The four characteristics are listed and described as follows.

1. Monte Carlo the Success of Refueling: A random number is selected and the monte carlo process (as explained in Offensive Systems-Aircraft (Launch), number 1) is used for each aircraft to determine if refueling was successful.

2. Spare Tanker Refueling: The program considers that two tankers are preplanned for use in areas where one is needed. This technique increases the probability of success in case one tanker aborts.

3. Change Mates Within the Refueling Area: The program allows an aircraft to change from its assigned tanker to another tanker in the same area if problems have developed with the original tanker.

4. Change Mates Outside the Refueling Area: The program allows an aircraft to change from its assigned tanker to another tanker in any area if problems have developed with the original tanker.

Table XIII compares the four models against these

Aircraft (Air Refueling) characteristics. As the table reveals, none of the four models reviewed by this study considered air refueling events.

Recovery. This fourth and final subcategory addresses recovery characteristics. Although none of the models possess either of the two characteristics, this subcategory was included to make the generic framework more complete. A listing and discussion of the two characteristics follows.

1. Monte Carlo Accumulated Attrition: Rather than looking at recovery events, a monte carlo technique is used by drawing a random number to determine if a particular aircraft was or was not recovered.

2. Dynamic Attrition: (a) Blast, (b) Flash Blindness, (c) Fire Storm, (d) AAA, (e) SAM: Aircraft recovery is determined dynamically by looking at one or all of the five events involved in recovery.

The tabular representation of the Aircraft (Recovery) characteristics is found in Table XIV. As is readily apparent, none of the models considers Aircraft (Recovery) characteristics.

Missiles. This second category under Offensive Systems also contains four subcategories. The subcategories are titled: Vehicles, Launch, Post-Boost, and De-Boost. These subcategories address the various events that a missile can encounter with the exception of penetration. Penetration is dealt with in the Offensive/Defensive Interactions area.

Vehicles. This first subcategory addresses the various types of vehicles that can be used in a strategic role. A discussion of the four characteristics follows.

1. Single RV: The program considers single re-entry vehicles.

2. MRV: The program considers multiple re-entry vehicles.

3. MIRV: The program considers multiple independently targetable re-entry vehicles.

4. FOBS: The program considers fractional orbit bombardment systems.

Table XV shows a tabular comparison of the four models with the Missile (Vehicles) characteristics. As shown in the table, all the models consider single RVs. However, the AEM model does not consider MRVs or MIRVs, while the other three models do consider them. Also, the OASIS model is the only one which considers fractional orbit capabilities (FOBS).

Launch. This second subcategory addresses those characteristics associated with missile launch. Some of the characteristics involve the types of trajectories as well as launch tactics. A discussion of the 11 characteristics follows.

1. Monte Carlo the Launch: The monte carlo technique (as described in Offensive Systems-Aircraft (Launch), number 1) is used to determine if the entire launch process is or is not successful.

2. Monte Carlo the Events: (a) Missile in Commission, (b) Launch Survivability, (c) Launch Abort, (d) Failure in Powered Flight, (e) Separation: Again, the monte carlo technique is used to determine the success or failure of each of the events.

3. Dynamic Destruction of Launch Site: The amount of destruction of the launch site is determined by considering previous events such as the detonation of an enemy warhead.

4. Enemy Detection of Our Missiles: (a) Use SIOP Trajectory Specifications: The program considers launch specifications developed for the Single Integrated Operational Plan. (b) Use Depressed or Lofted Trajectories: The program considers lofting or depressing trajectories to avoid detection. (c) Use Boost Glide Trajectories: After separation, the RV is boosted again to change its trajectory and thus avoid advanced knowledge of the impact area. (d) Use Standard Trajectory Templates/Profiles: The program uses a set of precomputed trajectories to place the RV on a target. (e) Use Generalized Keplarian Trajectory Calculations: The program dynamically computes trajectories to fit specific needs.

5. Use Pen-Aid Trajectories (decoys): The program considers the use of missile decoys.

6. Use Rotated Spherical Earth: The program considers the missiles to be launched with the rotation of the earth.

7. Use Nonrotated Spherical Earth: The program considers the missiles to be launched against the rotation of the earth.

8. Command and Control Link Check: The program considers the command and control link to the missiles for launch purposes. For example, in the case of short range tactical missiles, the information on which direction to fire could radically affect the probability with which the missile hit its target.

9. Monte Carlo Command and Control: The monte carlo technique is again used to determine the success of the command and control netting.

10. Launch Tactics: (a) Launch on scheduled simulation time (b) Launch on Free Time, (c) Launch on SIOP/RISOP Timing, (d) Not Considered: The timing of the missile launches can either be on SIOP/RISOP timing (c), or they can be launched when there are no incoming missiles in the launch area (b), or they can be launched at a time schedule by the simulation itself (a), or finally, the model may be aggregated enough that it does not consider launch tactics (d).

11. Target Reprogramming Prior to Launch: The program considers that the missiles can be reprogrammed to another target just prior to their launch.

The tabular representation of the Missiles (Launch) characteristics used for comparison of the four models is found in Table XVI. It is readily apparent that both the QUICK and OASIS models consider many of these launch characteristics, while the AEM model considers none of them and the SWADE model considers them only in the aggregated sense.

Post-Boost. This third subcategory describes events which occur when the vehicle is placed into orbit. A listing and discussion of the five characteristics follows.

1. Monte Carlo Deployment of Warheads: A monte carlo technique is used to determine if the deployment of the warhead(s) was (were) successful or not.

2. Monte Carlo Missile Velocity Vector: A determination is made to see if the missile achieved a ballistic state by the monte carlo technique.

3. Monte Carlo Orbit Velocity: A determination is made to see if the vehicle reached orbit velocity by the monte carlo technique.

4. Compute Object Locations: The program keeps track of the position of all of the warheads and decoys by dynamic computation.

5. Use Precomputed Object Locations: The program uses precomputed trajectory paths throughout the simulation. This information is received as input before the simulation has run.

Table XVII shows the tabular comparison of the Missile (Post-Boost) characteristics. Only the OASIS and SWADE models consider post-boost events. Even these two models use only the precomputed trajectory path characteristic.

De-Boost. This subcategory describes events which occur when the RV is retrofired and re-enters the atmosphere. Now, it should be noted that most missile systems today do not deal with the de-boost problem. The reason for this is that most RVs are not inserted into orbit (which generates a need for de-boost, so they can return to earth), but they are placed on their target ballistically. Thus, with a ballistic placement, no orbital velocity is reached, and no de-boost is needed. The FOBS system is an example of one type of RV that can be inserted into orbit. A listing and discussion of the four characteristics follows.

1. Monte Carlo the Re-Entry: The monte carlo technique is used to determine if the missile succeeded in slowing down for re-entry.

2. Monte Carlo the Timing Error: The monte carlo technique is used to determine if the missile retrofire came at the exact time. An error in this timing could cause the RV to miss the target and the CEP to enlarge.

3. Calculate Missed Distance: The program calculates the distance that the warhead missed the target. This is the difference between the desired ground zero (DGZ) and the actual ground zero (AGZ).

4. Change of Trajectory: The program considers the possibility that the trajectory can be changed by paraphernalia that the enemy has put into the air in the vicinity of the missile.

The tabular comparison of the four models with the Missiles (De-Boost) characteristics is found in Table XVIII. As shown in the table, QUICK is the only model which considers any of the characteristics, and it considers only the calculated missed distance.

Satellites. This category considers some of the possible types of satellites that might be used as offensive weapons. It is not a comprehensive list, but it is intended to help make a complete listing of offensive systems. A listing and discussion of the three characteristics follows.

1. Multiple Orbit Bombardment System (MOBS): The program considers MOBSs because they are able to change orbits and cause confusion.

2. Sensor: The program considers sensor type satellites.

3. Destructor: The program considers satellites which have the capability to destroy other satellites.

A tabular presentation of the Satellite characteristics is found in Table XIX. As shown in the table, the only characteristic considered by any of the four models is the Multiple Orbit Bombardment System, and only the OASIS model considers this.

Other Offensive Systems. This fourth and final category considers some other possible types of offensive systems. Admittedly, many more items could be listed, but the list was intended to include viable systems and not all possible future systems. A listing and discussion of the three characteristics follows.

1. Shipborne Anti-Ballistic Missile (SABMIS): The program considers the capability of ships to carry ABMs.

2. Submarine: The program considers submarines in a nuclear exchange.

3. Carrier: The program considers aircraft carriers in a nuclear exchange.

Table XX lists the Other Offensive Systems characteristics and compares them against the four models. As can be seen from the table, only the AEM model considers any of the characteristics and those considered are the submarine and the Shipborne Anti-Ballistic Missile.

Defensive Systems

This fifth area focuses on defensive systems currently in use. If new technology generates new types of defensive systems, they can easily be added into this area. The five categories addressed are: ABM Sites, SAM Sites, AAA Sites, Fighters, and Radars. Again, for each category, a listing and discussion of the characteristics is made followed by a discussion of which models possess these characteristics, while the table showing the characteristics is found at the end of the chapter.

ABM Sites. This first category contains eleven characteristics. It addresses subjects like potential location, communications links, and guidance. A listing and discussion of these characteristics follows.

1. Potential Locations: (a) Ground Based, (b) Sea Based, (c) Air Based: The simulation considers these three types of ABM sites.

2. Inventory: (a) Number of ABMs, (b) Number of Launchers: The program considers the number of ABMs available and in use and/or it considers the number of launchers.

3. Communications Links: (a) Self-Contained, (b) Not Self-Contained: The program considers the communications links used for acquisition and tracking as either contained within the ABM (a), or not (b).

4. Firing Delay: (a) Reload Delay, (b) Fire Delay: The program considers that the ABM can be delayed because of the capability to reload the launcher or because of the delay encountered when the site must complete its guidance sequence on one missile before another can be fired.

5. Guidance: (a) Radio, (b) Terminal, (c) Laser, (d) TV: The program considers the guidance of the ABM force under one of the above categories, or a combination of them.

6. Direction Center Assignments: The program considers the sequence where after the acquisition is made, the tracking information is turned over to a central targeting center (Direction Center) where the targeting assignments are made.

7. Single Missile-Type Site: The program considers that the site has only one type of ABM.

8. Multiple Missile-Type Site: The program considers that the site has multiple types of ABMs.

9. Locations Stored in Simulation: The locations of the ABM sites are specified in a coordinate system and are stored within the program. This information would allow the user to perform ranging calculations and to make damage assessments.

10. Area Defense: The program will consider any geographic region within which the ABM will defend.

11. Terminal Defense: The program considers the ABM to be designated to defend a specific target.

Table XXI is the tabular comparison of the four models against the ABM site characteristics. As shown in the table, only the QUICK and AEM models consider any of these characteristics. Also, besides the ground based locations, which both the AEM and QUICK models consider, the AEM model considers sea and air based locations.

SAM Sites. This second category investigates characteristics of Surface to Air Missile sites. Some of the issues involved are fixed versus movable location sites and single versus multiple types of missiles at a site. A listing and discussion of the 12 characteristics follows.

1. Locations Stored in Simulation: The locations of the SAM sites have been specified in a coordinate system and stored within the program.

2. Single Missile-Type Site: The program considers that the site has only one type of SAM.

3. Multiple Missile-Type Site: The program considers that the site has multiple types of SAMs.

4. Fixed Location Site: The program considers the SAM sites fixed and not movable.

5. Movable Location Site: The program considers that the SAM site is movable.

6. Firing Delay: (a) Reload Delay, (b) Fire Delay: Refer to Defensive Systems-ABM Sites, number 4.

7. Number of Missiles Capable of Being Controlled at One Time: The program considers that there is a limit to the number of missiles that can be controlled at one time.

8. Command and Control Links: The program considers that information about the position of the enemy is shared (communicated) between SAM sites.

9. Command Guidance: At launch, a ground control aims the SAM at its target.

10. Passive Guidance: The SAM is directed toward its target from an internal source.

11. Semi-Active Guidance: The SAM is initially pointed at its target, but receives no other information until it gets close to the target. It then receives active guidance from a ground radar.

12. Firing Doctrine: The program considers a precise set of rules to determine what type of SAM to use against a specific target.

The tabular comparison of the models with the SAM Site characteristics can be found in Table XXII. As shown in the table, only the AEM model considers the characteristics in detail. Both the QUICK and SWADE models consider SAM Sites, but only in the aggregated sense. The AEM model considers fixed locations and single as well as multiple missile-type sites.

AAA Sites. This third category addresses the Anti-Aircraft Artillery characteristics. Although some people may view this category as obsolete, in a strategic exchange model, it was included to assure completeness of the generic framework. The listing and discussion of the five characteristics follows.

1. Locations: The locations of the AAA sites have been specified in a coordinate system and are stored within the program.

2. Effective Altitude: The program considers the maximum altitude that the AAA can reach.

3. Tracking Time: (a) Radar Guidance on Gun, (b) Optical Guidance on Gun: The program considers the tracking time needed by the radar or optical guidance system to establish a predicted trajectory or flight path.

4. Preset Probability of Kill: The probability of kill for the AAA has been predetermined before the simulation is run.

5. Computed Probability of Kill: A probability of kill is computed for each AAA event.

Table XXIII is the tabular comparison of the four models against the AAA characteristics. As the table shows, none of the models considers AAA Sites.

Fighters. This fourth category addresses fighters which are used in the defensive role. Examples of this include fighters used to intercept incoming bombers or fighters that are orbited above an installation to protect it. The 11 characteristics are listed and discussed as follows.

1. Locations: The locations of the fighters have been specified.

2. Number of Aircraft: The program considers events on each aircraft, rather than aggregating their events.

3. Monte Carlo Launch Abort: The abort of each fighter being launched is determined by a monte carlo technique. The monte carlo technique establishes an abort probability, then a random draw is performed to see if that particular aircraft launched or was aborted.

4. Monte Carlo In Flight Abort: The abort of each fighter, while in flight, is determined by a monte carlo technique.

5. CAP Capability: Fighters are used to provide a cover for various systems. For example, fighters would provide a cap over a bomber during penetration, or fighters would form a cap over a missile site to protect it.

6. Firing Doctrine: A precise set of rules is used to establish the number and types of fighters sent up against an aggressor.

7. Fighter Engagement Capabilities: (a) Clear Air Mass, (b) All Weather, (c) Look Down Dopler: The fighter engagement capability is considered for clear air mass (no radar available), all weather (radar available), or look down dopler (radar available plus look down capability).

8. Data Link: The program simulates a system where the aircraft can be controlled directly by a ground station without pilot input.

9. Search and Track Airborne Radar: The program considers the airborne radar to have a search and track capability.

10. Radar Guided Missile: The aircraft is considered to have the capability of using air to air radar guided missiles.

11. Heat Seeking Missile: The aircraft is considered to have the capability of using air to air heat seeking missiles.

The tabular comparison of the four models with the Defensive Systems-Fighter characteristics is found in Table XXIV. As the table shows, only the QUICK and SWADE have any fighter characteristics. Additionally, both of these models only consider locations and only in an aggregated sense.

Radars. This fifth and final category considers those characteristics associated with radars. The two characteristics are listed and discussed as follows.

1. Scan Capability: (a) Mechanical Scan, (b) Electrical Scan (Phased Array): The program has the capability to scan mechanically or electrically (which is much faster than mechanical).

2. Acquisition and Track: (a) Identification, (b) Discrimination, (c) Continuous Track, (d) Interceptor Track, (e) Track Interrupt and Reacquire, (f) Triangulation: The program considers that the radar system has the aforementioned items. Discrimination means the ability to differentiate between decoys and real vehicles. Interceptor track means that the tracking information can be supplied to an interceptor. Triangulation means that multiple radars are used together for a positive track which allows less sophisticated radar to be used.

Table XXV shows the tabular comparison of the models against the Defensive Systems-Radars characteristics. As the table shows, only the SWADE model considers radars, and even then it aggregates the effect into its penetration probability.

Offensive/Defensive Interactions

This sixth and final area represents one of the two areas (the other is Offensive Systems) in which model builders appear to spend most of their time. As a result, the two categories in this area, Aircraft Penetration and Missile Penetration, have a large amount of detail. The Aircraft Penetration category contains five subcategories, while the Missile Penetration category contains three subcategories.

Aircraft Penetration. This category addresses the various systems that a penetrating aircraft might encounter, as well as addressing the impact of weapons. The five subcategories are titled as follows: General, SAM Engagements, AAA Engagements, Enemy GCI and AWACS Detect, and Weapon Impact. Each subcategory is examined as a separate entity.

General. This subcategory explores those characteristics which do not fall under any specific category. This includes such items as fighter engagements, command and control netting, and electronic countermeasures. A listing and discussion of the 24 characteristics follows.

1. Fighter Engagements: (a) Clear Air Mass, (b) All Weather, (c) Look Down Dopler: The program considers that the enemy fighters have radar (a), or all weather capability (b), or look down and search and track capability (c).

2. Data Link: The program simulates a system where the aircraft can be controlled directly by a ground station without pilot input.

3. CAP Activity: The program considers offensive protection in the battlefield area. For example, the fighters would orbit around bombers as they penetrate to help protect the bombers.

4. Fighter Loiter: The program considers that enemy fighters are orbiting to provide protection (CAP) for their bases.

5. Fighter Refueling/Turnaround: The program considers the capability of aircraft refueling and considers the time to get the aircraft back into action.

6. Fighter Single Pass: The program considers that the fighter can make only one pass at the same target.

7. Fighter Multiple Pass: The program considers that the fighter can make multiple passes at the same target.

8. ECM Self Defense: The program considers that a specific aircraft can rely only on its own ECM systems to help itself penetrate.

9. ECM Mutual Support: The program considers that any aircraft can help another penetrate by sharing their ECM system.

10. Radar Control: (a) Data Link, (b) Voice: The program considers the enemy's ability to prevent penetration. The enemy can pick up incoming aircraft on radar and direct intercept with voice (b), or it can direct intercept with a data link (a) (as described above in number 2).

11. Enemy ADDC Degredation: The program considers the enemy ADDC capability and the degree to which it operates.

12. Enemy AWACS Linkage: The program considers the enemy AWACS capability.

13. Enemy Command and Control Netting: The program considers the effects of the enemy command and control netting.

14. Hard Logic Doctrine (Offensive and Defensive): The intercept and penetration doctrines remain the same each time the program is run.

15. Hard Logic Doctrine Changed by Control Card: The intercept and penetration doctrines can be changed just prior to the game with control cards.

16. Variable Doctrine: The intercept and penetration doctrine can be changed interactively while the simulation is running or a change in doctrine can be preprogrammed to occur after a certain event.

17. Monte Carlo the Probability of Intercept: A determination of whether each aircraft is intercepted or not is made by using the monte carlo technique (as described in Offensive Systems-Aircraft (Launch), number 1).

18. Accumulate Attrition: Attrition is determined by drawing a random number for each aircraft to see if it penetrated. Then, a running total is kept of those that did and did not penetrate.

19. Enemy Aircraft Search and Track: The program simulates enemy aircraft which have search and track capability to prevent penetration.

20. Mobile Aircraft Defenses: The enemy's defensive forces can be moved. Thus, it would be harder to destroy this enemy defensive capability.

21. Optical Acquisition and Track: The program considers that optical acquisition and tracking may occur. In this case, the penetrating aircraft does not know that someone is tracking him.

22. Timing Control Line Events: (a) Hold For a Period of Time, (b) Monte Carlo Communications, (c) Determine Go Timing: The timing control line is the last controlled timing point before the aircraft drops its weapons. The aircraft can hold (a) at the line and wait for further instructions. The aircraft can then either receive or not receive the message (b). Finally, the aircraft can (after receiving communications) determine its proper timing into the target (c).

23. Electronic Countermeasures (ECM): (a) Mutual Defense (decoy) Missiles, (b) Monte Carlo Mothership Losses, (c) Monte Carlo Decoy Abort, (d) Accumulate to Determine Air Defense Direction Center (ADDC) Saturation: The program considers ECM devices. One aircraft can use another aircraft's decoys (a). The loss of th; aircraft (mothership) is determined by monte carlo techniques. The abort of the decoy (c) is determined by monte carlo techniques. Also, the program accumulates missiles and decoys to see if the ADDC radar (d) has been saturated.

24. Route Points: (a) Start Low, (b) Start High: The bombing runs of the aircraft are considered to either start low (a) or high (b).

A tabular representation of the Offensive/Defensive Interactions-Aircraft Penetration (general) characteristics and a comparison of the four models is found in Table XXVI. The table reveals that only the QUICK model considers enemy command and control netting, and only the AEM model considers penetration doctrines. Additionally, the QUICK and AEM models consider accumulated attrition. Finally, only the QUICK model considers ECM characteristics.

SAM Engagements. This second subcategory addresses engagements involving Surface to Air Missiles. Some of the characteristics address command and control netting as well as various types of delays. A listing and discussion of the 14 characteristics follows.

1. Accumulate Attrition: Attrition is determined by drawing a random number for each bomber to see if it penetrated the SAM defenses. Then, a running total is kept of those bombers that did and did not penetrate.

2. Monte Carlo Probability of Intercept by considering: (a) SAM Inventory, (b) Reload Delay, (c) Fire Delay, (d) SAM Abort, (e) Aborted SAM Replacement: A monte carlo technique is used (as described in Offensive Systems-Aircraft (Launch), number 1) to determine whether the SAM was successful in intercepting the incoming aircraft. It considers each of the five items.

3. Command and Control Netting: The SAM site has the ability to use radar information from other SAM sites to help it track incoming aircraft.

4. Individual Search and Track: The program considers that each SAM has the radar capability to search and track incoming targets.

5. Communications Delay: The program considers the delay of messages sent between SAM sites.

6. ECM Self Defense: The program considers that an incoming aircraft can mask itself from the SAM tracking radar.

7. ECM Mutual Support: The program considers that an incoming aircraft can help to mask out other incoming aircraft from the SAM tracking radar.

8. Mobile SAM Sites: The program considers movable SAM sites. For example, the game could be allowed to randomly place the SAM sites.

9. Enemy's Ability to Discriminate: The program considers that the enemy has the ability to discriminate between aircraft, decoys, and chaff.

10. Multiple Launch Capability of SAM Site: The program considers that SAM sites have the ability to launch a multiple number of SAMs at one time.

11. Saturation of Tracking Radar: The program considers that the SAM tracking radar can be saturated if too many aircraft, decoys, and chaff are in the air.

12. Hard Logic Doctrines of SAM Sites: The program considers that the SAM site has the same doctrine each time the program is run.

13. Control Card Doctrine of SAM Site: The launching doctrine of the SAM site can be changed from one run to the next by using control cards.

14. Variable Doctrine of SAM Site: The launching doctrine can be changed interactively while the simulation is running or it can be changed by some preprogrammed mechanism after a certain event occurs.

Table XXVII is the tabular comparison of the four models with these Aircraft Penetration (SAM Engagements) characteristics. As shown in the table, only the AEM model addresses the doctrine characteristics. Additionally, only the QUICK model considers the saturation of the tracking radar.

<u>AAA Engagements</u>. This third subcategory addresses the characteristics involved with Anti-Aircraft Artillery during penetration. A listing and discussion of the seven characteristics follows.

1. Monte Carlo Aircraft Kills by: (a) Effective Altitude of AAA, (b) Radar Control of AAA, (c) Manual Control of AAA: The program uses the monte carlo technique (as described in Offensive Systems-Aircraft (Launch), number 1) to determine aircraft kills by AAA.

2. Accumulate Attrition: Rather than considering all AAA events, a random number is drawn to determine if penetration was successful or unsuccessful.

3. ECM Self Defense: The program considers that an incoming aircraft can mask itself from the AAA.

4. ECM Mutual Support: The program considers that an incoming aircraft can help to mask out other incoming aircraft from the AAA.

5. Mobile AAA: The program considers movable AAA sites.

6. Comand and Control Netting: The AAA has the ability to use information (visual or radar) from other AAA sites to help it track incoming aircraft.

7. Communications Delay: The program considers delays in messages sent between AAA sites.

The tabular comparison of the models with the Aircraft Penetration (AAA Engagements) characteristics is shown in Table XXVIII. As the table reveals, none of the models consider any of the characteristics.

Enemy GCI and AWACS Detect. This fourth subcategory deals with characteristics which involve Ground Control System capabilities. The characteristics range from the type of doctrine used to communications netting. A listing and discussion of the 11 characteristics follows.

1. Track Determination: The program considers that the GCI or AWACS can track incoming aircraft.

2. Track Maintained for Intercept: The program considers that the GCI or AWACS can continue to track incoming aircraft long enough for intercept.

3. ECM Self Defense: The program considers that an incoming aircraft can mask itself from the enemy GCI or AWACS.

4. ECM Mutual Support: The program considers that an incoming aircraft can help to mask out other incoming aircraft from the enemy GCI or AWACS.

5. Communications Netting: The program considers the capability of the enemy GCI or AWACS to provide

tracking information to the SAM sites, AAA sites, and any others considered.

6. Fighter Assignment: The GCI and/or AWACS makes a determination of which aircraft should be intercepted first, which second, etc.

7. Early Warning: The simulation considers a perimeter radar which allows early warning of penetration and may result in event timing changes for missiles or launch of fighters/interceptors.

8. Attack Controlled Doctrine: The intercept doctrine is based on what type of penetrating attack is made.

9. Hard Logic Doctrine: The intercept doctrine remains the same each time the program is run.

10. Saturation of GCI Site: The GCI radar can be saturated when too many incoming vehicles are in the air at once.

11. Accumulated Attrition: Rather than looking at attrition from each event, the simulation picks a random number to decide if the aircraft penetrated all of the defenses (AAA, SAM, fighter interceptors, etc.) or not.

Table XXIX shows the tabular comparison of the models against the Aircraft Penetration (Enemy GCI and AWACS Detect) characteristics. As shown, none of the four models considers any of these type of characteristics.

Weapon Impact. This fifth and final subcategory deals with those issues involved in the impact of weapons. For example: are the Air Launched Cruise Missile tactics considered? Is the Shoot Look Shoot tactic used? A listing and discussion of the ten characteristics follows.

1. Monte Carlo Accumulated Attrition: The monte carlo technique (as described in Offensive Systems-Aircraft (Launch), number 1) is used to determine if the weapon impacted or not, by drawing a random number.

2. Dynamic Aircraft Attrition to Impact: A determination is made of whether the aircraft made it to the weapons release point and released weapons by dynamically considering events prior to this point. Events such as AAA engagements, ASM engagements, etc.

3. Dynamic Degradation of Defenses: The degradation of defensive sites by weapon impact is computed dynamically by considering previous events.

4. Dynamic Damage Assessment: Damage is computed dynamically by considering previous events such as the height of burst, the fire ball, and the thermal blast.

5. ALCM Tactics: The program considers tactics used by the ALCM.

6. SRAM Tactics: The program considers tactics used by the SRAM.

7. Shoot Look Shoot Tactic: This tactic involves deciding if a target needs another warhead placed on it after assessing the damage from the first warhead.

8. Weapon Vehicle Conflicts: (a) Blast, (b) Flash Blindness, (c) Fire Storm: The program considers any one or two, or all three of the weapon detonation effects on incoming vehicles.

9. Communications Degradation: (a) Launch to Attack Immediately, (b) Launch and Orbit Until Word to Attack: The program considers two levels of sophistication in weapons release. These are: launch and attack immediately when arriving over the target (a), and/or launch and wait (orbit) until the word is received to attack (b). Both (a) and (b) involve communication, and the program considers the effects of degradation of these communications.

10. Strike Reporting: Information on the number of hits is passed back to the command and control network of the offense so that they can more efficiently utilize their remaining capability.

Table XXX shows the tabular comparison of the four models with the Aircraft Penetration (Weapon Impact) characteristics. As the table shows, both the AEM and SWADE models accumulate attrition using a monte carlo technique. Also, only the QUICK model considers Dynamic Damage Assessment.

Missile Penetration. This second category investigates penetration issues associated with missiles. Since, by the time the missile is involved in penetration, its booster has been expended, the actual hardware considered is the reentry vehicles (RV). Thus, the three subcategories addressed are titled: RV Detection, RV Engagement, and RV Impact.

RV Detection. This first subcategory addresses issues which are involved in the detection of the RV. Some of the areas considered are detection, acquisition, and track time. A listing and discussion of the 23 characteristics follows.

1. Single Radar Detection: The program considers that the detection of RVs can occur with a single radar.

2. Multiple Radar Detection: The program considers that the detection of RVs can occur with more than one radar.

3. Monte Carlo the Acquisition: For all missiles, the monte carlo technique is used to determine if acquisition of the RV has occurred.

4. Acquisition as a Determined Event: The missiles that fly through the radar sweep area are subjected to a monte carlo technique to determine if acquisition has been made. The missiles which did not fly through the radar sweep area have avoided detection.

5. Compute the Acquisition: The missiles that fly through the radar sweep area are tracked for a prescribed length of time and are subjected to a monte carlo technique to determine if acquisition has been made. Those missiles which did not fly through the radar track area or were not tracked for a long enough period of time have avoided detection.

6. Preset Track Time: A predetermined track time is input into the program and all vehicles must be tracked for this length of time.

7. Variable Track Time: The track time of a vehicle can vary, depending on how many objects the radar is tracking at one time. The more objects being tracked simultaneously, the more track time is needed per object.

8. Track Considered After Proper Time: The vehicle is considered to have been tracked after it has been viewed for a predetermined amount of time.

9. Monte Carlo the Track: (a) Preset Track Probability, (b) Computed Track Probability: The monte carlo technique is again used to determine the success of the track. The probability of track can be preset (a) or it can vary with the number of vehicles on the radar scope (b).

10. Delayed Communications to Missile Site: The program considers that communications from the missile site (i.e., ABM), that first saw the incoming missile, to other missile sites are delayed.

11. Single Doctrine Application: The program considers a doctrine where only one missile is sent up to knock out each incoming missile.

12. Multiple Doctrine Application: The program considers a doctrine where more than one missile is sent up to knock out each incoming missile.

13. Variable Doctrine: The program considers a flexible doctrine where one or more than one missile can be sent up to knock out an incoming missile, based on some preprogrammed logic. For example, if the site had plenty of missiles available, it will send up three missiles against the incoming missile, but if the site had very few missiles left in inventory, it will send up only one missile.

14. Optimizing Doctrine: The program uses an optimization routine to allocate the number of missiles sent up to knock out an incoming missile.

15. Doctrine Called by Control Card: The doctrine is controlled by control cards in the sense that it can be changed just prior to the simulation run with a control card.

16. Monte Carlo Command and Control: The success of the command and control network in relaying information is determined by a random number draw using the monte carlo technique.

17. Command and Control Netting: (a) Designed in Logic, (b) Control Card Keyed: The enemy has the capability to track incoming vehicles by using several radars at a time (an example would be a triangulation technique). The doctrine it uses can be predetermined and designed into the logic (a), or changed for each run of the simulation with control cards (b).

18. Single ABM Assignment: A single ABM is assigned against an incoming vehicle. If the ABM is destroyed, the incoming vehicle will not be opposed.

19. ABM Reassignment: A single ABM is assigned against an incoming vehicle. If the ABM is destroyed, another ABM is assigned to destroy the incoming missile.

20. Saturation of Detection Radar: The detection radar can be saturated and rendered ineffective if too many vehicles are in the area.

21. Radar Retrack for Definition: The radar will track the incoming vehicle over multiple intervals of time to define its position and impact area more accurately.

22. Single ABM Type Assignment: The program allows only one type of ABM to be used on specific incoming vehicles (targets).

23. Multiple ABM Type Assignment: The program allows several types of ABMs to be used on incoming vehicles (targets).

A tabular comparison of the four models against the Missile Penetration (RV Detection) characteristics is found in Table XXXI. As is readily apparent, only the AEM model considers RV Detection. The AEM model considers single and multiple doctrines as well as Single ABM Assignment and ABM Reassignment.

<u>RV Engagement</u>. This second subcategory addresses

issues involved when the defense tries to knock out the incoming RVs. Some of these issues involved are ABM fire out queuing as well as intercept in the dynamic sense. A listing and discussion of the 15 characteristics follows.

1. Monte Carlo Intercept: The success of intercept of each incoming RV is determined by selecting a random number and using the monte carlo technique (as described in Offensive Systems-Aircraft (Launch), number 1).

2. Preset Probability of Intercept: The number of incoming RVs that are intercepted is predetermined before the running of the simulation.

3. Dynamic Intercept: (a) ABM Radar Tracks ABM Only, (b) ABM Radar - Search, Track, Guide, (c) Exoatmospheric Engagements, (d) Endoatmospheric Engagements, (e) Compute ABM Fireout, (f) Compute Miss Distance: The intercept of an RV is determined dynamically by looking at each event in the process. The ABM radar may be able to track the ABM only (a), or it may be able to search, and track the target and guide the ABM into the target (b). The simulation can consider encounters above 300,000 feet (c) or below 300,000 feet (d). Also, the program can calculate the burn time of the ABM (e) and compute the missed distance (f).

4. Compute Kill Probability: The probability of kill of the RVs has been predetermined and this is used to find the number of RVs destroyed.

5. Shoot Look Shoot Tactic: When an ABM is fired out to destroy an incoming RV, the site looks to see if the ABM was successful or not. If not, then another ABM is launched.

6. ABM Fire Out Queuing: The program considers the queuing problem when multiple ABM sites are firing missiles.

7. ABM Reload: The program considers the reload capability of the ABM sites.

8. Multiple Hit Accidental: The program considers the accidental destruction of other incoming vehicles due to the blast from one weapon.

9. Multiple Hit Computed: The program calculates the destruction of other incoming vehicles due to the blast from one weapon.

10. Multiple Hit Optimized: The program optimizes the most destruction that an outgoing ABM can inflict on incoming vehicles.

11. Monte Carlo ABM Abort: A random number is drawn on each ABM launch attempt and the monte carlo technique is used to determine whether the launch was successful or unsuccessful.

12. Aborted ABM Substitution: The program considers the effects of substituting another ABM for the one which was aborted.

13. Aborted ABM No Substitution: The program does not consider the effects of substituting an ABM for one that has just aborted.

14. Single ABM Launch: The ABM launch radar can handle the launch of only one ABM at a time.

15. Multiple ABM Launch: The ABM launch radar can handle the firing of more than one ABM at a time.

A tabular comparison of the four models against the Missile Penetration (RV Engagement) characteristics is shown in Table XXXII. The table shows that the AEM model addresses the most characteristics in this subcategory. It considers dynamic intercept, as well as the Shoot Look Shoot tactic and single and multiple ABM launch characteristics. Also, the QUICK model addresses intercept with a monte carlo technique while the SWADE model uses a preset probability.

<u>RV Impact</u>. This third and final subcategory addresses issues involved with the impact of the nuclear weapon itself. A listing and discussion of the seven characteristics follows.

1. Monte Carlo Dud Weapon: A random number is selected and the monte carlo technique is used to determine if the weapon on the RV was a dud or not.

2. Actual Ground Zero (AGZ Determination): (a) Dynamic Attrition of Defenses, (b) Dynamic Attrition of Launch Bases, (c) Dynamic Damage Assessment, (d) Communications Damage: The actual point of impact of the weapon is computed dynamically and it takes into consideration the attrition of the defenses (a), the attrition of the launch bases (b), the damage to operating and nonoperating launch bases (c), and the damage to the communications capability (d).

3. Calculate Dust Problem: To determine if dust has affected the RV, a calculation is performed on the size of the dust particles and the number of each of the sizes. If some specified limit is reached, then the missile is affected.

4. Monte Carlo Dust Problem: A random number is selected and the monte carlo technique is used to determine if the dust problem affected the RV.

5. Calculate Fratricide: The program calculates the effects of one missile detonating and destroying other missiles that are near the point of detonation.

6. Strike Reporting: Information on the number of hits is passed back to the command and control network so that they can more efficiently use their remaining capability.

7. RV Effects from Ablation and Errosion: The program considers the effects of ablation and/or erosion on the RV.

The tabular comparison of the four models with the Missile Penetration (RV Impact) characteristics is shown in Table XXXIII. The table reveals that only the QUICK and OASIS models deal with these characteristics. The SWADE model can consider the monte carlo of dud weapons, but this capability is rarely used.

As this chapter has shown, there are many characteristics which make up a particular strategic simulation model. In fact, there are so many that it is extremely difficult to remember all of them. Thus, the tables which follow were designed not only to compare the four strategic simulation models, but also to aid the individual in his ability to remember the characteristics.

Table I

General Features - Simulation Design Type

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Event Sequence Simulation	X	-	-	X
2. Fixed Time Increment Simulation	-	X	X	-
3. Dynamic Event Store	-	-	-	-
4. Event Sequence and Dynamic Event Store	-	-	-	-
5. Dual Event Store Simulation	-	-	-	-
6. Regenerative Simulation	-	-	-	-
7. One-Sided Exchange	X	X	X	X
8. Two-Sided Exchange	X	-	X	-
9. More Than Two-Sided Exchange	-	-	-	-
10. Time in Minutes	X	-	-	-
11. Time in Seconds	X	-	-	X

Table II

General Features - Simulation Method

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Probabilistic Attrition (Aircraft)	X	-	X	X
2. Probabilistic Attrition (Missiles)	X	-	-	X
3. Dynamic Attrition (Aircraft)	-	-	-	-
4. Dynamic Attrition (Missiles)	-	X[a]	X	-
5. Dynamic Degradation (Offensive)	X	X	-	-
6. Dynamic Degradation (Defensive)	X[b]	X	-	-
7. Dynamic Damage Assessment	X	X[c]	-	-
8. One Step Inspection Model	-	-	-	-
9. Multiprogram Single Operation Model	-	-	-	-
10. Complete Single Operation Model	-	-	-	-
11. Multiplay Operation Model	-	-	-	-
12. Multicase Operation Model	X	-	-	-
13. Multiplan Operation Model	X	-	-	-
14. Statistical Weighing of the Results	-	-	-	-

a) This is attrition due to an incoming attack (Ref 8).
b) This applied to ABM zone defense sites and fighter/interceptor launch bases only (Ref 14).
c) OASIS considers damage only to incoming RVs, outgoing ICBMs, and silos (Ref 8).

Table III

General Features - Simulation Content

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Aircraft Events	X	-	X	X
2. Missile Events	X	X	X	X
3. Satellite Events	-	X	-	-
4. Mobile Targets	-	-	X	-
5. Port Ties	-	-	-	X[a]
6. Vehicle Hardness	-	X	-	X
7. POL Storage	-	-	-	X[b]
8. Damage Levels	-	-	X	X[c]
9. Industrial Growth Industrial Worth (IGIW)	X	-	X	X
10. Population Considerations	X	-	X	X
11. Launch and/or Recovery Bases	X	X	-	-
12. Alive/Dead Status	X	X	-	-
13. Number of Alert and Nonalert Vehicles	X	-	-	-
14. Launch Tactics:				
a) Dynamic	-	-	-	-
b) SIOP/RISOP Only	-	-	-	-
15. Command and Control Timing	-	-	-	-
16. Command and Control Probabilities	X[d]	-	-	-
17. Communication Damage Assessment	-	-	-	-
18. Simulation From Real Time Situation	-	-	-	-
19. Recovery Base Saturation	X	-	-	-

Table III (Continued)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
20. Coordinate Systems				
a) Earth Centered Inertial (ECI)	-	X	-	-
b) Earth Centered Rotational (ECR)	-	X	-	-
c) Longitude, Latitude, Altitude	X	X	-	-
d) Flat Earth	-	X	-	-
e) Range, Altitude, Azimuth from a Point	-	X	-	-

a) SWADE considers port locations prior to the simulation (Ref 6).

b) These areas are considered as targets, but the effects of them on the game are not considered (Ref 6).

c) SWADE considers various levels of damage on each clustered group (Ref 6).

d) Command and control probabilities are considered in area attrition zones (Ref 13:16).

Table IV

General Features - Simulation Flexibility

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Control Card Changes Prior to Simulation	X	-	X	X
2. Control Card Changes During Simulation	-	-	-	-
3. Last Minute Add or Delete	X	-	X	-
4. Print of All Preset Variables:				
a) Presimulation	-	-	-	X
b) Postsimulation	-	-	-	X
5. Man Intervention Simulation	-	-	-	-
6. Man Observation Simulation	-	X	-	-
7. Tactic Decision Simulation (Offensive and Defensive)	-	-	-	-
8. Add or Delete Before Simulation:				
a) Vehicles	-	X[a]	X	X
b) Units	-	X[a]	X	X
c) Events	-	X[a]	X	X
9. Add or Delete Interactively During the Simulation:				
a) Vehicles	-	-	-	-
b) Units	-	-	-	-
c) Events	-	-	-	-
10. Delay or Speed up Time For:				
a) An Event	-	X[a]	-	-
b) All Events	X	X[a]	-	-
c) Units	-	X[a]	-	-
11. Pseudoimpacts	-	X	-	-

a) This is true provided the change is preprocessed (Ref 8).

Table V

General Features - Output Information

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Fractional Play Summaries	-	-	-	-
2. Situation Initiated Summaries	-	-	-	-
3. Immediate Summaries	-	X	-	-
4. Detailed Summaries Following the Simulation	X	X	X	X[a]
5. Summary Information Obtainable On:				
a) Hard Copy	X	X	X	X
b) CRT	X	-	-	-
c) Magnetic Tape	X	X	X	X
d) DISC	X	X	X	X

a) SWADE does not deal in detail, it aggregates (Ref 6).

Table VI

Targeting Methods and Weapon Effects - Target Values

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Value is Precomputed	X	-	-	X
2. Value is Computed During Game	-	-	X	-
3. Not Valued	-	X	-	-

Table VII

Targeting Methods and Weapon Effects - Weapon Allocation

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Allocation Designated Prior to Game	-	X	-	-
2. Allocation Computed Prior to Game	-	-	-	-
3. Allocation is the First Step of Game	X	-	X	X
4. Allocation with Cross Targeting	X	-	X	X
5. Allocation - Mission Purity	X	-	-	X
6. Allocation - Target Island	X	-	X	-
7. Allocation - Time Dependent Targets	-	-	-	-

Table VIII

Targeting Methods and Weapon Effects - Fallout Considerations

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Fallout Levels	(a)	-	X	-
2. Fallout Analysis with Static Winds	-	X[b]	X	-
3. Fallout Analysis with Dynamic Winds	-	X[b]	-	-
4. Shielding Factors	-	-	-	-
5. Casualties	-	-	X	X[c]
6. Unlimited Monitoring Points for Fallout	-	-	-	-
7. Limited Monitoring Points for Fallout	-	-	-	-

a) QUICK does not consider fallout (Ref 14).
b) The winds are considered only with respect to the vehicles (Ref 8).
c) SWADE can provide this information, but it is rarely solicited (Ref 6).

Table IX

Targeting Methods and Weapon Effects - Damage Analysis

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Blast Effects	X[a]	X	X	X
2. Heat Effects (Thermal Radiation)	-	X	-	-
3. Radiation Effects (Nuclear Radiation)	-	X	X	X[b]
4. Blackout Effects	-	-	-	-
5. Electromagnetic Pulse (EMP)	-	X	-	-
6. Dust	-	X	-	-
7. Compound Damage	-	X	-	-
8. Transient Radiation Effects on Electronics (TREE)	-	X	-	-
9. Fission Product Cloud Dose	-	X	-	-
10. Cratering and Overburden	-	X	-	-
11. Nuclear Winds	-	X	-	-

a) Radiation effects are only considered for fatality count and is available only on request (Ref 14).
b) The blast effect is used for computing kill probability only (Ref 6).

Table X

Error and Security Checks

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. A Data Record Check Subroutine to Half the Process	-	-	-	-
2. An Error Check to Insure All Data Which Needs Multiple File Cross-Reference is Correct	-	-	-	-
3. Each Program That Uses Data, Error Checks the Data	-	-	-	-
4. Simulation Halts When Errors Exceed a Limit or Number of Errors Change Between Successive Plays	-	-	-	-
5. Error Recovery Attempts by Simulation	-	X	-	-
6. Error Records Allowed With Ample Messages to User	-	-	-	-
7. Use of Minimax Values for Testing Errors in Data	-	-	-	-
8. Use of CRT for Checking Input Control Cards and Correcting Errors in Data	-	-	-	-
9. Two Step Error Correction Process	-	-	-	X[a]
10. Boundary Controls on All Probability Calculations	-	-	-	X[b]

a) This is performed when time and manpower permits (Ref 6).

b) SWADE checks to see if the probability is less than zero or greater than one (Ref 6).

Table XI

Offensive Systems - Aircraft (Vehicles)

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Bomber With Gravity Weapons	X	(a)	X	X
2. Bomber With Missile Weapons	X	-	X	X
3. Bomber With Gravity and Missile Weapons	X	-	X	X
4. Missiles Considered:				
a) Air Launched Cruise Missile (ALCM)	-	-	-	X
b) Short Range Attack Missile (SRAM)	-	-	-	X
c) Air to Surface Missile (ASM)	X	-	X	-
d) Decoys	X	-	X	-
5. Airborne Warning and Control System (AWACS)	-	-	-	-
6. Tankers	X	-	-	-
7. Post Attack Command and Control System (PACCS)	-	-	-	-
8. Minuteman Alternate Launch Control (ALC) Aircraft	-	-	-	-
9. Airborne Anti-Ballistic Missile (AABMIS)	-	-	-	-

a) The OASIS model does not consider aircraft events (Ref 8).

Table XII

Offensive Systems - Aircraft (Launch)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Monte Carlo Prelaunch Survivability	-	(a)	-	(a)
2. Dynamic Destruction of Prelaunch Survivability	X	-	-	-
3. Monte Carlo Launch Abort	X	-	-	-
4. Monte Carlo Command and Control Survivability	-	-	-	-
5. Dynamic Destruction of Command and Control Capability	-	-	-	-
6. Launch on Schedule	X	-	-	-
7. Launch on Schedule Modified by Input Distribution of the Launch Deviations	-	-	-	-
8. Launch Adjusted to Situation	-	-	-	-
9. Satellite Basing of Bombers	-	-	-	-
10. Airborne Alert-Bombers	-	-	-	-
11. Airborne Sortie Replacement	-	-	-	-
12. Abort Sortie Regeneration	X	-	-	-
13. Monte Carlo Tanker Launch	X	-	-	-
14. Tanker Abort Replacement	-	-	-	-
15. Tanker Abort Regeneration	X	-	-	-
16. Aircraft Damage Assessed After Enemy Impact	-	-	-	-
17. Launch and Loiter of Non-alert Sorties	-	-	-	-
18. In Flight Abort Played Immediately After Launch	X[b]	-	-	-

Table XII (Continued)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
19. In Flight Abort Played Prior to Weapons Release	X[b]	-	X	-
20. PACCS Events	-	-	-	-
21. AWACS Events	-	-	-	-
22. Fighter Deployment for Incoming Bombers	-	-	-	-
23. Fighter Launch for Loiter	-	-	-	-

a) The OASIS and SWADE models do not consider any Aircraft (Launch) events (Ref 8; Ref 6).
b) The time that the abort is played is random (Ref 13:14).

Table XIII

Offensive Systems - Aircraft (Air Refueling)[a]

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Monte Carlo the Success of Refueling	-	-	-	-
2. Spare Tanker Refueling	-	-	-	-
3. Change Mates Within the Refueling Area	-	-	-	-
4. Change Mates Outside the Refueling Area	-	-	-	-

a) None of these four models considers Aircraft (Air Refueling) events.

Table XIV

Offensive Systems - Aircraft (Recovery)[a]

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Monte Carlo Accumulated Attrition	-	-	-	-
2. Dynamic Attrition				
a) Blast	-	-	-	-
b) Flash Blindness	-	-	-	-
c) Fire Storm	-	-	-	-
d) AAA	-	-	-	-
e) SAM	-	-	-	-

a) None of these four models considers Aircraft (Recovery) events.

Table XV

Offensive Systems - Missiles (Vehicles)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Single RV	X	X	X	X
2. MRV	X	X	-	X
3. MIRV	X	X	-	X
4. FOBS	-	X	-	-

Table XVI

Offensive Systems - Missiles (Launch)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Monte Carlo the Launch	-	-	(a)	(b)
2. Monte Carlo the Events:				
a) Missile in Commission	X	-	-	-
b) Launch Survivability	-	-	-	-
c) Launch Abort	-	-	-	-
d) Failure in Power Flight	X	-	-	-
e) Separation	-	-	-	-
3. Dynamic Destruction of Launch Site	X	X	-	-
4. Enemy Detection of Our Missiles				
a) Use SIOP Trajectory Specifications	-	-	-	-
b) Use Depressed or Lofted Trajectories	-	-	-	-
c) Use Boost Glide Trajectories	-	-	-	-
d) Use Standard Trajectory Templates/Profiles	-	X[c]	-	-
e) Use Generalized Keplarian Trajectory Calculations	-	X[c]	-	-
5. Use Pen-Aid Trajectories (decoys)	-	-	-	-
6. Use Rotated Spherical Earth	-	X	-	-
7. Use Nonrotated Spherical Earth	-	X	-	-
8. Command and Control Link Check	-	-	-	-
9. Monte Carlo Command and Control	-	-	-	-
10. Launch Tactics:				
a) Launch on Scheduled Simulation Time	X	-	-	-
b) Launch on Free Time	-	-	-	-

Table XVI (Continued)

Characteristic	Model QUICK	OASIS	AEM	SWADE
c) Launch on SIOP/RISOP Timing	-	-	-	-
d) Not Considered	-	X	X	-
11. Target Reprogramming Prior to Launch	X	-	-	-

a) The AEM model does not consider any Missiles (Launch) events (Ref 5).
b) SWADE uses an aggregated probability for its success of launch (Ref 6).
c) If one of the ten templates will not work, then a Keplarian trajectory is calculated (Ref 8:40-47).

Table XVII

Offensive Systems - Missiles (Post-Boost)

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Monte Carlo Deployment of Warheads	(a)	-	(a)	-
2. Monte Carlo Missile Velocity Vector	-	-	-	-
3. Monte Carlo Orbit Velocity	-	-	-	-
4. Compute Object Locations	-	-	-	-
5. Use Precomputed Object Locations	-	X	-	X
a) The QUICK and AEM models do not consider Missiles (Post-Boost) events (Ref 13; Ref 5).				

Table XVIII

Offensive Systems - Missiles (De-Boost)

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Monte Carlo the Re-Entry	-	(a)	(a)	(a)
2. Monte Carlo the Timing Error	-	-	-	-
3. Calculate Missed Distance (DGZ)	X	-	-	-
4. Change of Trajectory	-	-	-	-
a) The OASIS, AEM, and SWADE models do not consider Missiles (De-Boost) events (Ref 8; Ref 5; Ref 6).				

Table XIX

Offensive Systems - Satellites

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Multiple Orbit Bombardment System (MOBS)	(a)	X	(a)	(a)
2. Sensor	-	-	-	-
3. Destructor	-	-	-	-

a) The QUICK, AEM, and SWADE models do not consider satellite events (Ref 13; Ref 5; Ref 6).

Table XX

Offensive Systems - Other Offensive Systems

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Shipborne Anti-Ballistic Missile (SABMIS)	(a)	(a)	X	(a)
2. Submarine	-	-	X	-
3. Carrier	-	-	-	-

a) The QUICK, OASIS, and SWADE models do not consider these offensive systems (Ref 13; Ref 8; Ref 6).

Table XXI

Defensive Systems - ABM Sites

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Potential Locations				
a) Ground Based	X[a]	(b)	X	(b)
b) Sea Based	-	-	X	-
c) Air Based	-	-	X	-
2. Inventory				
a) Number of ABMs	X	-	X	-
b) Number of Launchers	-	-	-	-
3. Communications Links				
a) Self Contained	-	-	-	-
b) Not Self Contained	-	-	-	-
4. Firing Delay				
a) Reload Delay	-	-	-	-
b) Fire Delay	-	-	-	-
5. Guidance				
a) Radio	-	-	-	-
b) Terminal	-	-	-	-
c) Laser	-	-	-	-
d) TV	-	-	-	-
6. Direction Center Assignments	-	-	-	-
7. Single Missile-Type Site	-	-	-	-
8. Multiple Missile-Type Site	-	-	-	-
9. Locations Stored in Simulation	-	-	X[c]	-
10. Area Defense	X	-	X	-
11. Terminal Defense	X	-	X	-

a) The locations are defined in terms of zones. The total number of zones used by both sides together cannot exceed 20 (Ref 13:26).

b) The OASIS and SWADE models do not consider ABM sites (Ref 8; Ref 6).

c) The location is a random association. It is not tied to latitude or longitude (Ref 5).

Table XXII

Defensive Systems - SAM Sites

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Locations Stored in Simulation	X[a]	(b)	X[c]	(d)
2. Single Missle-Type Site	-	-	X	-
3. Multiple Missile-Type Site	-	-	X	-
4. Fixed Location Site	-	-	X	-
5. Movable Location Site	-	-	-	-
6. Firing Dealy				
a) Reload Delay	-	-	-	-
b) Fire Delay	-	-	-	-
7. Number of Missiles Capable of Being Controlled at One Time	-	-	-	-
8. Command and Control Links	-	-	-	-
9. Command Guidance	-	-	-	-
10. Passive Guidance	-	-	-	-
11. Semi-Active Guidance	-	-	-	-
12. Firing Doctrine	-	-	X	-

a) The SAM sites are aggregated so that QUICK considers only the number of SAM sites within a certain zone (Ref 13:21).
b) The OASIS model does not consider SAM sites (Ref 8).
c) The location is a random association. It is not tied to latitude or longitude (Ref 5).
d) SWADE combines the effects of SAM sites, fighters, and radars into its penetration probability (Ref 6).

Table XXIII

Defensive Systems - AAA Sites[a]

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Locations	-	-	-	-
2. Effective Altitude	-	-	-	-
3. Tracking Time				
a) Radar Guidance on Gun	-	-	-	-
b) Optical Guidance on Gun	-	-	-	-
4. Preset Probability of Kill	-	-	-	-
5. Computed Probability of Kill	-	-	-	-

a) None of the four models in this study considered AAA Sites.

Table XXIV

Defensive Systems - Fighters

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Locations	X[a]	(b)	(b)	(c)
2. Number of Aircraft	-	-	-	-
3. Monte Carlo Launch Abort	-	-	-	-
4. Monte Carlo In Flight Abort	-	-	-	-
5. CAP Capabilities	-	-	-	-
6. Firing Doctrine	-	-	-	-
7. Fighter Engagement Capabilities				
a) Clear Air Mass	-	-	-	-
b) All Weather	-	-	-	-
c) Look Down Dopler	-	-	-	-
8. Data Link	-	-	-	-
9. Search and Track Airborne Radar	-	-	-	-
10. Radar Guided Missiles	-	-	-	-
11. Heat Seeking Missiles	-	-	-	-

a) Base Locations are aggregared into zones (Ref 13).
b) The OASIS and AEM models do not consider Fighter events (Ref 8; Ref 5).
c) SWADE combines the effects of SAM sites, fighters, and radars into its penetration probability (Ref 6).

Table XXV

Defensive Systems - Radars

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Scan Capability	(a)	(a)	(a)	(b)
a) Mechanical Scan	-	-	-	-
b) Electrical Scan (Phased Array)	-	-	-	-
2. Acquisition and Track				
a) Identification	-	-	-	-
b) Discrimination	-	-	-	-
c) Continuous	-	-	-	-
d) Interceptor Track	-	-	-	-
e) Track Interrupt and Reacquire	-	-	-	-
f) Triangulation	-	-	-	-

a) The QUICK, OASIS, and AEM models do not consider Radar events (Ref 13; Ref 8; Ref 5).
b) SWADE combines the effects of SAM sites, fighters, and radars into its penetration probability (Ref 6).

Table XXVI

Offensive/Defensive Interactions -
Aircraft Penetration (General)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Fighter Engagements	(a)	(b)	(c)	(d)
a) Clear Air Mass	-	-	-	-
b) All Weather	-	-	-	-
c) Look Down Dopler	-	-	-	-
2. Data Link	-	-	-	-
3. CAP Activity	-	-	-	-
4. Fighter Loiter	-	-	-	-
5. Fighter Refueling/Turnaround	-	-	-	-
6. Fighter Single Pass	-	-	-	-
7. Fighter Multiple Pass	-	-	-	-
8. ECM Self Defense	-	-	-	-
9. ECM Mutual Support	-	-	-	-
10. Enemy Radar Control				
a) Data Link	-	-	-	-
b) Voice	-	-	-	-
11. Enemy ASSC Degredation	-	-	-	-
12. Enemy AWACS Linkage	-	-	-	-
13. Enemy Command and Control Netting	X	-	-	-
14. Hard Logic Doctrine (Offensive and Defensive)	-	-	-	-
15. Hard Logic Doctrine Changed by Control Card	-	-	X	-
16. Variable Doctrine	-	-	-	-
17. Monte Carlo the Probability of Intercept	-	-	-	-
18. Accumulate Attrition	X	-	X	-

Table XXVI (Continued)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
19. Enemy Aircraft Search and Track	-	-	-	-
20. Mobile Aircraft Defenses	-	-	-	-
21. Optical Acquisition and Track	-	-	-	-
22. Timing Control Line Events:				
a) Hold for a Period of Time	-	-	-	-
b) Monte Carlo Communications	-	-	-	-
c) Determine Go Timing	-	-	-	-
23. Electronic Countermeasures (ECM):				
a) Mutual Defense (Decoy) Missiles	X	-	-	-
b) Monte Carlo Mothership Losses	-	-	-	-
c) Monte Carlo Decoy Abort	-	-	-	-
d) Accumulate to Determine Air Defense Direction Center (ADDC) Saturation	-	-	-	-
24. Route Points:				
a) Start Low	-	-	-	-
b) Start High	-	-	-	-

a) An attrition probability is calculated for each leg of the mission. This probability is then compared with a random number to determine if the aircraft is killed. If it is killed, then further events are not planned for the aircraft (Ref 14).

b) The OASIS model does not consider Aircraft Penetration events (Ref 8).

c) Once penetration probability is calculated, it is treated as a modification to weapon system reliability (Ref 5).

d) The penetration probability is aggregated into the probability of arrival (Ref 6).

Table XXVII

Offensive/Defensive Interactions -

Aircraft Penetration (SAM Engagements)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Accumulate Attrition	-	(a)	X[b]	X[c]
2. Monte Carlo Probability of Intercept by Considering:				
a) SAM Inventory	-	-	-	-
b) Reload Delay	-	-	-	-
c) Fire Delay	-	-	-	-
d) SAM Abort	-	-	-	-
e) Aborted SAM Replacement	-	-	-	-
3. Command and Control Netting	-	-	-	-
4. Individual Search and Track	-	-	-	-
5. Communications Delay	-	-	-	-
6. ECM Self Defense	-	-	-	-
7. ECM Mutual Support	-	-	-	-
8. Mobile SAM Sites	-	-	-	-
9. Enemy's Ability to Discriminate	-	-	-	-
10. Multiple Launch Capability of SAM Site	-	-	-	-
11. Saturation of Tracking Radar	X[d]	-	-	-
12. Hard Logic Doctrine of SAM Site	-	-	X	-
13. Control Card Doctrine of SAM Site	-	-	X	-
14. Variable Doctrine of SAM Site	-	-	-	-

a) The OASIS model does not consider Aircraft Penetration events (Ref 8).

b) Once the Penetration probability is calculated, it is treated as a modification to weapon system reliability (Ref 5).

Table XXVII (Continued)

c)	The penetration probability is aggregated into the probability of arrival (Ref 6).
d)	Saturation is determined by considering the number of decoys the bomber uses (Ref 14).

Table XXVIII
Offensive/Defensive Interactions -
Aircraft Penetration (AAA Engagements)[a]

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Monte Carlo Aircraft Kills By:				
a) Effective Altitude of AAA	-	-	-	-
b) Radar Control of AAA	-	-	-	-
c) Manual Control of AAA	-	-	-	-
2. Accumulate Attrition	-	-	-	-
3. ECM Self Defense	-	-	-	-
4. ECM Mutual Support	-	-	-	-
5. Mobile AAA	-	-	-	-
6. Command and Control Netting	-	-	-	-
7. Communications Delay	-	-	-	-

a) None of the four models considers Aircraft Penetration (AAA Engagements) events.

Table XXIX

Offensive/Defensive Interactions -

Aircraft Penetration (Enemy GCI and AWACS Detect)[a]

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Track Determination	-	-	-	-
2. Track Maintained for Intercept	-	-	-	-
3. ECM Self Defense	-	-	-	-
4. ECM Mutual Support	-	-	-	-
5. Communications Netting	-	-	-	-
6. Fighter Assignment	-	-	-	-
7. Early Warning	-	-	-	-
8. Attack Controlled Doctrine	-	-	-	-
9. Hard Logic Doctrine	-	-	-	-
10. Saturation of GCI Site	-	-	-	-
11. Accumulated Attrition	-	-	-	-

a) None of the models considers Aircraft Penetration (Enemy GCI and AWACS Detect) events.

Table XXX

Offensive/Defensive Interactions -

Aircraft Penetration (Weapon Impact)

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Monte Carlo Accumulated Attrition	-	(a)	X	X[b]
2. Dynamic Aircraft Attrition to Impact	-	-	-	-
3. Dynamic Degradation of Defenses	X	-	-	-
4. Dynamic Damage Assessment	X	-	-	-
5. ALCM Tactics	-	-	-	-
6. SRAM Tactics	-	-	-	-
7. Shoot Look Shoot Tactic	-	-	-	-
8. Weapon Vehicle Conflicts:				
a) Blast	-	-	-	-
b) Flash Blindness	-	-	-	-
c) Fire Storm	-	-	-	-
9. Communications Degradation				
a) Launch to Attack Immediately	-	-	-	-
b) Launch and Orbit Until Word to Attack	-	-	-	-
10. Strike Reporting	-	-	-	-

a) The OASIS model does not consider Aircraft Penetration events (Ref 8).

b) SWADE normally uses damage expectancy, but it does have the capability to use a monte carlo technique (Ref 6).

Table XXXI

Offensive/Defensive Interactions - Missile Penetration (RV Detection)

Characteristic	Model QUICK	OASIS	AEM	SWADE
1. Single Radar Detection	(a)	(a)	-	(a)
2. Multiple Radar Detection	-	-	-	-
3. Monte Carlo the Acquisition	-	-	-	-
4. Acquisition as a Determined Event	-	-	X	-
5. Compute the Acquisition	-	-	-	-
6. Preset Track Time	-	-	-	-
7. Variable Track Time	-	-	-	-
8. Track Considered After Proper Time	-	-	-	-
9. Monte Carlo the Track				
a) Preset Track Probability	-	-	-	-
b) Computed Track Probability	-	-	-	-
10. Delayed Communications to Missile Site	-	-	-	-
11. Single Doctrine Application	-	-	X	-
12. Multiple Doctrine Application	-	-	X	-
13. Variable Doctrines	-	-	-	-
14. Optimizing Doctrines	-	-	-	-
15. Doctrines Called by Control Cards	-	-	X	-
16. Monte Carlo Command and Control	-	-	-	-
17. Command and Control Netting				
a) Designed in Logic	-	-	-	-
b) Control Card Keyed	-	-	-	-

Table XXXI (Continued)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
18. Single ABM Assignment	-	-	X	-
19. ABM Reassignment	-	-	X	-
20. Saturation of Detection Radar	-	-	-	-
21. Radar Retrack for Definition	-	-	-	-
22. Single ABM Type Assignment	-	-	-	-
23. Multiple ABM Type Assignment	-	-	-	-

a) The QUICK, OASIS, and SWADE models do not consider RV Detection events (Ref 13; Ref 8; Ref 6).

Table XXXII

Offensive/Defensive Interactions -

Missile Penetration (RV Engagements)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Monte Carlo Intercept	X	(a)	-	-
2. Preset Probability of Intercept	-	-	-	X[b]
3. Dynamic Intercept				
a) ABM Radar Tracks ABM Only	-	-	-	-
b) ABM Radar - Search, Track, Guide	-	-	-	-
c) Exoatmospheric Engagements	-	-	X	-
d) Endoatmospheric Engagements	-	-	X	-
e) Compute ABM Fireout	-	-	-	-
f) Compute Miss Distance	-	-	-	-
4. Compute Kill Probability	X	-	-	-
5. Shoot Look Shoot Tactic	-	-	X	-
6. ABM Fireout Queuing	-	-	-	-
7. ABM Reload	-	-	-	-
8. Multiple Hit Accidental	-	-	-	-
9. Multiple Hit Computed	-	-	-	-
10. Multiple Hit Cptimized	-	-	-	-
11. Monte Carlo ABM Abort	-	-	-	-
12. Aborted ABM Substitution	-	-	-	-
13. Aborted ABM No Substitution	-	-	-	-
14. Single ABM Launch	-	-	X	-
15. Multiple ABM Launch	-	-	X	-

a) The OASIS model does not consider RV Engagements events (Ref 8).

b) SWADE aggregates this probability into the probability of arrival (Ref 6).

Table XXXIII

Offensive/Defensive Interactions -

Missile Penetration (RV Impact)

Characteristic	Model			
	QUICK	OASIS	AEM	SWADE
1. Monte Carlo Dud Weapon	X	X	(a)	X[b]
2. Actual Ground Zero (AGZ) Determination				
a) Dynamic Attrition of Defenses	X	-	-	-
b) Dynamic Attrition of Launch Bases	X	X	-	-
c) Dynamic Damage Assessment	X	X[c]	-	-
d) Communications Damage	-	-	-	-
3. Calculate Dust Problem	-	X	-	-
4. Monte Carlo Dust Problem	-	-	-	-
5. Calculate Fratricide	-	X	-	-
6. Strike Reporting	-	-	-	-
7. RV Effects from Ablation and Errosion	-	X	-	-

a) The AEM model does not consider RV Impact events (Ref 5).

b) SWADE normally uses damage expectancy, but it does have the capability to use a monte carlo technique (Ref 6).

c) OASIS considers damage to silos only (Ref 8).

IV. The Significant Issues

The Model Similarities and Differences

The first general area of focus is on each individual model. In this way an adequate review of the strong points of each model can be viewed. These areas of strength are the foundations which show the differences between the models. Thus, the following discussion will proceed in a manner similar to the previous chapters where the QUICK model will be discussed followed by the OASIS, AEM, and SWADE models.

The QUICK model as well as the AEM model are the only models which are capable of simulating a two-sided conflict, as shown in Table I. This is significant because, for example, both a first strike by one country and a retaliatory strike by the other country can be simulated at one time. The other programs model only one-sided exchanges which means that if they want to investigate a retaliatory strike after absorbing a first strike, they must run their simulation again. This second running of the model can add much time and frustration to obtaining the same results that QUICK can obtain in one run. A second strength of the QUICK model is that it considers many of the aircraft launch characteristics, as shown in Table XII. If detail is needed in the aircraft launch area (such as launch abort, launch on schedule, sortie regeneration, or tanker events), then, of the four models reviewed, the QUICK model is definitely the one to use.

A strength of the OASIS model is that it can produce immediate summaries, as shown in Table V. This is an extremely useful characteristic if a model is large. To review, an immediate summary is one in which the user can interactively look at certain parameters in the game in their current state, whether the simulation has been completed or not. Thus, the user could find out how many and which of the missile sites were destroyed with the first wave of a Soviet attack, rather than finding out how many and which of the missile sites had been destroyed after the entire exchange of both countries. Knowing this information at an intermediate step could significantly alter the U.S. defensive strategy. A second strength of OASIS is its comprehensive treatment of nuclear damage effects revealed in Table IX. If a detailed investigation of nuclear damage effects is needed, then, of the four models which were investigated, the OASIS model is definitely the choice.

The AEM model has two main strengths. First, its scheme of allocating weapons to targets is one that iterates to achieve an optimal allocation. As shown in Table VII, all of the models possess some allocation characteristics, but the AEM model is the only one of the four which tries to optimize the allocation. The discussion of the AEM model in Chapter II addresses this point. The second strength of the AEM model is the detail with which it treats SAM sites, as shown in Table XXII. Although it does not incorporate all of the characteristics, of the four models, the AEM would definitely be the most useful in this area.

The SWADE model also has several strengths. First of all, it is a highly aggregated and quick-running model. The simulation time is spoken of in terms of minutes, not hours or days. Thus, many areas of a strategic exchange can be investigated quickly and fairly accurately. However, an aggregated model can only deliver results which are general in nature. For example, when SWADE aggregates its targets into 40 clustered groups, one cluster group may be all of the airfields. Therefore, when the results of the simulation say that 60% of the airfields have been destroyed, we cannot say which specific airfields have been destroyed. The output indicates only that 60% of the airfields have been destroyed. A second strength is one which involves placing boundaries on its probability calculations, as shown in Table X. What the SWADE algorithm actually does is check to see if the calculated probability is greater than 1.0 or less than 0.0. If it is either greater than 1.0 or less than 0.0 the simulation is halted. Although this boundary condition checks for gross errors only, it helps to reduce the workload for the manual checking that is performed.

The second area of focus is on the similarities and differences of the models. First of all, the models are similar in several aspects. For example, each of the four models can simulate at least a one-sided exchange. They are also similar in that none of them considers AAA, as shown in Table XXIII. A third similarity is that three of the models do not have Error and Security Checks, while the fourth model considers only one characteristic from this area (see Table X). This is significant because none of the models appears to do a thorough job of checking for errors. For example, none of the simulation models have subroutines which check the data records as they are passed from one program to the next. If some data records are inadvertently destroyed while being passed to another program, it would be virtually impossible for the operator to catch this, yet this small error could cause larger errors in the output. Although error checking may be done by people before and after simulation runs, error checking routines within the programs do not exist, at least in the manner described in the Error and Security Checks area. Thus, it appears that much time and effort is expended in developing intricate details of allocation and nuclear effects, and other aspects, but very little effort is put into error checking routines. This may be a valid approach to strategic simulation modeling, but it seems reasonable that some time must be expended in developing error and security checks to add to the credibility of the models.

The differences between the models can best be explored by a discussion of the specialized areas into which each model delves. The QUICK model contains a fair amount of detail in both aircraft events (see Tables XI, XII, XIII, and XIV) and in missile events (see Tables XV, XVI, XVII, and XVIII). It is the only model, of the four investigated, that deals with some detail in both aircraft and missiles, and the allocation of weapons. The OASIS model does not consider aircraft events, but considers only missile events (see Tables XI and XV). However, this model has much more detail than QUICK does in the nuclear missile effects area (see Table IX) and the missile trajectory area (see Table XVI). In contrast, the AEM model considers missiles in a shallow sense (see Table XV) and focuses on aircraft and an allocation scheme. Also, the AEM model has the most thorough allocation optimizing scheme of the four models. Finally, the SWADE model considers most of the areas which are considered by the other three models, but only in an aggregated sense. Because of this aggregating and clustering, SWADE achieves fast run times and sacrifices the details that the other models focus on. Thus, SWADE can explore a large number of scenarios quickly and cheaply.

Decision Situations

One of the primary forces behind the comparison of the four simulation models was the quest to develop a generic framework. This study, although focused on the development of a generic framework, has helped to expose possible general classifications for and possible elements of a decision tree for strategic models. The format for the discussion that follows will address the general classifications area first, followed by a discussion of a possible decision tree.

Then, concluding this section will be a discussion of some of the present uses of the four models reviewed in the study.

While the reviewing of the models and the development of the framework was taking place, several general areas of classification became more apparent. Four of these general areas seem to be more easily substantiated than some of the others. Perhaps the easiest way to view these concepts is to look at the classification area as a continuum with two end points. Then, most models can be placed somewhere between these end points. The first area is the level of aggregation. Of the four models in the study, each falls

Detailed Model ----------- Aggregated Model

somewhere between the end points. The most highly aggregated is the SWADE model, while the most detailed is the OASIS model. The level of aggregation has some obvious implications. First, the more aggregated the model, the faster the run time. With a faster run time, a model can explore numerous scenarios in a short length of time, but the user must be very careful with the output data. Second, the data from an aggregated model must only be used in general terms. The output cannot tell us which specific Soviet airfields were destroyed, but it can tell us what percentage of the Soviet airfields were destroyed. Third, although the detailed models are nice to have, the user pays a high price for the amount of time needed to run the simulation.

The second general classification is that of data preprocessing. For this area, all of the models studied

Data Preprocessing Required	----------------	No Data Preprocessing Required

required some data preprocessing except SWADE. Although there is some "human" preprocessing required for the SWADE data, no machine preprocessing is required. First of all, what is meant by preprocessing is that the data to be used as input must be arranged in a proper format so that the simulation program can accept it as input data. Thus, it is easy to see that the more detailed the consideration of the events are, the more input information is needed which leads to more preprocessing. As the models get larger, the more the users rely on computer programs to speed up the necessary preprocessing time. Therefore, it can be seen that this second area is tied very closely to the first. The more detailed the model, the more it must rely on preprocessing programs.

The third general classification is that of the number of different sides which exchange weapons. This particular area delves into how many different sides (countries), which

Multi-Sided Exchange	--------------------	One-Sided Exchange

have offensive and defensive strategic weapons, are modeled in the simulation. Of the models studied, both the OASIS and SWADE models are one-sided. Typically, the allocation of weapons to targets occurs much faster in a one-sided exchange, which means that these types of models run faster. This is true for the SWADE model, but OASIS uses this time saving to buy more detail in the missile events. Thus, even though a one-sided exchange may be a quicker running simulation, it may trade this time off to obtain greater detail in other areas. The point is that when two or more sides are considered by the program, the weapon allocation process starts eating up vast amounts of computer space and time. This is a result of the computer having to keep track of the destroyed strategic sites after each wave of the attack, and then sorting through which sites have been destroyed and which sites have not.

The fourth and final general classification area is that of weapon allocation doctrine. Given that everything

All Allocations With Rigid Doctrine	-----------	All Allocations With Flexible Doctrine

is identical between two programs, if the weapon allocation is made with rigid doctrine, the simulation time would be much faster than with flexible doctrine. Flexible doctrine would take more coding to check parameters as the simulation progressed, thus leading to longer simulation times. An example of a flexible doctrine would be as follows: if a particular ABM site had 40% or more of its original inventory remaining, it would fire 2 ABMs at each incoming target. But, if it has less than the 40%, it would fire only 1 ABM at each incoming target. A rigid doctrine would be one where the above mentioned ABM site would fire two ABMs at every incoming target until its inventory was exhausted. It is clear that the best way to run a simulation is under a flexible doctrine, because it better reflects what would happen in a "real world" situation. But, a price is paid in spending more computer time and memory.

A decision tree is another way to focus on the results of this study. Although the prime effort was designed to develop a generic framework, another entire study could be devoted to the development of a decision tree for strategic simulation models. The decision tree primarily directs the user into certain areas of models by posing certain questions. Not only can it help the user find a set of models, but the decision tree can be an aid to help the user focus his thinking about some critical areas of strategic simulation.

Figure 6 shows a first attempt at the development of a decision tree. As shown, the first question addresses what type of exchange capability is desired: one-sided, two-sided, or more than two-sided. This is followed by a question of whether a quick running model is desired or not. Some organizations desire quick running models because they may want to look at numerous types of scenarios without waiting weeks or months between each investigation. Additionally, the highly aggregated, quick-running models lend themselves nicely to the investigation of future force structures. Because future accuracies of weapons and actual weapon systems cannot be "accurately" measured, it makes no sense to waste the time that a highly detailed model would spend. Finally, in each area (detailed and aggregated)

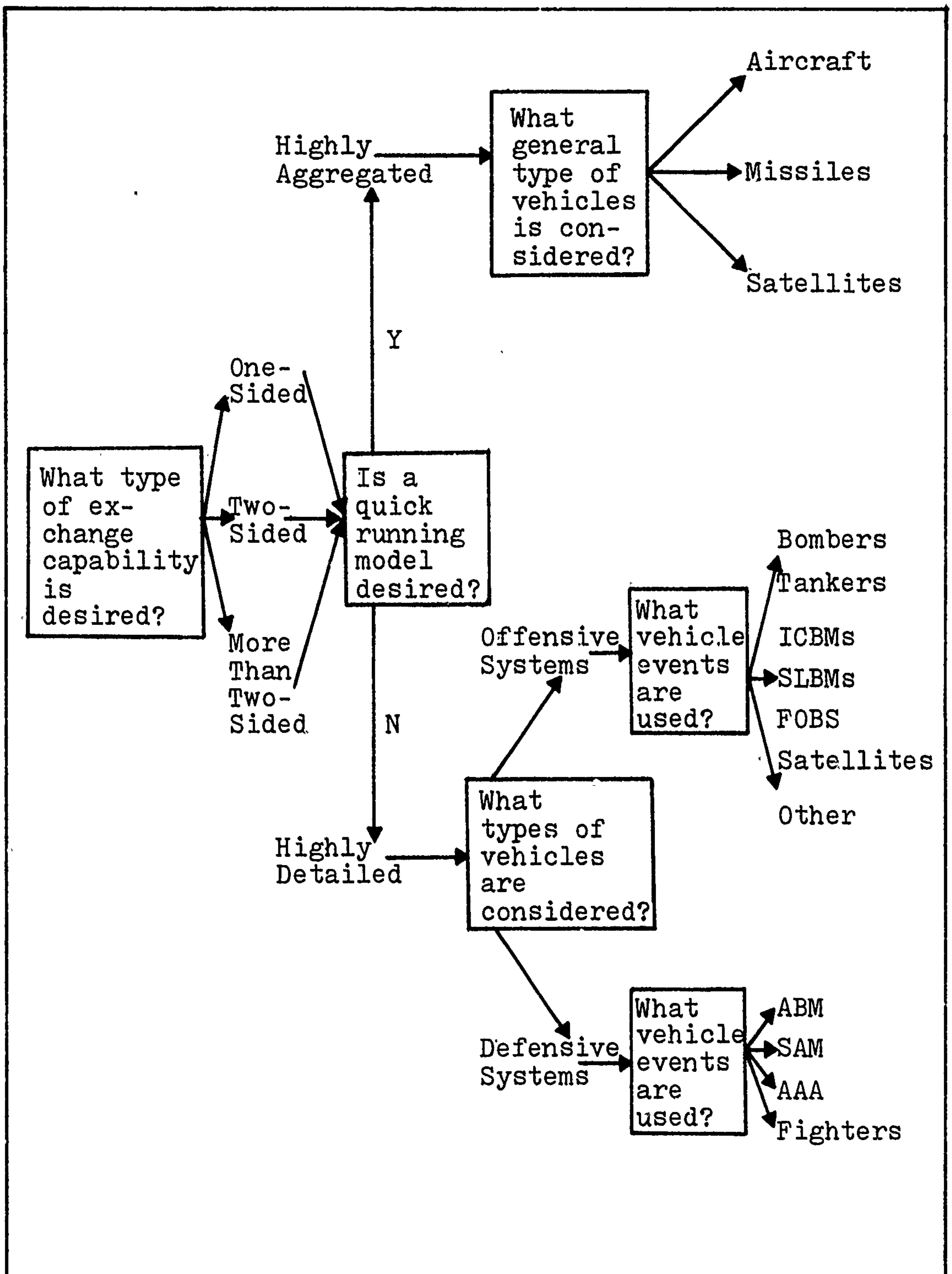

Figure 6. A Decision Tree

questions are asked about what type of vehicle events are desired. Should the model include ICBMs, SLBMs, and FOBS? Should the model include tankers as well as bombers? Should the model include satellites?

The above mentioned decision areas seem to be common to all strategic simulation models, at least to the four models which were studied. Obviously, this decision tree could be more fully developed and refined.

As a matter of fact, the development of a decision tree could be an idea to pursue for further research. Although the research performed for this study reveals that no specific attempt is being made to develop decision networks, two specific pieces of literature are available for background information. The first is the Joint War Gaming Manual published by the Joint War Games Agency which discusses general concepts and strategies of war gaming (Ref 16). The second is a study performed by Science Applications Incorporated (SAI) called "A Review of Selected Strategic Force Models," which compares 30 strategic simulation models against 24 general characteristics (Ref 4).

To conclude this section, a discussion of how the models are currently being utilized follows. One part of the QUICK model is currently being used by SAGA to generate theoretical nuclear war plans for the United States. Although this model is capable of more simulation detail in aircraft and missile systems than the other three models, it is used only to generate these war plans and is not used for the simulation. The development of this nuclear war plan entails the allocation of weapons to targets as well as the specific routes and timing of all of the delivery vehicles. Once QUICK completes this plan, the information is fed into the Nuclear Exchange Model (NEMO) for the simulation of the exchange. The net result is to compare this theoretical plan developed by QUICK with the actual SIOP so that some assessment of the effectiveness of the SIOP can be made. This information was obtained from Mr. Gus Thomson of SAGA.

The OASIS model is primarily being used by the JSTPS to investigate the present force structure. Although OASIS is an extremely flexible simulation model, the JSTPS is currently using it to simulate two types of scenarios. One of the scenarios is the investigation of how well the present force structure can survive a surprise first strike by a hostile country. The other scenario investigates how well the present force structure can penetrate a hostile environment. Thus, the essence of their current investigation is the vulnerability and survivability of ICBMs. This information was obtained from Major Roger Scott of the JSTPS organization.

The AEM model is currently being used by AF/PAC to compare the effectiveness of the MX missiles against the effectiveness of the Air Launched Cruise Missile. These studies are only one-sided to the extent that the simulation is modeling the U.S. weapons against the Soviet defenses. The reverse scenario of Soviet weapons against U.S. defenses is not currently being studied because of the lack of a complete data base. Although the AEM model has the capability of considering systems costs, this capability is not frequently used. This information was obtained from Capt. Greg Tsoucalas of the AF/PAC organization.

Finally, the SWADE model is currently being used by SAC/XPS to investigate future force structures. Because of its fast run times, it is able to investigate a broad range of scenarios for our future force structure. For example, it is continually investigating various aspects of the Triad, from scenarios with only one operational leg of the Triad to scenarios with all three operational legs. SWADE also continues to investigate the role of the advanced strategic bomber as well as the role of the Air Launch Cruise Missile (ALCM) and Short Range Attack Missile (SRAM). It is also studying the effects of redefining the roles of the trident and minuteman missile systems. This information was obtained from Major Norman Burger of SAC/XPS.

The Value of a Generic Framework

Value is something which is hard to measure unless it is spoken of in terms of dollars and cents. The value of a generic framework is, in the same sense, difficult to measure. But, in an attempt to describe its value, this study focuses on four main values. The first two values are its use as a tool for learning and its use as a check list. As a tool for learning, the framework can be extremely valuable to a novice. It will immediately help to focus in specific, concrete areas. It can help by positioning a novice farther along the learning curve. Less time and money will be spent developing a common level of knowledge. The second point, use as a check list, can help not only the novice, but the experienced simulation veteran as well. Even though an experienced modeler can remember great quantities of details, there is always a chance of overlooking a detail. Thus, the check list can help him avoid any oversights. Also, the check list can be used as a reference for comparing one simulation model against another. This could help the modeler to decide which of several similar models to use. Thus, the generic framework can be another useful tool for the analyst.

The last two values of a generic framework are the way in which it orders strategic thought and the actual methodological development used to generate the framework. The way in which a framework orders strategic thought provides one way to view our present strategies. Just a different way to analyze our strategies may have profound effects. Various oversights might be revealed in our missile and bomber strategies. The second point is value associated with the methodological development. By tracing through the development of the framework an individual may see ways to develop new modeling techniques, or he may even see ways in which to develop entirely new models which will more closely resemble the strategic environment.

In conclusion, it may be easier to see how a generic framework can have value as a tool for learning and as a check list, while its value in promoting strategic thinking and future model development may be somewhat harder to see or measure. However, it is important to remember that any change in strategic thinking will take years to evolve and may involve several types of inputs. A generic framework of characteristics may be just the catalyst needed to increase the velocity of this evolutionary process. Thus, it is extremely difficult to gage how this framework will change strategic thinking and of what value it will have in the future, but it is hoped that the framework will at least be a useful tool for the simulation community.

V. Summary, Conclusions, and Recommendations

Overview of the Research Approach

This research effort involved two primary driving forces. The first was the development of a generic framework within which strategic simulation models can be compared. The second was the actual comparison of four strategic simulation models, each from a different organization. Although these were originally viewed as two separate driving factors, they often overlapped. The following is a discussion of how these two factors affected the study.

The one objective which was the hallmark of this study was the development of a generic framework. The original approach was to review several strategic simulation models and to use these models as a basis for the generic framework. Then, after the framework was developed, each model would be compared against the others within the framework. As the research into strategic models began, an individual was found who had many years of simulation experience. This individual was Lieutenant Colonel Edward T. Akerlund. His expertise helped to guide the research effort to models which possessed adequate documentation. Finding models with adequate documentation is a crucial point, because many models in the simulation arena lack clear concise documentation.

Lieutenant Colonel Akerlund also provided valuable inputs during the development of the generic framework. He possessed a list of characteristics which had been developed over many years by inputs from his simulation associates and co-workers. This list of characteristics provided the cornerstone of the generic framework. As a result of researching the users manuals from each model and of inputs from the model operators themselves, addition, modification, and deletions were made to this original list of characteristics. The end product was the final generic framework. Then, it was within this framework that each of the four models were compared.

The first step of the model comparisons was a research effort to investigate how each program actually functioned. This information can be found in Chapter II. The next step involved finding out which of the characteristics each model possessed as described in the generic framework. The results of this research are found in Chapter III. The generic framework, thus, provided the basis for which key similarities and differences between models can easily be seen. A discussion of these similarities and differences is found below in the Summary of Findings and Conclusions section and in Chapter IV. Thus, it can easily be seen that the generic framework provided not only a new way to think about strategic simulation models, but it also provided a straightforward means with which to compare models.

Summary of the Findings and Conclusions

First of all, this study puts forth a comparison of four strategic simulation models. Each of these models was selected from a different organization in an attempt to explore the diverse means with which the Department of Defense attacks the strategic simulation problem. Thus, it was found that each model focused on certain areas which were different than the others, as well as some common areas.

The QUICK model and the AEM model are capable of a two-sided exchange (see Table I). What this basically means is that these two models can simulate the offensive and defensive interactions of a first strike, followed by the offensive and defensive interactions of the retaliatory strike by the other side. Having this capability to simulate both sides of the exchange can enable the model to more realistically simulate an actual war. Also, QUICK is the only model to consider aircraft launch events as shown in Table XII. If an analyst would want detail in this area, QUICK would be the model to use.

The OASIS model is the only model of the four which deals with nuclear effects in great detail (see Table IX). It basically models the effects that nuclear weapon detonations have on incoming missiles. Additionally, OASIS provides a unique output capability. It allows the user to interactively look at various parameters as the game progresses (see Table V). This capability allows the observer to actually see how various strategies are working in a dynamic sense.

The only model which has the capability to provide detailed SAM events, as shown in Table XXII, is the AEM model. Although not all of the characteristics are addressed, the AEM model would be the one to use when investigating SAM events. Also, the AEM model uses a cost optimization scheme to optimize its weapon to target allocations. This scheme can be extremely beneficial if weapon costs need to be considered.

Finally, the unique capability of the SWADE model is that it takes into account many of the characteristics from the other three models, in an aggregated sense, and it has a quick run time. Despite the aggregation, useful results are obtained when the output is used to identify trends (as in future force structures) rather than to identify specific requirements. Additionally, SWADE is the only model which attempts any error checking (see Table X). It will automatically stop the simulation when probability calculations exceed a preset upper or lower bound.

A final comment needs to be made concerning the Error and Security Checks area. Even though SWADE considers one possible way to check for errors, none of the models studied seemed to take error checking seriously. It is certainly true that much time and effort has been spent in working out the intricate details of computer simulation techniques, but it appears that very little time is spent in developing algorithms to check for errors. Obviously, some human time is allotted for error checking, but it seems reasonable that a systematic approach must be incorporated into the algorithm to insure the credibility of the output.

The conclusions of this study are as follows:

1. Most strategic simulation models are designed for specific purposes; thus, each model has its own unique qualities which make it different from other models.
2. Many models (all of the models reviewed for this study) lack error and security checking algorithms within their program. This lack of systematic checking can lead to a degradation of the credibility of the output of a model.
3. A generic framework within which to analyze strategic models can serve as a useful tool in the simulation community. It not only will serve as a check list, but as a guide to the comparison of models.

Recommendations for Further Study

The development of a generic framework is really the focal point from which many other studies can be launched in the strategic simulation arena. The following is a list of these possible paths for exploration.

1. Based on this generic framework, a study could be made into the general classifications of strategic simulation models. As is evident from this study, several classification areas have already evolved. One of these classifications is aggregated models versus detailed models. Another is models which require preprocessing versus models which do not require preprocessing.

2. The second area which is ripe for development is that of a strategic simulation decision network. This could involve various decision situations under which all strategic models fall, as well as individualized decision situations. For example, all models are either one-sided, two-sided, or more than two-sided.

3. A third area for exploration is the development of a similar generic framework for areas other than the strategic environment. For example, a generic framework could be developed for tactical simulation models as well as airlift and sealift simulation models.

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFIT/GOR/SM/78D-5	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A FRAMEWORK FOR THE COMPARISON OF FOUR MILITARY STRATEGIC SIMULATION MODELS		5. TYPE OF REPORT & PERIOD COVERED MS Thesis
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Thomas E. Denesia Captain USAF		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Air Force Institute of Technology (AFIT-EN) Wright-Patterson AFB, Ohio 45433		12. REPORT DATE December, 1978
		13. NUMBER OF PAGES 162
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

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

18. SUPPLEMENTARY NOTES

APPROVED for public release; IAW AFR 190-17

JOSEPH P. HIPPS, Major, USAF
Director of Information 19 Jan 79

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Computer Simulation Model
Strategic Simulation
Generic Framework

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

This study goes beyond the comparison of four strategic simulation models and attempts to develop a generic framework within which any strategic simulation model can be compared. The framework itself evolved with several iterations of changes. The first set of characteristics for the framework was developed with the help of an expert in the simulation community. This list was then added to or deleted from as various discussions and interviews proceeded with the operators and users of the four models

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specifically addressed in this study. Following this, a review of the overall philosophy of the framework was made, and a final form of the generic framework was established. After the framework had taken its final form, a comparison of the four strategic simulation models was made. Thus, within this standard basis for comparison (the generic framework), one can more easily see what specific characteristics a model possesses and what specific characteristics it does not.