LEVEL 12

RADC-TR-81-111
Final Technical Report
June 1981

AUTOMATED SCENARIO GENERATION AND INTERACTION TECHNIQUES

Martin Marietta Aerospace Corporation

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
RADC-TR-81-111	AD-A102 332	

4. TITLE (and Subtitle)	5. TYPE OF REPORT & PERIOD COVERED
AUTOMATED SCENARIO GENERATION AND INTERACTION TECHNIQUES.	Final Technical Report. June 79 — Nov 80.
	6. PERFORMING ORG. REPORT NUMBER
	MCR-80-642

7. AUTHOR(s)	8. CONTRACT OR GRANT NUMBER(s)
N. R. Routon K. B. Sawyer J. T. Berger	F30602-79-C-0183 new

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Martin Marietta Denver Aerospace P. O. Box 179 Denver CO 80201	45941623

11. CONTROLLING OFFICE NAME AND ADDRESS	12. REPORT DATE
Rome Air Development Center (IRDE) Griffiss AFB NY 13441	June 1981
	13. NUMBER OF PAGES
	56

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report)
Same	UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A

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)

Same

18. SUPPLEMENTARY NOTES

RADC Project Engineer: William G. McClellan (IRDE)

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

Automated War Gaming
Automated Scenario Generation
Automated War Game Interaction

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

This report describes automated war games in use today, with special emphasis on tactical air/land operations (TALON) and proposes a gaming model, specifying extended capabilities and requirements for model to fill future needs in training commanders.

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NOTE: For the purposes of this report the terms Commander,
Strategist, gamer, user, game participant and game player
are used to refer to those who are acting participants
in the command, control and communication system of a
scenario being played.

1.0 INTRODUCTION

This report is submitted to the Rome Air Development Center (RADC), Griffis Air Force Base, New York, to support contract requirements set forth in Request for Proposal (RFP) F30602-79-C-0183. This report addresses the Contract Data Requirements List (CDRL) Number A002 of the contract which this effort supported; i.e., computer simulated war scenarios.

For the purpose of this report, reference to "ASGI concept" or "ASGI" is to imply a proposed automated scenario generator and the capability to interact with it (play that scenario).

Computer simulated war scenarios currently used by the U.S. military for training exercises have proven to be effective in approaching a cost-effective means by which flag grade and field grade commanders can experience true-to-life combat situations. The ability to allow commanders to make certain decisions given a specific set of circumstances and to analyze these decisions provides data which can be used to construct a baseline for determining the effectiveness of command, control, and communications decisions.

A computerized simulated war program currently in use by the U.S. Air Force and U. S. Army is the TACTICAL AIR/LAND OPERATIONS (TALON) computer program which simulates Blue force reconnaissance (RECCE), Red and Blue forces ground warfare, and Blue force Close Air Support (CAS) and Mobile Interdiction (MI) air strike operations. Although the TALON program is an effective training aid, it has definite limitations in the scope of its true-to-life simulation.

An effective combat gaming model simulates movements by the military elements of both friend and foe. Each player, where player is defined as one who is an active participant in the scenario being played, should have the same capabilities when engaging in a combat game, i.e., each player should have the option of undertaking an offensive or defensive role according to how he determines his mission objectives can best be fulfilled. For example, the Blue player should have the same resources and weapons access capabilities as the Red player; moreover, both players should have the same options of mobility and tactical definition of weapons use. Additionally, the use of any weapons by either player should be subject to conditions including but not limited to the Rules of Engagement (ROE) for each participant and weather, terrain, tactical situation. These limitations and the number of limitations should be open ended in extent and scope.

Game play should be conducted in an environment where all players maintain a complete interactive operational mode with the gaming program to allow all players to react to responses of his adversary. The advantages to this method are: (1) the ability to analyze a player's response to a given situation at the time that the situation arises; (2) to allow each player to construct mission objectives which would result in the gain or the loss of overall objectives in the combat situations; (3) to give all the players a continuous overall picture of the theater in which a combat situation is being modeled.

1.

The combat gaming model described called, The Automatic Scenario Generation and Interaction (ASGI), is a concept employing a complete interaction environment by all players engaged in computerized combat games. In addition, the development of the scenarios themselves by the operational staff would be interactive in nature, thereby reducing the time required to develop new scenarios. The use of an ASGI concept allows rapid construction of elements needed to represent any given situation and to expose gamers to that situation in a timely and cost effective manner.

2.0 OBJECTIVES

The objectives of this report are: (1) to analyze and investigate the application of present scenario generation and interaction techniques as they are being applied to training exercises; (2) to present the re·..ts of interviews with U.S. Air Force and U.S. Army personnel which examined the human impacts on training exercises; (3) to describe the capabilities and limitations of the present techniques in scenario generation and interaction; (4) to describe the technical approaches proposed by Martin Marietta for developing the advanced ASGI concept.

3.0 APPROACH

In accomplishing the objectives, it was necessary to analyze the available documentation for the various U.S. Air Force Command, Control and Communications (C3) training exercises, to provide a summary of results of the analysis, to annotate recommendations for correction of perceived deficiencies, and to provide a top level discussion of a theoretical automated war scenario generator and interaction system which could be implemented by the U.S. Air Force to conduct C3 training exercises.

Models other than the U.S. Air Force Tactical Air/Land (TALON) program were examined, such as the Scenario Oriented Recurring Evaluation System (SCORES). The structure of TALON is very similar in design and design philosophy to that of SCORES, which is limited to a ground war model. The capabilities of TALON with respect to scope and interactive use by the operations personnel and the system users are as extensive as any automated system surveyed. In addition, the TALON documentation used in this study is unclassified whereas the SCORES documentation available was classified. In order to fully explore the capabilities, design and structure of a representative automated gaming system in use, TALON was chosen for an in-depth study to illustrate the state of the art being used operationally. The study of TALON provides some understanding of the effectiveness of the model.

The approach taken in conducting this analysis was two phased. The first phase consisted of conducting interviews with U.S. Air Force personnel who are associated with the planning, conducting, and analysis of C3 type combat exercises. Data collected from these interviews provided a requirements baseline from which the proposed automated scenario generator (ASGI) in this report was conceived.

Phase two of the approach consisted of the analysis and comparison of the U.S. Air Force TALON computer model and the proposed ASGI concept described

2.

in this report. The format of this analysis is broken down by subject or function. The TALON model and its capabilities and limitations are discussed. Following the TALON discussion is a review of the porposed ASGI concept. Where applicable, comparisons will be made between the TALON and the ASGI concepts in the latter discussion.

4.0 INTERVIEW RESULTS

Martin Marietta personnel conducted interviews with key individuals associated with U.S. Air Force TAC C3 training exercises for the purpose of establishing user perceptions. Questions were centered around the BLUE FLAG training exercise and the TALON computer model. Answers to these questions were supportive of the BLUE FLAG type training exercises, although responses indicated some skepticism with regard to the TALON model.

The major complaint concerning the BLUE FLAG type exercise was the lack of communications during the planning and/or logistical (implementation of planned operations) phases of an exercise of such magnitude. When asked about implementing automated logistics, most of the individuals interviewed were not acquainted with sophisticated automation techniques, and could not contribute. The majority of the individuals interviewed expressed interest in the results of any study which might determine the impact of automated planning and logistics for exercises of the scope of BLUE FLAG. Automated planning and logistics could provide for an inherent communications capability for all phases of a BLUE FLAG type of exercise.

All of the individuals interviewed expressed interest in the ASGI concept and were hopeful that the system could be built and implemented. Most of these interviewees did not have a background in software design techniques to enable them to engage in detailed discussion on the impacts of a highly interactive system such as is proposed in the ASGI.

5.0 TALON ANALYSIS

Analysis of the TALON program was accomplished by examining the support documentation for TALON and through interviewing key personnel associated with the use of the TALON program. The discussion of the current TALON program focused on its capabilities and limitations.

6.0 OVERVIEW OF THE TALON MODEL

TALON was introduced into the Air Force by the Tactical Systems Division and has been accepted by the tactical training centers at both TRADOC of the U.S. Army and the Tactical Air Command of the U.S. Air Force. TALON is a valid representation of combined air and ground warfare for use in joint Air Force/ Army studies.

The ground war model is a modified version of the Tactical Warfare Simulation Program (TWSP) developed at McDonnell-Douglas and the Center for Naval Analysis. The tactical air operations and graphic output were produced by the U.S. Air Force, General Purpose and Airlift Forces, Studies and Analysis.

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The interactive features were produced at the Tactical Forces Weapons Center, Studies and Analysis (TFWC/SA).

TALON is currently being used by both the Air Force and the Army at AF/SAGR// AF/SAGC, Washington, D.C.; TFWC/SA, Nellis Air Force Base, Nevada, and CADA, Ft. Leavenworth; and TRASANA, White Sands, New Mexico. The technical contact for TALON is Major Robert Boyde at Nellis AFB, telephone: 702-643-2676.

The TALON program models three (3) independent, but interactive, combat operations. These are (1) ground combat model; (2) air/ground model not including air to air combat; (3) reconnaissance model which includes data collection, fusion, and display. The TALON model is an extension of the hand-played war game philosophy. Tactical decisions are left to the players; bookkeeping and computational chores are given to the computer. However, tactical planning for a TALON game only attempts to parallel actual operational planning.

The TALON model organizational structure is composed of a main routine and eleven subroutines. The organizational structure is illustrated in Figure 1. Six subroutines are currently operational with the remaining five subroutines to be developed. As indicated in Figure 1 TALON receives input data from an outside source to stimulate a ground combat situation. Specific data concerning terrain, weapon types for allied and enemy troops, troop mass, reconnaissance, capabilities and limitations, and the type of scenario to be simulated are part of the input stream. The input stream itself is a data file on magnetic tape or can be a resident file built by the TALON staff either interactively or through batch processing. Currently, ground combat simulation is baselined on a U.S. Army generated ground combat scenario called SCORES, which is discussed below. The baseline itself is a result of micro-simulations of battalion level combat operations carried out by the Army at Ft. Leavenworth. The output from these simulations is a "killer-victim scoreboard" which is used to derive sets of simultaneous equations relating unit strengths to combat losses. TALON uses the input data supplied by the SCORES scenario to generate interactive input/output with the game players to enable the players to decide what type of operation is desired. TALON takes the player's response and calls one or more of the eleven subroutines to perform the gaming task.

As indicated in Figure 1, each routine is designed to perform a specific function. These routines are written in FORTRAN IV and utilize an overlay structure to minimize core requirements. Total resource in core is a result of the sum of the lengths of the longest overlay path used by the system. Core required for TALON is approximately 200K words. Communication between modules is accomplished by common areas of data and data file activities.

- o   MAIN   - This routine serves as the interactice link between
                       the players and the computer manages the calling of
                       all of the subroutines.

- o   GLADIATOR   - This subroutine performs air logistics and close air
                       support simulation for ground combat modeling.

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OPERATIONAL SUBSYSTEMS:
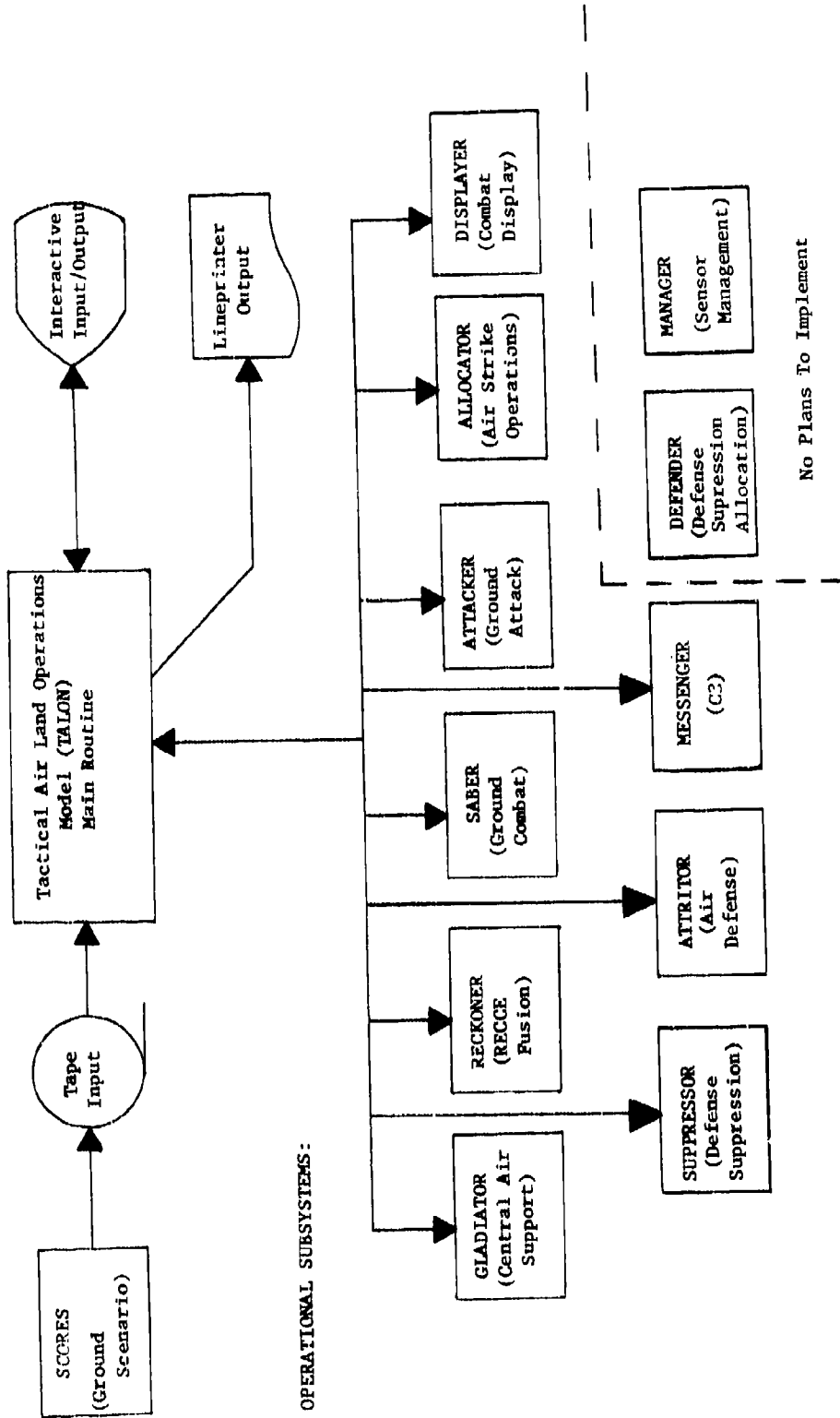
FIGURE 1 TALON MODEL ORGANIZATION

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o RECKONER — This subroutine performs reconnaissance modeling and data fusion correlation.

o SABER — This subroutine is the ground combat simulator.

o ATTACKER — This subroutine performs ground attack planning and weapon support for the ground combat simulator.

o ALLOCATOR — All air strike operations to be used in support of ground combat simulation are defined by this subroutine.

o DISPLAYER — This subroutine performs the processing necessary to display graphically the combat game being played.

o SUPPRESSOR — This subroutine performs defense suppression modeling and analysis for attacking combat masses.

o ATTRITOR — Similar to the defense suppression subroutine, this subroutine performs air defense modeling and analysis for attacking combat masses.

o MANAGER — This subroutine models sensor or advanced warning detection simulation.

o DEFENDER — This subroutine performs defense suppression definition for the defense suppression simulator.

o MESSENGER — All command, control and communication synthesis is simulated by this subroutine.

In addition to providing graphics display of the combat game and player interactive capability, TALON provides a hard copy printed output of the simulation results to be used during off-line simulation analysis.

When completed, the TALON model is supposed to be capable of interactively simulating every aspect of an air/ground battle engagement.

6.1 TALON PLAYER/COMPUTER INTERACTION

As illustrated in Figure 2, TALON play interaction is done in three (3) major areas; air support, ground operations, and reconnaissance operations. The TALON program prompts and responds to the player to enable the player to set up initial conditions for the program to operate. The interaction itself utilizes Tectronix 4014 or 4081 graphic terminals for graphic displays. The player enters commands by selection of menu items or entering commands through the keyboard on the graphic terminals.

The TALON program incorporates combined command elements (Division, Regiment and Battalion) essentially on one command level: divisional command staff which usually is comprised of Flag Staff or Field Grade personnel.

Since the operation of TALON is an event-sequenced process, specific displays can be requested by the players at player prescribed time intervals to aid in decision making. These output displays show the player graphic representations of the perceived ground war, as obtained from reconnaissance flights, a summary of ground operation, and results of air strikes. The player can
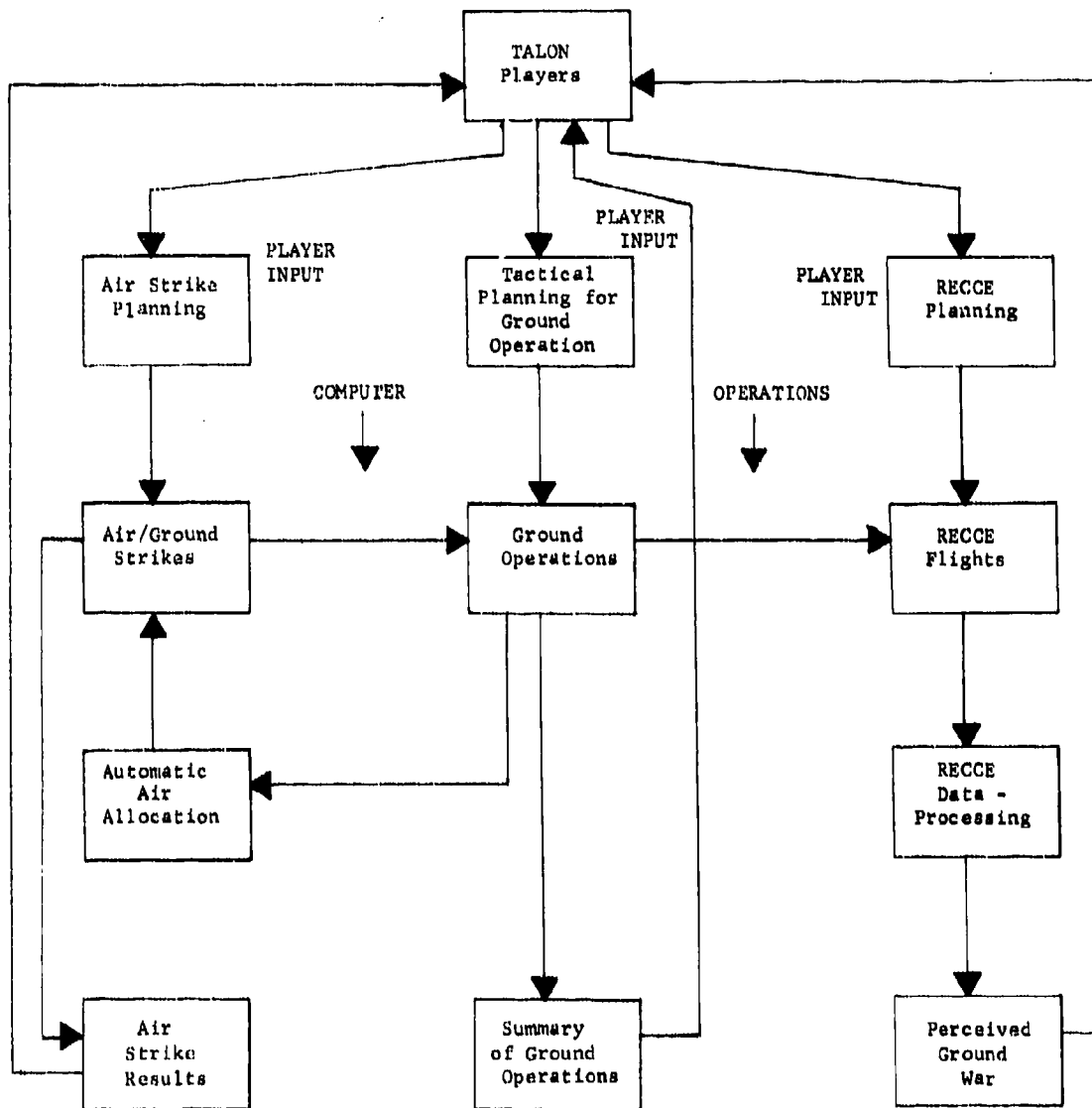
FIGURE 2   TALON PLAYER/COMPUTER INTERACTION

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then display the true ground war situation in order to compare that with the perceived situation. Also, the player can choose the option of automatic airstrike allocation should the situation warrant. Variations from the pre-planned response threads are permitted whenever the events indicate a change in tactics. The displays are generated and sent to the graphics terminals by the DISPLAYER module. These displayes are "snap shots" of the war situation at pre-selected intervals. The intervals determine the "real time" nature of the display capability, since intervening situational data is not available for display. "Time" is by definition a simulation variable.

6.2 GRAPHIC DISPLAYS: TALON CONCEPT

A typical TALON display is the visual representation of troop movement or troop moments as illustrated in Figure 3. As shown in Figure 3, troop movements are indicated by a number and a vector of some length. The number represents the size of the troop unit in tank-units. The vectors indicate the direction of movement and the vector length represents distance traveled from a known position. Most of the TALON displays are static.

6.3 GAME OPERATIONS AREA: TALON

The TALON gaming program incorporates ground and ground air support operations only. While the TALON program is useful as a tactical training tool, its ground/ground air support limitations inhibit real-world combat simulations due to the fact that TALON players are not given the ability to simulate any other combined military operations.

The TALON program does not include the command, control and communication capabilities to support a combined tactical, tactical nuclear and strategic operations environment. It's development was intended and therfore limited to ground and tactical air (Air Force) operations. Accomodating the extension to include combined operations definitely requires a redesign of the MESSENGER module, most likely other modules would require some revision if not complete functional duplication including a parallel capability for the C3 environment of a combined force. A complete assessment of the impacts of such development for TALON was not made. Recent improvements to TALON allow for combined NATO operations for the tactical environment.

6.4 GAME COMMAND LEVELS: TALON

The TALON program incorporates combined command elements on one basic command level: divisional command staff. These elements are division, regiment and battalion level only.

6.5 GROUND COMBAT OPERATION: TALON

The TALON ground war simulator handles the movement and attrition of combat and supporting units. The ground units are divided into two sets: RED units for offensive or aggressing play and BLUE units for defensive play. The differences between an offensive unit and a defensive unit lie principally in how their movements are controlled. The routines for both unit types are chosen by the gamers prior to simulation execution and are specified by their X-Y coordinates. However, an offensive unit is not constrained from movement unless prevented by the terrain, its opponents, or direct orders from its

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OFFENSIVE MOMENTUM

FEBA

147

23

2321

42

85

1φ6

25

2φ75

1175

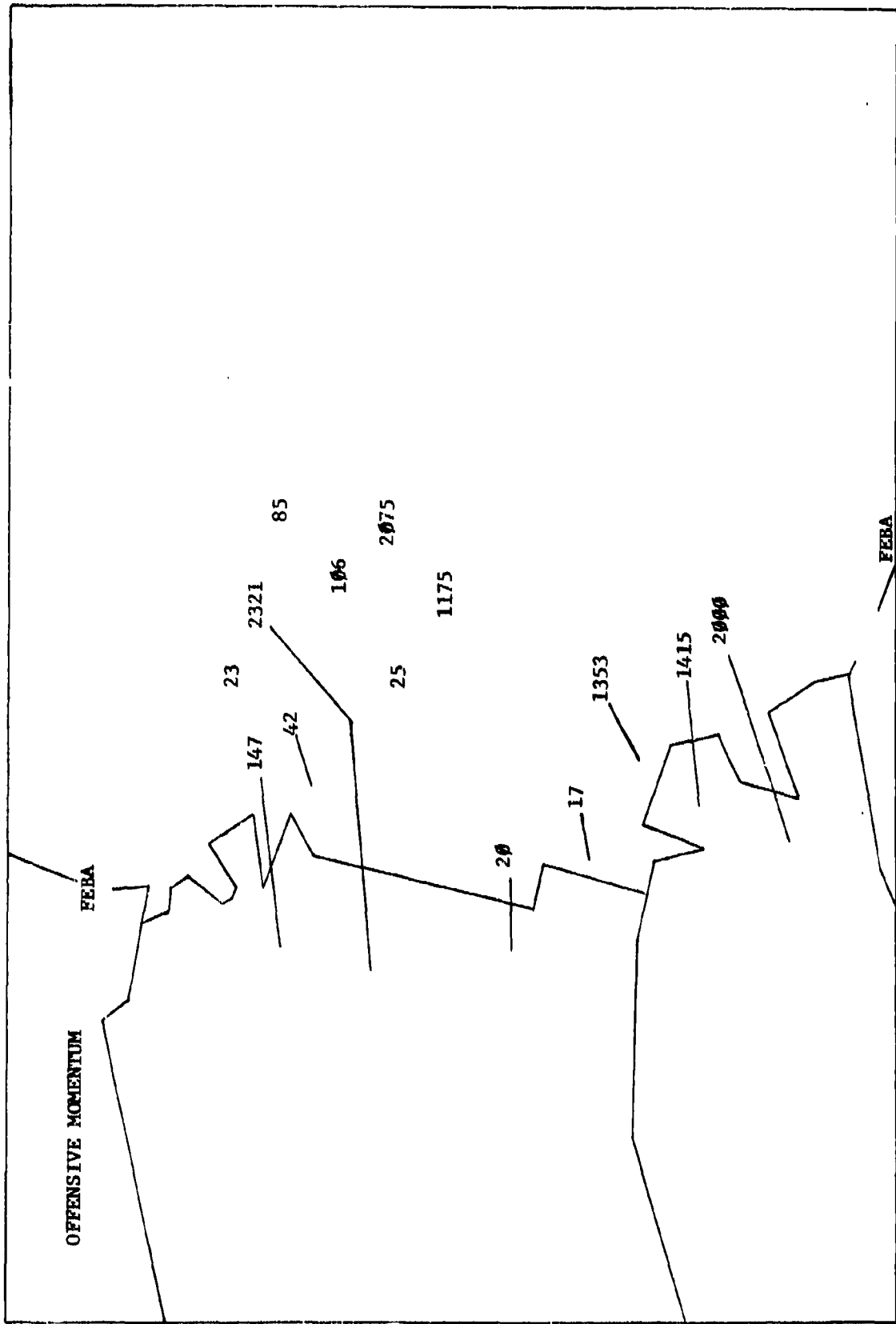1353

17

2φ

1415

2φφφ

FEBA

FEBA

FIGURE 3   TYPICAL TALON DISPLAY: TROOP MOMENTA AT THE FEBA

gamer commander. In other words, the offense must remain in motion. A defensive unit is constrained in place unless its movement is triggered by a gamer set option. This option is set prior to simulation execution. The TALON program is supposed to incorporate new features which will eliminate these constraints and allow free movements for both RED and BLUE units.

The TALON program defines combat engagement at the moment the control zones of the respective units overlap as illustrated in Figure 4. The circles represent the control zones of the RED and BLUE units. When any portion of the RED and BLUE zones overlap, combat engagement is considered to be happening. Total engagement is considered to be happening when one of the circles is superimposed upon the other.

Attrition during combat is computed from a modified form of the Lanchester equations based on the following principles:

o The rate of attrition suffered by a unit during combat is directly proportional to the combat strength of its components.

o The total attrition suffered by a unit is the sum of the attrition rates achieved by each of its opponents.

o A unit divides its fire power equally against all of its opponents.

o A supporting unit divides its fire power equally against all close combat opponents of the units it is assigned to support.

The attrition achieved by a unit is the product of its strength and the killing rate assigned to its type.

$$\text{Attrition} = (\text{Unit Strength}) \times (\text{Unit Killing Rate})$$

The unit strength in the TALON program is defined as a measure of the unit's ability to reduce its opponents' strength; that is, the strength of a unit is a measure of its ability to engage in combat and the killing rate of a unit is the unit's ability to reduce its opponent's capability for combat. Thus, the concepts of "unit strength" and "unit killing rate" are closely related and are defined in terms of a common measure: tank units. "Unit strengths" are expressed as "tank equivalents" and "unit killing rates" are expressed as "tank equivalent kills per unit time." Therefore, attrition is defined as:

$$\text{Attrition} = (\text{Unit Strength}) \times \text{Tank-Equivalence/Unit Strength}$$

$$\times$$

$$(\text{Unit Killing Rate}) \times \text{Tank-Equivalence/Unit Killing Rate}$$

$$\text{Attrition} = (\text{Tank-Equivalence})^2/\text{Time}.$$

TALON defines tank equivalence as follows:

o Three combat infantrymen = 1 Tank unit

o Two armored personnel carriers = 1 Tank unit

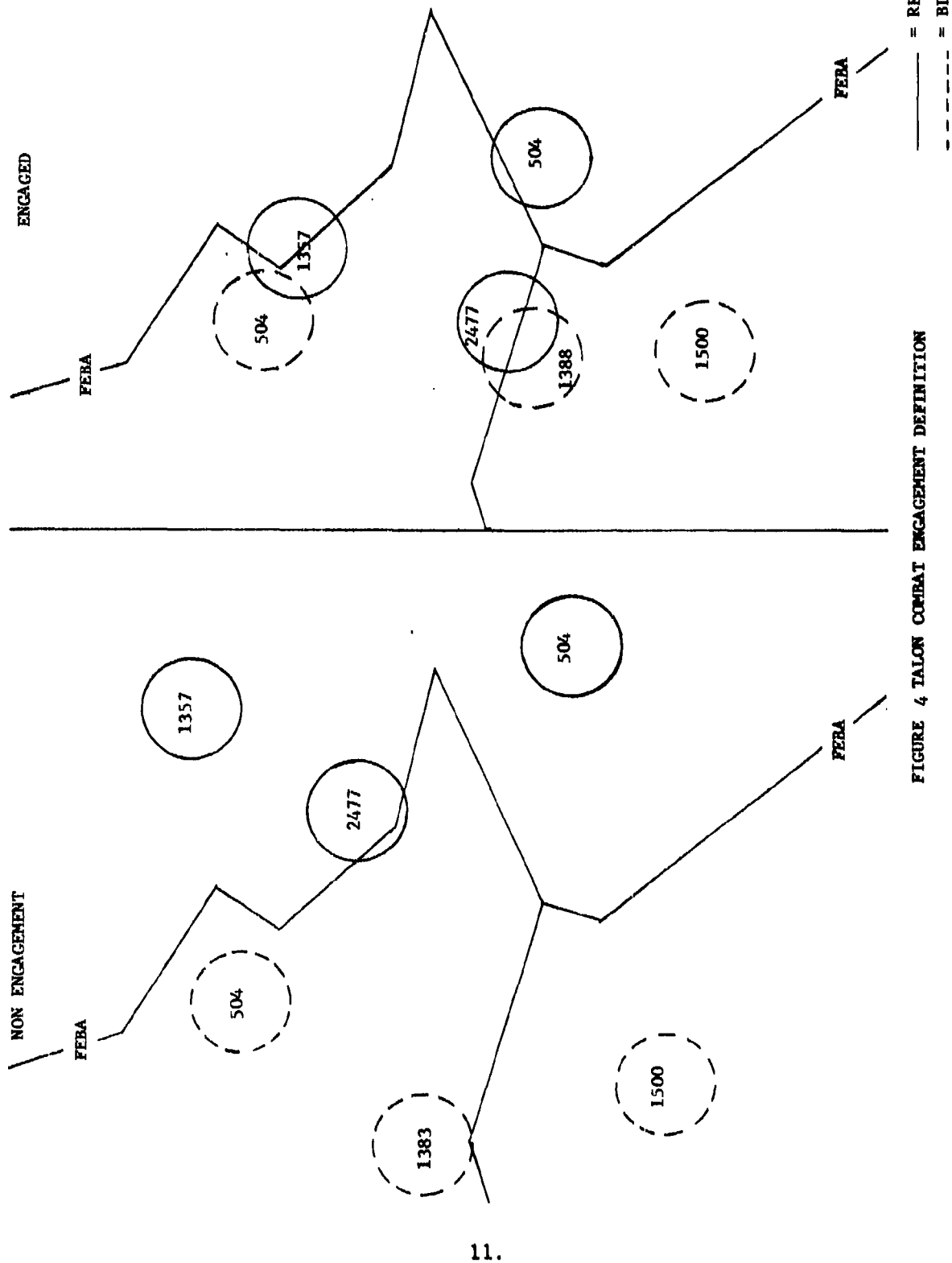o One heavy artillery piece, self propelled (155mm or larger) or one M60 Tank = 1 Tank unit

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FIGURE 4 TALON COMBAT ENGAGEMENT DEFINITION

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The Tank unit is based on the performance characteristics of the Soviet Union's T-62 heavy tank. Equating one M60 tank or one self-propelled artillery piece of 155mm or larger to one Soviet T-62 tank is apparently an acceptable equivalence for this type of modeling. However, there is a problem in equating three infantrymen with one T-62 tank, although that may be true depending upon the weapons available to those particular men. In any case, military problems simulated by the TALON model yield only a rough approximation to the solution of those problems. Although the tank equivalencies for weapons strength assessments makes the probability of success and attrition computations very simple, a great deal of computations are required in determining the various effort factors and uncertainty parameters which are generated during operation of the simulation. These calculations are done during the data reduction and analysis phase of the war game operation which requires additional man-hours and often requires that the same simulation, partial or in total, be re-run in order to clarify portions of the simulations.

6.6 AIR RECONNAISSANCE OPERATIONS: TALON

Air reconnaissance operations in TALON include both data gathering and data fusion to produce a "perceived" picture of the battlefield. The results of the reconnaissance operations may be used by the gamers in the air strike planning, or directly by analysts in studies of the reconnaissance operations themselves. Data gathering is accomplished through reconnaissance flights and intelligence from combat units. The fusion itself is accomplished by the RECKONER module and the methods used are discussed below.

All air reconnaissance missions are entered by the gamers from a terminal and executed during later gaming. The terminals used are CRT's, either graphic or non-graphic devices. The program permits two (2) types of mission planning:

o Single reconnaissance flights entered individually.

o Periodic missions entered once, with each flight causing the next to be scheduled after a specified delay.

Both Army and Air Force reconnaissance systems are available to the gamers. Any reconnaissance system may be programmed into the model depending on the desires of the TALON gaming Study Director.

Both reconnaissance flights produce a sensor "footprint" over the combat area and each enemy unit lying within this footprint is examined to determine if it has been detected. The process of detection is simulated by computing the probability of detection, depending on terrain, weather, aircraft altitude, and sensor characteristics. Random numbers are used with these computed probabilities to determine if the target is detected. The identities, locations and velocities of the detected enemy ground units are stored for transmission to the data fusion center.

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Target data from the airborne sensors are received by the data fusion center (1) if reconnaissance aircraft survives the mission, or (2) if the aircraft has a data-link to the center. If an aircraft having a data-link to the fusion center fails to survive the mission, all data collected previous to the aircraft destruction or incapacitation will be received by the fusion center.

Additional data target information is collected and sent to the data fusion center by sensors accompanying the ground units. The "perceived" picture of the battlefield is a composite of information from both airborne and ground sensors. Information is allowed to decay over a period of time and the information received from a sensor is weighted according to the sensor's known accuracy.

The TALON model for reconnaissance is quite sophisticated and appears to perform adequately for gaming purposes.

6.7 AIR SUPPORT OPERATIONS: TALON

Superimposed upon the ground component of TALON is a representation of tactical air operations. The air/ground strike operations are carried out in two phases: preparation of the air strike assignments and computation and ground target losses.

Unlike the ground unit tactics, which are determined by the decisions of the game players, the planning for air strike operations may be done by either the players themselves or it may be done by the program. In the automatic mode, the program prepares three target nomination lists:

o All engaged enemy units whose strengths combined with their supporting units are greater than the strengths of the BLUE units and their supporting units (the Close Air Support candidates).

o All moving enemy units (the "momentum" targets).

o All enemy ground units (the "mass" targets).

These target lists are weighed according to the square of the distance of the unit distance from a designated Fire Support Coordination Line (FSCL), and ranked according to their weighted value. As nearly as possible, the program assigns the preferred aircraft/weapon mix to the target and at specified periodic intervals, these allocations are displayed to the game players, who may accept them as they are or modify them as they wish.

Air strike execution in TALON is done at a designated time known as time-over-target (TOT). As this TOT the strike aircraft appear in the target areas at their specified altitudes. When the close air support aircraft are given the location of their targets, the aircraft are sent to the location predicted

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from the last known position and velocity of the target unit. Once in the target area, the pilot searches within his visual detection range for targets matching his munitions load. For example, if the aircraft is equipped with anti-armor weapons, then the first type of target sought is an armored unit. The search is modeled in two stages:

o A random number is compared with the computed coverage probability
   to determine if the target is obscured by terrain or by cloud cover.

o If the target is in the clear, then a new random number is compared
   with the target detection probability to determine if the pilot does
   see the target.

An attack on a target occurs when the target passes both tests and is considered "detected." Attrition to the ground units by an air strike is a deterministic process. Each pass of the attacking aircraft destroys some quantity of ground unit strength. This depends upon the target type and the munitions used against it. These damage factors are based on weapon effectiveness tables in the Joint Munition Effectiveness Manual (JMEM).

6.8 COST, SCHEDULE, AND MANPOWER REQUIREMENTS: TALON

Accounting estimates in the TALON gaming model are divided into two (2) areas: major studies and minor studies.

A major study effort is one for which the entire data base must be developed. The study director and study team create the combat scenario. U. S. Army personnel are tasked to produce the TALON ground war input which is done using the SCORES (Scenario Oriented Recurring Evaluation System) gaming model produced at the Combined Combat Arms Center, Fort Leavenworth, Kansas. The SCORES input consists primarily of the definition of the ground maneuver and supporting units with their path points.

In addition to the development of a complete data base, a major study effort often requires program modifications to support the simulation of a specific exercise.

A minor study may use a data base that has already been developed in the course of some other study and will not require significant program changes, if any.

Projected scheduling, cost and manpower requirements for the TALON model including the generation of the SCORES ground data input source are discussed.

6.9 SCHEDULING

The SCORES program is used to generate data for the TALON model gaming exercises and must be considered as part of the scheduling criteria for scenario generation. SCORES is used to generate data for either major or minor studies.

Major studies require the modification of some of the application software routines. The number and the extent of modifications to be done is determined by a study team. Changes to an existing data base for complete development of a new data base is also a necessary factor in the generation of the SCORES ground war data. All changes to software used in SCORES is accomplished through the submittal of punched cards. After compilation and error correcting activities are complete, the simulation system must be built by performing a system generation operation (SYSGEN). The SCORES program is now ready to run or more likely to begin its first round of testing for eventual run. Time requirements for SCORES execution depends upon the complexity of the major study. Analysis is performed on the resulting output data before the data is submitted to the Air Force for use in the TALON model. Scheduling requirements for the complete sequence of events to obtain usable SCORES data for a major study appears to be:

1) 2 to 4 months to obtain study requirements.

2) 1 to 2.5 months to effect program modification and data base development.

3) 3 to 4 month of SCORES execution to obtain usable data.

4) 1 to 3 months to perform data analysis activities to determine validity of generated data.

For a major study effort, a maximum of 13 months and a minimum of 7 months are required to generate SCORES input data for TALON combat gaming.

Minor study efforts require minimal changes to the applications programs and/ or data base. Therefore, minor study scheduling requirements are:

1) 1 to 2 months for study requirements.

2) 1 month or less for program modifications and data base changes.

3) 1 to 2 months of SCORES execution time to obtain usable data.

4) 1 to 3 months to conduct data analysis activities to determine validity of generated data.

The maximum time needed for a minor study effort is 8 months with a minimum time of 3 months.

The TALON scheduling itself is similar to that of the SCORES program. For major studies with the TALON program, modification to certain application routines is needed along with necessary changes to data bases to be used. In many cases, development of a new data base is required. All program editing and data base inputs are accomplished by using punched cards as in SCORES. A SYSGEN operation is required before TALON can execute. Data

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reduction and analysis can be done as the TALON program executes, however, most of the data analysis activity is done after TALON execution completion. The scheduling requirements for a major study effort using the TALON combat gaming program are:

1) 2 to 3 months to obtain study requirements.

2) 1 to 2 months to effect program and data base changes.

3) 3 to 4 months of TALON execution to complete the desired combat simulations.

4) 3 to 4 months to perform data reduction and analysis activities.

Total scheduling requirements for a TALON major study are 13 months maximum and 9 months minimum.

Minor study efforts using TALON do not necessarily require changes in the applications programs or the data bases to be used. If any changes are done, they are generally minor in nature and require that a SYSGEN be accomplished. Scheduling requirements for TALON minor study are:

1) 0 to 1 month to obtain study requirements.

2) 0 to 1 month to effect program and data base changes, if any.

3) 1 to 2 months to perform data reduction and analysis activities.

Total TALON scheduling requirements for completion of a minor study are 6 months maximum to 2 months minimum.

6.10 COST

Cost factors associated with automated war gaming exercises are inconsistent in relation to other military operating costs. Unlike hardware and other logistical items, the software, the hosting computer and associated hardware require different cost projections. The type of hardware chosen, the type or types of software used, maintenance and updating of that software and user utilization of the hardware and software influence the cost of supporting automated war gaming capabilities.

Projected cost of the TALON exercise including activities required to generate the SCORES input data used in the TALON model are included in Figure 5.

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All following estimates are of the form: time span / man months*

SCORES	HIGH	LIKELY	LOW	$RATE/hr.
Major Study				
1) Study requirements	4/12	3/9	2/6	38
2) Program/data base mod	2.5/7.5	1.75/5.25	1/3	33
3) Execution	4/12	3.5/10.5	3/9	28
4) Analysis of data	3/9	2/6	1/3	28
Minor Study				
1) Study requirements	2/4	1.5/3	1/2	38
2) Program/data base mod	1/2	0.5/1	0/0	33
3) Execution	2/4	1.5/3	1/2	28
4) Analysis of data	3/6	2/4	1/2	28

TALON				
Major Study				
1) Study requirements	3/9	2.5/7.5	2/6	38
2) Program/data base mod	2/6	1.5/4.5	1/3	33
3) Execution	4/12	3.5/10.5	3/9	28
4) Analysis of data	4/12	3.5/10.5	3/9	28
Minor Study				
1) Study requirements	1/2	0.5/1	0/0	38
2) Program/data base mod	1/2	0.5/1	0/0	33
3) Execution	2/6	1.5/3	1/2	28
4) Analysis of data	2/6	1.5/3	1/2	28

TOTALS	HIGH	LIKELY	LOW
SCORES Major Study	$214.38K	$162.22K	$110.06K
SCORES Minor Study	$ 82.67K	$ 56.94K	$ 31.21K
TALON Major Study	$201.20K	$169.57K	$137.95K
TALON Minor Study	$ 79.35K	$ 36.67K	$ 9.30K

* 1 Man-Month = 166 hours

FIGURE 5

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7.0 ASGI ANALYSIS

Analysis of the ASGI concept was done by establishing goals that the ASGI would meet and then, through proven design concepts, establishing a conceptual model for those goals. Many of the criteria used in these concepts have been well proven in Martin Marietta's own C3 Laboratory. The goals of an advanced ASGI are:

1. To provide a man-machine interface (MMI) that will establish a "friendly" environment to both game players and game supervisory personnel.

2. To provide advanced graphic display capabilities including the facility to interactively create new displays or display formats and the ability to save those permanently or temporarily for later use.

3. To provide a gaming system whose characteristics are data controlled, i.e., whenever a change is desired in the gaming scenario, only the data needs alteration and software need not be modified.

4. To provide the ability to change the scenario interactively even when the game is in progress.

5. To provide a software architecture which would allow for future upgrading of the existing system with minimum impact upon existing software.

7.1 MAN-MACHINE INTERFACE (MMI): ASGI

The MMI will provide a "friendly" environment: A "friendly" environment is one which allows non-computer personnel to easily understand the options available and to be able to select an option with no need for prior knowledge of any contrived and/or complex command language.

The man-machine interface shall provide menus whenever possible for option selection with either light pens, when available, or keyboard input. Additionally, the MMI shall provide displays of ground/air/sea situations using standard symbols maintained by the system in a symbol library. These symbols will include naval symbols for weapons systems, aerial symbols for aircraft and aircraft types and ground unit symbols normally used to display types of ground units including designations for unit size. The MMI will also provide the ability for users to create additional symbols interactively and assign them to the symbol library or to establish special purpose symbol libraries. Other features of the MMI include the ability to change scale easily (zoom or pan), change the display area, and/or displayed overlays by the use of menu selections. An overlay in the ASGI concept would each be independent of the other overlays (meaning that each could be selected or deselected independently for display, not that each may or may not affect the other in the modeling itself) and would include:

1. A terrain model overlay.

2. A weather model overlay.

3. A cultural overlay (towns, cities, industrial centers, etc.).

4. A ground transportation network overlay.

5. Lines of communication overlay (two for each team (1) known LOC's for friendlies, (2) perceived LOC's for enemy).

6. A line of advance (LOA) or retrograde overlay (two for each team (1) known LOA's for friendlies, (2) perceived LOA's for enemy).

7. A weapons situational overlay (two for each team (1) known positions and strength for friendlies (2) perceived positions and strength for enemy).

The MMI would allow for the definition and specification of new overlays interactively, whose interaction with the modeling system would be determined by the user. Further discussion of overlays will follow.

7.2 ADVANCED GRAPHICS: ASGI

The concepts of the advanced graphics in the ASGI are closely related to the capabilities of the MMI. Although the MMI allows the user to interact with the graphic functions, it does not define those functions. (We will discuss the graphic capabilities proposed for ASGI in this section.) The advanced graphics capabilities include:

1. High resolution vector graphics.

2. Full color.

3. Light pen.

4. Rapid context switching to include scale change, overlay selection/deselection.

5. Extended line quality features to include vector generation intensity change, blinking, and dash, dashdot, or similar line features.

7.2.1 High resolution graphics allows complex information to be easily displayed and understood by the viewer. Specifically, complex maps with features that might include roads, cities, terrain features via symbols and text must be displayed simultaneously in a gaming environment such as ASGI.

7.2.2 Full color requirements are derived from the ASGI concepts that allow selection/deselection of numerous overlays, many of which might be viewed simultaneously. In this case if only black and white were used, even with intensity selection available, overlays would tend to wash together; and the situational environment on complex maps would become very confusing to the strategist. Full color allows each overlay to receive a user defined color, thereby, clearly defining and separating the overlays that are displayed simultaneously. These colors may also be redefined interactively for particular overlays even while that overlay is being displayed. This might be done in order to accentuate that overlay or to move it further into the background of visual perception.

7.2.3 There are many requirements in the proposed ASGI concept for light pen capabilities. These include requirements for:

1. Selection of menu options displayed by the MMI.

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2. Designation of weapons sytems for a variety of reasons.

3. Selection or alteration of existing routes for weapons systems interactively.

4. Acknowledgement of high priority conditions presented by the ASGI system, i.e., the acknowledgement of engagement commencing for strike delayed or cancelled, etc.

5. Defining user oriented symbols interactively.

6. Defining new or altering existing overlays interactively.

7.2.4 Rapid context switching allows users to select new areas of interest, new combinations of overlays and new viewing scales and to have the requested display as quickly as possible. No estimate is given for response time because response time will vary with the complexity of the display requested and the load on the mainframe at the time the request is made. For the purpose of the ASGI concept "rapid" should be considered to mean less than five (5) seconds for complex displays; although, the computer resource available at the time of any request will determine response. In order to accommodate rapid context switching the ASGI system was designed to give priority to MMI requests and the system allocates CPU resources in order to provide maximum real-time interaction between man and machine.

7.2.5 The extended line quality features referred to in 7.2, Item No. 5 are required by the ASGI system in order to enhance the display abilities of the system over and above the capabilities provided by full color. Whenever the requirement exists to change a pathway for a moving weapons system, the ASGI system should provide a low intensity mask of the existing route for that system. The existing path may also be a dashed line of a selected color to prevent confusion with the background overlays being displayed. Referring to the displayed path, the user may choose to alter only the destination of one or more of the way points along the path; or he may choose to designate a totally new route whose graphic features may again be some new combination of intensity, line quality, etc., in order to differentiate the new path from the old and from the other overlays being displayed. The display, designation, or alteration of routes for weapons systems is used only as an example of the utility of the extended line quality features.

7.3 DATA CONTROLLED SYSTEM: ASGI

The concepts involved in the specification and development of a software system that is controlled by incoming data are well developed. Affecting a change in the operation of a gaming system should require only a change in the "rules" (in this case data) and should not require changes in the software system itself. To accomplish this goal, the proposed ASGI system includes a weapons modeling system that relies only on data to determine either success/failure ratios for possible conflicts or attrition rates for conflicts that occur. The data used is provided by the game participants and from the data bases generated by the game operations personnel. The game participant or gamer would provide a local tactical direction such

as requiring a weapons unit to "dig in" or to camouflage, or the gamer might determine a route that allows the unit to maintain high ground along a route or in some way affect another tactical advantage. These tactical situations would not be limited to ground warfare, but would include any weapons system whose use may be affected by the tactical environment. Another example would be an interdiction mission to be flown against a known Surface to Air Missile Sight (SAM) or any other ground based threat. In this case the gamer might determine both the ingress/egress routes and the tactics to be employed. These tactics might include a choice of low level, medium level, high level ingress and/or egress coupled with type of attack which might include choices such as laser designation, laser guided bombs, conventional weapons using a conventional attack or conventional bombs with curvilinear attack (where the option exists). In each case both the chance of mission success and the probability of friendly weapons system survival are greatly affected by the choice of tactics and routes. To add to the complexity of these problems, there are other situations, the number of which should be arbitrary, that either significantly or marginally affect the outcome of engagements between weapons systems. These include but are not limited to the affects of fire support availability, both organic and temporarily assigned, weather, terrain conditions, communications systems (LOC's), lines of supply, or even soil conditions in the battle area. There is a limit to what is feasible to include in a data base for war game scenarios, but the point is that the ASGI would provide the mechanism both to establish the data in the data base and to provide the algorithim that would account for the factors available in the data base to compute probability of success and any required attrition rates.

7.4   INTERACTIVE SCENARIO ALTERATION: ASGI

Because the proposed ASGI system and its actions are keyed from data that reside in the overlay data files and weapons system files, affecting those data affects the gaming itself. The ASGI concept provides the game supervisors with utilities that use the MMI to allow the alteration of overlay data on-line or weapons data for either or both players on-line. This could be done while the game is being played, thereby creating a dynamically changing gaming situation for the game players. This interaction allows the same scenario to be flexible enough to exercise both the commanders and the established lines of communication for many tactical situations.

7.5   SOFTWARE SYSTEM ARCHITECTURE: ASGI

The ASGI system software architecture design was derived from the philosophies developed in Martin Marietta's own C3 laboratory over the last three years. These philosophies involve a central process known as the Master Executive whose function it is to maintain communications between and execution of a number of dependant tasks. Each of these tasks has a unique function and may communicate with and/or request the execution of any number of other functional tasks through interaction with the Master Executive. One advantage of this approach is that new capabilities may be added to the system by development of new tasks for integration into the software system. Because of the modularity of the system, these new tasks can be integrated with the minimum impact to the existing system. The new task would com-

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municate to the system through the Master Executive and would be able to utilize any system facility that already existed. Communication itself occurs utilizing a standard binary transaction message protocol or a standard character oriented message format. These messages are then passed to the Master Executive for handling. The Master Executive in turn notifies an already executing task of a message pending or even schedules the required task for execution in order to accommodate the message transaction request. Other advantages involve the integration of upgraded versions of existing tasks. Because the only interaction between tasks is that of message traffic that is handled by the Master Executive, the performance of any new or upgraded modules or tasks can be monitored by examination of the critical message traffic. Problems in any new or modified software can be quickly identified and exhaustive testing can be accomplished minimizing the time required in the testing phases.

Another advantage to the proposed ASGI design concept is that the system is a top down design that can easily be moved into a multi-processor or network environment where the Master Executive would reside in more than one CPU. The Centralized Communications Buffer could be moved to shared memory or without shared memory, machines may be networked by utilizing the capabilities of vendor network operation systems. If both of the previous options were not feasible, special purpose communications drivers could be written to update the centralized communications buffer in any CPU to reflect message traffic occurring between tasks regardless of where that task might be executing.

7.6 TASKS WITHIN THE ASGI

Following is a discussion of the function of each task in the proposed ASGI. This includes a discussion of the interaction between tasks. For clarity tasks will also be referred to by their alpha-numeric designations as shown on the functional system diagram in Figure 6.

1. The Master Executive-A0 or (B0)

    The Master Executive or in the case of a second CPU, the Calculator Processor Master Executive, controls the execution of all tasks within the system. Moreover, the Master Executive notifies executing tasks of messages in queue for that task and receives notification of messages from executing tasks that need to be processed. The Master Executive schedules tasks for execution for reasons other than message handling. The Master Executive also executes the Simulated Clock Manager (A6) upon interrupt from the hardware system clock when resources are available. For each occurrance of the simulated unit time, the Master Executive schedules the Scenario Event Manager (A2). The simulated unit time is not necessarily the same as the hardware system clock. If the Simulated Clock Manager notifies the Master Executive to schedule the next execution of the Scenario Event Manager (A2) before the last execution is completed, then simulated time will be deferred to allow completion of the last event series.

2. The Event Sequence Manager - A1

The main function of the Event Sequence Manager is that of initiation of user and/or operation requested events. These events may be the launch of a reconnaissance or air strike sortie or the destruction of a key bridge at a time specified by the operations personnel in order to affect the tactical situation. One of the actions that is scheduled through the Event Sequence Manager is that of recording the existing scenario environment. Because of this function the Event Sequence Manager can also be thought of as a situational camera system whose job it is to save all pertinent event data necessary to "replay" the scenario from that simulation time. In the process of reviewing any game played, the Event Sequence Manager can also play through the situations saved in any requested order, designated by simulation time. This provides the system the maximum flexibility to assist in the educational process. Although the Event Sequence Manager does maintain event tables, the historical data is managed through interaction with the Event Files Access Manager (A3).

3. The Scenario Event Manager - A2

All key model events are maintained by the Scenario Event Manager. The job is not only that of determining that an event has occurred, such as two weapons systems becoming engaged, but maintaining engagement status of weapons systems and requesting the activation of the Probability of Success/Attrition Model Manager (B2) and passing the required data for attrition computation through interaction with the Master Executive and the use of the Centralized Communications Buffer. For all weapons systems, moving or not, the Scenario Event Manager maintains a Track Status File. The Scenario Event Manager also requests service from the Track Performance Modeling Manager for all moving weapons units to compute new positional data for each.

4. Event File Access Manager - A3

All direct data base access is performed by the Event Files Access Manager. This process maintains a scenario data file, a master scenario data file and a history file. Any process within the ASGI system can request data from the Event Files Access Manager or request storage of new data into either the scenario file or the history file. The master scenario data file is the starting point for the scenario itself. The scenario file is used by the system as the dynamic model and may be updated by any process within the system.

5. Card/Interactive Input Manager - A4

All non-graphic terminals and card inputs are received for system dissemination by the Card/Interactive Input Manager. In the case where particular overlays such as terrain, transportation, or cultural models require input for generation of a new scenario or the interactive editing of existing data, the Card/Interactive Input Manager communicates through the Master Executive (A0) to the Event Files Access Manager in order to effect the scenario master file. Any weapons data that is not graphic in nature can be edited or entered via interactive terminals through this process.

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6. Display File Creation Manager - A5

The Display File Creation Manager is a key element in the man-machine
interface. This process allows the user to create new displays by in-
dicating desired display scales, formats, overlays, color and intensity
schemes, symbol usage, etc. These designated displays may be specified
and the criteria saved either temporarily or permanently for later use.
The Display File Creation Manager interacts extensively with the Graphics
I/O Manager in order to complete the graphics portion of the man-machine
interface.

7. Simulation Clock Manager - A6

The Simulation Clock Manager is a task that determines the rate at which
the simulation will run. Simulation time may be slowed or even stopped;
or simulation time may be accelerated to speeds limited only by the CPU
resource availability. The limit to how fast a simulation can occur is
directly proportional to the computer resource available and inversely
proportional to the complexity of the simulated scenario. The simulated
time can be changed by gaming operations personnel through communications
originating from the Post Test/On-Line Support Manager. No consideration
has been given to running the Simulation Clock Manager backwards in time
since the facility to snapshot the dynamic system at any time has been
provided.

8. Graphics I/O Manager - A7

The Graphics I/O Manager maintains communication with the Display File
Creation Manager through the use of the binary message protocol. The
speed of communication between the Graphics I/O Manager and the Display
File Creation Manager (A5) is critical in order to assure quick responses
to display requests from the viewers. All graphic displays are routed
through the Graphics I/O Manager. Change requests such as color, inten-
sity, scale (where data is local) and menu changes are made internal to
the Graphics I/O Manager, but any other requests will require further
inter-task communications.

9. Radar Simulation Manager - B1

Radar is one of the critical tools in modern warfare. There are many
types of radar. Some are used for target acquisition, others for track-
ing or ranging. The Radar Simulation Manager will have the capability to
determine when or if a target can be sighted and tracked for any given
radar capability and target return characteristics. The model will by
necessity be somewhat simplistic in nature in order to simulate any
radar. The Radar Simulation Model Manager will provide each player with
a view of the "as Received" aerial warfare model to assist in decision
making. Additional capabilities include limited simulation of acquisi-
tion radars that may be airborne in weapons systems of either team. In
this case the Scenario Event Driver (A2) would request target acquisi-
tion probabilities of a known target from the Radar Simulation Manager.
Relative altitudes of the airborne systems would be provided along with
weapon types and radar types. After computation of the acquisition

probabilities, the Radar Simulation Model would return results to the Scenario Event Manager (A2).

10. Probability of Success/Attrition Model Manager - B2

The Probability of Success/Attrition Model Manager calculates either probability of success for engagements in the perceived or in the real warfare models. In the case of a request for a calculation of the probability of success from a gaming participant, it is the gamer's responsibility to obtain intelligence about the position, strength and type of opponent forces. Because calculations are done using his perceived model, the commander will receive proper results from those calculations only if his perceived model is equivalent to the real model in the area local to the calculations. Attrition rates are always based on the real models of the scenario. The methodology used in these calculations of attrition will be discussed later in this report.

11. Message Queue Manager - B3

The Message Queue Manager queues messages and time tagged events associated with message traffic occurring on the centralized communications buffer. This process works closely with the Master Executive to manage the centralized communications buffer, which is, in fact, a dynamic region whose size is determined by the Message Queue Manager. Using the traffic activity rate to calculate resource required, the Message Queue Manager either allocates or deallocates space as needed to maintain the efficiency of the centralized message buffer.

12. Track Performance Modeling Manager - B4

Any moving system has mobile characteristics that might include the ability to maneuver, travel within particular speed ranges or travel over or through rough terrain. The Track Performance Modeling Manager is activated by request from the Scenario Event Manager (A2) to provide the updated position of every weapons unit given its present speed and direction, desired speed and direction and the weapons system type. New positions, new headings and speeds are calculated using data determined by the weapons characteristic file that is accessed by the Track Performance Modeling Manager. The new data is returned to the Scenario Event Manager (A2) after computation.

13. Positional Transformation Manager - B5

The Positional Transformation Manager is used to establish new coordinate transformations at simulator time for each dynamic overlay within the gaming model. Moving models are those that have characteristics similar to the weather model overlay. These overlays act like moving units that may translate and rotate across the terrain overlay model. Moving overlay models that would depend on the weather model (winds) include overlays for determination of affected areas in nuclear, nerve gas or biological warfare confrontations. The Positional Transformation Model Manager provides the ability to move these overlays over the terrain model to simulate moving weather or to establish threat from nuclear or other weather dependent weapons systems.

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14. Intelligence/Reconnaissance Model Manager - B6

The Event Files Access Manager maintains a file named the Scenario File. This file contains a complex set of data including, among other things, a perceived situational model for the Blue team of Red team positions and weapons strengths, a perceived situational model for the Red team of the Blue team positions and weapons strengths and an actual model of Red and Blue positions and weapons strengths. It is the responsibility of the commanders of each team to assure proper reconnaissance so that the perceived models are updated to the greatest extent possible in order to assure reliable information upon which to base command decisions. Whenever an intelligence gathering vehicle is active, the Scenario Event Manager requests activation of the Intelligence/Reconnaissance Model Manager to determine if that vehicle has detected an enemy position. This process first determines if the intelligence vehicle has the capability to detect the specific weapons system, given the sensors available to that vehicle. Then, if detection can occur, a calculation is made to determine if detection did occur. If detection was made, then the process continues by determining what intelligence was gathered given the sensors used. The Intelligence/Reconnaissance Modeling Manager notifies the Scenario Event Manager of any intelligence gathered for the sighting. Thus, the perceived adversary models for each team are updated.

15. Interactive Scenario/Overlay Modification Manager - B7

While the game is in progress, the game operations personnel can activate the Interactive Scenario/Overlay Modification Manager. This process provides the ability to update or change any data used by the ASGI in determining model activities. This includes all overlays, weapons systems characteristics and moving model speeds or rates of rotation. This process is operated either through the Graphics I/O Manager (A7) or through the Card/Interactive Input Manager (A4). Where map data must be affected, the updates must take place through the Graphics I/O Manager (A7). All other types of updates can be affected through either a graphics station or a character oriented interactive station.

16. Post Test/On-Line Support Manager - B8

The Post Test/On-Line Support Manager provides the tools for system resource monitoring by the operations technicians. From this process the status of CPU resource and status of mass storage devices is monitored. System changes can be made if necessary during game play to prevent overflow of open-ended files such as the Event Files Access Manager's history file. After the game has been terminated, the Post Test/On-Line Support Manager can produce user related reports of the battle situations at the intervals saved on the history file and can produce parallel system reports for operations purposes. These reports are statistical in nature and indicate player performance and effectiveness according to methods not yet determined.
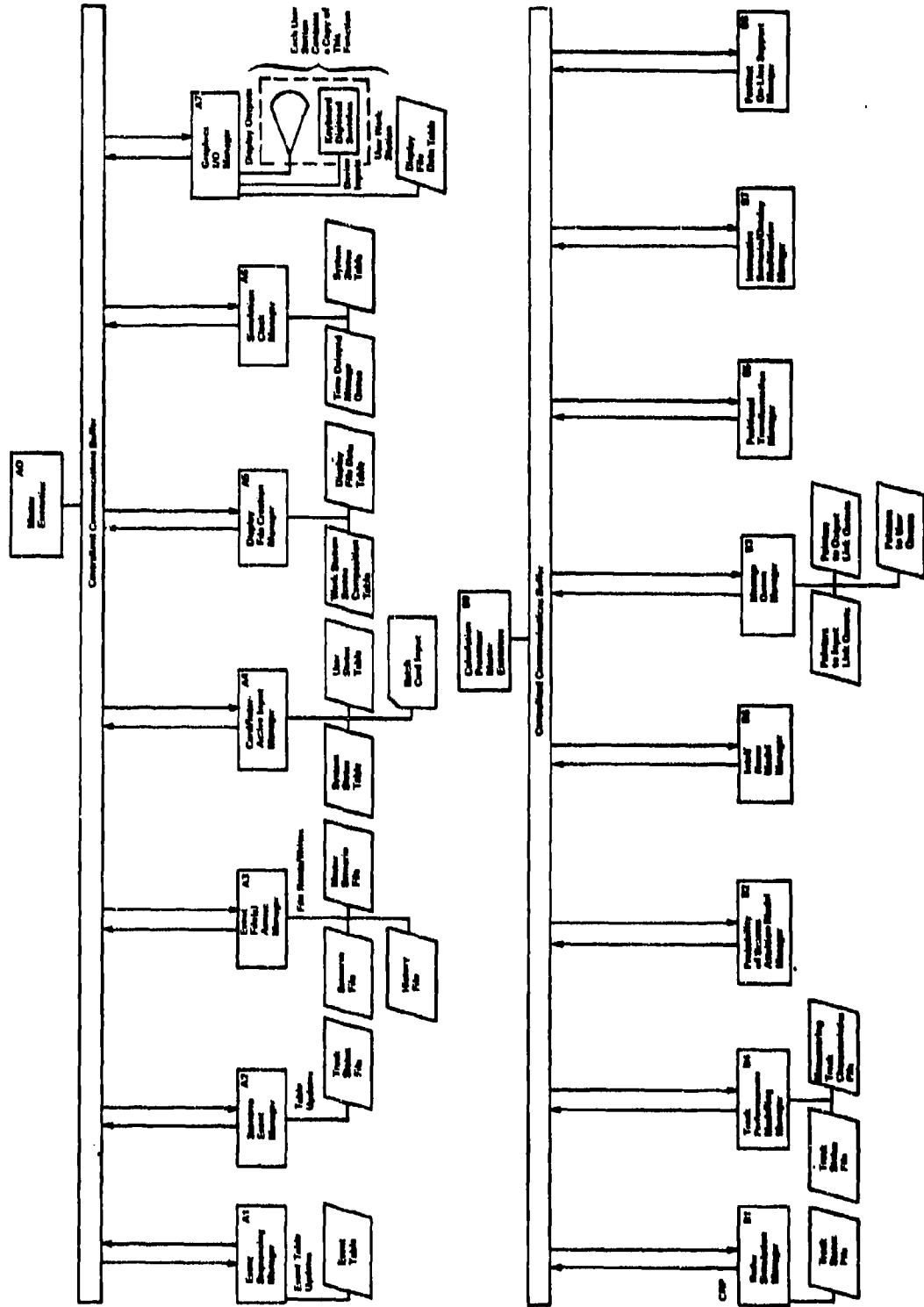
ASGI Application Software Architecture

Figure 6

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7.7 ASGI PLAYER/COMPUTER INTERACTION

Figure 7 illustrates a typical ASGI concept of player/computer interaction. The symbols for ground units are typical of those generally in use and the colors used will be blue or red to indicate team. Their positions are updated to reflect true positions at simulator time. In the case of either blue or red team displays, however, the scene will reflect only the perceived environment according to what intelligence each has gathered. Additional features such as cultural overlays or transportation overlays are incorporated on demand (see Figures 7a, 7b). These features will be available from menu selections via the lightpen or keyboard input at the user's option. Any overlay within the system will be available for immediate callup. As previously mentioned, any of these overlays can be individually addressed and their colors and/or intensity changed and those criteria saved for later use in the same display or for displays of other areas.

As play progresses in the ASGI concept, commanders can specify lines of advance for his units and interactively request from the computer probability of success computed for contemplated engagements. The commander may also issue orders to units to maintain high ground or dig in or indicate some other tactical option for that unit. When the option does not already exist in the data base, the ASGI system will query the operations personnel to either provide the necessary data for computing probability of success and attrition rates against units most likely to be engaged; or if the decision is made not to allow the request of the commander, a message, selected or written by the operations personnel will indicate non-compliance.

The intelligence model and the air warfare model (air to air and air to ground) are separate overlays that interact with the ground model. The air to air model will in turn interact with the air to ground model. A commander may request intelligence sorties displayed on the ground model map. The overlay would indicate routes of flight and times for the route way points (see Figure 8). The commander can alter these at will. The ASGI assumes communication availability according to the communications model within the data base. If the communications model allows the indicated sorties to be affected, then the new routes and/or times will be complied with. If not, the flight would be flown as previously scheduled.

Although most flights are scheduled, some user specified resources sit alert with ordinance loaded as per commander's request. The scenario may include an air environment preplanned, but any resource may be rescheduled or planned weapons loadings may be altered by the commanders. Naturally, commanders may alter planned routes or weapons loads only for sorties directly under their control. In order to affect other changes, he must exercise the communications of the game to request changes of the proper commanders.

The ASGI concept of player/computer interaction is that of a completely dynamic system with any overlay easily selectable for immediate viewing. The scene represents the present simulator time perceived picture with easily understood symbols whose positions represent the positions of the units in question. The user may request further information about any unit by indicating a unit with a light pen and pointing to a menu option that requests

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UNIT	TYPE	AR	DIS
FORCE = RED			
A	WB	.15	300
B	WB	.15	12
C	RB	.01	100
D	MRB	2.00	100
E	ABB	.04	24

UNIT	TYPE	AR	DIS
FORCE = BLUE			
A	WB	.06	100
B	WB	.10	14
C	WB	.01	18
D	HAB	.16	22
E	HAB	.98	300

SUPPORT MENU

Air Sorties
Naval Battery
Logistics
Medical
RECCE
Artillery
Return

| BKGRD | OVL | SCEN | SAVDPL | B | N | F | 14:35:23 | DDB | RUN | FREEZE |

COMMAND LEVEL = BATTALION
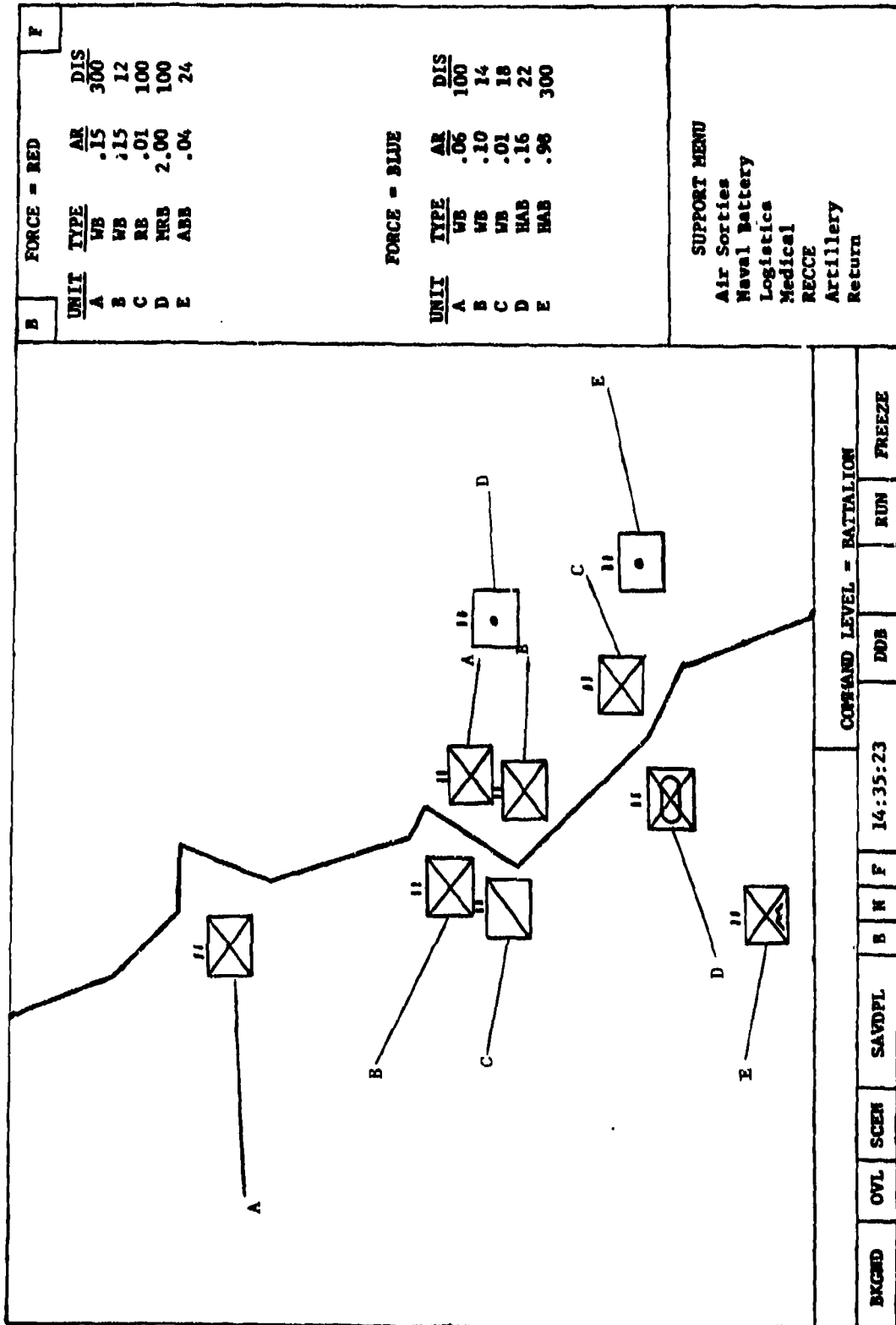
FIGURE 7 ASGI CONCEPT DISPLAY: TROOP MOMENTA AT THE FEBA

FORCE = RED

UNIT	TYPE	AR	DIS
A	WB	.15	300
B	WB	.15	12
C	RB	.01	100
D	MRB	2.00	100
E	ABB	.04	24

FORCE = BLUE

UNIT	TYPE	AR	DIS
A	WB	.06	100
B	WB	.10	14
C	WB	.01	18
D	HAB	.16	22
E	HAB	.98	300

SUPPORT MENU

Air Sorties
Naval Battery
Logistics
Medical
RECCE
Artillery
Return

KEYVILLE

OIL REFINERY

SUPPLY

OVLY=CULTURAL

| BKGRD | OVL | SCEN | SAVDPL | B | N | F | 14:35:23 | DDS | RUN | FREEZE |

COMMAND LEVEL = BATTALION
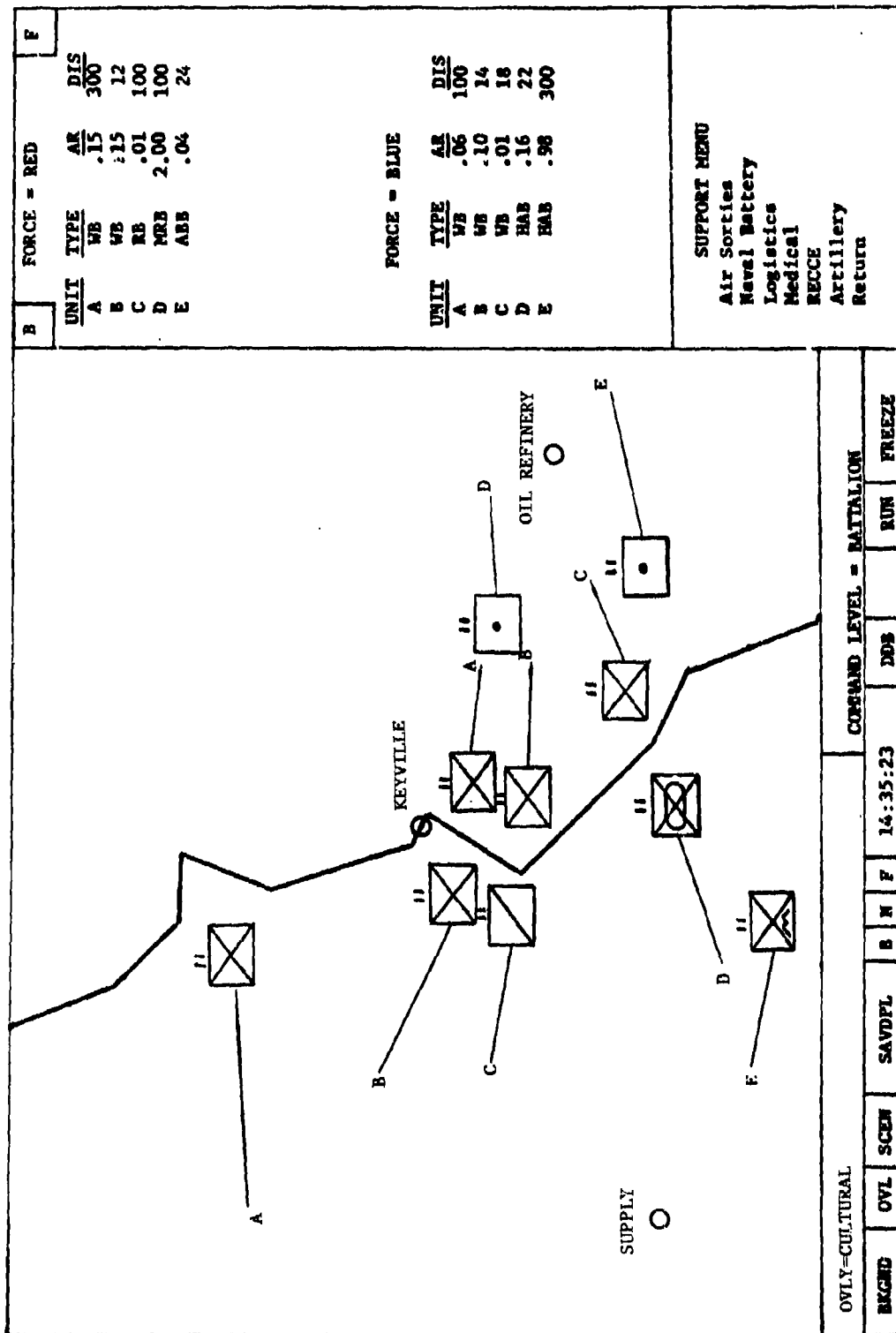
Figure 7a   ASCI CONCEPT DISPLAY: TROOP MOVEMENTS AT THE FEBA

FORCE = RED

UNIT	TYPE	AR	DIS
A	WB	.15	300
B	WB	.15	12
C	RB	.01	100
D	MRB	2.00	100
E	ABB	.04	24

FORCE = BLUE

UNIT	TYPE	AR	DIS
A	WB	.06	100
B	WB	.10	14
C	WB	.01	18
D	HAB	.16	22
E	HAB	.98	300

SUPPORT MENU

Air Sorties
Naval Battery
Logistics
Medical
RECCE
Artillery
Return

OVLY=TRANSPORTATION

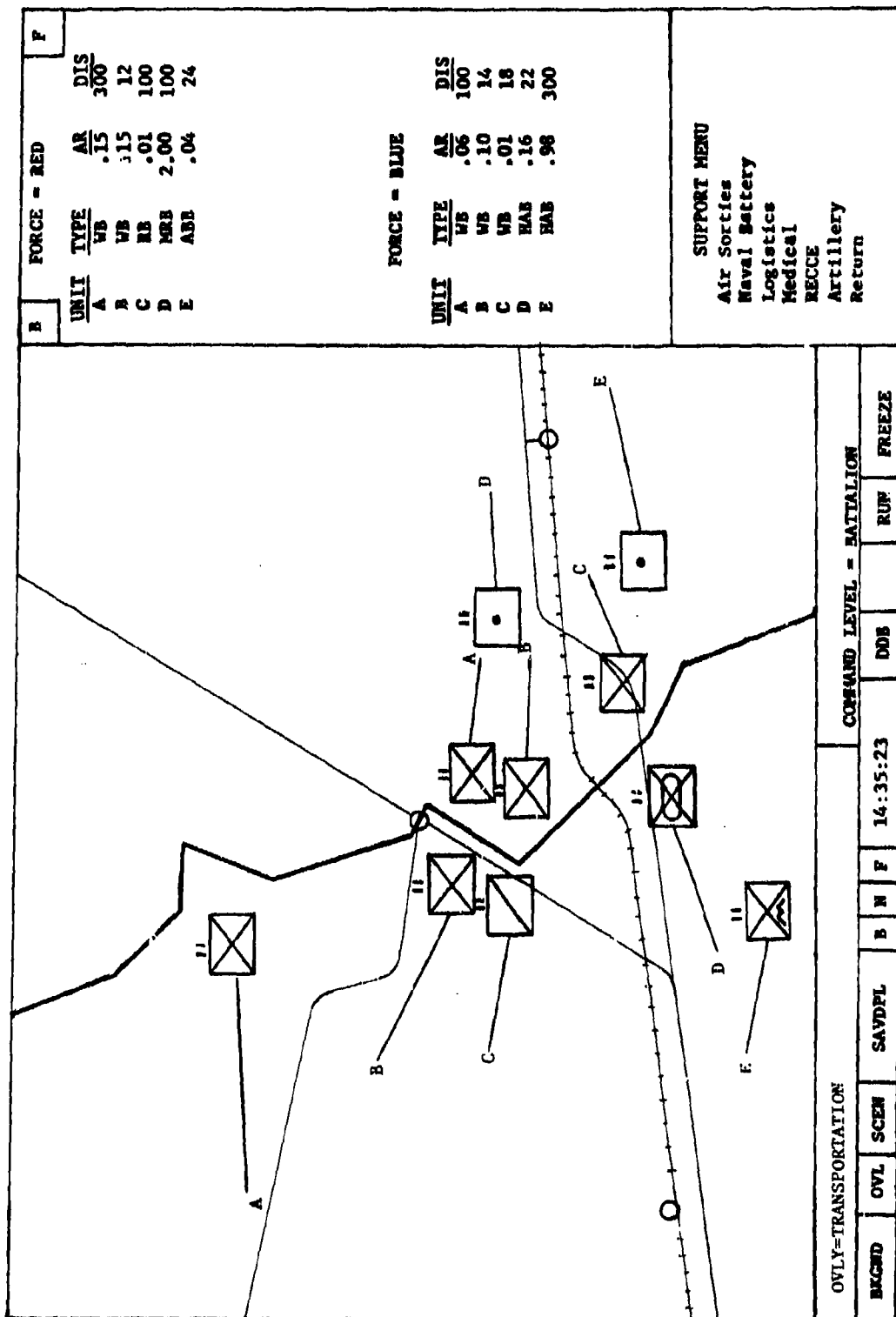| BKGRD | OVL | SCEN | SAVDPL | B | N | F | 14:35:23 | COMMAND LEVEL = BATTALION | DDB | RUN | FREEZE |

Figure 7b   ASGI CONCEPT DISPLAY: TROOP MOMENTA AT THE FEBA

Figure 8 ASGI CONCEPT DISPLAY; TROOP MOMENTA AT THE FEBA

32.
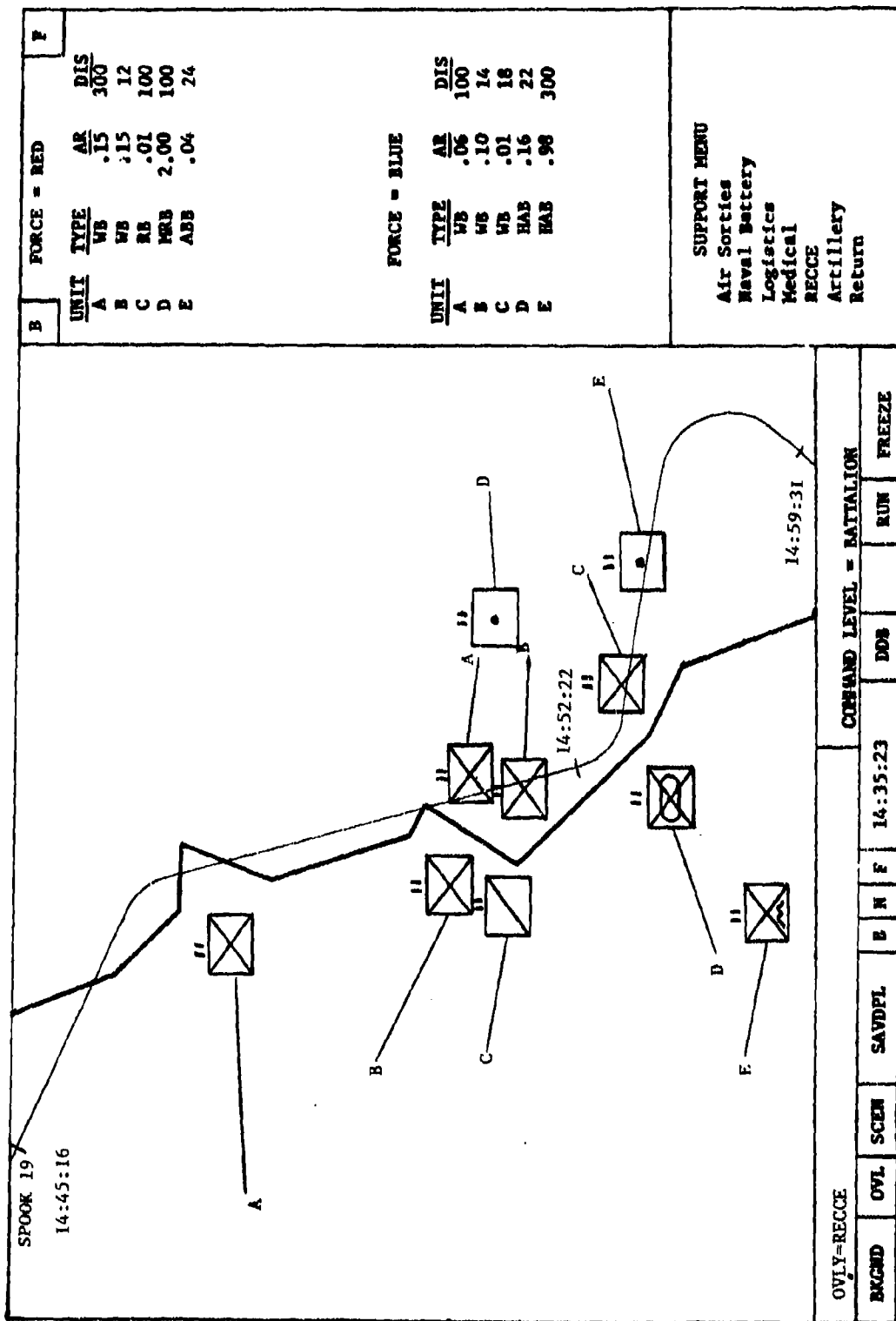
unit strength. In the menu box will appear the unit strength, weapons available, percent attrition inflicted, and weapons units in support.

7.8 ASGI GAME OPERATIONS AREAS

The proposed ASGI system would support five operations areas for gaming scenarios. These are:

1. Ground
2. Air
3. Naval
4. Strategic
5. Combined

The incorporation of these areas is a matter of including the desired overlays to the ground model for gaming. Where TALON allows ground and ground/air support operations only, ASGI would offer a greatly enhanced capability to simulate war scenarios. The communications environment can be specified to realistically portray any combined operations desired.

7.9 ASGI GAME COMMAND LEVELS

The ASGI would employ five (5) levels of command:

1. Divisional
2. Regimental
3. Battalion
4. Company
5. Combined

Gaming scenario generation to the company level gives an ASGI system the versatility to simulate a wide range of military exercises.

7.10 GROUND COMBAT OPERATIONS: ASGI

The ASGI ground combat operations works with each individual weapons system moving within their respective overlays. Eminent conflict is defined when the areas controlled by adversary units begin to come into contact. When contact occurs, the Probability of Success/Attrition Model Manager Task queries the weapons data base for the variables used to compute attrition. To understand this calculation, the data contained within the data base must be examined.

The data in the weapons data base is similar to a multi-layered two dimensional table with every weapons system contained in both row and column (see Figure 9). If an aircraft is engaging a ground target, for example, then the appropriate factor is retrieved for that engagement in the given environment. That figure is used in the attrition calculation. Weapons systems themselves are not equivalenced to some common weapons unit strength as in TALON. This lends realism to the gaming environment where a tank may be easy prey to an A-10 aircraft, but the A-10 aircraft might not be able to cope with a quad-23mm gun that is camouflaged. The quad-23mm gun, however, may be no match for a large tank, thus completing the triangle.

EXAMPLE OF WEAPONS TABLES

RED TEAM WEAPONS

BLUE TEAM WEAPONS	A-10 Aircraft	M-1 Tank
Quad-23mm w/ radar ranging	120	62
T-62 Tank	48	104

Example of four weapons table entrys Range of values= 1 to 200, the total numbers range= 0 to 255, 0 and 201-255 reserved for special purposes.

Conditions= weather=clear;terrain= rolling hills; Blue tactical condition= dug in; Red tactical condition= moving.

NOTE: Each change in tactical condition brings up a new two dimensional table.

Figure 9

34

The algorithm for computing attrition and probability of success has not been developed. The equations would be alterable by operations personnel without software changes. One of the inputs proposed for the Post Test/On-line Support Manager is the attrition and probability of success equations to be used by the Probability of Success/Attrition Model Manager Task. This feature will allow interactive empirical testing of new equations.

7.11 AIR RECONNAISSANCE OPERATIONS: ASGI

All air reconnaissance missions must be scheduled. The schedules generally would be provided in the preplanned scenario including routes and flight times. These would be set up much as any reconnaissance profile with commanders altering flight times and/or routes of flight to best gather the necessary intelligence.

Intelligence gathered would be determined by the Intelligence/Reconnaissance Model Manager Task. Factors involved in this determination would include data concerning:

- o Weather conditions
- o Terrain in the surveillance window
- o Type of aircraft used
- o Surveillance altitude
- o Sensor types carried
- o Aircraft radar signature
- o Intercept avoidability
- o ECM capability

These factors would not only determine what intelligence was gathered, but also be used to determine if the aircraft involved would survive, considering route of flight and threats. The intelligence gathered, assuming that the information is recovered, is used to update the perceived situation for the team commanders.

7.12 AIR SUPPORT OPERATIONS: ASGI

All ASGI's air operations are assigned as sorties. The scheduling of sortie resources is totally in the hands of the gaming commanders. Types of sorties are:

- o Air to Air (CAP)
- o Close Air Support (CAS)
- o Forward Air Observation for naval fire support (FAO)
- o Forward Air Controller for Close Air Support (FAC)
- o Air Lift Assault, Helicopter (ALAH)
- o Air Lift Supply/Re-supply (ALS)
- o Air Lift Medivac (ALM).

For each of the above the scenario would specify the following:

- o The number of aircraft available
- o Location of airfields and the type(s) of support offered by each
- o Maximum effective operating ranges for types of aircraft from specified airfields.

Figure 10 illustrates a typical menu for ASGI air operations selection. After a selection is made, the item is entered into the schedule for the Scenario Event Manager in order to activate the planned route of flight at the appropriate simulation time.

Close Air Support occurs within specified areas of the environment. In order to have close air support operations, either an airborne FAC or a ground FAC must be available to control the air strike. This is a case where the Rules of Engagement (ROE) must be considered. Other operations affected by ROE are any Air to Air confrontations and any airlift operations. The rules of engagement determine capabilities of weapons systems and support systems to operate. These rules may be entirely different for each team.

Any of these air operations are affected by:

   o Weather conditions and terrain
   o Actual target air defense capabilities
   o Suspected vs actual enemy positions
   o Air intercept capabilities of enemy fighters.

The air missions can result in failure from any adverse condition, including in-flight mechanical problems, resulting in mission aborts. In the case of multiple ship flights, escorts are provided for aborting aircraft according to the rules set up in the ROE.

Attrition for engagements are calculated by the Probability of Success/ Attrition Model Manager Task using the data in the weapons data base. In the air to ground engagements, the tactics employed by the air and ground units are considered in these calculations. Where a one pass attack is specified for aircraft against a ground target, the chance for aircraft survival is maximized. The ground target itself would sustain minimal damage also. Conversely, in an attack with multiple passes, both the attrition rate for aircraft and the weapons systems under attack are greatly affected, assuming the ground system offers some threat to the aircraft. The munitions carried by the aircraft will also determine how effective each pass is in destroying enemy capabilities. Again, the attrition formulae are not developed, but will be interactively specified to the Attrition Model Manager by use of the Post Test/On-line Support Manager.

The TALON system, in comparison, is "hard coded", meaning that any change in the attrition or probability of success formulae must be re-programmed by software systems or applications personnel. In addition, all weapons systems are equivalenced to some common weapons unit, limiting the ability to define complex weapons capabilities. Although the TALON model accounts for the tactical situation, the flexability of tactical situation specification in the ASGI system along with the complete freedom of defining weapons system capabilities against any other weapons system provides the ability to realistically portray the interactions of complex war scenario situations.

7.13 NAVAL OPERATIONS: ASGI

Naval operations in the proposed ASGI system are an extension of the type of weapons modeling already discussed for ground and air operations. The dif-

CLOSE AIR SUPPORT - PAGE 1

AIRCRAFT	AVAILABILITY	ORDINANCE	FLIGHT	ASSIGNMENT
1. F4J	15	HE,NP	2	ALPHA
2. A8V8	10	HE	4	ZULU
3. A10	10	30 MM	4	MIKE
4. F14	25	HE,NP	10	OMEGA
5. UH1J	19	ARW, 40 MM	2	LIMA
6. OV10	21	WP, LAW	1	LIMA
7. OV10	21	WP, LAW	2	OMEGA
8. OV10	21	WP, LAW	1	ALPHA
9. -				
10.				
11.				
12.				

F

ORDINANCE

HE
WP
NP
HEI
20 MM
30 MM
40 MM
LAW
ZR5
BP5

B

SORTIES

CAS
FAO
ALAH
AIAP
ALS
ALM

RETURN

CLOSE AIR SUPPORT SELECTED, ENTER 12 MISSIONS THIS PG | COMMAND LEVEL = BATTALION

| B | N | F | 00:00:00 |

| BKGND | GVL | SCEN | SAVDPL | DDB | RUN | FREEZE |

FIGURE 10 ASGI AIR SORTIE OPERATIONS MENU (TYPICAL)

37.

ference between ground based and naval based air operations is that the
naval based air operations moves with the aircraft carrier. The other
naval weapons capabilities include missile and gun weapons systems. As in
the ground weapons systems, all naval weapons capabilities are defined in
the weapons data base such that any new resource can be defined in terms of
the other weapons systems and by the tactical situations in which they can
be employed. For an individual ship in a task force, capabilities would
include radar acquision and tracking, gun and missile ranges, speed range
for the ship itself and its manuevering characteristics. Any naval based
weapons system could operate in support of ground based units limited by
the ranges of the various weapons available for naval use. This capability
of combined operations is constrained by the lines of communication (LOC's)
and the rules of engagement model in addition to the physical geographic
model depicting sea/land topography.

A typical naval combat gaming situation is illustrated in Figure 11. In
this case the weapons unit is made up of a task force, each with air, mis-
sile and gun capabilities. As in the ground environment, symbols from the
standard symbol library or symbols generated interactively by operations
personnel or users represent weapons platforms in appropriate colors. The
display itself is dynamic and represents actual or in the case of
intelligence dependent displays for the team commanders the perceived
locations at simulator time. Like the ground environment, commanders
schedule air sorties for intelligence, defense and attack, along with
determining movements of the ships that make up the task force. Factors
for calculating probability of success and/or attrition are identical in
nature to any other weapons systems.

7.14   STRATEGIC OPERATIONS: ASGI

The area of strategic operations differs from any other discussed thus far
in three (3) areas:

1) The rules of engagement are separate from those mentioned earlier
   and are stringent in nature, limiting commander's options.
2) The weapons systems themselves have little or no flexibility
   once launch has occurred and these launches are generally not
   scheduled, but are options available for reaction to the perceived
   strategic situation.
3) The lines of communications are generally not the same as those
   used for conventional welfare.

These three conditions require that the rules of engagement be defined
for the strategic environment, that the lines of communication, when
different from the conventional LOC's, be defined for the environment. The
fact that the weapons systems cannot be retargeted after launch only
restricts the commander's options and requires only an entry to indicate
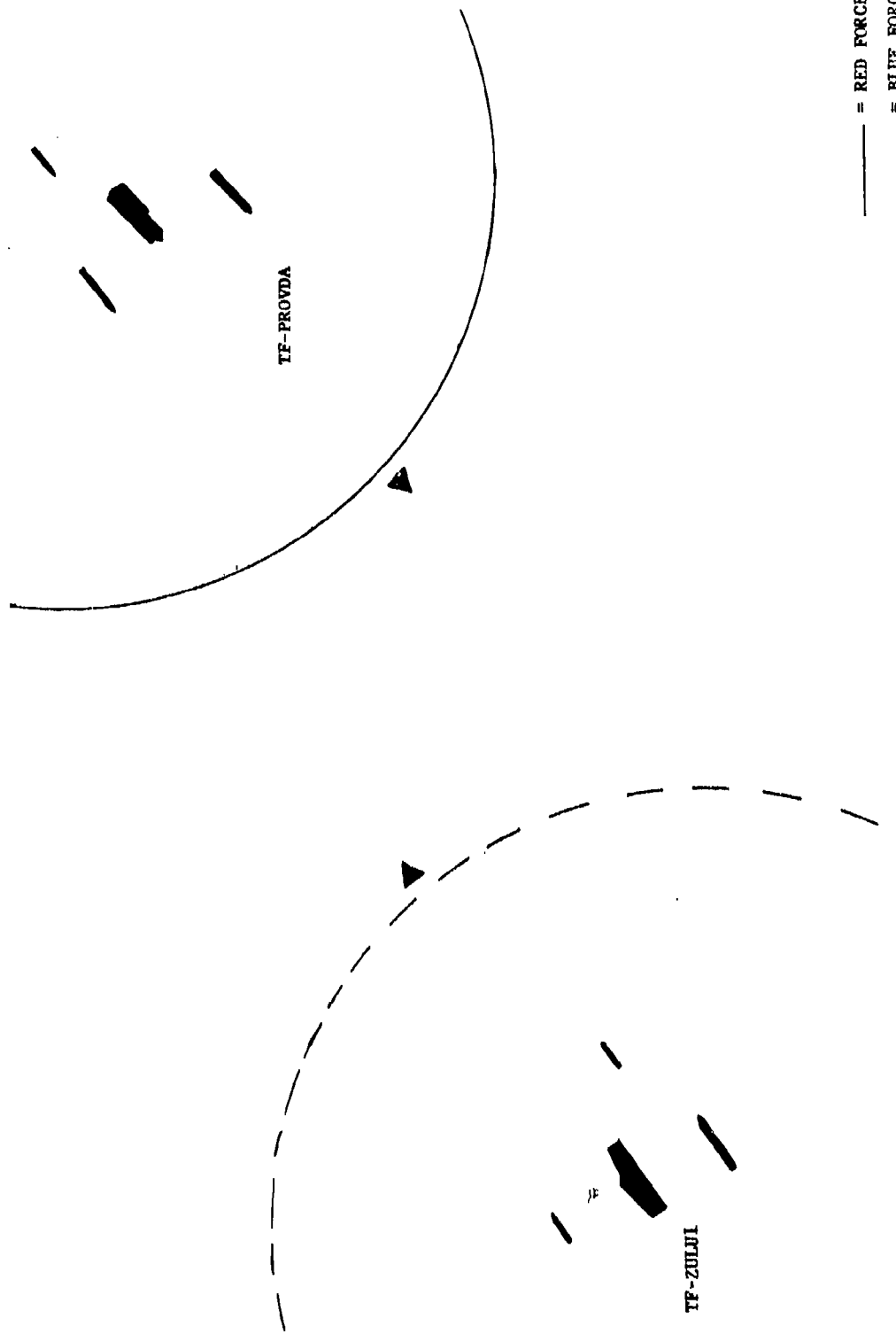this limitation at weapons definition time.

TF-PROVDA

TF-ZULU1

= RED FORCE
= BLUE FORCE

FIGURE 11 ASGI CONCEPT: NAVAL COMBAT GAMING TASK FORCE CONTROL ZONES

39.

7.15 COST, SCHEDULE AND MANPOWER REQUIREMENTS: ASGI

In order to estimate the cost of this software system, a preliminary design was derived from the goals presented earlier. The software Martin Marietta has developed over the last three years in its own Command, Control and Communications laboratory was used as a basis for software estimates to minimize estimating risks. The software developed to date is estimated to provide 29% of the total software needed for the ASGI system. To some degree, this code must be modified to accommodate all the capabilities necessary to accomplish the ASGI derived requirements.

7.15.1 COST: ASGI

The cost of software development for the proposed ASGI system was estimated using development models which include three phases. Each of the phases in turn are separated as shown in Figure 12a. Martin Marietta has established a software development model to help estimate the cost of software for each phase in the development cycle. Some of the factors accounted for in the model include complexity factors, high level code vs assembler code, and system software vs applications software. The cost of the software is cross checked by developing a bottoms up engineers cost estimate and balancing that against a top down designed software model that is used to estimate lines of code. The result of this estimating procedure is shown in Figure 12b. These costs are broken down by task, each of which is divided into new lines of code and modified lines used from Martin Marietta's C3 software. Totals for the entire system are presented in Figure 12d. This cost represents only software development. If the project was supported by Martin Marietta for computer time, assuming 33% of development time spent at a terminal On-line and one hour of hook-up time costing $10.00 per hour, the computer bill would be approximately $360,000.00. This computer estimate uses current rates charged for the VAX 11/780 at the Central Software Engineering Facility at the Waterton Facility of Martin Marietta, Denver Aerospace.

7.15.2 SCHEDULE AND MANPOWER: ASGI

The optimum manning of the software effort for the as proposed ASGI system would require 27 months of effort. This includes all phases of the software development cycle. Manning itself is presented in Figure 12e. Scheduling the project for more or less than the specified 27 months would result in a more expensive development effort.

7.16 IMPORTANT FEATURES: ASGI

The proposed ASGI concept is a modular software system that maximizes on-line man-machine interaction to both game players and to operations personnel. The function of building scenario's can be done interactively by operations personnel, though some functions, such as terrain model and weather model specification and weapons system definition, cannot be appreciably affected by an advanced interactive input process. These data are complex and will consequently be labor intensive for input in any environment. At some point, technology may automate the process of digitizing complex terrain and weather data into a data base, at which time that facility could be added to the ASGI.

Phase and Subphase of Software Development

Requirements			Design			Test				Operational and Maintenance Phase
Sys Reqts	Sys Alloca-tion	S/W Reqt	Prel Design	Detail Design	Code	Check-out	Unit	Integra-tion PQT/FQT	System	

SPR SRR SDR PDR CDR TRR FCA PCA FQR
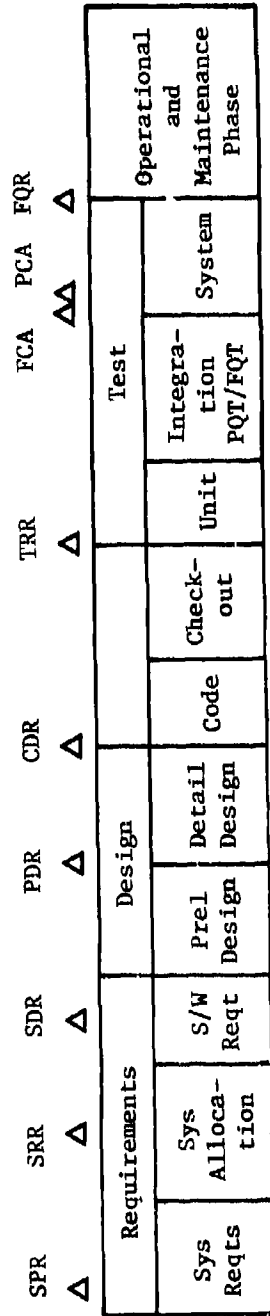
SPR — Sys Planning Review
SRR — Systems Reqts Review
SDR — Systems Design Review
PDR — Preliminary Design Review
CDR — Critical Design Review
TRR — Test Readiness Review

FCA — Functional Configuration Audit
PCA — Physical Configuration Audit
FQR — Formal Qualification Review
PQT — Preliminary Qualification Test
FQT — Formal Qualification Test

Figure 12a

41.

	New Code	Mod Code	Source LOC Total	Hrs.	M/M
A0 Master Executive (HOL) (Mos. for S/W Dev. 6.5 Mos.)	500	800	1300	2475	15
A1 Event Sequencing Manager (HOL) (Mos. for S/W Dev. 7.0 Mos.)	650	1000	1650	2875	17
A2 Scenario Event Manager (HOL) (Mos. for S/W Dev. 7.0 Mos.)	1030	450	1480	2823	17
A3 Event File Access Manager (HOL) (Mos. for S/W Dev. 4.0 Mos.)	200	800	1000	1050	6
A4 CARD Interactive Input Manager (HOL) (Mos. for S/W Dev. 13.0 Mos.)	7850	4900	12,750	18,026	109
A5 Display File Creation Mgr.(HOL) (Mos. for S/W Dev. 8.0 Mos.)	1000	3250	4250	5250	32
A6 Simulation Clock Manager (HOL) (Mos. for S/W Dev. 1.0 Mo.)	0	200	200	175	1
A7 Graphic I/O Manager (HOL) (Mos. for S/W Dev. 6.0 Mos.)	200	1550	1750	2194	13

	New Code	Mod Code	Source LOC Total	Hrs.	M/M
(Mos. for S/W Dev. 16.0 Mos.)	11,430 (47%)	12,950 (53%)	24,380	34,868	210

$$\frac{34868}{24380} = 1.43 \text{ Hrs. per LOC}$$

35
‾‾‾‾‾

$1,220,380

FIGURE 12b

	New Code	Mod Code	Source LOC Total	Hrs.	M/M
B1 Radar Simulation Manager (HOL) (Mos. for S/W Dev. 15.0 Mos.)	14,400	0	14,400	36,000	217
B2 Probability of Success/ Attrition Model Management(HOL) (Mos. for S/W Dev. 5.0 Mos.)	600	0	600	1,050	6
B3 Message Queue Manager (HOL) (Mos. for S/W Dev. 11.0 Mos.)	5,500	600	6,100	10,150	61
B4 Track Performance Modeling Manager (HOL) (Mos. for S/W Dev. 6.0 Mos.)	800	800	1,600	2,100	13
B5 Positional Transformation Manager (HOL) (Mos. for S/W Dev. 7.5 Mos.)	1,500	0	1,500	2,625	16
B6 Intelligence/Recon Model Manager (HOL) (Mos. for S/W Dev. 9.5 Mos.)	3,600	0	3,600	7,200	43
B7 Interactive Scenario/Overlay Modification Manager (HOL) (Mos. for S/W Dev. 7.5 Mos.)	1,600	0	1,600	3,200	19
B8 Post Test/Online Support Mgr. (HOL) (Mos. for S/W Dev. 9.5 Mos.)	2,000	3675	5,675	7,675	46
Offline Support S/W (HOL) Non Vendor Supplier (Mos. for S/W Dev. 8.0 Mos.)	2,300	0	2,300	4,025	24
(Mos. for S/W Dev. 24.0 Mos.)	32,300 (86%)	5,075 (14%)	37,375	74,025 35	445

$2,590,875

$$\frac{74025}{37375} = 1.98 \text{ hrs. per LOC}$$

FIGURE 12c
43

| | Source LOC | | | | |
	New Code	Mod Code	Total	Hours	M/M
A	11,430	12,950	24,380	34,868	210
B	32,300	5,075	37,375	74,025	446
	43,730	18,025	61,755	108,893	656

(Mos. for S/W Dev. 27.0 Mos.)

$$\frac{108,893 \text{ hrs}}{61,755 \text{ LOC}} = 1.76 \text{ hr/LOC}$$

$$\frac{108,893 \text{ hrs}}{35} \text{ (1981 \$)} \quad 656 \text{ M/M}$$

3,811,255 Total Software Development Estimate

1 manmonth = 166 hrs.
1 manyear = 2000 hrs.

FIGURE 12d

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ASGI

Engineering		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Calendar Mos
		SDR			SRR			SDR		PDR			CDR						TRR									AR	
Sys Rqmts	9	12.0	11.5	10.0	8.5	7.0	6.0	4.0																					50
Sys Allocation	5	2.0	3.0	4.0	6.0	6.5	6.0	5.5																					33
S/W Rqmts	9	7.0	7.0	7.0	7.0	8.5	10.0	12.5																					59
Prel Design	7						1.5	2.0	24.5	18.0																			46
Detail Design	15									7.0	26.5	27.5	27.5	8.0	4.5														89
Code	13												1.0	19.0	18.0	15.5	13.5	12.5	5.5	3.0	1.5								85
Checkout	8														2.0	8.5	10.0	8.0	6.0	3.0	1.5								29
Unit Test	9															4.0	4.0	2.5	9.5	15.0	16.0	16.0							59
Integration	7																4.0	4.0	1.5	4.0	4.0	5.0	18.5						46
System Test	20																		4.0	4.0	4.0	4.0	5.0	7.0	13.0	18.5	18.0	17.5	131
		21.0	21.5	22.0	22.5	23.0	24.5	26.0	25.5	26.0	27.5	26.5	28.5	29.0	28.5	28.0	27.5	27.0	26.5	26.0	25.5	25.0	21.5	20.0	19.0	18.5	18.0	17.5	654 MM

Figure 12e

45.

One important feature of the ASGI is that the system is data driven. This means that the software system itself, possibly an unclassified system, might model using highly classified data and weapons systems specifications. The ASGI would remain unclassified and would only operate with the classified data.

Once weapons, terrain, weather, and other labor intensive data is specified for an area, the specification of the remainder of the scenario can be very expeditious to implement. Using the graphics capabilities of the MMI, operations personnel can easily specify position and routes of advance or retrograde for weapons units. This capability does not affect the time necessary to obtain requirements. Should scenarios use the same areas, terrain, weather and weapons models, scenario generation can be very quickly done.

Because the ASGI is functionally modular, any new system, such as the "Rosie" modeling system could be incorporated into the ASGI and use the facilities provided by the ASGI. The system is designed for expeditious upgrade capabilities, allowing for future growth.

The software architecture provides for an eventual or immediate application to a distributed computing system, thereby increasing response to user inputs and allowing scenarios of extreme complexity to be accommodated.

The goals identified for the ASGI are ambitious. The design concepts for the ASGI are proven and realistic. The sizing, cost and scheduling of the software development effort are preliminary in nature, but provide a realistic picture of the investment required to implement such a system. Should requirements for a new gaming system be determined that are not as extensive as those presented here, the design criteria of functional modularity, centralized communications buffer and standardized message formatting should be used to insure the capability of implementing new features.

7.17 HARDWARE RECOMMENDATIONS: ASGI

Because the proposed ASGI requires advanced graphic capabilities, and intelligent graphic stations minimize the computer impact to a critical CPU resource, the Evans and Sutherland full color graphic display terminals with picture processor and picture system software are recommended. In order to satisfy the requirement that Blue and Red teams interact using graphics along with operations personnel, three graphics stations are necessary. The total hardware recommended to develop ASGI is as follows:

o   1-PDP-11/70 computing system including two (2) RP06 disk drives, eleven (11) terminals, one (1) high speed line printer, one (1) tape drive, operating system and system software and hardware maintenances. Approximate cost - $218,000.00.

o   3-Evans and Sutherland full color graphics display terminals, picture system processor, picture system software and maintenance for software and hardware. Approximate cost - $400,000.00.

Buying computer time for this project would cost in excess of $300,000.00 (see Para. 7.15.1) and justifies acquisition of dedicated hardware for the software efforts. In addition, integration of the Evans and Sutherland to a system to be delivered with software already installed minimizes installation time. Total cost of hardware is approximately $618,000.00.

The choice of the PDP-11/70 was recommended in order to be able to utilize to a maximum extent the software Martin Marietta has developed to date on PDP-11/70 computers in its own C3 laboratory. This software is now being moved to a VAX 11/780 which allows utilization of C3 software if more modern hardware should be considered. Experience has shown that the PDP-11/70 computer should be considered a minimum resource for this kind of development effort. In any case, every effort to make the ASGI software transportable should be made in order to be able to take advantage of any hardware improvements by rehosting the ASGI with the minimal effort.

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