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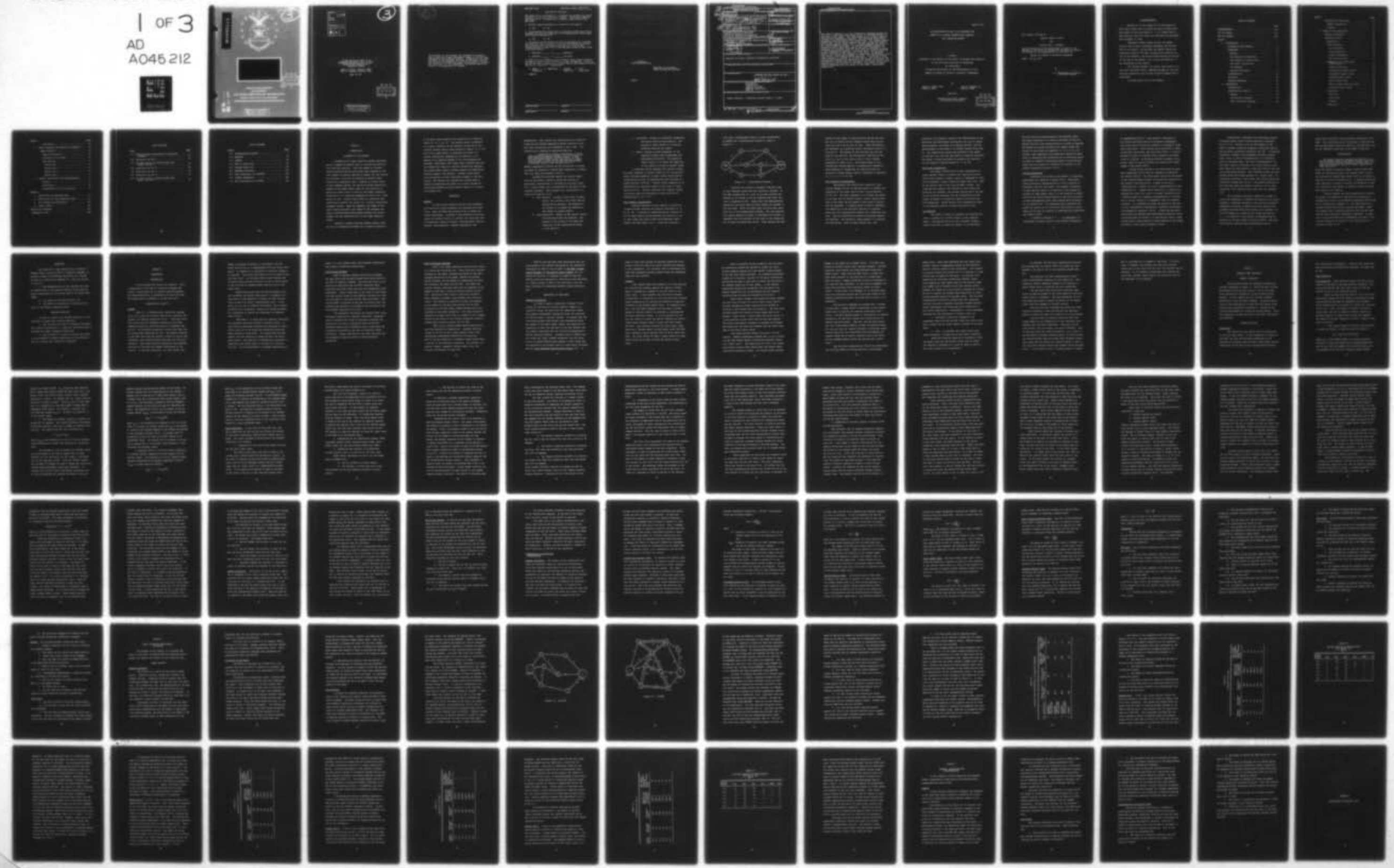

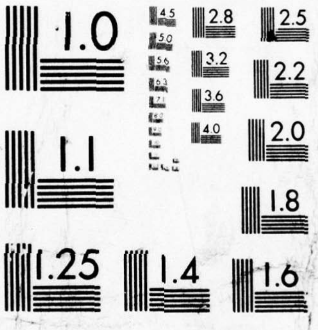

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AN APPLICATION OF GASP IV TO DETERMINE THE EFFECT OF A LIMITED INTERDICTION CAMPAIGN ON A LOGISTICS SYSTEM

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This thesis simulates a 15 day interdiction campaign against the logistics system supporting enemy troops at the Forward Edge of the Battle Area (FEBA). The interdictor has a limited number of aircraft for interdiction attacks. The following three attack strategies are available to the interdictor: (1) attacks against trucks only, (2) an attack against one link in the road network and attacks against trucks, and (3) attacks against two links in the road network and trucks. An optional defense suppression capability can be used with each of the above strategies. If selected, all aircraft used are taken from the aircraft assigned to the interdiction campaign. The enemy has a limited number of trucks available to move supplies to the FEBA. To maximize vehicle use, trucks are assigned to routes with the shortest round trip times to the maximum extent possible. To minimize losses, truck movement is limited to 12 hour period. The effects of the interdiction campaign are measured by the number of aircraft lost, the number of trucks that are destroyed, and several ratios which compare supplies delivered to the FEBA to the enemy's planned supply requirement and its effect on the enemy's operational flexibility.

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A Thesis
Presented to the Faculty of the School of Systems and Logistics
of the Air Force Institute of Technology
Air University
In Partial Fulfillment of the Requirements for the
Degree of Master of Science in Logistics Management

By

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This thesis, written by

Captain James W. Geith

and

Captain Paul A. Openhym

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN LOGISTICS MANAGEMENT

DATE: 15 June 1977

COMMITTEE CHAIRMAN

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Chapter 1

INTRODUCTION

STATEMENT OF THE PROBLEM

Interdiction of enemy logistics systems represents one of a number of possible uses of tactical aircraft during a military conflict. Since the number of aircraft sorties available may be quite small when compared to the total number of sorties required to support all the tactical air missions, it may not be possible to perform interdiction on a continuous basis. However, a limited interdiction campaign against the logistics system supporting a segment of the enemy forces might be very effective in halting an enemy attack or reducing the enemy's defensive capabilities in a specified geographical region for a fixed period of time. Factors which should be considered when attempting to predict the results of a limited interdiction campaign include: enemy air defenses, the number of aircraft sorties available, the length of the proposed campaign, aircraft/weapon effectiveness against the various targets, and the characteristics of the enemy logistics system.

Currently, several existing computer models allow the user to determine the effect of a specific allocation of aircraft sorties against the components of a logistics system (2; 5; 7; 10; 17). The smaller models concentrate on a single component of the logistics system and do not consider attacks against other logistics targets (2; 5; 10). Use of the larger models to determine the effect of a limited interdiction campaign may be possible (7; 17). However, this approach appears to be time-consuming and extremely inefficient since these models consider many factors beyond the scope of a limited interdiction campaign. The larger models require enormous amounts of preparation, computer support, and analysis. Further, these models lack the ability to treat continuous changes in the simulation. The tactical air interdiction planner needs a method of determining the effect of a given strategy of allocating available aircraft against targets in a logistics system (13).

BACKGROUND

General

In any military conflict the air force commander will have only limited resources for attaining his objectives. Thus, he faces the problem of how to employ his forces effectively. Included in this problem is the allocation of aircraft sorties to tactical air operations such as counterair, close air support, reconnaissance, electromagnetic countermeasures, defense suppression, and interdiction. Only limited air interdiction of a logistics system and the defense suppression effort required to support this interdiction are considered in this study. Air interdiction is defined as operations that are

> . . . conducted to destroy, neutralize, or delay enemy military potential before it can be brought to bear effectively against friendly forces, at such distance from friendly forces that detailed integration of each air mission with the fire and movement of friendly forces is not required [25:7-1].

Defense suppression involves the use of aircraft in attacking enemy air defenses to reduce their capability to defend their air space and resources (25:5-1).

Interdiction missions against the various components of the enemy's logistics system are one way of destroying, neutralizing, or delaying his military potential. These attacks can be categorized on the basis of the targeted component. Some categories of interdiction of a logistics system are (2:2):

a. Anti-capacity: attacks on the roads, bridges, canals, and railroad lines which form the transportation network. The purpose of the attacks is to reduce the capacity of the network to handle traffic.

b. Anti-capability: attacks on the trucks, trains, and boats which move the material. The purpose of the attacks is to reduce the capability of the transportation fleet to move material.

c. Anti-goods: attacks on stockpiles, warehouses, and depots which contain material. The purpose of these attacks is to destroy materials required for combat.

d. Other: attacks on other components of the logistics system, such as personnel and maintenance facilities. The purpose of these attacks is to reduce the capability of the logistics system to support combat.

A literature review revealed that several studies have been conducted on various facets of air interdiction. Ashley included summaries of eight studies which address interdiction of Lines of Communication (LOC) networks or supply vehicles (2:59-60). Beasley listed summaries of 14 applications of simulation models to the study of interdiction (4:4-6). Several algorithms and computer simulation models have been developed to study tactical air interdiction (1; 5; 7; 17).

Anti-capacity Interdiction

Previous research on anti-capacity interdiction included network modeling and analysis techniques (2; 5; 8; 14; 19). A network is established which consists of a set of nodes (points which represent the junction of two or more links) and links (lines which represent roads, canals, railroad lines, etc.). A node may represent a city, port, transshipment point, or route intersection. An example of a transportation network is shown in Figure 1-1.

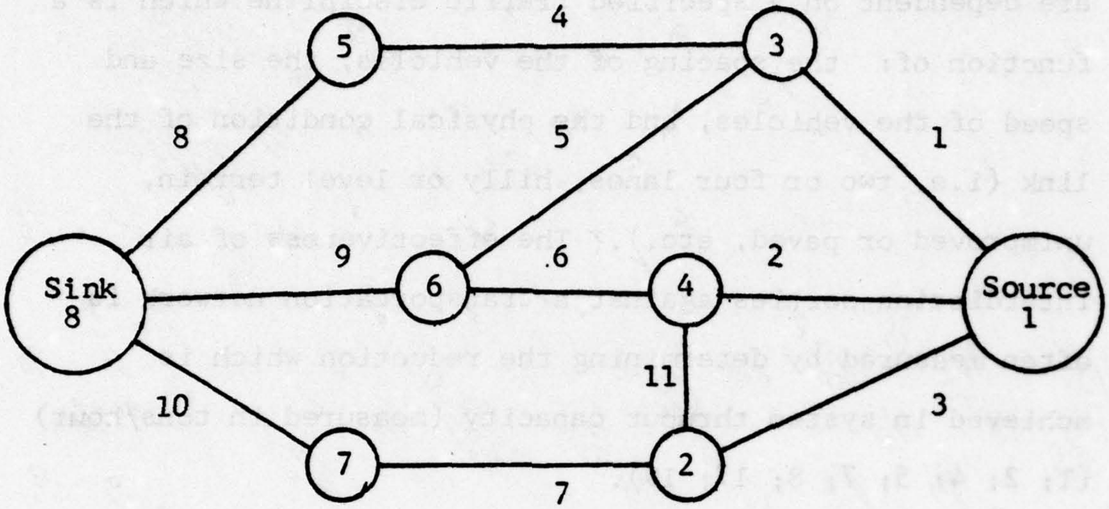


Figure 1-1. Transportation Network

Carriers are limited to movement along the links as they transport goods from one location to another. It has been assumed that if a link is cut then carriers are delayed or are forced to use an alternate path until the link is repaired (5:5-8). Goods enter the transportation network at the source node and flow through the network to the sink node. After the goods reach the sink node, they drop out of the transportation network. The time required for a given quantity of goods to transverse the network is dependent upon the capacity of the links in the system and the distance the goods must travel. Link capacity has been defined as the number of vehicles which can use the link per unit of time or as the tonnage of goods which can be moved over the link per unit of time. These definitions are dependent on a specified traffic discipline which is a function of: the spacing of the vehicles, the size and speed of the vehicles, and the physical condition of the link (i.e. two or four lanes, hilly or level terrain, unimproved or paved, etc.). The effectiveness of air interdiction sorties against a transportation network is often measured by determining the reduction which is achieved in system thruput capacity (measured in tons/hour) (1; 2; 4; 5; 7; 8; 17; 19).

Anti-capability Interdiction

Researchers have studied anti-capability interdiction through the use of computer models to simulate the capability of the enemy vehicle fleet to move material (5; 10; 17). The basic approach is to estimate the capacity of each type of vehicle (trucks, trains, boats) available to the enemy and the number of each type of vehicle that he possesses. A computer model is used to determine the capability of the available vehicles to transport goods over the transportation network for a specified time span. Then air interdiction attacks are directed against the vehicles. The success of these attacks is a function of many factors. Some of these factors are: the probability of locating a vehicle, the effectiveness of the particular aircraft/weapon load against the type of target being attacked, the number of attacking aircraft, and the effectiveness of the enemy's air defense system (5:121-138; 9). Air interdiction results are measured by the number of aircraft lost, the type and number of vehicles destroyed, the amount of goods destroyed by attacking the vehicles, and the amount of thruput denied (1; 5; 10; 17).

Anti-goods Interdiction

Anti-goods interdiction has been investigated by using computer models to estimate the results of an aircraft attack against a target, such as a warehouse or stockpile of material, using a specified weapon load (16). Some of the factors used in this type of model include: the speed and dive angle of the aircraft at the instant the munitions are released, the expected aiming error, the number of munitions released, and the vulnerability of the target to damage or destruction caused by the munitions kill mechanisms. Attack results can be measured in terms of the expected quantity of goods destroyed (16:18).

Air Defenses

The effect of enemy air defenses on attacking aircraft is treated in a similar manner by most computer models. The sophistication of this treatment, however, varies from model to model and appears to be consistent with the level of sophistication of the specific model. The normal procedure is to resolve the effect of the air defense system on the attacking force (in terms of reducing the number of aircraft attacking the target) before the results of the attack are computed (1; 3; 5; 7; 16; 17). Finally, some researchers have added more realism to their model by subjecting the attacking force to attrition caused by enemy air defenses encountered enroute to and from the target and by allowing for allocation of aircraft to the defense suppression mission (7:I-2).

Computer Simulation

Simulation is defined as the process of conducting experiments on a model of a system (18:1). Researchers employ simulation techniques when it is not practical to experiment with the real world. For example, simulation is used when the system to be modeled is too complex for analysis by other means, when it is not feasible to experiment with the actual system because of the costs involved, or when experimenting could cause unreasonable disruption in the system (3:6). The researcher first abstracts the essential aspects of the system and then develops a model which can be used for purposes of experimenting, prediction, and control (20:9).

A system is defined as ". . . an aggregation or assemblage of objects joined in some regular interaction or independence [15:1]." Each system is influenced by activities occurring within its boundaries (endogenous activities) and by activities outside its boundaries (exogenous activities). Every system can be described in terms of entities, attributes, and activities (15:2). An entity denotes an object of interest which interacts with other items in a system. An attribute denotes a property of an entity, while an activity defines any process that causes change in the system (15:2).

A model can be defined as "an abstraction of some real system that can be used for purposes of prediction and control [20:9]." The ideal model identifies the system in the simplest manner without distorting the operation of the system in the real world. A model is not only a "substitute for a system, but also a simplification of the system [15:7]." A model can be described as a physical or mathematical model with static or dynamic characteristics. A physical model is a tangible representation of a system, but is usually reduced to a manageable size for research purposes. In a mathematical model the aspects of the system are represented by mathematical variables interrelated by mathematical equations (15:10). A model having static characteristics displays the relationships among the system attributes when the system is in equilibrium, while a model having dynamic characteristics allows modeling of the change processes in the system attributes (15:11).

Historically, researchers have developed computer simulation models using discrete simulation techniques (1; 5; 7; 17). However, with the development of the GASP IV computer simulation language, researchers can now use continuous simulation techniques (21; 22). In discrete simulation, changes in the dependent variables (events) start, stop, or occur "instantaneously" at a specified point in simulated time. The term "instantaneously," as used here, means an occurrence of an event within a very short period of time relative to the time scale of the overall process being modeled. Only scheduled events can occur. Between events the system operates in a steady state. In continuous simulation, events occur when certain prescribed conditions (thresholds) are met. The dynamic processes in the model may cause the system to arrive at one or more thresholds, thus creating events that were not scheduled (13).

The continuous simulation capability of GASP IV allows the researcher to increase the realism of his model. Although a researcher attempts to use the best simulation techniques available, he cannot be certain that he will determine the most effective solution to his problem. He can only operate on a model of the system and then use ". . . his analysis of the results to determine what he believes is the best course to follow [9:323]." The real world results obtained after implementation may be significantly different from the results predicted by the model. This difference may be attributed to variables and their relationships which are present in the real world but are not adequately described in the model (9:322-324).

JUSTIFICATION

> The general tactical interdiction problem is to select target elements from among vehicles, road links, rail nets, and waterways supplying a combat force in order to effectively reduce the combat capability of that force [8:1].

Since the number of possible targets usually exceeds the number of available aircraft, the planner needs to avoid the selection of targets which have little or no effect in reducing the flow of supplies (3:3). A computer simulation model employing a method to estimate the reduction of supplies resulting from attacks on specific targets can help the planner in his efforts.

Limited research has been accomplished to identify the effect of allocating a proportion of available air interdiction sorties to the defense suppression role during an air interdiction campaign (7). The application of a limited interdiction force to disrupt the enemy's logistics effort over a specified period of time has not been modeled using continuous simulation techniques. In addition, Bailey and Szwarc have recommended that GASP IV simulation techniques be applied to the interdiction of a logistics system (3:50).

OBJECTIVE

The objective of this research was to develop a computer model, using the GASP IV simulation language, to provide a method of determining the effect of a limited tactical air interdiction campaign on a logistics network in light of:

1. The characteristics of the vehicles and lines of communication in the enemy's logistics system and the supply requirements at the forward edge of the battle area (FEBA);
2. The number of available sorties; and
3. The effect of diverting air interdiction aircraft to the defense suppression role.

RESEARCH QUESTIONS

In order to satisfy the research objective, it was necessary to answer the following questions:

1. How can GASP IV be used to determine the effect that limited interdiction of a logistics system may have in reducing the enemy's freedom of operation?
2. How can GASP IV be used to evaluate the impact of an investment in defense suppression on the effectiveness of a limited air interdiction campaign?

Chapter 2

METHODOLOGY

INTRODUCTION

In this chapter we discuss two subjects: first, a description of the GASP IV simulation language and second, a description of the scenario that was modeled. The interdicting force is referred to as the blue force. The ground force is referred to as the red force.

DESCRIPTION OF GASP IV

General

GASP IV is a FORTRAN-based, simulation language which can be used for discrete simulation, continuous simulation, or combined simulation (21:3). "Discrete simulation occurs when the dependent variables of the model change discretely at specified points in simulated time [21:8]." In continuous simulation, events occur when certain prescribed conditions are met. The dynamic processes in the model may cause the system to arrive at one or more thresholds, thus creating events that were not initially scheduled. When using combined simulation, the dependent variables in the model may change continuously or discretely. In combined simulation, the time variable may change by discrete intervals or continuously (21:3-8). Events which occur at a predetermined time are called time-events. An example of a time-event is the daily ordering of supplies. Time-events are stored in a file based on the time they occur. An attribute vector which contains the variables which describe the event is used to store events in the file and to withdraw events from the file at the proper time.

Events which occur when the system reaches a certain condition are called state-events. An example of a state-event is the reduction in supply use when the supplies on hand fall below a predetermined level. State-events can be used to schedule time-events, add or delete variables from an equation, change rules governing behavior, accelerate or prevent the occurrence of scheduled events (22:3).

When GASP IV is being used for combined simulation, the simulated time moves forward in discrete steps. At each step the continuous variables are evaluated to determine if they are at or beyond the prescribed conditions which describe a state-event. If a state-event has been passed, the time variable is backed up until the state-event occurs. The time-step is automatically adjusted to insure all time-events occur at the end of a time-step (22:3-4). Use of state-events in combined simulation can result in a very dynamic model that includes interactions that cannot be predicted analytically.

User-written Programs

GASP IV requires several user-written programs. The user must write the MAIN program which gains access to the GASP IV supplied programs. The user must write a subroutine for each event and an EVNTS subroutine which identifies the event codes and calls the appropriate event subroutine. Initial conditions at the start of the simulation and initial values of user-defined variables are read into the model in the user-written INTLC subroutine. Subroutine OTPUT is written by the user to provide final calculations and printout of information not provided by the GASP SUMMARY subroutine (21:56-66).

Two additional subroutines are required when using continuous simulation or combined simulation. Equations used to calculate the value of continuous variables are provided by the user in subroutine STATE (21:58-64). Threshold values used to determine when a state-event has occurred are provided by the user in subroutine SCOND (21:64-66). Unique statistics on the state variables can be collected if the user writes a SSAVE subroutine (21:66-67).

GASP IV Supplied Programs

GASP IV has three subroutines which collect statistics during the simulation run. These statistics include: estimates of the means, standard deviations of the data, standard deviations of the means, maximum and minimum values observed, and the number of observations on which the statistics are based (21:129-133). The COLCT subroutine collects statistics which are not weighted by the length of time that a value of variable exists (21:133-134). Subroutine TIMST collects statistics variables which maintain a constant value between data collection points. The statistics collected by TIMST are weighted by the length of time the value existed (21:134-135). Statistics on variables which change between events are collected by the TIMSA subroutine. The TIMSA subroutine computes an average value which is assumed to be an approximation of the value of the variable during the interval between data collection points (21:137-138).

GASP IV has a pseudo-random number generator for use with probablistic computations. Separate starting values can be set for each random number stream, thus maintaining independence between the distributions. GASP IV has the capability to generate random values from a variety of distributions, including: the uniform, triangular, normal, lognormal, Erlang, gamma, beta, and Poisson distributions (21:158-175).

GASP IV also has many other subroutines that are used primarily for internal processing of the simulation. Information on GASP IV can be found in The GASP IV Simulation Language and The GASP IV User's Manual (21; 22). Details of the GASP IV language as loaded on the AFLC CREATE system are contained in "Construction and Evaluation of a Cardin System of GASP IV for Inclusion in the Air Force Institute of Technology Graduate School Curriculum [6]."

DESCRIPTION OF THE MODEL

General Information

In order to apply a particular strategy of allocating air interdiction aircraft against targets in a logistics system, the blue force air operations planner must gather intelligence information about the structure of the red force's logistics network. We assumed that the blue force planner could obtain valid information about the number of red force supply trucks, the condition and capability of each link and node in the road network, and the traffic discipline that the red force transportation officer typically employs. Variables such as repair time for trucks and links, network absorption, and the probability of weapon effectiveness against a given target may be estimated by the planner based on intelligence estimates and the Joint Munitions Effectiveness Manuals (26). In order to avoid the problems of handling classified information, we did not depict an actual interdiction scenario in this simulation. All variables used in developing this model were assigned arbitrary values within the reasonable range for each variable.

Scenario

The scenario which was modeled is a 15 day tactical air interdiction campaign against the logistics system which is supporting a segment of the red forces on the front lines. In this scenario the blue force commander (interdictor) is attempting to limit the red force's ground combat capabilities by reducing the quantity of supplies available in the forward combat units. To accomplish this goal, the blue force commander directed that a limited number of aircraft sorties be allocated to attacking the red force logistics system. It is not possible for the blue air forces to attack the heavily defended red force's supply depot (network source) located 100 miles behind the FEBA. Upon leaving the major red force supply depot, there are a limited number of roads going toward the FEBA until reaching a point (network sink) 10 miles behind the FEBA. Ten miles behind the FEBA, a dense network of roads begins which can be used to reach the forward combat units.

After an analysis of the situation, the blue force air operations planner has decided to direct the interdiction campaign against the road network located between 10 and 100 miles behind the FEBA. If a defense suppression capability is desired, a portion of the daily interdiction sorties may be used in that role to reduce the red force's air defense capability at each target. If the defense suppression attacks are successful, the red force's air defense capability will be neutralized and the expected attrition rate of follow-on aircraft will be zero.

Since roads, bridges, and tunnels are fixed targets, the blue force aircraft can locate these targets easily. Aircraft assigned to attack trucks face the problem of locating a truck before they can attack it. The blue force aircraft search for trucks by flying along roads in an attempt to spot trucks. Since trucks are fairly small, it is not possible to spot every truck on the road network. Blue force intelligence information includes the strength and location of red force air defenses and the roads being used by red force supply trucks.

Blue force aircraft employ two weapon delivery tactics. Defense suppression aircraft and aircraft attacking the road network employ the multiple-aircraft-single-pass (MASP) tactic. When employing this tactic all attacking aircraft release their entire bomb load before target destruction evaluation occurs. The attack either produces damage to the target or no damage occurs. In either case, follow-on aircraft attack their assigned targets. Aircraft attacking trucks employ the single-aircraft-single-pass (SASP) tactic. When using the SASP tactic, a single aircraft drops one-half of its munitions in a single pass. After the pass, a damage evaluation is made to determine if the truck has been destroyed. If the truck is damaged, aircraft with munitions loads remaining search for other trucks. If the truck is not damaged, it is attacked again. Since the attacking aircraft are in the same flight as the original attacking aircraft, the truck does not have to be redetected.

The red force commander has ordered that a reserve of three days' maximum supply be maintained in the forward combat units to provide the required operational flexibility. One day's maximum supply is the quantity of supplies consumed by the red force combat units during one day of maximum intensity combat. Each day, the red force combat unit will order enough supplies to meet the expected usage for next day plus any supplies required to bring the supply reserve back up to the established three day maximum consumption level and to replace supplies used by the trucks and air defense weapons during the previous day's operations.

The red force transportation officer has established the following method of moving supplies to the forward combat units. Each truck departing the rear supply area (source) carries a homogeneous mixture of the different types of supplies needed at the battlefront. This mixture of supplies reduces the possibility of a shortage of a particular type of supply at the front. To minimize truck losses due to blue force interdiction efforts, supply trucks depart the rear supply area and the forward combat area (FEBA) with a distance of one mile between trucks. Further, the trucks will only operate a maximum of 12 hours per day to prevent the assumed high destruction by interdicting aircraft during the daylight hours. The red force transportation officer has decided that this departure interval provides an adequate compromise between meeting supply requirements and minimizing truck losses due to blue force interdiction. Consequently, a route assignment procedure has been developed to increase truck use.

1. Sufficient trucks are assigned to the unassigned route with the shortest round trip time to provide a steady flow of trucks spaced a minimum of one mile apart.

2. Step 1 is repeated until there are no more trucks available, or there are no more routes available.

Sufficient handling capacity is available at both the supply depot and the forward combat area to permit the loading or unloading of a truck to begin as soon as the truck arrives at its destination.

In addition, the red force transportation officer has directed that all supply trucks will empty the road network by the end of the 12 hour operating period each day.

The excellent red force communications system allows instantaneous reporting of road conditions. This capability permits immediate changes in the routing of supply trucks prior to starting the day's operations.

The red force motor pools have sufficient capability to keep 80 percent of the total number of red force supply trucks in operation. Red force mechanics can salvage sufficient parts to repair 60 percent of the supply trucks which are damaged by aircraft attacks.

The red force civil engineer has sufficient transportation resources to move any supplies and equipment needed to repair the roads and bridges of the road network.

The red force air defense system has been positioned based on the vulnerability of the individual road network links and their importance. Some parts of the road network, such as bridges, are heavily defended. Most of the roads have only sparse protection. As a result of the red force's excellent warning system, all blue aircraft are detected before they can attack their assigned targets. This allows the red force's air defense weapons to fire at the blue force aircraft before they release their munitions loads. If an aircraft is hit, it cannot attack its target and is considered to be damaged or destroyed. If an aircraft is damaged, this reduces the blue force aircraft sortie rate by one sortie per day until the aircraft can be repaired. If an aircraft is destroyed, this reduces the blue force aircraft sortie rate by one sortie per day for the remainder of the campaign.

Chapter 3

DESIGN OF THE SIMULATION

GENERAL DISCUSSION

The simulation model was designed following the scenario described in Chapter 2. While the model follows the general outline of the scenario, use of data input files provides for flexibility in the situation being modeled. In this chapter we first provide a general description of how the model operates. Detailed instructions on the construction of data files and output interpretation are contained in Appendix B. Second, we discuss the measurement of interdiction effectiveness. Third, the assumptions we made and some of the model limitations are presented.

SIMULATION CYCLE

Preparation

The simulation cycle begins with the preparation of the data input files. A basic assumption in design of the model was that the necessary information can be obtained or estimated using available intelligence sources. Preparation of the data files is accomplished following the instructions in Appendix B. Once the data files have been constructed and verified for accuracy, the model can be run.

Model Operation

Initialization. Model operation begins with the initialization of the GASP IV and user-supplied variables. During initialization, the input data files are read and printed as part of the simulation output.

After the data files are read in, all of the feasible routes through the road network are determined using the methodology developed by Beaumaster and Robinson. These feasible routes are stored in a matrix for later use (5:107-111). Next, the number of aircraft required to attack each link and the number of defense suppression aircraft required to support each attack are computed. The number of aircraft required to attack a target is computed as follows:

1. The minimum number of aircraft after exposure to enemy air defense is found by using the formula:

$$N_{ac} = \log(1-P_s)/\log(1-P_{ac})$$

where N_{ac} is the minimum number of surviving aircraft required to attack the target with a predetermined probability (P_s) that the target will be killed; and P_{ac} is the probability of kill for a single aircraft attack against the target (12:8). P_{ac} values may vary from target to target for targets within the same class (i.e., different links) and between target classes (links, defense suppression, trucks). We assumed that all targets could be killed by a single aircraft. Since N_{ac} may be a real number, it is rounded up to the next highest integer when a fractional value occurs. For example, a value of N_{ac} = 2.35 would be rounded up to 3. We used a P_s value of .9 in the current model.

2. The number of aircraft required to conduct the attack (N) is computed. This number represents the number of expected aircraft losses due to enemy air defense action plus N_{ac}. The formula used for this calculation is:

$$N = N_{ac}/(1-P_{ads})$$

where P_{ads} is the probability of kill for the air defense system defending the target when shooting at a single aircraft.

The strength of the red force's air defense system was varied based on the type of target that is being defended and the criticality of that target to the operation of the logistics system. While air defense weapons can be moved, no attempt was made to change the initial air defense weapon deployment during the simulation. We assumed that the blue force intelligence information can be used to determine the location and number of the air defense weapons protecting each target in the system. We further assumed that the concentration of air defense weapons will be greater for a high value target, such as a bridge, than for a relatively lower valued target, such as a road. The deployment strategy of the air defenses impacts directly on the attrition rate for attacking aircraft. The probability of kill of an aircraft by an air defense system (P_{ads}) is calculated by using the formula:

$$P_{ads} = 1 - (1-P_{ad})^{N_{ad}}$$

where P_{ad} is the probability of success or kill of an aircraft by a single air defense weapon and N_{ad} is the number of identical air defense weapons in the complex encountered by the attacking aircraft (12:8). We assumed that the probability of kill for each air defense weapon is an independent event. An aircraft kill is defined to be damage or destruction to an aircraft which prevents it from attacking the assigned target.

A modifying factor is the blue force's capability to schedule defense suppression sorties against the air defense system. The probability of an air defense weapon complex neutralization by defense suppression aircraft (P_{sds}) is found using the formula:

$$P_{sds} = 1 - (1-P_{ac})^{N_{ac}}$$

where P_{ac} is the probability of one aircraft attack neutralizing an air defense weapon complex and N_{ac} is the number of attacking aircraft (12:15). An air defense weapon complex kill is defined as preventing all air defense weapons in the complex from firing at attacking aircraft for q minutes. For this research effort, q was arbitrarily set equal to 30. The quantity of supplies used by the air defense system is a function of the number of air defense weapons and the number of aircraft attacks. After initialization, the first scheduled event in the simulation cycle should be a daily operations event.

Daily operations. At the start of each model day, the day's operations for the red and blue forces are planned and the daily interdiction effectiveness indexes are computed. The actual sequence of events within the DAILYOPS subroutine is as follows:

1. Computation of the daily troop supply use rate and the daily supply order.

The hourly troop supply use rate is equal to the current day's planned supply use divided by 24 hours. If the stock of supplies on hand falls below a predetermined level, the red force commander reduces the daily supply usage rate for combat troops to a predetermined minimum level. If the quantity of supplies on hand at the FEBA at the start of the day is less than the minimum level, the hourly troop supply use rate is set equal to the daily minimum supply use value divided by 24.

The red force commander's demand for supplies varies from day to day depending on his projected activity. The estimate of daily supply usage is stored in an array and used to determine the red force's supply order and troop supply use rate. If the quantity of supplies received is less than the daily usage, the red force supply officer makes up the difference by withdrawing supplies from his supplies on hand. Thus, the daily supply order is equal to the sum of the quantity of supplies required to replace the previous day's truck and air defense weapon supply use, the next day's planned troop supply use and the quantity of supplies required to bring the supply stock at the FEBA up to the desired level.

2. Computation of the Unrestricted Support Index, Programmed Support Index, Minimum Support Index, Daily Combat Index, and the Daily Minimum Operations Index.

3. Scheduling and execution of interdiction attacks against links if authorized by the input data.

Three attack strategies are built into the model. These strategies are:

a. Use all aircraft to attack trucks;

b. Use aircraft to attack one link in the road network and use the remaining aircraft to attack trucks;

c. Use aircraft to attack two links in the road network and use the remaining aircraft to attack trucks.

In addition, a defense suppression capability option can be used with each of the above strategies. Since the blue force has a limited number of aircraft, all aircraft used in the defense suppression role are taken from the total number of interdiction aircraft. Therefore, there are six attack options available.

Selection of the link or links to be attacked is based on maximum thruput denial. For single link attacks, the effect of attacking a link is determined in the following manner. First, an estimate is made of the red force's daily thruput capability based on the current network conditions and the number of trucks available for use. Second, the current condition of the network is modified to reflect the effect of a successful attack against a single link. Third, an estimate is made of the red force's daily thruput capability based on the modified network conditions. Finally, the effect of attacking the link is found by subtracting the interdicted thruput capacity from the uninterdicted thruput capacity. This procedure is repeated until the effect of attacking every link in the network has been calculated. Actual target selection consists of selecting the link that results in the largest expected thruput reduction. The effect of attacking each link is weighted by the required repair time. For example, a link that would require a two day repair time, would have its one day expected thruput reduction multiplied by two.

Two link attacks are selected in a manner similar to one link attacks. The effect of attacking two links is initially determined by comparing the thruput capability of the interdicted network with the thruput capability of the uninterdicted network. Thruput reduction is based on the total reduction for the period of time that both links are damaged plus the thruput reduction of the damaged link with the longest repair time for the period of time between repair of the first link and the second link. The final thruput reduction value is the sum of three values. These values are:

a. The thruput reduction achieved by attacking the two links times the probability that both links will be damaged;

b. The thruput reduction achieved by attacking the first link times the probability that only the first link will be damaged;

c. The thruput reduction achieved by attacking the second link times the probability that only the second link will be damaged.

Actual target selection consists of finding the pair of links that, when attacked, result in the largest expected thruput reduction. Execution of the link attacks occurs instantaneously and the results of the attacks are used to modify the conditions in the road network. A random number generator is used to determine if each attack succeeds or fails.

4. Assignment of red force trucks to their routes, scheduling of the first truck departures, and scheduling of the last truck departure for the day.

The number of trucks that the red force transportation officer has available is limited. The actual number of trucks available in the system each day is reduced by the projected in-commission rate of the particular type of truck, the number of trucks destroyed by air interdiction, and the red force's repair and replacement rate of combat damaged vehicles. Only one type of truck is used in this model. The payload capacity of this type of truck is four tons.

Red force truck assignments are based on the network conditions after link interdiction has occurred and are maintained without change for the day's operation. Truck assignment is based on maximizing use of the routes starting with the route with the shortest round trip time. One half of the number of trucks required to saturate a route are assigned to that route from the trucks available for use at the source. The remaining trucks are assigned to the route from the trucks available for use at the sink. If there is a shortage of trucks at one end of the network, the model attempts to assign additional trucks to the route from the trucks available at the other end of the network. The model then assigns trucks to the next shortest feasible route that has useable capacity. This procedure continues until all of the operational trucks have been assigned to a route or the road network has been used to maximum capacity.

The maximum number of trucks which can be assigned to a link is found by multiplying the capacity of the route by the time required to complete a round trip using the route, including the time required for loading and unloading the vehicles. The route capacity is found by dividing the lowest maximum speed that a truck can travel while on the route by the minimum required distance between trucks. We assumed that the red force transportation officer would attempt to minimize his truck losses to interdiction aircraft by requiring a minimum distance between all trucks traveling in the same direction on the road network. Further, we assumed this distance could not be changed during the interdiction period.

Truck departures for each route are scheduled based on the route capacities in terms of the number of trucks per hour that can use each route. The truck scheduling events are stored in the event file. We assumed that the red force transportation officer has limited the use of the road network to 12 hours per day (the hours of darkness) to reduce truck losses. However, the 12 hour per day operation can be changed by using a different value during data input. Since truck travel on the network is limited to a given number of hours per day, the last possible truck departure for each route used is determined and placed in the events file. This last possible departure time is determined by subtracting the time required to travel from the source to the sink (sink to source times are equivalent) following each route from the number of hours that trucks can use the road network.

5. Scheduling of aircraft flights to conduct truck killing operations.

Four aircraft, and, if defense suppression capability is available, the required defense suppression aircraft are scheduled to patrol a link of the road network. Link selection is based on the expected number of trucks on each link. This number is found by multiplying the link capacity being used by the length of the link and dividing the product by the maximum speed the trucks can travel while on the link. After each link that is being used by the red force has been targeted, the procedure is repeated until the number of remaining aircraft is less than the number of aircraft required to conduct a truck killing patrol. Aircraft are scheduled to take off by mission attack number with ten minute intervals between mission takeoff times. The takeoff time for the first mission is scheduled so that the aircraft arrive over the link at approximately the same time as the first truck, using the longest route, arrives at the other end of the network. This completes the scheduling and planning operations.

Truck departure events actually compose five separate operations. First, the next truck departure event for the particular route is scheduled. Second, the model checks to see if the estimated thruput, based on earlier truck departures is equal to the daily order. When the day's estimated thruput equals the day's supply order, all subsequent truck departures from the source for the day are halted. If the estimated thruput falls below the daily order due to interdiction attacks, truck departures from the source are resumed. If the thruput is not equal to the daily order, the model proceeds to the third operation; truck departure from the source. If the thruput is equal to the daily order, the model proceeds to the fourth operation; truck departure from the sink. Third, the model checks to see if there is a truck at the source that is ready for departure from the source. If a truck is ready, a truck arrival event at the sink is scheduled. The time of the truck arrival event is equal to the time it takes the truck to travel to the sink plus one hour. The one hour time interval is used to account for the time required to unload the truck and prepare for the return trip. Fourth, the model checks to see if there is a truck at the sink that is ready to depart for the source. If a truck is ready, a truck arrival event at the source is scheduled in the above manner. In this case, the one hour time interval represents the time required to load the truck and prepare for the return trip. Fifth, truck readiness is determined by keeping track of how many trucks are ready to depart the source and the sink by the route to which the truck is assigned. When a truck departs from the source or sink, it is subtracted from the number of ready trucks assigned to that route at the proper end of the network. When a truck completes loading or unloading and is ready for a trip it is added to the number of ready trucks for its assigned route at the proper end of the network.

Truck arrival events are composed of several possible operations. If the event signals the arrival of a loaded truck at the sink two actions take place. First, the quantity of supplies at the FEBA is increased by four tons. Second, the truck is placed in the ready group of trucks for that route at the sink. If the event signals the arrival of an empty truck at the source, the truck is added to the group of ready trucks for that route at the source. If the event signals the arrival of a damaged truck, the truck is added to the group of damaged trucks at the appropriate end of the system. Damaged trucks arrive eight hours after their originally scheduled time.

When the last truck departure time-event occurs, the model searches the time-event file for the next truck departure event for the affected route. After locating the event, it is cancelled. This stops the input of trucks on the particular route and empties the road network of trucks at the end of the twelve hour period.

Three types of aircraft attacks may occur during a simulation. These are:

1. Defense suppression attacks;
2. Attacks against links;
3. Attacks against trucks.

Defense suppression attacks occur just before the link or truck attack that is being supported occurs. The following sequence of events occurs in every defense suppression attack. The air defense weapons, assigned to the link where the attack is taking place, fire at each of the defense suppression aircraft. The results of these attacks are determined using a random number generator. If an aircraft is successfully attacked, a second random number is drawn to determine the extent of damage that the aircraft receives. The range of damage is 1, 2, or 3 day repair or total destruction. All damaged aircraft are immediately withdrawn from the attack and do not attack the air defense weapons. The surviving defense suppression aircraft attack the air defense complex using the multiple-aircraft-single-pass bombing tactic. The combined probability of kill for all of the remaining attacking defense suppression aircraft is calculated. Again, the attack results are determined using a random number generator. If the air defense complex is damaged, all air defense weapons assigned to the link lose their firepower for 30 minutes. After the 30 minute period has expired, the unit becomes fully operational.

One additional procedure is applied to defense suppression attacks that support truck killing patrols. Since one link may be subjected to several truck killing patrols during the day, the enemy air defense complex defending the link may be knocked out when the patrol aircraft arrive. Therefore, defense suppression attacks at this time would not be required. To prevent unnecessary attacks, the status of the enemy air defense complex is checked during every flight along the link. Defense suppression attacks are withheld until the enemy air defense complex regains its capability to fire at blue force aircraft.

Aircraft attacks against links occur just before the red force begins its daily trucking operations. These attacks occur in the following manner. The red force air defense weapons assigned to protect the link fire at every attacking aircraft. Results are determined using a random number generator and all damaged aircraft are withdrawn from the attack immediately. The remaining aircraft make their attack using the multiple-aircraft-single-pass tactic. A total probability of kill is calculated for all attacking aircraft and the attack results are determined using a random number generator. Aircraft attacks against roads result in either no damage or damage which reduces the maximum speed of trucks on the road. Attacks against bridges and tunnels (high value targets) result in either no damage or damage which halts the flow of supplies along that link for a specified period of time. If the link is damaged, its condition is changed immediately and an event which signals the completion of repair activities on the link is scheduled. Initial damage effects remain until all repairs are completed.

Truck killing attacks are the most complex attacks in the model. After reaching their assigned link, the aircraft fly along the link until they reach the other end. Red force air defenses shoot at each aircraft as it flies along the link. The results of these attacks are determined using a random number generator. If any aircraft remain, a random number is drawn to determine if the aircraft have detected a truck on the link.

The probability of detecting a truck on a link is a function of the number of trucks on the link, the amount of vegetation along that link, and the method of detection that the interdictor is using. A single probability of detecting a truck must be input for each link. The probability that an aircraft patrolling a link will detect a truck is increased when there is more than one truck on the link (5:128-129). The total probability of detection is calculated using the following formula:

$$P(\text{Detection}) = 1 - (1-D)^T$$

where D is the probability of detecting a single truck on the link and T is the number of trucks on the link (5:129).

Since the probability of detecting a truck is a function of the number of trucks on the link, it is necessary to determine how many trucks are present. To make this determination, the model checks all of the routes being used to locate the route or routes that use the link. Then, the earliest possible arrival time and the latest possible arrival time that a truck on the link could reach each end of the network is calculated. The number of trucks on the link is found by searching the time event file for those loaded or empty truck arrivals that fall within the proper time interval for each route that uses the subject link. If a truck is detected, it is attacked using the single-aircraft-single-pass tactic. Each aircraft carries sufficient munitions to make two truck attacks. The result of each attack is determined using a random number generator. If an attack fails to damage the truck, another attack is made. These attacks continue until the truck is damaged or all of the aircraft have expended their munitions. If a truck is damaged, four random numbers are used to determine: which route the truck was using, which direction the truck was going, which truck was damaged, and whether the truck was damaged or destroyed. To determine which route the truck was using the model uses a cumulative probability distribution function which is based on the number of trucks, assigned to each route, that are on the link when the attack occurs. Next the truck's direction is determined by computing the probability that the truck was headed from the sink to the source based on the number of trucks traveling in each direction. The particular truck that was damaged is then determined by a random number based on the number of trucks headed in the selected direction. The model uses a .6 probability that a truck is damaged but repairable and a .4 probability that the truck was totally destroyed. If the truck is damaged, attribute four of the truck arrival event is changed to reflect the truck's new condition. If the truck is destroyed, it is removed from the simulation and its arrival event is cancelled. At the end of each attack, a check is made to determine if the aircraft have any munitions left and if they have sufficient flying range left to complete another flight along the link and return to their base. If both conditions are met, a new attack event is scheduled which represents the aircraft's next pass along the link. The time of the next attack is found by dividing the length of the link by the aircraft's flying speed and adding five minutes to simulate the conduct of an attack. Aircraft that have expended all of their munitions leave the mission and return to their base.

All aircraft are subject to the same types of damage if hit by red force air defenses. These damage types are categorized by how long it will take to repair the aircraft. We assumed each type of damage had an equal probability of occurring. The damage types are:

1. One day damage--the aircraft is ready for use the next day.
2. Two day damage--the aircraft is ready for use when the daily scheduling occurs the day after next.
3. Three day damage--the aircraft is ready for use when the daily scheduling occurs two days into the future.
4. Permanent damage--the aircraft is destroyed or cannot be repaired during the remainder of the simulation.

Supply consumption. Calculation of the red force's supply use is dependent on the type of supplies being used. The supplies used to support combat operations (troop use) are calculated on the basis of a constant use rate. At the beginning of the day the normal supply use rate is calculated and used if the quantity of supplies at the FEBA is above the predetermined minimum level. When the quantity of supplies at the FEBA falls below the minimum level, the minimum use rate is used. Every time an event occurs, an increment of supply use is calculated by multiplying the length of time since the last event by the supply use rate. Before adding the latest increment of supply use to the day's total the model checks to determine if that quantity of supply was available at the FEBA for use. If the actual quantity of supplies available is less than the calculated supply use, the quantity of supplies used is reduced to the appropriate value. This prevents the red forces from using more supplies than are available.

Air defense supply use is accumulated every time an air defense weapon or group of weapons fire at an aircraft. The incremental supply use is the product of the number of air defense weapons that fire and the supply use rate per weapon per aircraft engagement. A separate supply use rate is defined for the air defense weapons defending each link. Air defense weapons are resupplied from the supplies at the FEBA. This resupply action occurs at the end of the day and is limited to subtracting the day's air defense supply use from the supplies available at the FEBA.

Truck supply use represents the supplies used in repairing and preparing the trucks that are at the sink at the end of the day. Truck supply use is determined by multiplying the number of trucks at the sink (FEBA) by the truck supply use rate. Like air defense use, truck supply use is subtracted from the quantity of supplies at the FEBA at the end of the day.

End of day actions. At the end of each day, the maintenance actions for both forces are completed and the final statistics for the day are calculated. The red force maintenance actions consist of completing truck repairs and preparing the trucks for the next day's operations. Red force maintenance capabilities are limited to the extent that only 80 percent of the total number of trucks at each end of the network are available for use the next day. Blue force maintenance actions consist of completing repairs on aircraft with one day's work remaining so that the aircraft are available for use the next day. Daily statistics reported at this time include:

1. The day's thruput.
2. The day's supply use for the red force by major category of supply use: troop use, air defense use, truck use, and total supply use.
3. The number of trucks that were damaged or destroyed during the day and the number of damaged trucks that can be repaired.
4. The number of aircraft that were damaged during the day's operations by type of damage.

The above sequence of events is repeated each day of the interdiction campaign. At the end of the simulation, the final status of the system is provided.

The model can be run without interdiction to provide a base line for the distribution of trucks at the source and sink and the amount of thruput capable of being transported by the red force. Model output includes three types of data. First, the model prints out all values that are read in. Second, the model provides a day by day print out which contains a record of the day's statistics and operations. Finally, the model provides a summary of daily statistics at the end of the simulation.

Measurement of Interdiction Effectiveness

General discussion. The results of the interdiction campaign are evaluated using six indices of effectiveness which were designed specifically for use in this model. Since the conduct of any military operation requires the expenditure of supplies, the quantity of supplies available for use at the FEBA will have an impact on the range of possible military operations. If supplies are plentiful, they will not pose any restrictions. If supplies are limited, the red force commander may be forced to limit the size of an attack or cancel the attack and assume a defensive posture. A limited amount of supplies may also prevent the red force commander from pursuing blue ground forces who have been forced to retreat. If there are insufficient supplies to maintain a defensive position, the red force commander may be forced to retreat to avoid capture or reduce the size of his force. Thus, a comparison of the amount of supplies on-hand at the FEBA with the projected red force supply requirements provides a basis for measuring the effect of a limited interdiction campaign. This type of comparison has been used previously to measure the effect of long-term interdiction campaigns (11). Since the effect of interdiction can be viewed from several reference points, it is necessary to use the following indices to evaluate the results.

Unrestricted Support Index. The Unrestricted Support Index (USI) represents the quantity of supplies on hand (in tons) as a ratio of the quantity of supplies (in tons) consumed during n days of maximum intensity combat. This index measures how effective the logistics system is in meeting maximum supply demands. Decreases in the index occur when the daily quantity of supplies received at the FEBA is less than the amount required to support combat operations during the day. The index also measures how effective the logistics system is in maintaining the desired reserve of supplies required to provide the field commander with the desired operational flexibility. The USI is calculated using the following formula:

$$USI = \frac{So}{3\, D_{max}}$$

where

So = quantity of supplies on hand (in tons) at the forward combat units at the beginning of the day.

D_{max} = quantity of supplies (in tons) consumed during one day of maximum intensity combat.

The range of this index is defined to be from 0 to an unlimited upper bound. Since the daily supply use can never exceed the supplies available for consumption, negative values do not occur. Values in excess of 1.0 may occur because the transportation system attempts to deliver supplies the day before the supplies are required. Values between 0.0 and 1.0 indicate that only that fraction of the three day reserve is on hand in the red force forward combat units.

Programmed Support Index. The Programmed Support Index (PSI) represents the quantity of supplies on hand (in tons) as a ratio of the quantity of supplies (in tons) required to support the red force commander's plan of operation for the next three days. If the required amount of supplies is not on hand, then the red force commander may consider changing his plan of operation. It may be necessary for the red force commander to delay or reduce the scope of any planned attacks or to accept a higher risk of failure in meeting his planned goals. The PSI is calculated using the following formula:

$$PSI = \frac{So}{Dp}$$

where Dp = the quantity of supplies (in tons) required for the planned combat operations over the next three days.

The range of the PSI has a lower limit of 0.0 and an unbounded upper limit. Values in excess of 1.0 indicate that more supplies are available in the forward combat units than are required to support the planned level of combat for the next three days. Values between 0.0 and 1.0 indicate what fraction of the planned supply requirement for the next three days can be met by supplies on hand in the forward combat units.

Minimum Support Index. The Minimum Support Index (MSI) represents the quantity of supplies (in tons) available in the forward combat units as a ratio of the supplies (in tons) required to support minimum operations for three days. Minimum operations are limited to the feeding and care of the personnel and the redistribution of supplies within the forward combat units. All supplies required to support any combat operations, including air defense, are excluded from this definition. The MSI is found using the following formula:

$$MSI = \frac{So}{3\ D_{min}}$$

where D_{min} = the quantity of supplies (in tons) consumed during one day of minimum operations.

The range of this index is defined to have a lower limit of 0.0 and an unbounded upper limit. Daily values of this range should be well in excess of 1.0. When values of less than 1.0 are recorded, the quantity of supplies on hand are not sufficient to meet the minimum demand for three days.

Daily Combat Index. The Daily Combat Index (DCI) represents the quantity of supplies on hand (in tons) available in the forward combat units as a ratio of the supplies (in tons) required to support maximum intensity combat for the next day. The DCI is calculated using the following formula:

$$DCI = \frac{So}{D_{max}}$$

The range of values for this index is defined to be from 0.0 to an unbounded upper limit. Values less than 1.0 indicate that less than one day of maximum intensity combat can be supported by the supplies on hand in the forward combat units. When the DCI is below 1.0, the red force may be incapable of repulsing a ground attack.

Daily Minimum Operation Index. The Daily Minimum Operation Index (DMOI) represents the quantity of supplies on hand (in tons) as a ratio of the quantity of supplies (in tons) required to support minimum operations for the next day. The DMOI is calculated using the following formula:

$$\text{DMOI} = \frac{\text{So}}{D_{\text{min}}}$$

The range of values for this index is defined to be from 0.0 to an unbounded upper limit. If the value of this index falls below 1.0, the red force combat units may have insufficient supplies on hand to support minimum operations. The red forces may be close to total collapse and may not be able to avoid defeat and capture if attacked unless large quantities of supplies are received.

Achieved Thruput Index. The Achieved Thruput Index (ATI) represents the quantity of supplies (in tons) received at the forward combat units as a ratio of the quantity of supplies (in tons) that were ordered for delivery that day for the following purposes: (1) to replace the previous day's air defense weapon use; (2) to replace the previous day's truck use; (3) to provide the supplies for the next day's planned combat operations. The ATI is found using the following formula:

$$ATI = \frac{I}{Q}$$

where Q = sum (in tons) of the previous day's truck and air defense supply use plus the supplies required for the next day's combat operations.

Assumptions

We have made the following assumptions in constructing the model and developing the scenario. In actual application, the user must alter these assumptions to fit the situation he is analyzing.

Red force. The following assumptions were made concerning the red forces:

1. The red force commander desires his stockpile to contain three days' maximum supply demand and he will adjust his daily supply order to maintain the desired three day level.
2. The red force commander will reduce the unit's consumption to minimum usage when the stock on hand reaches three days' minimum usage.
3. The red force has sufficient equipment and supplies to repair links, and movement of repair materials to the damaged link does not require trucks from the logistics network.
4. Minimum repair time for a damaged link is twelve hours.

5. The red force transportation officer will establish a traffic discipline and use it throughout the simulation.

6. The red force will use the round trip time as a basis for selecting which routes to use.

7. The movement of red force repair vehicles will not disrupt the logistics system and will not affect the probability of detecting a supply truck.

8. The uninterdicted red force supply system has the capability of transporting more supplies than the forward combat units demand.

9. Red force combat units can only receive supplies from one source.

10. The size of the red force combat units being supplied does not change during the period of interdiction.

11. Two-way traffic is possible on all links.

12. There is unlimited handling capability at the source and sink.

13. Air defense weapons will detect all attacking aircraft and will fire first.

14. The red force has motor pool facilities at the source and at the sink.

15. To reduce truck losses, the red transportation officer has limited truck use of the road network to the hours of darkness (12 hours per day).

16. The number of trucks the red force has cannot be increased during the interdiction period.

Blue force. The following assumptions were made concerning the blue force:

1. The logistics system can be accurately defined.
2. Air defenses will be known and remain constant during the simulation.
3. The blue force has the option of applying defense suppression sorties to reduce the expected attrition rate of attacking aircraft due to air defense weapon action.
4. Each aircraft can fly only one sortie per day.
5. The availability of munitions is limited; therefore, aircraft will only attack their assigned targets.
6. The source and sink are inappropriate targets for interdiction.
7. All defense suppression aircraft sorties are taken from the number of aircraft available to conduct interdiction missions.
8. Defense suppression aircraft can attack only one target.
9. Defense suppression missions are conducted before attacks are conducted against the targets that the air defense weapons are defending.

10. The blue force commander will employ only one attack strategy during the interdiction campaign.

General. The following general assumptions were made:

1. Weather conditions are not a factor in finding and attacking targets.

2. The results of all attacks are known instantly.

3. Targets are either damaged or not damaged.

4. Only the types and levels of damage described in the model description are possible.

5. When a link is attacked, there is no collateral damage to trucks on the link.

6. Instantaneous communication is possible between all components of the military forces.

7. The use of supplies by combat troops at the FEBA is a continuous function.

8. The FEBA does not move.

9. No new links will be added to the existing logistics system during the period of interdiction.

Limitations

1. The model considers only truck transportation.

2. Only one type of truck and one type of aircraft are considered.

3. Only two types of weapon delivery tactics are considered. One for attacking air defense and fixed targets (links) and the other for attacking moving targets (trucks).

Chapter 4

MODEL VALIDATION AND ANALYSIS OF RESULTS

The purpose of this chapter is to present the extent of the model validation that was conducted and to present and analyze the results of our simulation runs.

MODEL VALIDITY

General Discussion

The validity of a model can be tested on three levels: technical validity, operational validity, and dynamic validity. Technical validity requires that the differences between the model and the real world be identified. All assumptions, data, and manipulations of the data should be open to review and the model should be constructed to follow a logical flow and mix of elements. In addition, all predicted outcomes should be consistent with the expected or known outcomes (23:644-649).

Operational validity is concerned with the importance of the differences in the model from the real world. Among these considerations are the degree of improvement over existing systems, the sensitivity of the model to the testing of extreme values of input parameters and the confidence that the real world will respond in a manner similar to the model (22:649-652).

The final test of validity is the dynamic characteristics of the model. Dynamic validity considers whether the model will continue to be operationally valid. Provisions should be made for changing input parameters and expanding the model (22:652-653).

Validation of the Model

Validation of the model was limited due to the manpower and time available to perform this research, and the inability to conduct real world experiments to verify model predictions.

We reviewed all assumptions, logic, simulated data, and manipulations of data to insure they were reasonable and proper. Each subroutine and the main program were tested as it was developed to insure that it functions as intended. As larger units of the model were assembled, they were tested to insure that adequate interface between the parts of the model had been provided and that they worked properly. After the entire model was built, it was tested to insure it functioned properly. Two testing procedures were used. First, events were traced through the model to ensure all required actions occurred in the proper sequence. Second, the values of various variables and data files were printed out to insure that they contained the proper values. Finally, the model was run using several different random number seeds. This was accomplished by changing the seeds for the seven random number generators at day 5 and day 10 during the simulation. These seeds were changed in order to minimize any bias in the simulation that could be caused by the stream of random numbers.

In researching the scenario that was modeled, we reviewed the literature to determine possible plausible scenarios. We also talked to students in AFIT who had been combat pilots in Vietnam and asked about their experiences in combat and the tactics used by the enemy. We considered the scenario modeled to be realistic although some assumptions and modifications had to be made to limit the complexity of the model.

Data Analysis

To answer our research questions, we developed a model of the interdiction scenario using the GASP IV simulation language. The model allows the user to select from three general interdiction strategies and includes an option which allows the user to employ interdiction aircraft in a defense suppression role. Two logistics networks were developed to show the flexibility of the model in handling logistics networks of varying sizes. The first logistics network modeled consisted of eleven links and eight nodes. For purposes of identification, this logistics network was called SHORTNET. Figure 4-1 presents a diagram of the network and Figures B-3 and B-4 present the particular parameters required to describe the network. This network consisted of five feasible routes or paths through the network. All links were roads with various constraining road speeds and on link eight we positioned a high value target such as a bridge or a tunnel.

The second logistics network consisted of 27 links and ten nodes. For purposes of identification, this logistics network was called LONGNET. Figure 4-2 presents a diagram of the network and Figures B-5 and B-6 present the particular parameters required to describe the network. In this network, links four through twelve were described as having alternate links. (A specific explanation of an alternate link is listed in Appendix B under IALTLINK.) There were 69 feasible routes through the network. A high value target was located on link six and on link eight.

For both networks we arbitrarily selected the length of the links, the speed on the links, the number of air defense weapons, and probabilities of kill for air defense weapons and interdiction aircraft within the constraints of the scenario that was modeled. Damage to roads was set equal to a 10 percent reduction in speed on these roads with the exception of links that are high value targets. On these links, all truck traffic was prevented

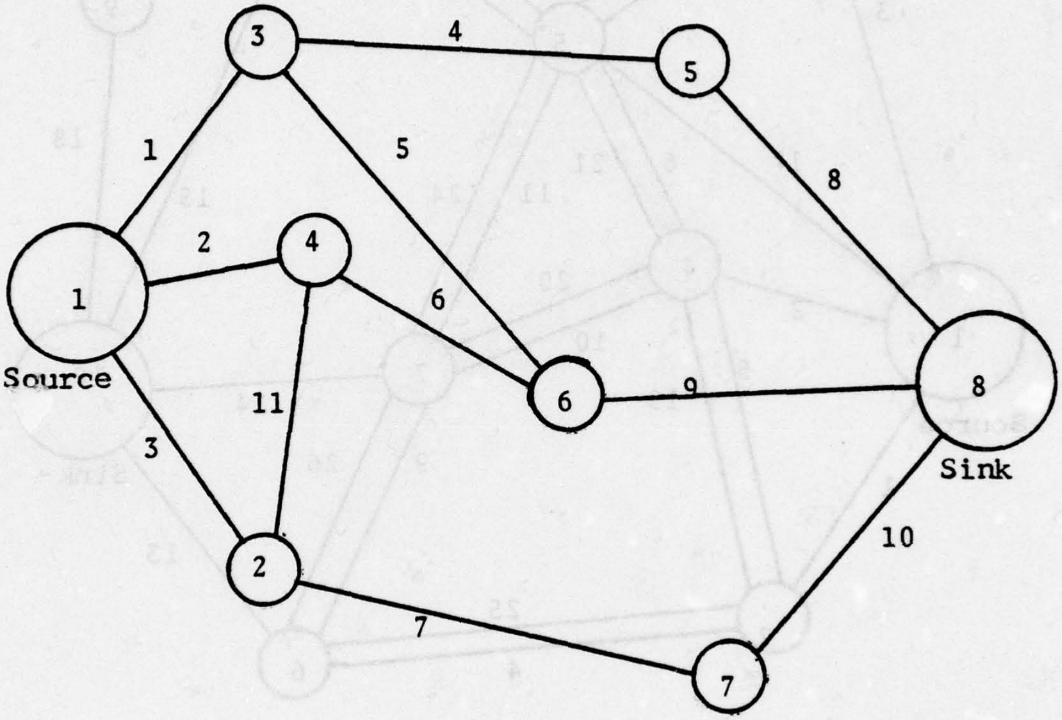


Figure 4-1. SHORTNET

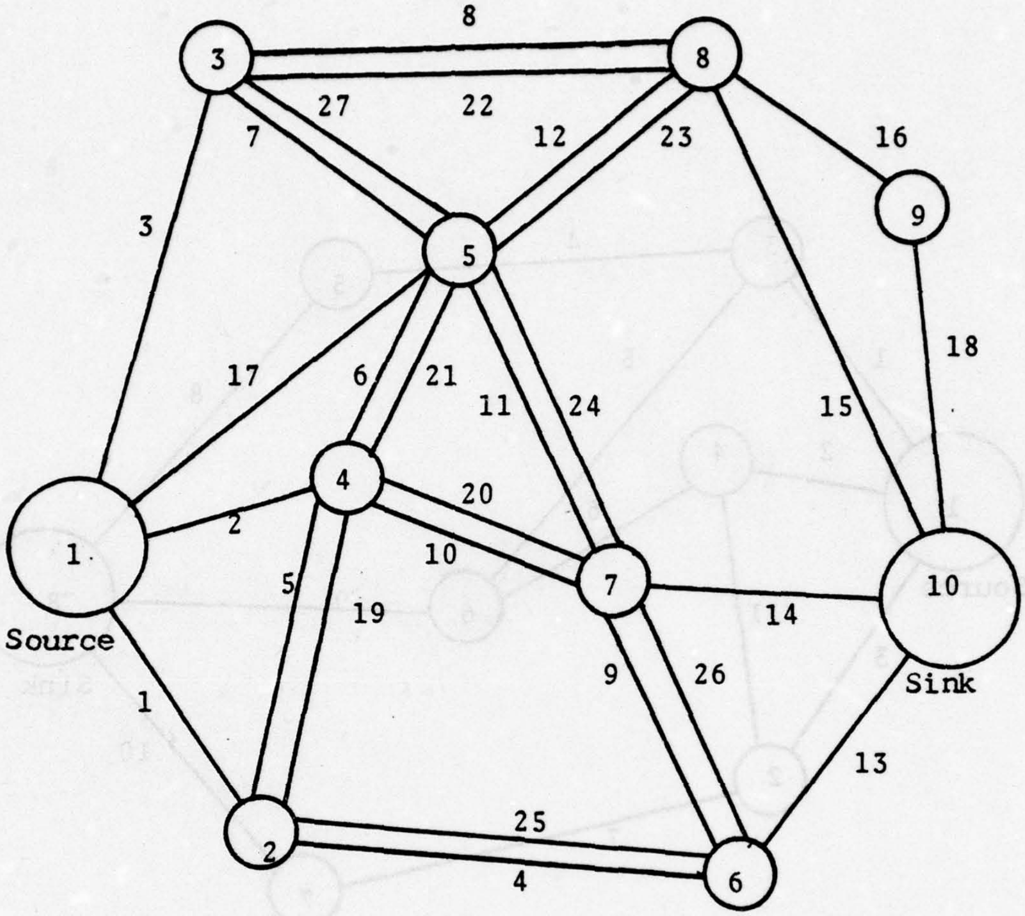


Figure 4-2. LONGNET

if the target was successfully attacked. Potential capacity for each link was calculated in the model and stored in DLNK(I,15). Capacity in trucks per hour was calculated by dividing the speed on the link by the minimum required distance between trucks. In accomplishing preliminary research runs, we found that the computer run time for the LONGNET was considerably greater than the run time with the SHORTNET when a two link attack was scheduled. The average run times for a two link attack using LONGNET was 2.75 hours and .13 hours using SHORTNET. Therefore, most of our research runs were accomplished using SHORTNET.

In order to evaluate the effect of a limited interdiction campaign on a specific logistics network we held constant the number of trucks available to the red force and the number of interdiction aircraft available to the blue force. With these values held constant, we changed the interdiction strategy and defense suppression capability for each set of simulation runs. Simulation runs were accomplished using both logistics networks. We made 18 research runs using SHORTNET. Each set of runs consisted of six simulations. Six runs were made using 500 trucks and 100 interdiction aircraft (Set 1). Six runs were made using 1,000 trucks and 100 interdiction aircraft (Set 2) and the last set of runs was accomplished using 1,000 trucks and 200 interdiction aircraft (Set 3). Only six runs were made using LONGNET with the number of trucks set equal to 500 and the number of interdiction aircraft set equal to 100 (Set 4). For each set of simulation runs there were six possible combinations of interdiction strategy and defense suppression capability. The following codes were used to identify the combination of a particular interdiction strategy and the defense suppression capability option:

1. 0-1--This type of attack option only required attacks against trucks and the blue force was able to assign interdiction aircraft in a defense suppression role.

2. 0-2--This type of attack option required attacks against trucks, but the blue force did not have a defense suppression capability.

3. 1-1--This type of attack option required an attack against one link in the logistics network and all remaining interdiction attacks assigned against trucks. Defense suppression capability was available.

4. 1-2--This attack option required an attack against one link in the logistics network and all remaining interdiction attacks assigned against trucks. Defense suppression capability was not available.

5. 2-1--This attack option required attacks against two links in the logistics network and all remaining interdiction attacks assigned against trucks. Defense suppression capability was available.

6. 2-2--This attack option required attacks against two links in the logistics network and all remaining interdiction attacks against trucks. Defense suppression capability was not available.

Prior to accomplishing the actual research runs, we ran the model for a 15 day period without interdiction to determine the distribution of trucks at the source and the sink for each set of simulation runs. These runs were also used to insure that the model reached a steady state condition. Based on the results of these computer runs, out-of-commission trucks were assigned to the source and the sink in a similar ratio as the in-commission trucks. The particular allocation of trucks assigned at the source and at the sink for each set of runs is found in Table 4-1. In addition, these preliminary runs were also used to determine the actual thruput per day that the red force could expect given the number of trucks and the traffic discipline employed by the red force transportation officer.

In order to run the model, we had to input specific parameters describing the overall system. The parameters which were held constant in all research runs can be found in Appendix B. Table 4-1 contains the parameters that were varied between research runs. Each set of parameters shown in Table 4-1 was run using each of the attack strategies with and without defense suppression.

Table 4-1

Starting Truck Distribution in Logistics Networks

Set	Description	Useable Trucks at Source	Useable Trucks at Sink	Trucks Under Repair at Source	Trucks Under Repair at Sink
1	SHORTNET 500 Trucks 100 Aircraft	280	120	70	30
2	SHORTNET 1,000 Trucks 100 Aircraft	800	0	200	0
3	SHORTNET 1,000 Trucks 200 Aircraft	800	0	200	0
4	LONGNET	298	102	74	26

The results of the simulation runs are listed in Tables 4-2 to 4-7. The data presented in these tables were collected from the summary statistics for the respective sets of runs. The following items were considered in the evaluation of the interdiction strategies used and the impact of an allocation of interdiction aircraft to a defense suppression role:

1. The amount of supplies-on-hand at the FEBA at the end of the interdiction period.

2. The number of aircraft destroyed during the interdiction period.

3. The number of trucks destroyed during the interdiction period.

4. The days on which the indices of effectiveness for the red force were below 1.0, which indicated that the interdiction effort had an effect on the operational flexibility of the red force.

<u>Results Set 1</u>. In Set 1 all attack options reduced the supplies-on-hand at the FEBA to the 2,000 ton range at the end of the simulation. This amount was significantly different from the level of supplies-on-hand required at the FEBA by the red force. The required level of supplies-on-hand was 7,500 tons. This requirement included the red force commander's desire to maintain three days maximum supply use of 6,000 tons on hand at all times plus the preplanned supply requirement of 1,500 tons for the next day's

Table 4-2

Statistics for Set 1

Attack Option	Destroyed Aircraft	Destroyed Trucks	Supplies on Hand at End of Interdiction Period	Day Combat Troop Supply Use Fell Below Planned Usage
0-1	26	280	1998.8	13
0-2	55	284	1961.1	12
1-1	21	252	2026.0	14
1-2	51	261	1990.8	12
2-1	20	219	2071.3	14
2-2	45	231	2033.0	12

Table 4-3

Day When Indices of Effectiveness Fall Below 1.0-- Set 1

Attack Option	USI	PSI	MSI	DCI	DMOI	ATI
0-1	8	10	14	--	--	2
0-2	7	9	13	15	--	2
1-1	7	10	14	--	--	2
1-2	7	9	13	--	--	2
2-1	8	10	15	--	--	2
2-2	7	9	13	--	--	2

operation. In these simulation runs, the critical factor for the red force was the number of trucks it could use to transport supplies to the FEBA. The uninterdicted thruput capability for a 12 hour operating period was 2,216 tons compared to a maximum planned daily demand of 2,000 tons. Since the red force had a limited number of trucks it was unable to capacitate the road network. Therefore, the interdiction strategy to assign aircraft to attack trucks and not to attack links proved to be more effective in reducing supplies-on-hand. The results of these simulation runs do not point to any interdiction strategy that was significantly more effective than the other strategies. Attack options 0-1 and 0-2 destroyed more trucks than the other options, but at a higher cost in destroyed aircraft. All interdiction strategies forced the red force commander to limit his plan of operation during the last days of the interdiction period. Each attack option reduced the following indices of effectiveness below the 1.0 level: (1) USI, (2) PSI, (3) MSI, and (4) ATI. However, there was no significant difference in the time when these indices were lowered. From the results of these simulation runs, it appears that there is little difference in choosing whether to attack just trucks, to attack one link and trucks, or to attack two links and trucks with a logistics network designed as in Set 1.

In assessing the option of allocating some aircraft to a defense suppression role, we found that using the defense suppression capability reduced the number of aircraft damaged or destroyed by at least one half. The interdictor was able to accomplish approximately the same level of supply denial without losing as many aircraft. Attack options 0-2, 1-2, 2-2 had an earlier effect (1 Day) on the operational capability of red force as compared to attack options 0-1, 1-1, 2-1. Again, the earlier impact on the red force cost the interdictor twice as many destroyed aircraft. From these results, we believe an investment in defensive suppression is worthwhile.

Results Set 2. In Set 2, the interdictor was faced with a capacitated logistics network. With 1,000 trucks available to the red force, the blue force was unable to have any impact on the red force's planned supply use or its flexibility of operations. The maximum 12 hour uninterdicted thruput in this scenario was 3,992 tons. The desired end supplies-on-hand requirement at the FEBA was met regardless of the attack option used to conduct interdiction. Each index of effectiveness did not fall below the 1.0 level during the interdiction period. The number of trucks destroyed ranged from 263 for attack option 2-1 to 308 for attack option 1-2. Since there was no impact on the red force's operational capability, interdiction does not appear to be effective in this scenario. If one

Table 4-4

Statistics for Set 2

Attack Option	Destroyed Aircraft	Destroyed Trucks	Supplies on Hand at End of Interdiction Period	Day Combat Troop Supply Use Fell Below Planned Usage
0-1	23	305	7543.7	--
0-2	52	306	7581.3	--
1-1	20	299	7537.0	--
1-2	48	308	7550.9	--
2-1	18	263	7539.9	--
2-2	43	268	7564.2	--

extrapolates the effect of losing trucks to interdiction aircraft, then we can assume that the interdiction effort will show satisfactory results in a longer interdiction period. Given the parameters of the logistics network, the blue force's desire to accomplish interdiction and the attack options available, the results lead the interdictor to use attack option 2-1. This attack option resulted in the lowest amount of supplies-on-hand at the FEBA at the end of the interdiction period. In addition, the interdictor using this attack option suffered the fewest aircraft losses.

In assessing the impact of defense suppression aircraft, we found that the blue force suffered twice as many aircraft losses without the defense suppression option as with the defense suppression option. In addition, each of the attack strategies using the defense suppression option allowed a smaller amount of thruput through the logistics network during the interdiction period and a smaller stockpile of supplies-on-hand at the end of the simulation.

Results Set 3. In Set 3, the interdictor was faced with the same red force as in Set 2, but he had twice as many interdiction aircraft as in Sets 1 and 2. For all attack options the supplies-on-hand at the end of the interdiction period was below the level required by the red force

Table 4-5

Statistics for Set 3

Attack Option	Destroyed Aircraft	Destroyed Trucks	Supplies on Hand at End of Interdiction Period	Day Combat Troop Supply Use Fell Below Planned Usage
0-1	51	617	6673.5	--
0-2	117	605	6753.0	--
1-1	39	655	5423.0	--
1-2	104	662	4965.2	--
2-1	39	614	6180.9	--
2-2	103	607	5962.0	--

commander. The achieved thruput index was the only index of effectiveness that was below the 1.0 level for all attack options. There was no significant impact on the red force's planned supply use or its operational flexibility. In assessing the attack options, the results of the simulation runs point to employing either attack option 1-1 or 1-2. Attack option 1-1 allows the smallest amount of thruput through the logistics network and suffers the fewest aircraft losses. Attack option 1-2 destroys more trucks and has a lower ending quantity of supplies-on-hand, but this option results in 2.67 times more aircraft being lost. Given a logistics network and interdiction force as described in Set 3, the interdictor should employ attack option 1-1.

An investment in defense suppression aircraft again proved to be effective. The number of aircraft losses sustained without the defense suppression option were 2.29 and 2.67 times as great as those with the defense suppression option.

Results Set 4. In Set 4, the interdictor encountered a larger logistics network in terms of the number of links and, therefore, a larger number of potential targets. The red force had a limited number of trucks and it was unable to capacitate the network. The maximum number of tons of supply that could be delivered by 500 trucks during a 12

Table 4-6

Statistics for Set 4

Attack Option	Destroyed Aircraft	Destroyed Trucks	Supplies on Hand at End of Interdiction Period	Day Combat Troop Supply Use Fell Below Planned Usage
0-1	23	292	1997.6	14
0-2	54	303	1892.2	13
1-1	20	256	2045.5	14
1-2	51	269	1997.3	13
2-1	20	223	2135.9	15
2-2	46	255	2032.3	13

Table 4-7
Day When Indices of Effectiveness Fall Below 1.0--
Set 4

Attack Option	USI	PSI	MSI	DCI	DMOI	ATI
0-1	11	11	15	--	--	2
0-2	8	10	14	15	--	2
1-1	8	11	15	--	--	2
1-2	8	10	14	--	--	2
2-1	9	11	--	--	--	2
2-2	8	10	14	--	--	2

hour operating period without any interdiction is 2,396 tons. Since the maximum planned supply use was 2,000 tons, the logistics system only had the capability of delivering 20 percent more supplies than the maximum planned usage. Consequently, any interdiction effort against trucks will show an earlier impact on the red force's flexibility of operations and on the indices of effectiveness than in Sets 2 and 3. All attack options reduced the supplies-on-hand at the end of the interdiction period to a level below that required by the red force commander. Each attack option reduced the USI, PSI, MSI, and ATI indices of effectiveness below the 1.0 level. Attack options without the defense suppression capability reduced these indices below the 1.0 level one day prior to those attack options with the defense suppression capability. There was no attack option that had a significantly greater impact on the red force's planned supply use or flexibility of operations.

Once again the use of attack options with defense suppression capability reduced the number of aircraft losses to approximately one half. The effect of interdiction for these attack options reduced ending supplies-on-hand relatively close to the 2,000 ton level.

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In this chapter, we have summarized the research effort, presented our conclusions, and discussed areas recommended for future study.

Summary

In any limited interdiction scenario, the commander of the blue force needs a method to determine the allocation of his interdiction sorties against targets in the logistics network.

The objective of this thesis was to develop a computer model using the GASP IV simulation language to provide a method of determining the effect of a limited tactical air interdiction campaign. Of the possible categories of interdiction only anti-capacity and anti-capability interdiction were considered in this model. In developing the model, we limited the number of trucks and aircraft available to the opposing forces, included repair capability for links, aircraft and trucks, and provided a method of allocating trucks to routes in the logistic system using the routes with the shortest round trip time. In addition, we provided methods to employ one of three interdiction strategies and also an option to employ some interdiction aircraft in a defense suppression role.

In accomplishing our simulation runs, we developed two logistics networks and a specific interdiction scenario. Interdiction was accomplished against both a capacitated and uncapacitated network. The parameters that were changed in our simulation runs were: the number of aircraft, the number of trucks, the interdiction strategy, and the defense suppression capability.

The model also has the capability of being run for any length of interdiction provided the supply file, the summary statistic file (DAYDATA), and the event for terminating interdiction in the PRISCARD file are changed accordingly. The model also provides for any specified distance between trucks on a route going in the same direction and a variable operating time for the logistics network.

Conclusions

Two research questions were posed in Chapter 1 and were the basis for our simulation runs. These questions were:

1. How can GASP IV be used to determine the effect that limited interdiction of a logistics system may have in reducing the enemy's freedom of operation?

2. How can GASP IV be used to evaluate the impact of an investment in defense suppression on the effectiveness of a limited air interdiction campaign?

We found that in using the simulation model, we were able to determine the effect of a particular interdiction strategy on a given logistics network. The type of strategy that proved to be more effective depended on the number of trucks in the system and the supply demand put on the logistics system. We also found that an application of some interdiction aircraft in a defense suppression role was worthwhile to the interdictor in terms of reducing aircraft losses and attaining a relatively equal amount of supply denial.

Recommendations for Future Study

The use of computer simulation as a method of investigating interdiction problems should be continued. Additional computer simulations could be run with our model using different input parameters to further investigate the interaction among the numerous variables. There are a number of modifications that could be made to the model to study the effects of limited interdiction. Some of the areas that could be researched are:

1. The impact of a specified attrition rate for interdiction aircraft on the selection of targets in a logistics network.

2. The effect of moving the FEBA during the interdiction period.

3. The effect of changing the air defense weapon and interdiction aircraft encounter by using a random number generator to determine which weapon system fires first.

4. The effect of including the source and sink as viable targets in the logistics network.

5. The impact of changing the truck assignment strategy during the interdiction period. This could include varying the traffic discipline and the criteria for assigning trucks to routes.

6. The effect of moving the air defense weapons from route to route.

7. The effect of considering the movement of troops and combat equipment in the logistics network.

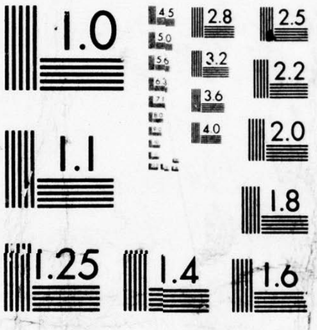
8. Formulation of a methodology which will permit consideration of attacking more than two links in the logistics network while minimizing the required computer processing time.

APPENDIX A

DEFINITIONS OF VARIABLES USED

AD-A045 212   AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC   F/G 15/7
AN APPLICATION OF GASP IV TO DETERMINE THE EFFECT OF A LIMITED --ETC(U)
JUN 77   J W GEITH, P A OPENHYM
UNCLASSIFIED   AFIT-LSSR-14-77A   NL

2 OF 3
AD
A045 212


1.0
4.5
5.0
5.6
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

Variable Definition

AATRIB(I) - Attributes for events in the simulation.

AATRIB(1) - Time the event occurs.

AATRIB(2) - The type of event.
1 - Truck arrival (TRKARL).
2 - Daily ops (DAILYOPS).
3 - Aircraft attack (ACATK).
4 - Truck scheduling (TRKSCH).
5 - Cancels truck scheduling for a given route (MISEVT).
6 - Repair of air defense weapons (MISEVT).
7 - Link repair (MISEVT).
8 - Set pointer to begin interdiction campaign (MISEVT).
9 - State event has occurred.
    (a) Supplies on hand less than SUCP1.
    (b) Supplies on hand greater than SUCP1.
    (c) Thruput is greater than the order - terminate truck scheduling.
10 - Changes the random number seeds for all random number streams.

AATRIB(3) for a:
1 - Truck arrival event, AATRIB(3), is the route used.
2 - Daily ops event, AATRIB(3), is not used.
3 - Aircraft attack event, AATRIB(3), is the row number in the KACAT (attack) matrix which contains specific information describing the attack.
4 - Truck scheduling event, AATRIB(3), is the number of the route appearing in the truck assignment plan, i.e. Route 1, Route 2, etc.
5 - Cancel truck scheduling event, AATRIB(3), is the number of the route appearing in the truck assignment plan.

Variable Definition

6 - Repair of air defense weapon event, AATRIB(3), is the link number.
7 - Link repair event, AATRIB(3), is the number of the link.
8 - Interdiction pointer event, AATRIB(3), is not used.
9 - State event, AATRIB(3), is not used.
10 - Random number change event, AATRIB(3), is the random number generator.

AATRIB(4)
for a:

1 - Truck arrival event.
  (a) If AATRIB(4) is a 1, a full truck has arrived at the sink.
  (b) If AATRIB(4) is a 2, an empty truck has arrived at the source.
  (c) If AATRIB(4) is a 3, a damaged truck arrives at the source.
  (d) If AATRIB(4) is a 4, a damaged truck arrives at the sink.
2 - Daily ops event, AATRIB(4), is not used.
3 - Aircraft attack, AATRIB(4), is not used.
4 - Truck scheduling, AATRIB(4), is not used.
5 - Cancel truck scheduling event, AATRIB(4), is not used.
6 - Repair of air defense weapon event, AATRIB(4), is not used.
7 - Link repair event, AATRIB(4), is not used.
8 - Interdiction scheduling event, AATRIB(4), is not used.
9 - State event, ATTRIB(4), is not used.
10 - Random number change event, AATRIB(4), is the random number seed.

AC - Variable used in the ACATK subroutine to determine whether an aircraft damaged by air defense weapons has one or two weapons on it.

Variable	Definition
AC	- The number of aircraft required to damage a link with a .9 probability of success. The figure does not take into consideration aircraft that might be lost due to air defense weapons. This variable is used in the ACSCHED subroutine.
ACAP	- Variable used to determine the amount of link capacity used.
ACRNG	- Aircraft flying range for each aircraft.
ACS	- Aircraft speed.
ADS	- The number of defense suppression aircraft required to support a link attack.
ADU	- Amount of supplies used by air defense weapons.
AGAT	- Number of aircraft assigned to attack a target given a desired .9 probability of destruction.
ALD	- Variable used in the ACATK subroutine. ALD represents the route number of a route which uses the link which is being searched by blue force aircraft for trucks.
AMSI	- Minimum support index. The ratio of the quantity of supplies on hand at the FEBA divided by SUCP1.
ATI	- Achieved daily thruput index. The ratio obtained by dividing the day's thruput by the sum of the previous day's truck and air defense supply use plus the preplanned supplies required to support the next day's combat operations.
ATT	- Pointer used in the DAMAGE subroutine to aid in the generation of an event to either cancel the arrival of a destroyed truck or to change AATRIB(4) of a truck arrival event from full or empty to damaged.

Variable	Definition
BASEX	- X coordinate of the aircraft base.
BASEY	- Y coordinate of the aircraft base.
BLD	- Variable used in the DAMAGE subroutine to find the truck arrival event which represents the truck that has been damaged/destroyed.
DA	- Storage variable for the value in AATRIB(1) in the DAMAGE subroutine.
DAYDATA(I,J)	- Storage matrix for summary statistics. DAYDATA(NDAY,1) = ITAC DAYDATA(NDAY,2) = NACL DAYDATA(NDAY,3) = NAC1 DAYDATA(NDAY,4) = NAC2 DAYDATA(NDAY,5) = NAC3 DAYDATA(NDAY,6) = NACP DAYDATA(NDAY,7) = USI DAYDATA(NDAY,8) = PSI DAYDATA(NDAY,9) = AMSI DAYDATA(NDAY,10) = DCI DAYDATA(NDAY,11) = DMOI DAYDATA(NDAY,12) = ATI DAYDATA(NDAY,13) = SS(1) DAYDATA(NDAY,14) = ORDER DAYDATA(NDAY,15) = SS(2) DAYDATA(NDAY,16) = DUSE DAYDATA(NDAY,17) = USE DAYDATA(NDAY,18) = TRKUSE DAYDATA(NDAY,19) = ADV DAYDATA(NDAY,20) = ITRK DAYDATA(NDAY,21) = ITRKMAX DAYDATA(NDAY,22) = NTKD DAYDATA(NDAY,23) = NTR DAYDATA(NDAY,20) = ITRK DAYDATA(NDAY,24) = NTKD-NTR
DB	- Storage variable for AATRIB(2) in the DAMAGE subroutine.
DBT	- Distance between trucks on each route used in the network.
DC	- Storage variable for AATRIB(3) in the DAMAGE subroutine.

Variable	Definition
DCI	Daily Combat Index. The ratio of the quantity of supplies on hand at the FEBA divided by the quantity of supplies consumed by one day of maximum intensity combat.
DE	Storage variable used to store the value of AATRIB(3) in the DAMAGE subroutine.
DLNK(I,J)	Matrix used to store information about the logistics network.
(I,1)	Link number.
(I,2)	Beginning node.
(I,3)	End node.
(I,4)	For links that can have traffic in either direction, the corresponding link number.
(I,5)	The length of the link in miles.
(I,6)	The maximum speed in miles per hour that a truck can be driven over the link.
(I,7)	The percentage reduction in miles per hour on a link, given there has been a successful interdiction attack.
(I,8)	The repair rate of link in days.
(I,9)	The probability of link damage per aircraft.
(I,10)	The average number of air defense weapons encountered on a link.
(I,11)	The probability of aircraft kill per air defense weapon.
(I,12)	Supply use in tons per air defense weapon.
(I,13)	Probability of detecting a vehicle on the link.

Variable	Definition
(I,14)	- The probability of truck kill on the link per aircraft.
(I,15)	- The maximum capacity per link given the required minimum distance between trucks; this is calculated in the program.
(I,16)	- The new maximum truck speed in miles per hour on the link after a successful interdiction attack.
(I,17)	- The new probability of kill of aircraft per link.
DMOI	- Daily Minimum Operation Index. The ratio of the quantity of supplies on hand at the FEBA divided by the quantity of supplies required for one day of minimum operations.
DRAND(X)	- GASP IV function used to generate random numbers.
DUSE	- Total supply use per day; includes troop use, truck use, and air defense weapon use.
FDIST	- The distance that an aircraft must fly to travel from one end of a link to the other end.
GRID(I,J)	- Grid coordinates for nodes in the logistic system.
(I,1)	- Link number.
(I,2)	- X coordinate of the node closest to the air base.
(I,3)	- Y coordinate of the node closest to the air base.
(I,4)	- X coordinate of the node ending the link.
(I,5)	- Y coordinate of the node ending the link.

Variable	Definition
(I,6)	Distance from the airbase to the first node of the link.
(I,7)	Distance from the airbase to the end node of the link.
IAAC	The number of aircraft available to make interdiction or defense suppression attacks; this variable decreases as each successive attack is scheduled.
IACAS(I,J)	The total number of aircraft required to perform an attack against a link.
(I,1)	Number of aircraft assigned to attack a link.
(I,2)	Aircraft performing a defense suppression role in link attacks.
IADS	Integer number used to determine the required number of defense suppression aircraft per link.
IAGAT	The number of aircraft required to accomplish the required level of damage to a link with a .9 probability of success.
IALTLINK(I,J)	Matrix of alternate links between nodes.
IDS	The number of aircraft remaining that can be assigned to accomplish additional defense suppression or interdiction missions.
IDSCA	Variable which determines whether aircraft can perform a defense suppression role; 1 - defense suppression available, 2 - no defense suppression capability.
IDSI	The number of trucks that are short at the sink.
IDSO	The number of trucks that are short at the source; i.e., one half of the number of trucks required to capacitate the route less the number of trucks available to be assigned to that route.

Variable	Definition
IFRNOD(I)	- The "from" nodes corresponding to links selected for feasible routes.
IFRUIT(I,J)	- Matrix of feasible routes. Each row consists of the links which make up a route.
IHOLD	- Holds matrix element during minimum or maximum search.
ILD	- Variable used in the DAMAGE subroutine. It represents the route that a damaged truck was using.
IMIN	- Holds the last value during minimum or maximum search.
IN	- The number of links in the network.
INA	- Index variable.
INB	- Index variable.
IPILE(I,1)	- The number of trucks assigned to a route at the source (full trucks).
(I,2)	- The number of trucks assigned to a route at the sink (empty trucks).
IR	- Variable used in the MISEVT subroutine to go to the proper section of the subroutine when a particular MISEVT has occurred.
IRCAP(I,J)	- Matrix containing route capacity in number of trucks per hour for each link in a route.
IRT	- Temporary storage variable used to select the route with the shortest round trip time from the feasible routes.
IRU	- Index number; the number of feasible routes that allow maximum flow in the network.
IRUT(I)	- Working array of links used during the formulation of feasible routes.

Variable	Definition
IRUTCAP(I,J)	- Matrix containing the link capacity for each link in each feasible route.
IRUTUSE(I)	- Vector of routes used.
ISUM	- Temporary variable used to find the smallest capacity link in a feasible route.
IT	- The number of trucks at the sink assigned at the beginning of the day to a particular route.
ITAC	- The total number of aircraft available each day.
ITGTLK	- Variable used in the ACSCHED subroutine to store the number of the link being considered for a one link air interdiction mission.
ITK	- Temporary variable used to find the link with the highest expected truck density in the ACSCHED subroutine.
ITKDEN(I)	- Estimated truck density on each link at a given point in time.
ITOFR(I,J)	- The "from - to" matrix.
ITRK	- The number of trucks available in the system. Trucks are either operable or damaged.
ITRKAV	- The number of trucks available for use on the network.
ITRKMAX	- The number of trucks usable.
IS	- The number of trucks at the source assigned at the beginning of the day for a particular route used.
ISUMCAP(I)	- Capacity of a feasible route.
ISUPPLY(I)	- Matrix containing the desired troop supply use for a twenty day period.

Variable	Definition
ITEMP	- Variable used to determine the number of trucks needed to capacitate a route. It is used to determine whether rounding up is required.
JADS	- Variable used to determine the number of aircraft required in a defense suppression role.
JSUMCAP(I)	- Array containing the capacity of routes selected for use.
K	- The number of nodes in the network.
KACAT(I,J)	- Matrix containing the planned aircraft attacks.
(I,1)	- Type of attack; 1 is a link attack, 2 is a truck attack.
(I,2)	- The link number where the attack will occur.
(I,3)	- The number of aircraft assigned to attack the link or to attack trucks on the link.
(I,4)	- Defense suppression aircraft.
(I,5)	- Total number of weapons that a cell of four aircraft have remaining to accomplish additional truck attacks on a particular link.
(I,6)	- Total number of miles of flying range remaining.
(I,7)	- Pointer which tells which direction the aircraft are flying. A 1 indicates that the aircraft are flying away from the node, closer to the airbase; and a 2 indicates that the aircraft are flying toward the node, closer to the airbase.
KODE	- Variable used to store the number of a particular error that is detected while the program is executing. This error code is used in subroutine UERR.

Variable	Definition
KTRK	- Variable used to store information contained in AATRIB(4) of a truck arrival event. It is used to go to the proper section of the TRKARL subroutine to handle the particular type of truck.
LBAT	- Variable used in subroutine ACATK to store the value of the event in AATRIB(3), i.e. row in KACAT matrix.
LD	- Variable used to store the link number of the link being attacked.
LINKA	- Variable used in the ACSCHED subroutine to store the link number of the link which when successfully attacked reduces thruput the most in a two link attack.
LINKB	- Variable used to store the link number of the link that causes the second greatest reduction in thruput in a two link attack.
LINKUSE(I)	- Vector containing the used capacity for each link.
LLFLAG(I)	- GASP IV variable used to indicate the crossing of a threshold value for continuous simulation. (1) The supplies on hand are less than three days minimum usage. (2) The supplies on hand are greater than three days minimum usage. (3) The number of tons received at the sink (thruput) is greater than or equal to the day's supply order.
LNE	- Variable used to store the position number of the next event in the NSET/QSET matrix.
LSINK(J)	- Identification of links leading to the sink.
LU	- Variable used to store the information contained in AATRIB(3) in the MISEVT subroutine.

Variable	Definition
MA	- Variable containing the link number.
MAC	- Variable used to determine whether an aircraft damaged by the air defense weapons has one or two weapons on it.
MAC1	- Damaged aircraft available the next day; aircraft will be repaired in one day.
MAC2	- The number of damaged aircraft repairable in two days.
MAXFLOW	- The maximum number of tons of supply that can be transported through the network when no interdiction has taken place.
MAXUSE	- The maximum number of tons of supply used by the troop force per day of maximum intensity combat.
MD	- Alternate link to the link under consideration, i.e. the value (link) stored in DLNK(I,4).
MINUSE	- The minimum number of tons of supply used by the troop force in a single day of minimum operations.
MIQ	- Variable used in ACSCHED subroutine which represents the alternate link of the link under consideration.
MJQ	- Variable used in ACSCHED subroutine which represents the alternate link of the link under consideration.
MM	- Link identifier input and maximum feasible route index.
MMMM	- Variable used to store the value in AATRIB(3) in the truck scheduling subroutine.
MTALL	- Total number of damaged aircraft each day of interdiction; includes aircraft reparable in one, two, or three days and aircraft destroyed.

Variable	Definition
MTK	- Variable used to determine the specific truck damaged on a particular link.
MTKR(I)	- Variable used to store the total number of damaged trucks on a particular route after a truck attack.
MTSINK	- The number of usable trucks at the sink.
MTSOR	- The number of usable trucks at the source.
MTT	- Pointer used in the DAMAGE subroutine to aid in the generation of an event to either cancel the arrival of a destroyed truck or to change AATRIB(4) of a truck arrival event from full or empty to damaged.
NAC	- The number of aircraft required to cause damage to a target with a probability of success of .9.
NACL	- Total number of aircraft damaged or destroyed after an interdiction effort.
NACP	- The number of aircraft destroyed.
NACS	- The number of aircraft surviving an air defense weapon attack prior to the aircraft making their attacks.
NAC1	- The number of aircraft requiring one day repair.
NAC2	- The number of aircraft requiring two days repair.
NAC3	- The number of aircraft requiring three days repair.
NADW	- The average number of air defense weapons encountered on a link.
NATK	- The number of attacks that are scheduled to be conducted during one day's interdiction effort.
NDAY	- Variable corresponding to the day of the interdiction scenario.

Variable	Definition
NDR	- Indicator used to determine whether the aircraft is flying up (away from the airbase - 1), or down (toward the airbase - 2) the link.
NDTSINK	- The number of damaged trucks at the sink.
NDTSOR	- The number of damaged trucks at the source.
NET	- Net reduction of thruput given a one link or two link attack.
NETAC	- The number of aircraft required to attack a target, includes both air defense suppression sorties and aircraft assigned to attack the target.
NETREDUC(I)	- Net reduction in thruput given that a particular link is damaged.
NETWO(I,J)	- Matrix containing reductions of thruput when two links are attacked.
NLA	- Indicates the type of interdiction strategy planned. (0) Indicates an attack against trucks only. (1) Indicates attack against one link and trucks. (2) Indicates an attack against two links and trucks.
NQQ	- Variable indicating whether air interdiction is available; 1 indicates no air interdiction, 2 indicates air interdiction is available.
NRU	- The number of routes used.
NSAC	- The number of aircraft surviving air defense weapons attacks.
NTAR(I)	- Array used to store the number of trucks using a link for an hour.
NTKD	- The number of trucks damaged in a given day.

Variable	Definition
NTKE(I)	- The number of trucks going east (sink to source) on route (I).
NTKW(I)	- The number of trucks going west (source to sink) on route (I).
NTR	- The number of trucks damaged per day that can be repaired.
NTRY	- Variable used to store the location position of an event in the event file (QSET).
NTSTE(I)	- Pointer to first "east-bound" truck on the link under attack using route (I).
NTSTW(I)	- Pointer to the first "west-bound" truck on the link under attack using route (I).
NWL	- The number of aircraft weapons available after each attack by a cell of four aircraft attempting to attack trucks.
NWU	- The number of aircraft weapons used to attack trucks in one truck attack.
NX	- Variable used to determine the type of aircraft damage incurred: one day, two day, three day, or total destruction.
ONEWAYT(I)	- One way time for each route (either from the source to sink, or the sink to source); excludes loading or unloading time.
ORDER	- The quantity of tons of supply ordered each day.
PADN	- The probability of kill of a aircraft by air defense weapons for a particular link.
PAS	- The probability of damage of a link for those aircraft which successfully survive an air defense weapon attack.
PDSK	- The probability of damage to air defense weapons given that a number of air defense suppression sorties survive air defense weapon action and attack these weapons.

Variable	Definition
PDS	The probability of an air defense suppression sortie damaging an air defense weapon.
PIRU	Permanent storage variable for the number of routes used in a maximum flow situation.
PLINKUSE(I)	Array used to store the used capacity of each link in the network.
PMAX	Permanent storage variable used to store the maximum flow of trucks per hour given the interdiction of zero, one, or two links.
PPARM(I,J)	Input parameters.
(1,1)	MAXUSE.
(1,2)	MINUSE.
(1,3)	SS(1).
(1,4)	DSUPPLY.
(2,1)	ITRK.
(2,2)	DBT.
(2,3)	SUCPI.
(2,4)	VTRKUSE.
(3,1)	ITAC.
(3,2)	ACRNG.
(3,3)	ACS.
(3,4)	NQQ.
(4,1)	NLA.
(4,2)	VTIMOP.
(4,3)	IDSCA.
(4,4)	PDS.

Variable	Definition
(5,1)	- MTSOR.
(5,2)	- MTSINK.
(5,3)	- NDTSOR.
(5,4)	- NDTSINK.
PRUTUSE(I)	- Permanent storage vector for routes used in the maxflow situation.
PSGT	- The probability of a given number of aircraft causing damage to a particular link.
PSI	- Programmed support index. The quantity of supplies on hand at the FEBA as a ratio of the quantity of supplies required to support the next three days of planned operations.
PTKD	- The probability of detecting a truck on a particular link.
PTRKCAP	- Permanent storage variable representing the total estimated thruput for a day's operation.
PTRTIME(I)	- Permanent storage array that contains the round trip time for all feasible routes at a given time.
PUCAP(I)	- Permanent matrix used to store capacity used for each link in a maxflow situation.
PULINK(I)	- Permanent storage array showing the number of trucks per hour traveling from the source to the sink using link (I).
PUSE	- Variable used to calculate the incremental troop use; values are added to calculate total troop use for a given day.
Q	- Variable used in the process to determine whether a damaged aircraft has one or two weapons.

Variable	Definition
RAC	Amount of flying range remaining for a particular aircraft.
RECAP	The amount of thruput reduction in tons that can be realized if both links are successfully attacked.
RTH	Variable used to calculate the Achieved Thruput Index for a given day.
RTTIME(I,J)	Matrix containing the time required to travel each link in a feasible route. Each row in the matrix corresponds to a feasible route.
SDTRUT(I)	Array containing the one way distances (source to sink) of each feasible route in the network.
SH	The number of tons of supply required to be ordered to keep the supplies on hand equal to the "desired" supplies on hand.
SS(1)	Supplies on hand at the FEBA.
SS(2)	Amount of thruput for the current day.
STKE	The number of trucks traveling from the sink to the source assigned to a particular route and on a link where a truck attack is occurring.
STR	A variable used to determine which route the damaged truck was assigned to.
STRUT	Temporary variable used to store the shortest round time as a search is made to select the route with the shortest round trip time.
SUCP1	Variable used to store three times the minimum supply use by the troop force. This variable is used in the SCOND subroutine to determine whether the hourly troop supply use rate should be reduced to the minimum hourly supply usage rate or to continue at the supply usage rate planned for that day.

Variable	Definition
TCAP	- Variable used in ACSCHED during a two link attack to store the capacity of the first link.
TCAP2	- Variable used in ACSCHED during a two link attack to store the capacity of the second link.
TDATA	- Temporary variable used to rearrange the Grid matrix into numerical order, i.e. 1 to X.
TDTK	- Total number of trucks damaged during the simulation.
TE	- Variable used in the DAMAGE subroutine to determine whether the damaged truck was traveling from the source to the sink, or from the sink to the source.
TEMP	- Variable used to determine the number of trucks needed to capacitate a route.
TFA	- Delay time used in scheduling aircraft so that the aircraft begin attacks when the first truck using the route with the longest trip time reaches the end of the route.
TFLOW	- The total number of supplies delivered to the front.
TFSI	- Time from the sink to the source.
TFSO	- Time from the source to the sink.
TLAST	- Variable used to store the simulation time in order to calculate the supplies used by the troop force for a given period of time at a given supply usage rate.
TMPH	- Variable used in ACSCHED during a two link attack to store the current truck speed in miles per hour for the first link.

Variable	Definition
TMPH2	- Temporary storage variable used in the ACSCHED subroutine when a two link attack is authorized. Variable stores the current truck speed in miles per hour for second link being considered.
TORDER	- The sum of the daily supply orders for the number of days considered in the interdiction scenario.
TR	- Variable used in the process of determining which route a truck is using. This variable is used in the DAMAGE subroutine.
TRKCAP	- Estimated number of tons of supply that can be delivered to the sink, given the current condition of the network and the number of trucks available.
TRKUSE	- The total number of tons of supply used by the trucks during the interdiction scenario.
TRTIME(I)	- Array containing the round trip time for each link on a feasible route.
TSL	- The time which the last truck on the link being attacked would arrive at the source or sink.
TST	- The time which the first truck on a link being attacked would arrive at the source or sink.
TTNOW	- The current simulation time.
TUSE	- The total number of tons of supply consumed by the troop force, air defense weapons, and trucks throughout the interdiction scenario.
UCAP	- Estimated number of tons of supplies that can be delivered to the sink in a specified period of time, i.e. 12 hours for this simulation.
ULINK	- Amount of used capacity for a given link.

Variable	Definition
USE	- The number of tons of supply used by the troop force.
USERATE	- The rate of supply used by the troop force at the front.
USI	- The unrestricted support index.
VORDER	- The daily supply order minus one ton. This variable is used in the KROSS subroutine to trigger the scheduling of replacement vehicles for damaged trucks when sufficient loaded trucks had been dispatched from the source to satisfy the daily supply order.
VTIMOP	- The number of hours per day that the red truck force can use the road network.
VTRKUSE	- The supply use rate per truck for trucks ending the day at the FEBA.

APPENDIX B

USER'S GUIDE TO THE SIMULATION MODEL

This guide is designed to assist users of the simulation model in preparing the necessary data files to run the model and in reading the output. It is not a complete guide to the actual formating of all data files. If formating is necessary, the user should refer to the master's thesis written by Chaney and Hinneburg (6) and the GASP IV publications by Pritsker (21; 22). The first data file discussed will be the basic GASP IV input data file. The second will be the supply use data file. The third item discussed will be the transportation network data file. Interpretation of output is the last item in this appendix.

INPUT DATA

GASP IV Input Data

GASP IV Input Data as implemented on the AFLC Create system has provisions for 18 types of data cards. This program uses only ten of these cards. The eight types of cards not used are types 3, 4, 5, 6, 7, 16, 17, 18. These are used when statistics and histograms are collected, using GASP IV supplied subroutines, when plots are printed using GASP IV supplied subroutines, and when special printouts such as a QSED DUMP are desired. Examples of card types 0, 1, 2, 8, 9, 10, 11, 12, 13, 14, 15 can be found in Figure B-6. The definitions of all variables described on cards 1 through 18 can be found in references 6, 21, or 22.

Card Type 0

Card 0 provides information on the number of runs which are to be conducted and instructions for reading and printing each card type. The variables are as follows:

NNRUNS	The number of simulation runs to be made. For our runs, NNRUNS was set equal to 1.
KKSYO(I) I=1,17	Codes for the reading and printing of each card type. 0 means read and print card type I. 1 means read card type I. 2 means skip reading and printing of.

Card Type 1

Card type 1 contains identification information. The only variable on the card is NNAME which can be any alpha or numeric string of characters. The maximum length of the string is 60 characters.

Card Type 2

Card type 2 initializes 13 internal GASP IV operating variables. These variables are as follows:

NNCLT	The number of sets of non-time weighted statistics to be collected. For our runs, NNCLT was set equal to zero.
NNSTA	The number of time weighted statistics to be collected. For our runs, NNSTA was set equal to zero.
NNHIS	The number of histograms to be collected. For our runs, NNHIS was set equal to zero.
NNPRM	The number of parameter sets (the number of type 11 cards) that are used. Five parameter sets are used in this simulation.
NNPLT	The number of plots and/or tables to be constructed. For our runs, NNPLT was set equal to zero.
NNSTR	The number of *independent random number* streams used in the simulation. Seven independent random number streams are used in this simulation.
NNTRY	The maximum allowable number of entries in NSET. For a simulation involving 500 trucks, NNTRY was set to 700. Use of 1000 trucks in a simulation required NNTRY to be set at 900.
NNATR	The number of attributes per entry in QSET. Four attributes are used to describe each event in the simulation.

NNFIL	The number of files in NSET. Only one file, the event file, is used in the simulation.
NNSET	The dimension size for NSET/QSET. For a simulation where NNTRY is set to 700, NNSET was set to 4300. This provided the 4200 storage spaces required for 700 events and a buffer of 100 storage spaces. If NNTRY or NNATR is modified, this variable must be modified (NNSET = NNTRY * (NNATR + 2)).
NNEQD	The number of derivative equations used in the simulation. No derivative equations are used in the model.
NNEQS	The number of equations used to define state levels in the simulation. Two equations are used in the model.
NNFLAG	The number of state condition flags used in the simulation. Three state condition flags are used in the model.

Card Type 8

Card type 8 contains information concerning which attribute is to be used for ranking entries in each file. KKKRNK(7) was set equal to one because the first attribute of each event is the time at which the event is to occur.

Card Type 9

Card type 9 contains information concerning how the entries are to be ranked in each file. The possible values are:

1 -- low value first.
2 -- high value first.
3 -- first in, first out.
4 -- last in, first out.

A value of 1 was used since the only file stored in QSET is the time event file.

Card Type 10

Card type 10 contains information concerning the description of a state event, and the size of a time step increment. The variables used are as follows:

IIEVT	The event code used to signify the occurrence of a state event. A value of 9 is used for IIEVT in the model.
LLERR	The type of error check to be used in the Runge-Kutta integration. A value of zero was used in the simulation. For a detailed explanation of this variable and Runge-Kutta integration, see references 21 and 22.
AAERR	The amount of local truncation error allowed in the Runge-Kutta integration.

	This variable was set to zero because AAERR is not used when NNEQD = 0.
RRERR	The amount of relative local truncation error allowed in the Runge-Kutta integration. A value of 4 was arbitrarily used. (The value used is not important since no integration is required in the model. However, a value must be used for the model to run.)
DDTMIN	The size of the minimum allowable step. This variable is not used when NNEQD = 0. A value of .001 was arbitrarily used to insure the model would run.
DDTMAX	The size of the maximum allowable step. A value of 1. was used in all simulation runs.
DDTSAV	The increment of the independent variable between successive save times if NNEQT 0 (NNEQT=NNEQD + NNEQS). A value of 1. was used in all simulation runs.

<u>Card Type 11</u>

Card type 11 contains information concerning the input parameters for each simulation run desired by the user. The number of type 11 cards must equal the value of NNPRM on card type 2. Each card has five entries. The variables on each card are as follows:

I	The "row number" of the parameter set. The parameter sets are actually stored in a linear array. The conversion is accomplished using the formula PPARM[(I-1)*4+J) = PPARM(I,J)], where j is the column number and 4 is the maximum value of j.
PPARM(I,J)	The value of a particular parameter.

Each entry will be discussed individually.

PPARM(1,1)	is the maximum quantity of supplies that the red force combat troops at the FEBA (sink) can expend in a single day of maximum intensity combat. A value of 2,000 tons was used for all research runs.
PPARM(1,2)	is the quantity of supplies (in tons) required to support minimum operations for the red combat forces at the FEBA. This minimum supply useage does not provide any supplies for combat operations, only supplies required for feeding the personnel and the distribution of supplies within the forward units are considered in this definition. A value of 800 tons was used for all research runs.

PPARM(1,3)	is the quantity of supplies (in tons) on hand at the FEBA at the start of the simulation. A value of 7200 tons was used for all research runs.
PPARM(1,4)	is the desired supply reserve (in tons) that the red commander desires to have on hand at the FEBA. A value of three days' maximum supply use was incorporated for all runs. A value of 6,000 tons was used in all research runs.
PPARM(2,1)	is the total number of trucks in the red force vehicle fleet at the beginning of the simulation. The simulation uses only one type of vehicle. Table 4-1 contains the values used in the research runs.
PPARM(2,2)	is the minimum distance (in miles) between trucks that the red force transportation officer will accept. This spacing is used to reduce the probability that the trucks will be spotted by blue force aircraft. The spacing also prevents the possibility that two trucks will be damaged in a single aircraft attack. A value of one mile was used in all research runs.

PPARM(2,3) is the minimum quantity of supplies (in tons) necessary for the red force to follow its operational plans. Above this value normal operations occur and the preplanned supply use rates are followed. Supply use rates are reduced to the minimum level when the quantity of supplies at the FEBA falls below this value. A value of 2400 tons was used in all research runs.

PPARM(2,4) is the truck supply use rate (tons/truck) for all trucks ending the day at the sink. A value of .125 was used in all research runs.

PPARM(3,1) is the number of aircraft available to the blue force at the start of the simulation to conduct the interdiction campaign. If the defense suppression option is used, all aircraft used for defense suppression are taken from the interdiction force. Table 4-1 contains the values used in the research runs.

PPARM(3,2) is the combat range of the aircraft in miles. The combat range is used to determine how many passes can be made by aircraft assigned to a truck killing mission. Remaining aircraft range is computed every time the aircraft fly up or down the link. It is assumed that aircraft which attack links have sufficient range to reach their targets. Thus, aircraft range is ignored for link attacking aircraft and their defense suppression support aircraft. A value of 600 miles was used in all simulation runs.

PPARM(3,3) is the aircraft's flight speed in miles per hour. A single average value is used. For all simulation runs, a value of 500 was used.

PPARM(3,4) is the starting value of the pointer used to determine if aircraft attacks should be planned during the execution of the Dailyops subroutine at the start of each day. A value of:

1 -- means no interdiction attacks are to be conducted.

2 -- means interdiction attacks are to be scheduled and conducted during the current day.

If initially set at 1, this parameter can be changed to 2. The value of the pointer can be changed during the simulation by the occurrence of a type 8 event. This event must be loaded into the event file during program initialization.

PPARM(4,1) is the attack strategy to be used during the simulation. Possible values are:

0 -- only attack trucks.

1 -- attack one link; remaining aircraft attack trucks.

2 -- attack two links; remaining aircraft attack trucks.

PPARM(4,2) is the number of hours per day that red trucks use the road network. A value of 12 hours was used in all research runs.

PPARM(4,3) is the defense suppression capability indicator. Possible values are:

1 -- defense suppression capability is available; defense suppression aircraft will support all attacks where the expected attrition rate is greater than zero.

2 -- no defense suppression capability is available.

PPARM(4,4) is the probability of kill for a single defense suppression attack against all air defense weapons defending a target. It is assumed that only one air defense weapon complex can protect each target. Complexes of 2 to 6 weapons were used in the simulation. A value of .6 was used in all research runs.

PPARM(5,1) is the number of trucks at the source at the beginning of the simulation which can be used during the first day. Table 4-1 contains the values used in the research runs.

PPARM(5,2) is the number of trucks at the sink at the beginning of the simulation which can be used during the first day. Table 4-1 contains the values used in the research runs.

PPARM(5,3) is the number of damaged trucks at the source at the start of the simulation. These trucks cannot be used until day 2. Table 4-1 contains the values used in the research runs.

PPARM(5,4)	is the number of damaged trucks at the sink at the start of the simulation. These trucks are not available for use until day 2. Table 4-1 contains the values used in the research runs.

Card Type 12

Card type 12 contains the seeds for the independent random number streams. IISED(I), I=1,NNSTR is the initial value of the Ith random number seed.

Card Type 13

Card type 13 contains information used to initialize the starting conditions for each run. The variables appear on the card as follows:

MMSTOP	The means of specifying the method used to stop the run. Possible values are: 0 -- end of simulation is provided by the user. 1 -- stop simulation at TTFIN. A value of 1 was used for all simulation runs.
JJCLR	This variable specifies if statistical arrays are to be cleared during initialization. Possible values are: 0 -- do not clear arrays. 1 -- clear arrays.

	A value of 1 was used for all simulation runs.
JJBEG	The variable used for initializing the random number generators, the simulated time variables and the state variables. Possible values are: 0 -- do not initialize. 1 -- initialize. A value of 1 must be used for the simulation.
IICRD	The variable which indicates which type of card is the starting point for reading cards for subsequent runs. Since the simulation is designed for only one run at a time, this value should be set to zero.
TTBEG	The initial value for the simulation time at the start of the run. A value of zero was used in all runs.
TTFIN	The scheduled time for the end of the simulation in hours. A value of 360 was used in all runs since this represents a 15 day interdiction scenario.
JJFIL	The variable used to control initialization of the GASP IV files. Initialization is performed when JJFIL is any positive value.

Card Type 14

Card type 14 contains only one variable. This variable, NNIFE, is the number of entries that are to be read into NSET/QSET during initialization of the simulation. NNIFE was set equal to 16.

Card Type 15

Card type 15 contains one entry to be read into NSET/QSET during initialization. The variables on the card are:

IFILE	The file into which the entry is to be stored.

AATRIB(JK),JK,=1,NNATR. The attributes which describe the event. In this simulation, four attributes are used for each entry in the event file:

AATRIB(1) is the time the event occurs.

AATRIB(2) is the event type.

AATRIB(3) and AATRIB(4) provide additional information as required. See Appendix A for a full discussion of all possible values of each attribute.

Following the last event, the word "DONE" must be entered on the next

PRISCARD DATA FILE

```
010 1,0,0,0,2,2,2,2,0,0,0,0,0,0,0,0,2,2,2,1
020 GEITH-OPENHYM AFIT/SLG-77A
030 0,0,0,5,0,7,900,4,1,5500,0,2,4
040 1
045 1
50 9,0,1,4,.001,1.,1
51 1,2000,800,7200,6000
52 2,500,1,2400,.125
53 3,100,600,500,2
54 4,2,12,1,.6
55 5,280,120,70,30
060 1274321,342761,5317425,523416,1463257,1946073,4567892
70 1,1,1,0.,360.009,1
80 16
090 1,.01,2,0,0
100 1,360.,8,0,0
110 1,120.,9,1,9876543
120 1,120.,9,2,823741
130 1,120.,9,3,4327563
140 1,120.,9,4,731062
150 1,120.,9,5,5237628
160 1,120.,9,6,4240752
170 1,120.,9,7,1135793
180 1,240.,9,1,4246821
190 1,240.,9,2,6579824
200 1,240.,9,3,34289718
210 1,240.,9,4,2336822
220 1,240.,9,5,8795129
230 1,240.,9,6,6515485
240 1,240.,9,7,25731061
250 DONE
```

Figure B-1. GASP IV Input Data

line of the data file. The word is used as a signal to insure all entries are read.

Preplanned Supply Use Data

This data file contains the estimate of the red forces' preplanned supply use by day. The data are entered into the file in the following manner:

a. Five entries per line,

b. All entries are in units of tons of supply,

c. 20 entries are required for a simulation of 15 days.

A sample supply use data file is shown in Figure B-2.

Network Information

Two sets of data are constructed which provide much of the information required to run the simulation. The DLNK matrix provides information concerning network structure, link repair rates, the average number of air defense weapons defending a given link and various probabilities of kill. The Grid matrix contains the x and y coordinates of each node for the links in the network. It also contains the x and y coordinates of the base from which interdiction attacks are made. The two matrixes can be combined in a single data file or maintained separately.

SUPPLY DATA FILE

```
10 1200,1200,2000,2000,2000
20 2000,2000,1500,1500,1500
30 2000,2000,2000,2000,2000
40 1500,1500,2000,2000,2000
```

Figure B-2. Planned Supply Use

DLNK data. The first line of the DLNK data contains three variables. These variables are:

IN -- The number of nodes in the network.

K -- The number of links in the network.

LS -- The number of links leading to the sink.

Each of the remaining lines in the data file contains 14 variables. These data provide much of the information necessary to describe a link. The variables contained on each of the lines are as follows:

DLNK(I,1)	The link number. Links in the network must start at 1 and continue consecutively.
DLNK(I,2)	The node where the link begins, usually the node closest to the source. The source must be numbered 1. The sink must be assigned the highest number.
DLNK(I,3)	The node where the link ends, usually the node closest to the sink.
DLNK(I,4)	The alternate link for the link being described. All links are assumed to have two way traffic. An alternate link is defined to be a link sufficiently close to the link being described. That damage to the link being described will result in damage to an alternate link. If the link

	being described runs from node 3 to node 4, the alternate link must run from node 4 to node 3. An example of an alternate link might be two lanes of a four lane divided highway. (The remaining two lanes being the link being described.) If the alternate link is sufficiently removed that it is not affected by an attack on the link being described and it is protected by a separate air defense weapon site, then a zero must be entered here. If no alternate link exists, enter a zero.
DLNK(I,5)	The length of the link in miles.
DLNK(I,6)	The maximum speed in miles per hour that a truck can safely be driven over the link. In the simulation, this variable is used as the speed of all vehicles traveling on the link.
DLNK(I,7)	The decimal reduction, in the speed that a truck can maintain when traveling on a link, that results from a successful attack against the link. For our simulation runs, two values were used. Where links contained a

bridge or tunnel, a value of 1 was used. Where the only possible damage to links was damage to the road surface or a slight delay from driving around debris, a value of .1 was used.

DLNK(I,8) The time (in days) required to repair the link given a successful attack. In the simulation, the assumption was made that the minimum repair time was 12 hours. Since all attacks against links occur just before the trucks start their daily operations, and since the trucks are limited to 12 hours operation per day, the minimum repair time is one day.

DLNK(I,9) The probability that a single attacking aircraft will successfully damage the link. Since all aircraft that are attacking a link complete their attack before the results of the attack are determined, this value can be applied to area as well as point targets. The value can also be varied from simulation to simulation to show the result of using different types of weapons.

DLNK(I,10)	The average number of air defense weapons encountered by an aircraft attacking the link or a truck on the link.
DLNK(I,11)	The probability of kill for a single air defense weapon shooting at a single aircraft.
DLNK(I,12)	The average supply use in tons for an air defense weapon defending the route when the air defense weapon engages a single aircraft.
DLNK(I,13)	The probability that an aircraft will detect a single vehicle on the link.
DLNK(I,14)	The probability of kill for a single aircraft when it attacks a single truck on the link, given that the truck has been detected.

Sample DLNK data files are shown in Figures B-3 and B-5.

GRID data. As stated previously, the GRID matrix contains the x - y grid coordinates of important points in the transportation network. Only positive x and y values are to be used. Each line in the data file corresponds to one link. The values on each line are presented in the following manner:

GRID(I,1)	The link number.
GRID(I,2)	The x coordinate for the end of the link (node) closest to the air base.
GRID(I,3)	The y coordinate for the end of the link (node) closest to the air base.
GRID(I,4)	The x coordinate for the end of the link (node) farthest from the air base.
GRID(I,5)	The y coordinate for the end of the link (node) farthest from the air base.

The first line of the GRID file is different from the other lines in the file. It contains only two variables:

Base x -- The x coordinate of the blue force air base.

Base y -- The y coordinate of the blue force air base.

Before leaving the data files, it is necessary to make one more point. The model calls for the input variables in the order they have been described in this section: GASP IV, Supply, DLNK, and GRID. Any deviations in this order will cause the model to either abort or produce unlikely output statistics.

SHORT NET DATA FILE

```
40 11,8,3
50 1,1,3,0,33,35,.1,1,.25,2,.05,.125,.5,.7
60 2,1,4,0,30,30,.1,1,.25,2,.05,.125,.5,.7
70 3,1,2,0,25,50,.1,1,.3,2,.05,.125,.5,.7
80 4,3,5,0,40,50,.1,1,.2,2,.05,.125,.5,.7
90 5,3,6,0,59,30,.15,1,.25,0,.05,.125,.3,.7
100 6,4,6,0,35,40,.1,1,.25,2,.05,.125,.5,.7
110 7,2,7,0,58,40,.1,1,.15,2,.05,.125,.5,.7
120 8,5,8,0,46,50,1,2,.8,6,.05,.125,.3,.7
130 9,6,8,0,25,50,.1,1,.3,2,.05,.125,.5,.7
140 10,7,8,0,39,35,.1,1,.2,2,.05,.125,.5,.7
150 11,2,4,0,25,30,.15,1,.25,1,.05,.125,.5,.7
```

Figure B-3. SHORTNET Parameters

SHORT GRID DATA FILE

```
40 0.,0.
50 1,75,185,45,200
60 2,45,170,45,200
70 3,25,185,45,200
80 4,75,145,75,185
90 5,45,135,75,185
100 6,45,135,45,170
110 7,15,135,25,185
120 8,45,110,75,145
130 9,45,110,45,135
140 10,45,110,15,135
150 11,45,170,75,185
```

Figure B-4. GRID Coordinates for SHORTNET

LONGNET DATA FILE

```
10 27,10,4
20 1,1,2,0,25,50,.10,1,.3,2,.05,.125,.5,.7
30 2,1,4,0,30,40,.1,1,.25,2,.05,.125,.5,.7
40 3,1,3,0,33,35,.1,1,.25,2,.05,.125,.5,.7
50 4,2,6,25,58,40,.1,1,.15,2,.05,.125,.5,.7
60 5,2,4,19,25,30,.15,1,.3,0,.05,.125,.3,.7
70 6,4,5,21,19,25,1,5,.8,5,.05,.125,.3,.7
80 7,3,5,27,31,30,.15,1,.25,0,.05,.125,.3,.7
90 8,3,8,22,40,50,.1,1,.2,2,.05,.125,.5,.7
100 9,6,7,26,33,30,.15,1,.25,0,.05,.125,.3,.7
110 10,4,7,20,35,40,.1,1,.25,2,.05,.125,.5,.7
120 11,5,7,24,28,30,.15,1,.3,0,.05,.125,.3,.7
130 12,5,8,23,17,30,.15,1,.3,2,.05,.125,.3,.7
140 13,6,10,0,39,35,.1,1,.2,2,.05,.125,.5,.7
150 14,7,10,0,25,40,.1,1,.3,2,.05,.125,.5,.7
160 15,8,10,0,46,50,1,2,.8,6,.05,.125,.3,.7
170 16,8,9,0,26,35,.1,1,.17,2,.05,.125,.5,.7
180 17,1,5,0,43,30,.1,1,.2,2,.05,.125,.5,.7
190 18,9,10,0,27,35,.1,1,.17,2,.05,.125,.5,.7
200 19,4,2,5,25,30,.15,1,.3,0,.05,.125,.3,.7
210 20,7,4,10,35,40,.1,1,.25,2,.05,.125,.5,.7
220 21,5,4,6,19,25,1,5,.8,5,.05,.125,.3,.7
230 22,8,3,8,40,35,.1,1,.2,2,.05,.125,.5,.7
240 23,8,5,12,17,30,.15,1,.3,2,.05,.125,.3,.7
250 24,7,5,11,28,30,.15,1,.3,0,.05,.125,.3,.7
260 25,6,2,4,58,35,.1,1,.15,2,.05,.125,.5,.7
270 26,7,6,9,33,30,.15,1,.25,0,.05,.125,.3,.7
280 27,5,3,7,31,30,.15,1,.25,0,.05,.125,.3,.7
```

Figure B-5. LONGNET Parameters

LONG GRID DATA FILE

```
5 0.,0.
010 1,25,185,45,200
020 2,45,170,45,200
030 3,75,185,45,200
040 4,15,136,25,185
050 5,45,170,25,185
060 6,59,158,45,170
070 7,59,158,75,185
080 8,75,145,75,185
090 9,45,135,15,136
100 10,45,135,45,170
110 11,45,135,59,158
120 12,75,145,59,158
130 13,45,110,15,136
140 14,45,110,45,135
150 15,45,110,75,145
160 16,70,120,75,145
170 17,59,158,45,200
180 18,45,110,70,120
190 19,45,170,25,185
200 20,45,135,45,170
210 21,59,158,45,170
220 22,75,145,75,185
230 23,75,145,59,158
240 24,45,135,59,158
250 25,15,136,25,185
260 26,45,135,15,136
270 27,59,158,75,185
```

Figure B-6. GRID Coordinates for LONGNET

OUTPUT DATA

The output data produced by this model can be divided into three major parts. First, the model provides an echo check of some of the important variables that were read in as well as the results of some preliminary computations. Second, the model produces a day by day summary of the events that occurred and the index values. Third, the model provides a summary for the entire simulation period.

Preliminary Output

The preliminary output consists of four major parts. First is the echo check of the GASP IV variables, the supply values, the DLNK values, several of the more important parameters, and the GRID values. The GASP IV variables are printed in a manner that makes them self-explanatory. The supply values are printed out in the same manner they are read in, four lines of five values per line. The DLNK variables are also printed out in the same order that they are read into the simulation. An example of the preliminary output is provided in Appendix D.

Daily Output

The model provides a printout by day which provides all of the data discussed in Chapter 3. This information is self-explanatory. The only additional knowledge required is to remember when (during the day) the values are recorded. The Unrestricted Supply Index, the Programmed Support Index, the Minimum Support Index, the Daily Combat Index, the Daily Minimum Operation Index, the Supplies on Hand, the Daily Supply Order, the number of available aircraft, the number of trucks in the system, and the number of useable trucks are recorded at the beginning of each day. The red force truck assignments are made after all link attacks have been completed. The aircraft attack plan for truck attacks uses the expected red force truck assignments as a basic input in selecting those links to be attacked. The Thruput, Total Supply Use, Troop Supply Use, Truck Supply Use, AAA Supply Use, Achieved Daily Thruput Index, Trucks Damaged Today, Number of Damaged Trucks that are repairable, Daily Total Aircraft Damage, Aircraft Requiring One Day Repair, Aircraft Requiring Two Day Repair, Aircraft Requiring Three Day Repair, Aircraft Not Repairable values reflect the results of the day's activities and are recorded at the end of the day. An example of the daily output is provided in Appendix D.

Summary Output

At the end of the simulation, a summary of the statistics is presented. This summary is composed of five parts. These are:

1. Ending values;
2. Aircraft Statistics by day;
3. Support Indices by day;
4. Supply Statistics by day;
5. Truck Statistics by day.

Included in the ending values are:

1. The total quantity of supplies ordered during the simulation;
2. The total thruput achieved;
3. The total quantity of supplies used;
4. The quantity of supplies on hand at the FEBA at the end of the simulation;
5. The total number of trucks that were damaged by interdiction aircraft;
6. The number of trucks remaining at the end of the simulation;
7. The number of operationally ready aircraft and the number of aircraft in the various stages of maintenance at the end;
8. The total number of aircraft that were damaged and the number of aircraft that were destroyed.

An important qualification must be made at this point. The value shown for the supply order in any daily output listing is the total amount of supplies that are required during that day's operation to replace the previous day's air defense and truck use, to support the next day's planned operations and to bring the supply level at the FEBA up to the desired levels. The total quantity of supplies ordered includes only the supplies required to replace the previous day's air defense and truck use and to support the next day's planned operations. An example of the ending value output is provided in Appendix D.

The aircraft statistics summary includes the number of operationally ready aircraft at the beginning of each day and the daily aircraft damage which occurred. An example of this output is provided in Appendix D.

The support indices summary includes:

1. The Unrestricted Support Index;
2. The Programmed Support Index;
3. The Minimum Support Index;
4. The Daily Combat Index;
5. The Daily Minimum Operations Index;
6. The Achieved Thruput Index.

An example of this output is provided in Appendix D.

The supply statistics summary includes:

1. The quantity of supplies on hand each day;
2. The daily supply order;
3. The daily thruput;
4. The daily total supply use;
5. The daily troop supply use;
6. The daily truck supply use;

7. The daily air defense supply use.

An example of this output is provided in Appendix D.

The truck statistics summary includes:

1. The total number of trucks in the system at the start of each day;

2. The number of useable trucks at the start of each day;

3. The total number of trucks that were damaged or destroyed as a result of the day's interdiction effort;

4. The number of trucks that sustained combat damage during the day that can be repaired;

5. The number of trucks that were destroyed by the interdiction attacks (damaged beyond repair).

An example of this output is provided in Appendix D.

APPENDIX C

MAIN PROGRAM AND SUBROUTINES

INTRODUCTION

This appendix serves two purposes. First, it contains a short description of each program and subroutine that we wrote in constructing the model. Second, the appendix contains a copy of our main program and each of the subroutines.

DESCRIPTION

Main Program

The main program contains the instructions for getting on and off the computer, the instructions used during program compilation and execution, and the necessary Select and Selecta commands which cause the subroutines and data files to be inserted at the appropriate places before program compilation. The main program references eight files: G4 COMMON, USERM, NANCY, RUNBATCH, PRISCARD, SUPPLY, TEMP, and GRID. The G4 COMMON file contains the portion of COMMON which is required by GASP IV. The USERM file contains the portion of COMMON which supports our subroutines and the main program. The RUNBATCH file is a system file that causes the computer to search the appropriate files for the GASP IV subroutines and to attach the GASP IV subroutines to our program during compilation. RUNBATCH also contains the Execution command. The PRISCARD file contains the input variables which are required by GASP IV during the initialization phase of the simulation. The SUPPLY file contains the supply information described in Appendix B. The TEMP file contains the DLNK information which is described in Appendix B. The GRID file contains the information which is described in Appendix B.

INTLC

The INTLC subroutine is responsible for the initialization of the user defined variables, directs the determination of the feasible routes and the number of aircraft required to attack each link, and points out the initial output.

ROUTE (*)

The ROUTE (*) subroutine computes all of the feasible routes in the network.

ACREQ

The ACREQ subroutine computes the number of aircraft required to attack each link and the number of defense suppression aircraft required to support each attack.

THRUPUT

The THRUPUT subroutine computes the time required to travel each link, the one way and round trip times for each route and the capacity of each route. This information is used to select the routes which make maximum use of the road network based on round trip times.

TRKASG

The TRKASG subroutine estimates the system thruput capability based on the present network conditions and the number of trucks which can be used during the current day.

TRANSYS

The TRANSYS subroutine stores the current system thruput estimate in a "permanent" location. This value (PTRKCAP) is used in determining the effect of attacks against the links of the network.

ACSCHED

The ACSCHED subroutine handles all aircraft scheduling. This includes the selection of target links, if link attacks are selected, the selection of links where truck killing patrols will be made, and the arrival time of each mission over the target.

ACATK

The ACATK subroutine handles the conduct of all aircraft attacks. This includes: air defense attacks against aircraft, defense suppression attacks, link attacks, and truck attacks. The result of each attack (target hit or missed) is determined here. Subsequent passes of truck killing aircraft along the link are scheduled in this subroutine.

DAMAGE

The DAMAGE subroutine handles all damage functions including: determination of the level of aircraft damage; determination of the level of truck damage; determination of which truck was hit; the scheduling of repair events for damaged links and air defense complexes; and the modification of aircraft, truck, link and air defense conditions to reflect the attack results.

DAILYOPS

The DAILYOPS subroutine serves many purposes. At the beginning of each day, the DAILYOPS subroutine:

1. Computes the daily supply order and all of the measures of effectiveness except the Achieved Thruput Index.
2. Directs the scheduling of aircraft attacks against links and the execution of the attack.
3. Directs the selection of routes to be used.
4. Assigns the useable trucks to routes.
5. Initiates truck departures by route and establishes the last truck departure time for each route.
6. Directs the scheduling of truck killing missions using the remaining aircraft.

At the end of each day the DAILYOPS subroutine:

1. Determines how many trucks will be available for use the following day and their location (source or sink).

2. Calculates the Achieved Thruput Index.

3. Subtracts air defense and truck supply use from the supplies on hand at the FEBA (sink).

4. Determines how many aircraft will be available for use the following day.

5. Resets various variables in preparation for the next day.

TRKSCH

The TRKSCH subroutine schedules when the next truck departure event for a particular route will occur and checks to determine if a truck departure should occur at the present time. This subroutine handles truck departures from the source and the sink. If a truck departure occurs, the subroutine schedules a truck arrival event and subtracts one truck from the group of ready trucks assigned to the appropriate route. Everytime a truck departs the source, the subroutine adds four tons to the day's estimated thruput.

TRKARL

The TRKARL subroutine contains the functions associated with a truck arrival at the source or sink.

EVNTS

The EVNTS subroutine decodes the type of event that has occurred and directs control to the appropriate subroutine. Actions associated with the occurrence of state events are contained in the EVNTS subroutine.

STATE

The STATE subroutine contains the equations required to evaluate the first STATE conditions; the amount of supplies on hand at the FEBA.

SCOND

The SCOND subroutine contains the equations required to determine if a STATE event has occurred.

MISEVT

The MISEVT subroutine contains the actions required when several small events occur. These events include: the repair of a link, the return of an air defense complex to full operational capability, the changing of random number seeds, the cancellation of truck scheduling events at the end of the 12 hour operational period, and the change in the value of NQQ to direct interdiction attacks.

UERR

The UERR subroutine contains the error messages for the errors that we have defined in the program.

PROGRAM LISTINGS

The following pages in this appendix contain all of the routines we wrote in constructing the model as well as the G4COMMON file and the G4SUBCMN file which are part of the GASP IV system files.

MAIN PROGRAM

```
30000##N,R(SL)
30010$:IDENT:WP1191,AFITSL    GEITH 77A
30020$:OPTION:FORTRAN,NOMAP
30030$:FORTY:NFORM,NLNO,NLSTIN
30040$:LIMITS:03,33K,,4K
30050 PARAMETER G4FILES=1,G4ENTRY=900,G4ATRIBS=4
30060 PARAMETER G4COLCT=1,G4TIMST=1
30070 PARAMETER G4STREAM=7,G4PARAMS=5,G4URAND=1
30080 PARAMETER G4STATES=2,G4FLAGS=4
30090 PARAMETER G4HISTOS=1,G4PLOTS=1
30100$:SELECTA:GRADLIB/G4COMMON,R
30110$:SELECTA:77A59/USERM,R
30120 CALL GASP
30130 STOP
30140 END
30150$:SELECTA:NANCY
30320$:SELECT:GRADLIB/RUNBATCH
30330$:LIMITS:300,40K,,6K
30360$:DATA:I*
30365$:SELECTA:77A59/PRISCARD
30370$:SELECTA:77A59/SUPPLY,R
30380$:SELECTA:77A59/TEMP,R
30390$:SELECTA:77A59/GRID,R
30410$:ENDJOB
```

G4COMMON FILE

```
0060C*****************************************************
0070C*****************************************************
0080C      G4SIZE CONTAINS THE VARIABLES WHICH STORE
0090C      THE RUN-TIME DIMENSIONS OF GASP VARIABLES
0100C      ------------------------------------------
0110 COMMON /G4SIZE/ NNG4NSET,NNG4FILS,NNG4NTRY,NNG4ATR.,
0120& NNG4STRM,NNG4SEQS,NNG4FLGS,NNG4HIS,NNG4PLT,NNG4PARM,
0130& NNG4CLCT,NNG4TSTA
0140C****************************************************
0150 NNG4FILS=G4FILES;NNG4NTRY=G4ENTRY;NNG4ATR=G4ATRIBS
0160 NNG4STRM=G4STREAM;NNG4SEQS=G4STATES;NNG4FLGS=G4FLAGS
0170 NNG4HIS=G4HISTOS;NNG4PLT=G4PLOTS;NNG4PARM=G4PARAMS
0180 NNG4CLCT=G4COLCT;NNG4TSTA=G4TIMST
0190C*****************************************************
0200C   G4FL(X) CONTAINS FILE SYSTEM VARIABLES
0210C   ---------------------------------------
0220 COMMON/G4FL1/NNFIL,NNATR,NNAPO,NNTRY,NNAPT,MMFA
0230 COMMON/G4FL2/NNQ(G4FILES)/G4FL3/MMFE(G4FILES)
0240 COMMON/G4FL4/MMLE(G4FILES)/G4FL5/MMAXQ(G4FILES)
0250 COMMON/G4FL6/QQTIM(G4FILES)/G4FL7/KKRNK(G4FILES)
0260 COMMON/G4FL8/IINN(G4FILES)/G4FL9/EENQ(G4FILES)
0270 COMMON/G4FL10/VVNQ(G4FILES)
0280C****************************************************
0290C     G4CSTAT CONTAINS VARIABLES FOR COLCT
0300C     -------------------------------------
0310 PARAMETER G4LBLC=2*G4COLCT,G4SSOBV=5*G4COLCT
0320 COMMON/G4CSTAT/NNCLT,SSOBV(G4SSOBV)
0330 COMMON/G4LSTA/LLABC(G4LBLC)
0340C****************************************************
0350C      G4TSTAT CONTAINS VARIABLES FOR TIMST & TIMSA
0360C      --------------------------------------------
0370 PARAMETER G4LBLT=2*G4TIMST,G4SSTPV=6*G4TIMST
0380 COMMON/G4TSTAT/NNSTA,SSTPV(G4SSTPV)
0390 COMMON/G4LTST/LLABT(G4LBLT)
0400C****************************************************
0410C     G4CLOCK CONTAINS SIMULATION TIME VARIABLES
0420C     ------------------------------------------
0430 COMMON/G4CLOCK/TTNOW,TTFIN,TTNEX,TTBEG,TTCLR,TTSET
0440C****************************************************
0450C     G4TIME CONTAINS OPERATING TIME & TIME/DAY MARKERS
0460C     -------------------------------------------------
0470 COMMON/G4TIME/NNHOUR,NNMIN,XXTIME,XXTOTAL
0480C****************************************************
0490C     G4INFO CONTAINS RUN-TIME PARAMETERS
0500C     ------------------------------------
0510 COMMON/G4INFO/NNRUN,MMSTOP,NNRNS,NNCRDR,JJEVNT
0520C****************************************************
0530C     G4CHAR CONTAINS RUN LABEL AND DATE VARIABLES
0540C     --------------------------------------------
```

```
0550 COMMON/G4CHAR/NNAME,GCDATE
0560 CHARACTER NNAME*60,GGDATE*8
0570C***************************************************
0580C     G4PRNT CONTAINS OUTPUT DEVICE CODES
0590C     ===================================
0600 COMMON/G4PRNT/NNPRNT,NNPRNTI,NNPRNTS,NNPRNTM,NNPRNTE
0610C***************************************************
0620C     G4INIT CONTAINS INITIALIZATION VARIABLES
0630C     G4CARD CONTAINS DATIN CONTROL PARAMETERS
0640C     ========================================
0650 COMMON/G4INIT/JJBEG,JJCLR/G4CARD/IICRD,LLSUP(17)
0660C***************************************************
0670C     G4AL(X) CONTAINS ATTRIBUTE BUFFERS
0680C     ==================================
0690 COMMON/G4AL1/AATRIB(G4ATRIBS)/G4AL2/TTRIB(G4ATRIBS)
0700C***************************************************
0710C     G4RND(X) CONTAINS RANDOM PROCESSOR VARIABLES
0720C     ============================================
0730 PARAMETER G4PARM=4*G4PARAMS
0740 COMMON/G4RND1/NNSTR,NNPRM,PPARM(G4PARM)
0750 COMMON/G4RND2/IISEED(G4STREAM)/G4RND3/LLSEED(G4STREAM)
0760 COMMON/G4RND4/NNOBS,OOBS(G4URAND)
0770 COMMON/G4RND5/CCUM(G4URAND)/G4RND6/VVALUE(G4URAND)
0780 COMMON/G4RND7/LLOGNORM(G4PARAMS)
0790C***************************************************
0800C     G4HL(X) CONTAINS HISTOGRAM VARIABLES
0810C     ====================================
0820 COMMON/G4HL1/NNHIS,NNPRNTH,HHLOW(G4HISTOS)
0830 COMMON/G4HL2/HHWID(G4HISTOS)/G4HL3/NNCEL(G4HISTOS)
0840COMPUTE THE TOTAL HISTOGRAM CELL REQUIREMENTS AS G4CELLS
0850COMPUTE THE HISTOGRAM LABEL REQUIREMENTS AS G4LHIS
0860C-------------------------------------------------------
0870 PARAMETER G4CELLS=20*G4HISTOS,G4LHIS=2*G4HISTOS
0880 COMMON/G4HL4/LLABH(G4LHIS)/G4HL5/JJCEL(G4CELLS)
0890C***************************************************
0900C     G4PL(X) CONTAINS PLOT VARIABLES
0910C     ===============================
0920 COMMON/G4PL1/NNPLT,NNPRNTP,NNPRNTT,NNPTS(G4PLOTS)
0930 COMMON/G4PL2/LLPLT,PPHI(10),PPLO(10),LLPLO(10),
0940& LLPHI(10),LLSYM(10),LLABP(11,2),IITAP(G4PLOTS)
0950 COMMON/G4PL3/DDTPLT(G4PLOTS)/G4PL4/NNVAR(G4PLOTS)
0960C***************************************************
0970C     G4INTG CONTAINS INTEGRATION VARIABLES
0980C     =====================================
0990 COMMON/G4INTG/DDTNOW,DDTMIN,DDTMAX,DDTFUL,DDTSAV,
1000& TTSAV,TTLAS,LLSAV,AAERR,RRERR,LLERR,IITES
1010C***************************************************
1020C     G4SL(X) CONTAINS STATE VARIABLE ARRAYS
1030C     ======================================
1040 COMMON/G4SL1/NNEQT,IIEVT,NNEQD,NNEQS,IISEES
1050 COMMON/G4SL2/DD(G4STATES)/G4SL3/SS(G4STATES)
1060 COMMON/G4SL4/DDL(G4STATES)/G4SL5/SSL(G4STATES)
```

```
1070 COMMON/G4SL6/DDI(G4STATES)/G4SL7/SSI(G4STATES)
1080 COMMON/G4SL8/AA1(G4STATES)/G4SL9/AA2(G4STATES)
1090 COMMON/G4SL10/AA3(G4STATES)/G4SL11/AA4(G4STATES)
1100 COMMON/G4SL12/AA5(G4STATES)/G4SL13/AA6(G4STATES)
1110 COMMON/G4SL14/AA7(G4STATES)
1120C***************************************************
1130C     G4FLG CONTAINS THE LLFLAG ARRAY
1140C     ===============================
1150 COMMON/G4FLG/NNFLAG,LLFLAG(G4FLAGS)
1160C***************************************************
1170C     ASSIGN DEFAULT PERIPHERAL CODES
1180C     ===============================
1190 NNCRDR=5;NNPRNT=6;NNPRNTE=NNPRNT;NNPRNTH=NNPRNT
1200 NNPRNTI=NNPRNT;NNPRNTM=NNPRNT;NNPRNTP=NNPRNT
1210 NNPRNTS=NNPRNT;NNPRNTT=NNPRNT
1220C***************************************************
1230COMPUTE THE REQUIREMENTS FOR NSET/QSET SIZE
1240C------------------------------------------
1250 PARAMETER G4NNSET=G4ENTRY*(G4ATRIBS+2)
1260 NNG4NSET=G4NNSET
1270 DIMENSION NSET(G4NNSET)
1280 COMMON QSET(G4NNSET)
1290 EQUIVALENCE (NSET(1),QSET(1))
1300C***************************************************
1310C              M A I N      P R O G R A M
1320C            --------      -------------
```

USERM FILE

```
110 COMMON/USERM1/MAXFLOW,K,MM,IN,LS,NAC1,NAC2,NAC3,NACP
120 COMMON/USERM2/NETREDUC(30), NATK,ITOFR(15,15)
130 COMMON/USERM3/LI,RTTIME(70,15),IALTLINK(30,2)
140 COMMON/USERM4/UCAP(30),TRTIME(70),IRUTCAP(70,15),ACS
150 COMMON/USERM5/ISUMCAP(70),LINKUSE(30),LSINK(5),LD,TK
160C DIMENSION IFRUT IAW MAX FEASIBLE ROUTES
170 COMMON/USERM6/IFRUT(70,15),IRUT(15),IFRNOD(15),ITRKMAX
180C DIMENSION ITOFR IAW MAX NO. OF NODES
190 COMMON/USERM7/IRUTUSE(50),ULINK(30),IRU,DLNK(30,17)
200 COMMON/USERM8/SDTRUT(70),JSUMCAP(70),ITRKAV
210 COMMON/USERM9/PULINK(30),PIRU,PUCAP(30),PTRKCAP
220 COMMON/USERA1/PTRTIME(70),PLINKUSE(30),PRUTUSE(50)
230 COMMON/USERA2/PMAX,NETWO(30,30),PSGT(30),PDS,TRKCAP
240 COMMON/USERA3/IACAS(30,2),KACAT(50,7),ACATR,IAAC,NLA
250 COMMON/USERA4/PADN,ADS,IADS,AGAT,IAGAT,NETAC,ITGTLK
260 COMMON/USERA5/ITAC,DBT,ITKDEN(30),GRID(30,7),ACRNG,KDMGE
270 COMMON/USERA6/ISUPPLY(30),MAXUSE,MINUSE,DSUPPLY
280 COMMON/USERA7/ADU,TRKUSE,ORDER,VORDER,VTRKUSE,VTIMOP
290 COMMON/USERA8/PSI,AMSI,DCI,DMOI,ATI,TORDER,TFLOW,TUSE
300 COMMON/USERA9/NDAY,DUSE,USE,NTR,NTKD,MAC1,MAC2,MTACL
310 COMMON/USERB1/NACL,ITRK,ONEWAYT(70),IPILE(15,2),NDTSOR
320 COMMON/USERB2/NDTSINK,NQQ,MTSOR,MTSINK,NTKW(30)
330 COMMON/USERB3/NTSTE(30),NTSLE,USERATE,SUCP1,MD,LBAT
340 COMMON/USERB4/NRU,NTK,NTKE(30),TDTK,NTAR(30),ALD
350 COMMON/USERB5/DAYDATA(15,24),TACD,BASEX,BASEY,VT
360 COMMON/USERB6/IDCSA,NTSTW(30),MTKR(30)
```

G4SUBCMN FILE

```
10C*****************************************************
20 COMMON /G4SIZE/ NNG4NSET,NNG4FILS,NNG4NTRY,NNG4ATR,
30& NNG4STRM,NNG4SEQS,NNG4FLGS,NNG4HIS,NNG4PLT,NNG4PARM,
35& NNG4CLCT,NNG4TSTA
40 COMMON/G4FL1/NNFIL,NNATR,NNAPO,NNTRY,NNAPT,MMFA
50 COMMON/G4FL2/NNQ(1)/G4FL3/MMFE(1)
60 COMMON/G4FL4/MMLE(1)/G4FL5/MMAXQ(1)
70 COMMON/G4FL6/QQTIM(1)/G4FL7/KKRNK(1)
80 COMMON/G4FL8/IINN(1)
90 COMMON/G4CSTAT/NNCLT,SSOBV(1)/G4TSTAT/NNSTA,SSTPV(1)
100 COMMON/G4CLOCK/TTNOW,TTFIN,TTNEX,TTBEG,TTCLR,TTSET
110 COMMON/G4INFO/NNRUN,MMSTOP,NNRNS,NNCRDR,JJEVNT
120 COMMON/G4PRNT/NNPRNT,NNPRNTI,NNPRNTS,NNPRNTM,NNPRNTE
130 COMMON/G4CARD/IICRD,LLSUP(1)
140 COMMON/G4AL1/AATRIB(1)/G4AL2/TTRIB(1)
150 COMMON/G4RND1/NNSTR,NNPRM,PPARM(1)
160 COMMON/G4RND2/IISEED(1)/G4RND4/NNOBS,OOBS(1)
170 COMMON/G4RND6/VVALUE(1)/G4HL1/NNHIS,NNPRNTH
180 COMMON/G4PL1/NNPLT,NNPRNTP,NNPRNTT,NNPTS(1)
190 COMMON/G4INTG/DDTNOW,DDTMIN,DDTMAX,DDTFUL,DDTSAV,
200& TTSAV,TTLAS,LLSAV,AAERR,RRERR,LLERR,IITFS
210 COMMON/G4SL1/NNEQT,IIEVT,NNEQD,NNEQS,IISEES
220 COMMON/G4SL2/DD(1)/G4SL3/SS(1)
230 COMMON/G4SL4/DDL(1)/G4SL5/SSL(1)
240 COMMON/G4FLG/NNFLAG,LLFLAG(1)
250 DIMENSION NSET(1)
260 COMMON QSET(1)
270 EQUIVALENCE (NSET(1),QSET(1))
280C***************************************************
```

SUBROUTINE INTLC

```
10C
20 SUBROUTINE INTLC
30$:SELECTA:GRADLIB/G4SUBCMN,R
40$:SELECTA:77A59/USERM,R
50C MAXUSE EQUALS MAX POTENTIAL SUPPLIES USED BY
60C TROOP FORCE;MINUSE EQUALS MINIMUN SUSTAINING LEVEL
70C OF SUPPLIES FOR THE TROOPS;SS(1) EQUALS SUPPLIES
80C ON HAND AT THE FEBA
90C
100 MAXUSE=PPARM(1)
110 MINUSE=PPARM(2)
120 SS(1)=PPARM(3)
130 DSUPPLY=PPARM(4)
140 ITRK=PPARM(5)
150 DBT=PPARM(6)
160 SUCP1=PPARM(7)
165 VTRKUSE=PPARM(8)
170 ITAC=PPARM(9)
180 ACRNG=PPARM(10)
190 ACS=PPARM(11)
200 NQQ=PPARM(12)
210 NLA=PPARM(13)
220 VTIMOP=PPARM(14)
230 IDSCA=PPARM(15)
240 PDS=PPARM(16)
250 MTSOR=PPARM(17)
260 MTSINK=PPARM(18)
270 NDTSOR=PPARM(19)
280 NDTSINK=PPARM(20)
290 DO 17 I=1,20,5
300C
310C ISUPPLY IS THE PLANNED SUPPLY USAGE FOR THE SUCCEEDING
320C DAY'S ACTIVITY
330C
340 READ 100,ISUPPLY(I),ISUPPLY(I+1),ISUPPLY(I+2),
350&ISUPPLY(I+3),ISUPPLY(I+4)
355 PRINT 916
356 916 FORMAT(1H1,2X,"INPUT SUPPLY VALUES")
360 PRINT 334,ISUPPLY(I),ISUPPLY(I+1),ISUPPLY(I+2),
370 &ISUPPLY(I+3),ISUPPLY(I+4)
380 334 FORMAT(/1X,5(I6,2X))
390 17 CONTINUE
400C
410C IN=# OF LINKS IN THE NETWORK
420C K=THE NUMBER OF NODES IN THE NETWORK;LS= THE NUMBER
430C OF LINKS LEADING TO THE SINK
440C
450 READ 100,IN,K,LS
455 PRINT 111
```

```
460 PRINT 336,IN,K,LS
470 336 FORMAT(1X,"IN=",1X,I3,2X,"K=",1X,I3,2X,"LS=",1X,I3)
480C
490C DLNK MATRIX WILL CONTAIN INFORMATION DESCRIBING EACH
500C LINK OF THE NETWORK
510C
516 111 FORMAT(//20X,"INPUT DLNK VALUES")
520 DO 1 I=1,IN
530 READ 100,(DLNK(I,J),J=1,14)
540 PRINT 107,(DLNK(I,J),J=1,14)
545 107 FORMAT(1X,6(F3.0,2X),8(F6.3,2X))
550 100 FORMAT(V)
560 1 CONTINUE
565C
570C THAT BOTH LINKS ARE SUCCESSFULLY ATTACKED
575C
580 PRINT 337,DBT,ITRK,PDS,ITAC,NLA,IDSCA,ACRNG,ACS
590 337 FORMAT(/5X,"INPUT PARAMETERS",
600&//5X,"MINIMUM DISTANCE BETWEEN TRUCKS =",1X,F5.2,
610&/5X,"NO. OF TRUCKS AT THE BEGINNING OF THE SIMULATION",
615&" =",I6,
630&/5X,"PROBABILITY OF KILL PER AIR DEFENSE SUPPRESSION",
635&" SORTIE =",1X,F5.3,
640&/5X,"NO. OF AIRCRAFT AT THE BEGINNING OF THE SIMULATION",
645&"=",I6,
650&/5X,"NO. OF LINKS BEING ATTACKED =",I2,
660&/5X,"DEFENSE SUPPRESSION CAPABILITY =",I2,
670&/5X,"AIRCRAFT FLYING RANGE IN TOTAL NO. OF MILES =",1X,
680&F7.1,/5X,"AIRCRAFT SPEED =",1X,F7.1)
690C
700C REARRANGING DATALINK(DLNK) MATRIX FROM 1 TO MAX LINK
710C IF INITIAL DLNK MATRIX IS NOT PUT IN NUMERICAL ORDER
720C
730 INA=IN-1
740 DO 24 I=1,INA
750 INB=I+1
760 DO 25 J=INB,IN
770 IF(DLNK(I,1).LE.DLNK(I,1)) GO TO 25
780 DO 26 JA=1,17
790 TDATA=DLNK(I,JA)
800 DLNK(I,JA)=DLNK(J,JA)
810 26 DLNK(J,JA)=TDATA
820 25 CONTINUE
830 24 CONTINUE
840C
850C CALCULATING LINK CAPACITIES,MAX VEHICLE SPEED ON LINKS,
860C TOTAL AAA PROBABILITY OF KILL AGAINST AC BY LINKS,BUILD-
870C ING THE "FROM-TO-MATRIX" TO DETERMINE FEASIBLE ROUTES
880C
890 DO 3 I=1,IN
900 DLNK(I,16)=DLNK(I,6)
910 DLNK(I,15)=DLNK(I,16)/DBT
```

```
920 DLNK(I,17)=1-(1-DLNK(I,11))**DLNK(I,10)
930 ITOFR(DLNK(I,2),DLNK(I,3))=DLNK(I,1)
940 3 CONTINUE
950C
960C BASEX=X COORDINATE OF AC BASE
1000C BASEY=Y COORDINATE OF AC BASE
1010C
1020 READ 100,BASEX,BASEY
1030C
1040C LOADING GRID COORDINATES FOR THE START,MIDDLE AND
1050C END OF EACH LINK;CALCULATE THE DISTANCE FROM THE AC
1060C BASE TO EACH POINT
1070C
1075 PRINT 109
1076 109 FORMAT(1H1,10X,"INPUT GRID VALUES")
1080 DO 70 I=1,IN
1090 READ 100,(GRID(I,J),J=1,5)
1100 PRINT 108,(GRID(I,J),J=1,5)
1110 GRID(I,6)=SQRT((GRID(I,2)-BASEX)**2.+
1115&(GRID(I,3)-BASEY)**2.)
1120 GRID(I,7)=SQRT((GRID(I,4)-BASEX)**2.+
1125&(GRID(I,5)-BASEY)**2.)
1150 70 CONTINUE
1155 108 FORMAT(//1X,5(F7.3,2X))
1160C
1170C REARRANGE THE GRID MATRIX TO MATCH THE DLNK MATRIX
1180C
1190 PRINT 333,MAXUSE,MINUSE,SS(1)
1200 333 FORMAT(/1X,"MAXUSE=",I6,2X,"MINUSE=",I6,2X,
1210&"SS(1)=",2X,F9.2)
1220 INA=INA-1
1230 DO 71 I=1,INA
1240 INB=I+1
1250 DO 72 J=INB,IN
1260 IF(GRID(I,1)-GRID(J,1))72,72,73
1270 73 DO 74 JA=I,7
1280 TDATA=GRID(I,JA)
1290 GRID(I,JA)=GRID(J,JA)
1300 GRID(J,JA)=TDATA
1310 74 CONTINUE
1320 72 CONTINUE
1330 71 CONTINUE
1370 PRINT 170
1380 170 FORMAT(//1X,"*** FROM TO MATRIX IS ***")
1390 DO 5 I=1,K
1400 PRINT 105,(ITOFR(I,J),J=1,K)
1410 105 FORMAT( /1X,23I3)
1420 5 CONTINUE
1430C
1440C BUILD THE ALTERNATE LINK MATRIX;IE MATRIX ASSOCIATES
1450C WITH EACH TWO WAY LINK,THE LINK NUMBER GOING IN THE
1460C OPPOSITE DIRECTION
```

```
1470C
1480 DO 16 I=1,IN
1490 IALTLINK(I,1)=DLNK(I,1)
1500 16 IALTLINK(I,2)=DLNK(I,4)
1510 MM=1
1520 CALL ROUTE ($8)
1530 KODE=1
1540 CALL UERR(KODE)
1550 8 J=1
1560C
1570C BUILD MATRIX WITH ALL THE LINKS ENTERING THE SINK
1580C
1590 DO 9 I=1,K
1600 IF(ITOFR(I,K))80,9,80
1610 80 LSINK(J)=ITOFR(I,K)
1620 J=J+1
1630 9 CONTINUE
1640C GO TO 11
1645 CALL THRUPUT
1650 PRINT 115,MM
1660 115 FORMAT(1H1,1X,I3,2X,15HFEASIBLE ROUTES,20X,
1661&"ROUND TRIP TIMES",10X,"ROUTE DISTANCE")
1670 DO 4 I=1,MM
1680 DO 7 L=1,K
1690 IF(IFRUT(I,L))7,10,7
1700 7 CONTINUE
1710 10 J=L-1
1720 4 PRINT 207,(IFRUT(I,L),L=1,K),TRTIME(I),SDTRUT(I)
1725 207 FORMAT(/1X,10(I2,2X),16X,F9.4,16X,F9.4)
1730 11 CALL ACREQ
1740 NDAY=0
1750 RETURN
1760 END
```

SUBROUTINE ROUTE(*)

```
1770 SUBROUTINE ROUTE(*)
1780$:SELECTA:GRADLIB/G4SUBCMN,R
1790$:SELECTA:77A59/USERM,R
1800 DO 2 I=1,MM
1810 DO 3 J=1,K
1820 3 IFRUT(I,J)=0
1830 2 CONTINUE
1840 J=K
1850 MM=0
1860 L=K+1
1870 DO 4 I=1,K
1880 IF(ITOFR(I,J).EQ.0) GO TO 4
1890 GO TO 7
1900 4 CONTINUE
1905C
1910C *****SEARCH FROM TO MATRIX GOING RIGHT TO LEFT ****
1915C
1920 5 DO 6 I=1,K
1930 IF(ITOFR(I,J).EQ.0) GO TO 6
1940 DO 8 LI=L,K
1950 IF(I.EQ.IFRNOD(LI)) GO TO 6
1960 8 CONTINUE
1970 GO TO 7
1980 6 CONTINUE
1990 GO TO 9
2000 7 L=L-1
2010 IF(L.EQ.0) RETURN
2020 IFRNOD(L)=I
2030 IRUT(L)=ITOFR(I,J)
2040 IF(I.EQ.1) GO TO 10
2050 J=I
2060 GO TO 5
2065C
2070C  ****LOCATE LINKS ON BACKTRACK,SEARCH BY ROW*****
2075C
2080 11 L=L+1
2090 IF(L.GT.K) GO TO 20
2100 9 DO 12 I=1,K
2110 DO 13 J=1,K
2120 IF(ITOFR(I,J).EQ.IRUT(L)) GO TO 14
2130 13 CONTINUE
2140 12 CONTINUE
2150 KODE=12
2160 CALL UERR(KODE)
2165C
2170C ****SAVE FEASIBLE ROUTE****
2175C
2180 10 LI=K-L+1
2190 IL=L-1
```

```
2200 MM=MM+1
2210 DO 15 KI=1,LI
2220 IL=IL+1
2230 15 IFRUT(MM,KI)=IRUT(IL)
2235C
2240C ****SEARCH COLUMN FOR MULTIPLE ENTRIES****
2245C
2250 14 KI=I+1
2260 DO 16 I=KI,K
2270 IF(ITOFR(I,J).EQ.0) GO TO 16
2280 DO 17 LI=L,K
2290 17 IF(I.EQ.IFRNOD(LI)) GO TO 16
2300 GO TO 18
2310 16 CONTINUE
2315C
2320C ****NO MULTIPLE LINKS,BACKTRACK TO NEXT LINK****
2325C
2330 GO TO 11
2335C
2340C ****FOUND FEASIBLE MULTIPLE LINK****
2345C
2350 18 IRUT(L)=ITOFR(I,J)
2360 IFRNOD(L)=I
2370 J=I
2380 GO TO 5
2390 20 DO 21 I=1,MM
2400 SDTRUT(I)=0.
2410 DO 22 J=1,K
2420 22 SDTRUT(I)=SDTRUT(I)+DLNK(IFRUT(I,J),5)
2430 21 CONTINUE
2450 RETURN 1
2460 END
```

SUBROUTINE THRUPUT

```
2470 SUBROUTINE THRUPUT
2480$:SELECTA:GRADLIB/G4SUBCMN,R
2490$:SELECTA:77A59/USERM,R
2510C
2520C IRU = NUMBER OF ROUTES USED TO MAXIMIZE SYSTEM FLOW
2530C
2540 IRU=1
2550 DO 2 I=1,IN
2560C
2570C LINKUSE = VECTOR CONTAINING USED CAPACITY OF EACH LINK
2580C IN A MAX FLOW SITUATION
2590C
2600 2 LINKUSE(I)=0
2610 IMIN=0
2620 DO 3 I=1,MM
2630 DO 4 J=1,K
2640 IHOLD=IFRUT(I,J)
2650 IMIN=MAXO(IMIN,IHOLD)
2660 4 CONTINUE
2670 3 CONTINUE
2680 IF(IMIN.EQ.0) RETURN
2685C
2690C *** LOAD LINK CAPACITY FOR ALL FEASIBLE ROUTES***
2695C
2700 DO 6 I=1,MM
2710 DO 5 J=1,K
2720 IF(IFRUT(I,J).EQ.0) GO TO 7
2730 IRUTCAP(I,J)=DLNK(IFRUT(I,J),15)
2740 IF(IRUTCAP(I,J).LT.0) IRUTCAP(I,J)=0
2750 GO TO 5
2760 7 IRUTCAP(I,J)=999999
2770 5 CONTINUE
2780 6 CONTINUE
2785C
2790C *** COMPUTE TRAVEL TIME BY LINK ***
2795C
2800 DO 53 I=1,MM
2810 DO 54 J=1,K
2820 IF(IFRUT(I,J).EQ.0) GO TO 54
2830 IF(DLNK(IFRUT(I,J),16).EQ.0) GO TO 56
2840 RTTIME(I,J)=DLNK(IFRUT(I,J),5)/DLNK(IFRUT(I,J),16)
2850 GO TO 54
2860 56 RTTIME(I,J)=9999.
2870 54 CONTINUE
2880 53 CONTINUE
2885C
2890C *** COMPUTE ROUND TRIP TIME - ALL FEASIBLE ROUTES***
2895C
2900 DO 57 I=1,MM
```

```
2910 TRTIME(I)=0.
2920 DO 58 J=1,K
2930 TRTIME(I)=TRTIME(I)+RTITIME(I,J)
2940 58 CONTINUE
2950 ONEWAYT(I)=TRTIME(I)
2960 TRTIME(I)=2.*TRTIME(I)+2.
2970 57 CONTINUE
2975C
2980C *** COMPUTE CAPACITY OF ALL FEASIBLE ROUTES ***
2985C
2990 11 DO 50 I=1,MM
3000 ISUM=9999
3010 DO 51 J=1,K
3020 IF(IRUTCAP(I,J).EQ.0) GO TO 52
3030 IF(IRUTCAP(I,J).LT.0) GO TO 100
3040 IRCAP=IRUTCAP(I,J)
3050 51 ISUM=MIN0(ISUM,IRCAP)
3060 ISUMCAP(I)=ISUM
3070 GO TO 50
3080 52 ISUMCAP(I)=0
3090 50 CONTINUE
3095C
3100C *** SELECT ROUTES BY SHORTEST ROUND TRIP TIME ***
3105C
3110 STRUT=9999.
3120 DO 60 I=1,MM
3130 IF(ISUMCAP(I).EQ.0) GO TO 60
3140 IF(STRUT.LE.TRTIME(I)) GO TO 60
3150 STRUT=TRTIME(I)
3160 IRT=I
3170 60 CONTINUE
3180 IF(STRUT.EQ.9999.) GO TO 62
3190 IRUTUSE(IRU)=IRT
3200 JSUMCAP(IRU)=ISUMCAP(IRT)
3210 IRU=IRU+1
3220 I=IRT
3230 DO 61 J=1,K
3240 IRUTCAP(I,J)=IRUTCAP(I,J)-ISUMCAP(I)
3250 LINKUSE(IFRUT(I,J))=LINKUSE(IFRUT(I,J))+ISUMCAP(I)
3260 61 CONTINUE
3265C
3270C *** REDUCE LINK CAPACITIES OF LINKS IN SELECTED ROUTE
3275C
3280 DO 29 L=1,MM
3290 DO 30 LI=1,K
3300 IF(IFRUT(L,LI).EQ.0) GO TO 30
3310 DO 31 J=1,K
3320 IF(IFRUT(L,LI).EQ.IFRUT(I,J))IRUTCAP(L,LI)=IRUTCAP(I,J)
3330 IF(IALTLINK(IFRUT(L,LI),2).EQ.0) GO TO 31
3340 IF(IALTLINK(IFRUT(L,LI),2).EQ.IFRUT(I,J))IRUTCAP(L,LI)=
3350&IRUTCAP(I,J)
3360 31 CONTINUE
```

```
3370 30 CONTINUE
3380 29 CONTINUE
3390 GO TO 11
3400 62 IRU=IRU-1
3410 RETURN
3420 100 KODE=11
3430 CALL UERR(KODE)
3440 RETURN
3450 END
```

SUBROUTINE TRKASG

```
3460 SUBROUTINE TRKASG
3470$:SELECTA:GRADLIB/G4SUBCMN,R
3480$:SELECTA:77A59/USERM,R
3490C
3500C NRU = NUMBER OF ROUTES BEING USED
3510C
3530 NRU=0
3540 DO 1 I=1,IN
3550C
3560C ULINK = CAPACITY ON EACH LINK; NUMBER OF TRKS IN ONE
3570C DIRECTION
3580C
3590 ULINK(I)=0.
3600C
3610C UCAP= ESTIMATED QUANTITY OF SUPPLIES THAT CAN
3620C BE  DELIVERED USING THAT ROUTE IN A 12 HOUR PERIOD
3630C
3640 1 UCAP(I)=0.
3650 ITRKAV=MTSOR+MTSINK
3660 DO 2 I=1,IRU
3670 IP=IRUTUSE(I)
3680C
3690C COMPUTE THE NUMBER OF TRKS TO CAPACITATE A ROUTE
3700C
3710 TEMP=JSUMCAP(I)*TRTIME(IP)
3720 ITEMP=TEMP
3730 IF(TEMP-ITEMP)4,4,3
3740 3 ITEMP=ITEMP+1
3750 4 TEMP=ITEMP
3760 IF(ITEMP.LE.ITRKAV) GO TO 6
3770 ITEMP=ITRKAV
3780C
3790C SUBTRACT THE NUMBER OF TRKS REQUIRED TO CAPACITATE
3800C A ROUTE FROM THOSE TRKS AVAILABLE
3810C
3820 6 ITRKAV=ITRKAV-ITEMP
3830C
3840C ACAP = CAPACITY PER HR
3850C
3860 ACAP=(ITEMP/TEMP)*JSUMCAP(I)
3870 UCAP(I)=ACAP*4.*(VTIMOP-ONEWAYT(IRUTUSE(I)))
3880 DO 5 J=1,K
3890 ULINK(IFRUT(IP,J))=ULINK(IFRUT(IP,J))+ACAP
3900 5 CONTINUE
3910 NTAR(I)=ITEMP
3920 18 NRU=NRU+1
3930 IF(ITRKAV.EQ.0) GO TO 10
3940 2 CONTINUE
3950C
```

```
3960C COMPUTE AN ESTIMATE OF HOW MANY TONS OF SUPPLY CAN BE
3970C SENT VIA THE ROUTE DURING THE DAY'S OPERATION
3980C
3990 10 TRKCAP=0.
4000 DO 27 I=1,NRU
4010 TRKCAP=TRKCAP+UCAP(I)
4020 27 CONTINUE
4030 RETURN
4040 END
```

SUBROUTINE TRANSYS

```
4050 SUBROUTINE TRANSYS
4060$:SELECTA:GRADLIB/G4SUBCMN,R
4070$:SELECTA:77A59/USERM,R
4090C
4100C STORING INFO CONTAINING THE MAX LINKUSE GIVEN THE
4110C NETWORK; VALUES ARE USED IN COMPUTING THE
4120C THRUPUT REDUCTION THAT RESULTS WHEN A LINK IS
4130C SUCCESSFULLY ATTACKED. DATA IS USED IN ACSCHED ROUTINE
4140C
4160 2 MAXFLOW=0
4170 DO 12 I=1,LS
4180 12 MAXFLOW=MAXFLOW+LINKUSE(LSINK(I))
4190 6 PTRTIME(I)=TRTIME(I)
4200 DO 7 I=1,IN
4210 PMAX=MAXFLOW
4220 7 PLINKUSE(I)=LINKUSE(I)
4230 DO 8 I=1,IRU
4240 8 PRUTUSE(I)=IRUTUSE(I)
4250 PIRU=IRU
4260 1 DO 4 I=1,IN
4270 4 PULINK(I)=ULINK(I)
4280 PTRKCAP=TRKCAP
4290 DO 5 I=1,IRU
4300 5 PUCAP(I)=UCAP(I)
4310 RETURN
4320 END
```

SUBROUTINE ACSCHED

```
4330 SUBROUTINE ACSCHED
4340$:SELECTA:GRADLIB/G4SUBCMN,R
4350$:SELECTA:77A59/USERM,R
4370C
4380C KACAT=ATTACK MATRIX. COLUMN 1 CONTAINS THE ATTACK TYPE
4390C 1=LINK ATTACK;2=TRUCK ATTACK. COL.2 CONTAINS THE LINK
4400C WHERE THE ATTACK WILL OCCUR. COL.3 CONTAINS THE # OF
4410C ATTACKING AIRCRAFT. COLUMN 4 CONTAINS THE # OF DEFENSE
4420C SUPPRESSION AIRCRAFT. COLUMN 5 CONTAINS THE # OF TRUCK
4430C ATTACKS THAT CAN BE MADE WITH THE MUNITIONS ON THE
4440C ATTACKING AIRCRAFT.
4450C
4460 DO 43 I=1,30
4470 KACAT(I,1)=0
4480 KACAT(I,2)=0
4490 KACAT(I,3)=0
4500 KACAT(I,5)=0
4510 43 KACAT(I,4)=0
4520C
4530C NATK = NUMBER OF ATTACKS
4540C
4550 NATK=0
4560C
4570C NLA = NUMBER OF LINKS ATTACKED
4580C IF NLA  = 1 1 LINK IS ATTACKED
4590C IF NLA  = 2 2 LINKS ARE ATTACKED
4600C IF NLA = 0 NO LINKS ARE ATTACKED, JUST TRKS
4610C
4620C
4630C ITAC = TOTAL NUMBER OF AC AVAILABLE AT THE BEGINNING
4640C OF THE INTERDICTION PERIOD
4650C
4660 IF(ITAC.GT.IAAC) GO TO 21
4680 CALL TRANSYS
4690 GO TO (21,23,23),NLA+1
4700C
4710C PROCESS TO COMPUTE THE SYSTEM REDUCTION WITH ONE
4720C LINK INTERDICTED
4730C
4740 23 DO 2 I=1,IN
4750 2 NETREDUC(I)=0
4760 DO 1 IW=1,IN
4770 IF(PULINK(IW))80,1,81
4780 81 MD=IALTLINK(IW,2)
4790 IF(MD-0) 83,83,82
4800 82 IF(IW-MD)83,83,1
4810 83 TMPH=DLNK(IW,16)
4820 TCAP=DLNK(IW,15)
4830C
```

```
4840C COMPUTE THE MPH REDUCTION ON A LINK, IF LINK IS
4850C SUCCESSFULLY ATTACKED
4860C
4870 DLNK(IW,16)=DLNK(IW,6)-(DLNK(IW,6)*DLNK(IW,7))
4880C
4890C COMPUTES CHANGE IN CAPACITY FOR LINK
4900C
4910 DLNK(IW,15)=DLNK(IW,16)/DBT
4920 IF(MD.GT.0) DLNK(MD,16)=DLNK(IW,16)
4930 IF(MD.GT.0) DLNK(MD,15)=DLNK(IW,15)
4940 CALL THRUPUT
4950 CALL TRKASG
4960C
4970C NETREDUC = REDUCED THRUPUT DUE TO AN ATTACK ON LINK
4980C
4990 NETREDUC(IW)=(PTRKCAP-TRKCAP)*DLNK(IW,8)
5000 DLNK(IW,16)=TMPH
5010 DLNK(IW,15)=TCAP
5020 IF(MD.GT.0) DLNK(MD,16)=DLNK(IW,16)
5030 IF(MD.GT.0) DLNK(MD,15)=DLNK(IW,15)
5040 1 CONTINUE
5050 GO TO (91,28,24),NLA+1
5060 28 NET=0
5070C
5080C FOR 1 LINK ATTACK, SEEK THE LINK WITH THE GREATEST
5090C THRUPUT REDUCTION
5100C
5110 DO 5 I=1,IN
5120 NETAC=IACAS(I,1)+IACAS(I,2)
5130 IF(IAAC-NETAC)5,41,41
5140 41 IF(NET.GE.NETREDUC(I)) GO TO 5
5150 ITGTLK=I
5160 NET=NETREDUC(I)
5170 5 CONTINUE
5180 GO TO (91,42,24),NLA+1
5190C
5200C SCHEDULE EACH ATTACK
5210C
5220 42 IF(NET) 91,91,46
5230 46 KACAT(1,1)=1
5240 KACAT(1,2)=ITGTLK
5250 KACAT(1,3)=IACAS(ITGTLK,1)
5260 KACAT(1,4)=IACAS(ITGTLK,2)
5270C
5280C REDUCE THE NUMBER OF AC AVAILABLE FOR USE THAT DAY
5290C
5300 IAAC=IAAC-(IACAS(ITGTLK,1)+IACAS(ITGTLK,2))
5310 NATK=1
5320 GO TO 91
5330C
5340C COMPUTE THE NET REDUCTION WITH A 2 LINK ATTACK
5350C
```

```
5360 24 INB=IN-1
5370 DO 26 IQ=1,INB
5380 MIQ=IALTLINK(IQ,2)
5390 IF((IQ.GT.MIQ).AND.(MIQ.GT.0))GO TO 26
5400 INA=IQ+1
5410 DO 27 JQ=INA,IN
5420 MJQ=IALTLINK(JQ,2)
5450 NETWO(IQ,JQ)=0
5460 IF(IQ-MJQ)3,27,3
5470 3 IF((MJQ.GT.IQ).AND.(JQ.GT.MJQ))GO TO 27
5480 TMPH=DLNK(IQ,16)
5490 TCAP=DLNK(IQ,15)
5500 TMPH2=DLNK(JQ,16)
5510 TCAP2=DLNK(JQ,15)
5520C
5530C REDUCE THE MPH ON THE 2 LINKS BEING ATTACKED
5540C
5550 DLNK(IQ,16)=DLNK(IQ,6)-DLNK(IQ,6)*DLNK(IQ,7)
5560 DLNK(JQ,16)=DLNK(JQ,6)-DLNK(JQ,6)*DLNK(JQ,7)
5570 DLNK(IQ,15)=DLNK(IQ,16)/DBT
5580 DLNK(JQ,15)=DLNK(JQ,16)/DBT
5590 IF(MIQ)6,6,4
5600 4 DLNK(MIQ,16)=DLNK(IQ,16)
5610 DLNK(MIQ,15)=DLNK(IQ,15)
5620 6 IF(MJQ)8,8,7
5630 7 DLNK(MJQ,16)=DLNK(JQ,16)
5640 DLNK(MJQ,15)=DLNK(JQ,15)
5650 8 CALL THRUPUT
5660 CALL TRKASG
5670C
5680C RECAP = AMOUNT OF TONS OF THRUPUT REDUCED GIVEN THAT
5690C
5700 RECAP=PTRKCAP-TRKCAP
5710 IF(DLNK(IQ,8)-DLNK(JQ,8))29,30,31
5720C
5730C ACCOUNT FOR THE TIME DURING WHICH ONLY ONE LINK IS
5740C DEQRADED (BASED ON LINK REPAIR RATES)
5750C
5760 29 NETWO(IQ,JQ)=(RECAP*DLNK(IQ,8))+(NETREDUC(JQ)*
5770&(DLNK(JQ,8)-DLNK(IQ,8))/DLNK(JQ,8))
5780 GO TO 32
5790 30 NETWO(IQ,JQ)=RECAP*DLNK(IQ,8)
5800 GO TO 32
5810 31 NETWO(IQ,JQ)=(RECAP*DLNK(JQ,8))+(NETREDUC(IQ)*
5820&(DLNK(IQ,8)-DLNK(JQ,8))/DLNK(IQ,8))
5830 32 DLNK(IQ,16)=TMPH
5840 DLNK(IQ,15)=TCAP
5850 DLNK(JQ,16)=TMPH2
5860 DLNK(JQ,15)=TCAP2
5870 IF(MIQ)10,10,9
5880 9 DLNK(MIQ,16)=DLNK(IQ,16)
5890 DLNK(MIQ,15)=DLNK(IQ,15)
```

```
5900 10 IF(MJQ)27,27,11
5910 11 DLNK(MJQ,16)=DLNK(JQ,16)
5920 DLNK(MJQ,15)=DLNK(JQ,15)
5930 27 CONTINUE
5940 26 CONTINUE
5950C
5960C THE EXPECTED VALUE OF DAMAGE AGAINST BOTH LINKS IS
5970C COMPUTED; DECISION TREE APPROACH
5980C
5990 DO 33 I=1,INB
6000 INA=I+1
6010 DO 34 J=INA,IN
6020 NETWO(I,J)=(NETWO(I,J)*PSGT(I)*PSGT(J))+(PSGT(I)*
6030&(1-PSGT(J))*NETREDUC(I))+(PSGT(J)*(1-PSGT(I))*
6040&NETREDUC(J))
6047 34 CONTINUE
6050 33 CONTINUE
6060 NET=0
6070C
6080C DETERMINE IF THERE ARE ENOUGH AC AVAILABLE TO ATTACK T
6090C LINK,THEN DETERMINE THE SET OF LINKS THAT WILL BE
6100C ATTACKED. (THE SET OF LINKS WITH THE
6110C WITH THE HIGHEST NETREDUC WILL BE CHOSEN).
6120C
6130 DO 35 I=1,INB
6140 INA=I+1
6150 DO 36 J=INA,IN
6160 NETAC=IACAS(I,1)+IACAS(I,2)+IACAS(J,1)+IACAS(J,2)
6170 IF(IAAC-NETAC)36,38,38
6180 38 IF(NET-NETWO(I,J))37,36,36
6190 37 NET=NETWO(I,J)
6200 LINKA=I
6210 LINKB=J
6220 36 CONTINUE
6230 35 CONTINUE
6260 IF(NET)91,91,39
6270 39 IF(NETREDUC(LINKA))70,71,72
6280 71 LIA=LINKA
6290 LINKA=LINKB
6300 LINKB=LIA
6310 IF(NETREDUC(LINKA))70,91,72
6320C
6330C SCHEDULE ATTACKS AGAINST TWO LINKS
6340C
6350 72 KACAT(1,1)=1
6360 KACAT(1,2)=LINKA
6370 KACAT(1,3)=IACAS(LINKA,1)
6380 KACAT(1,4)=IACAS(LINKA,2)
6390 IAAC=IAAC-(IACAS(LINKA,1)+IACAS(LINKA,2))
6400 IF(NETREDUC(LINKB))70,74,75
6410 74 NATK=1
6420 GO TO 91
```

```
6440 KACAT(2,2)=LINKB
6450 KACAT(2,3)=IACAS(LINKB,1)
6460 KACAT(2,4)=IACAS(LINKB,2)
6470 IAAC=IAAC-(IACAS(LINKB,1)+IACAS(LINKB,2))
6480 NATK=2
6490 GO TO 91
6550C
6560C DETERMINE THE TRK ATTACKS BASED ON THE EXPECTED NUMBER
6570C OF TRKS ON THE LINK
6580C
6590 21 DO 47 I=1,IN
6600 IF(DLNK(I,16))49,47,48
6610C
6620C ITKDEN = EXPECTED TRK DENSITY ON EACH LINK
6630C
6640 48 ITKDEN(I)=PULINK(I)*DLNK(I,5)/DLNK(I,16)
6650C
6660C IDSCA = DEFENSE SUPRESSION CAPABILITY AVAILABILITY
6670C IF IDSCA = 1, YES; IF IDSCA = 2, NO
6720C
6730 47 CONTINUE
6740 INA=NATK+1
6750 INB=IN+INA
6760 DO 50 I=INA,INB
6810 JU=0
6820 ITK=0
6830 DO 51 J=1,IN
6840 76 IF(ITKDEN(J)-ITK)51,51,52
6850 52 ITK=ITKDEN(J)
6860 JU=J
6870 51 CONTINUE
6880 IF(ITK)49,25,53
6890C
6900C FOR EACH TRK ATTACK A CELL OF 4 AC IS ASSIGNED; THE
6910C NUMBER 4 IS ARBITRARILY SELECTED
6920C NAC = THE NUMBER OF AC REQUIRED TO ATTACK A LINK
6930C
6940 53 NAC=IACAS(JU,2)+4.
6950C
6960C CHECK- ARE THERE ENOUGH AIRCRAFT TO ATTACK
6965C THE LINK
6970C
6980C DETERMINE IF THERE ARE ENOUGH AIRCRAFT TO ATTACK THE
6990 55 NATK=NATK+1
7000 KACAT(NATK,2)=JU
7010 KACAT(NATK,3)=4
7020 KACAT(NATK,4)=IACAS(JU,2)
7030 KACAT(NATK,1)=2
7040 IAAC=IAAC-NAC
7050 78 ITKDEN(JU)=0
7060 50 CONTINUE
7070C
```

```
7080C SCHEDULING ATTACK TIMES
7090C MP = POINTER
7100C
7110 25 IF(NATK)91,91,77
7120 77 DO 12 I=1,NRU
7130 DO 13 J=1,IN
7140 MA=IFRUT(IRUTUSE(I),J)
7150 IF(MA) 12,12,14
7160 14 IF(IAAC-(IACAS(MA,2)+4))13,21,21
7170 13 CONTINUE
7180 12 CONTINUE
7190 MP=IRUTUSE(I)
7240 TFA=ONEWAYT(MP)-GRID(KACAT(1,2),6)/ACS
7250C
7260C SCHEDULES ALL ATTACKS AND ASSIGNS ATTACK TIME TO EACH
7270C ATTACK; THEN FILES EACH ATTACK IN THE TIME EVENT FILE
7280C
7290 DO 60 I=1,NATK
7300 KACAT(I,5)=2*KACAT(I,3)
7310 KACAT(I,6)=ACRNG-GRID(KACAT(I,2),6)
7320 KACAT(I,7)=1
7330 AATRIB(1)=TTNOW+TFA+(GRID(KACAT(I,2),6)/ACS)
7340 AATRIB(2)=3.
7350 AATRIB(3)=I
7360 AATRIB(4)=0.
7370 CALL FILEM(1)
7380C
7390C THERE ARE TEN MINUTES BETWEEN EACH AC ATTACK TAKEOFF
7400C TIME
7410C
7420 TFA=TFA+.166
7430 60 CONTINUE
7440 RETURN
7450 49 KODE=2
7460 CALL UERR(KODE)
7470 80 KODE=3
7480 CALL UERR(KODE)
7490 70 KODE=4
7500 CALL UERR(KODE)
7510 91 RETURN
7520 END
```

SUBROUTINE ACREQ

```
7530 SUBROUTINE ACREQ
7540$:SELECTA:GRADLIB/G4SUBCMN,R
7550$:SELECTA:77A59/USERM,R
7570 PRINT 836
7580 836 FORMAT(//10X,"AIRCRAFT REQUIRED TO ATTACK EACH ",
7590&"LINK",//2X,"LINK",5X,"AIRCRAFT ATTACKING LINK",5X,
7600&"DEFENSE SUPPRESSION AIRCRAFT")
7610 IAAC=ITAC
7620 20 DO 6 I=1,IN
7630 AC=ALOG(.1)/ALOG(1-DLNK(I,9))
7640 NAC=AC
7650 IF((AC-NAC).GT.0) NAC=NAC+1
7660 PSGT(I)=1-(1-DLNK(I,9))**NAC
7670 IACAS(I,1)=0
7680 IACAS(I,2)=0
7690 IF(DLNK(I,10))80,8,81
7720 81 GO TO(19,8),IDSCA
7730 19 IDS=IAAC-NAC
7740 ADS=ALOG(.1)/ALOG(1-PDS)
7800 ADS=ADS/(1.-DLNK(I,17))
7810 JADS=ADS
7820 IF(ADS-JADS)12,12,13
7830 13 JADS=JADS+1
7840 12 IADS=JADS
7900 14 IAGAT=NAC
7910 16 IACAS(I,1)=IAGAT
7920 IACAS(I,2)=IADS
7930 GO TO 77
7940 8 AGAT=NAC/(1-DLNK(I,17))
7950 IAGAT=AGAT
7960 IF(AGAT-IAGAT)17,17,18
7970 18 IAGAT=IAGAT+1
7980 17 IACAS(I,1)=IAGAT
7990 IACAS(I,2)=0
8000 77 PRINT 216,I,IACAS(I,1),IACAS(I,2)
8010 216 FORMAT(/3X,I3,15X,I4,25X,I4)
8020 6 CONTINUE
8030 GO TO 82
8040 80 KODE=5
8050 CALL UERR(KODE)
8060 82 RETURN
8070 END
```

SUBROUTINE ACATK

```
8080 SUBROUTINE ACATK
8090$:SELECTA:GRADLIB/G4SUBCMN,R
8100$:SELECTA:77A59/USERM,R
8140 LBAT=AATRIB(3)
8150 LD=KACAT(AATRIB(3),2)
8160 MD=IALTLINK(LD,2)
8165C
8170C DEFENESE SUPRESSION
8175C
8180 18 PADN=DLNK(LD,17)
8190C IF(LBAT.EQ.3) PRINT 800,LD
8200 NADW=DLNK(LD,10)
8205 IF(PADN)3,3,89
8210 89 IF(KACAT(LBAT,4))2,3,4
8229 4 NSAC=0
8230 DO 5 J=1,KACAT(LBAT,4)
8240 X=DRAND(1)
8250 ADU=ADU+(DLNK(LD,12)*NADW)
8260 IF(PADN-X)6,16,16
8270 6 NSAC=NSAC+1
8275 GO TO 5
8320 16 KDMGE=1
8330 CALL DAMAGE
8340 5 CONTINUE
8341 KACAT(LBAT,4)=0
8342 IF(NSAC)3,3,93
8343 93 PDSK=1-(1-PDS)**NSAC
8344 X=DRAND(2)
8345 IF(PDSK-X)3,7,7
8346 7 KDMGE=4
8347 CALL DAMAGE
8350 800 FORMAT(/2X,"LINK UNDER ATTACK",I3)
8380 3 GO TO (8,9),KACAT(LBAT,1)
8385C
8390C ATTACK AGAINST LINK
8395C
8400 8 IF(DLNK(LD,17).LE.0) GO TO 151
8410 NACS=0
8430 DO 10 JB=1,KACAT(LBAT,3)
8440 X=DRAND(3)
8450 ADU=ADU+(DLNK(LD,12)*NADW)
8460 IF(PADN-X)11,17,17
8470 11 NACS=NACS+1
8480 GO TO 10
8490 17 KDMGE=1
8500 CALL DAMAGE
8510 10 CONTINUE
8512 GO TO 51
8513 151 NACS=KACAT(LBAT,3)
```

```
8520 51 PAS=1-(1-DLNK(LD,9))**NACS
8530 X=DRAND(3)
8540 IF(PAS-X)25,12,12
8550 12 KDMGE=2
8560 CALL DAMAGE
8570 GO TO 25
8575C
8580C ATTACK AGAINST TRUCKS
8585C
8590 9 DO 201 IQ=1,NRU
8600 NTKE(IQ)=0
8610 NTKW(IQ)=0
8620 MTKR(IQ)=0
8630 DO 202 JQ=1,K
8640 IF(LD.EQ.IFRUT(IRUTUSE(IQ),JQ)) GO TO 203
8650 IF(0-MD)197,202,202
8660 197 IF(MD.EQ.IFRUT(IRUTUSE(IQ),JQ)) GO TO 198
8670 202 CONTINUE
8680 GO TO 201
8690 198 LMD=MD
8700 GO TO 199
8710 203 LMD=LD
8720 199 TFSO=0.
8725C
8730C  TIME FROM SOURCE TFSO
8735C
8740 TFSI=0.
8750C
8760C TFSI=TIME FROM SINK
8770C
8780 ALD=IQ
8790 DO 204 KQ=1,K
8800 LQ=K-KQ+1
8810 IF(IFRUT(IRUTUSE(IQ),LQ).LE.0) GO TO 204
8820 IF(LMD.EQ.IFRUT(IRUTUSE(IQ),LQ)) GO TO 205
8830 TFSI=TFSI+RTTIME(IRUTUSE(IQ),LQ)
8840C IF(LBAT.EQ.3) PRINT 871,TFSI
8850 871 FORMAT(1X,"TFSI=",1X,F9.4)
8860 GO TO 204
8865C
8870C TIME FIRST TRK ARRIVES AT SINK FROM LINK BEING ATK
8875C
8880 205 TST=TTNOW+TFSI+1.
8890 TSL=TST+RTTIME(IRUTUSE(IQ),LQ)
8920 GO TO 206
8930 204 CONTINUE
8935C
8940C LOCATION OF NEXT EVENT
8945C
8950 206 LNE=MMFE(1)
8960 209 IF(QSET(LNE+1).GE.TST) GO TO 215
8970 LNE=NSET(LNE+5)
```

```
8980 GO TO 209
8990 215 NTSTW(IQ)=LNE
9000 208 IF(QSET(LNE+2).NE.1.) GO TO 207
9010 IF(QSET(LNE+3).NE.ALD) GO TO 207
9020 IF(QSET(LNE+4).NE.1.) GO TO 207
9030 NTKW(IQ)=NTKW(IQ)+1
9040 207 LNE=NSET(LNE+5)
9050 IF(QSET(LNE+1).LE.TSL) GO TO 208
9055C
9060C EMPTY TRUCKS GOING WEST
9065C
9070 TFSO=ONEWAYT(IRUTUSE(IQ))-(TFSI+RTTIME(IRUTUSE(IQ),LQ))
9080 TST=TTNOW+TFSO+1.
9090 TSL=TST+RTTIME(IRUTUSE(IQ),LQ)
9130 LNE=MMFE(1)
9140 210 IF(QSET(LNE+1).GE.TST) GO TO 216
9150 LNE=NSET(LNE+5)
9160 GO TO 210
9170 216 NTSTE(IQ)=LNE
9180 211 IF(QSET(LNE+2).NE.1.) GO TO 212
9190 IF(QSET(LNE+3).NE.ALD) GO TO 212
9200 IF(QSET(LNE+4).NE.2.) GO TO 212
9210 NTKE(IQ)=NTKE(IQ)+1
9220 212 LNE=NSET(LNE+5)
9230 IF(QSET(LNE+1).LE.TSL) GO TO 211
9240 201 CONTINUE
9280 NTK=0
9290 DO 553 I=1,NRU
9300 MTKR(I)=NTKE(I)+NTKW(I)
9310 NTK=NTK+MTKR(I)
9330 553 CONTINUE
9370 NAC=KACAT(LBAT,3)
9380 NDR=KACAT(LBAT,7)
9390 NWL=KACAT(AATRIB(3),5)
9400 RAC=KACAT(LBAT,6)
9410 IF(NTK)2,23,133
9420 133 IF(DLNK(LD,17).LE.0.) GO TO 52
9430 NSAC =0
9440 DO 20 J=1,NAC
9450 X=DRAND(1)
9460 ADU=ADU+(DLNK(LD,12)*NADW)
9470 IF(PADN-X)21,22,22
9480 21 NSAC=NSAC+1
9490 GO TO 20
9500 22 KDMGE=1
9510 CALL DAMAGE
9520 AC=NWL/2.
9530 MAC=NWL/2
9540 IF(AC-MAC)2,33,34
9550 34 X=DRAND(3)
9560 Q=1./(1.+MAC)
9570 IF(Q-X) 33,35,35
```

```
9580 35 NWL=NWL-1
9590 GO TO 36
9600 33 NWL=NWL-2
9610 36 IF(NWL)25,25,20
9620 20 CONTINUE
9625C
9630C DETECT TRUCKS
9635C
9640 52 PTKD=1-(1-DLNK(LD,13))**NTK
9650C IF(LBAT.EQ.3) PRINT 711,PTKD,DLNK(LD,13)
9660 711 FORMAT(/1X,"PTKD",F8.4,2X,"P TRK SPT/TRK",F8.4)
9670 NWU=0
9680 IF(PTKD.LE.0) GO TO 23
9690 X=DRAND(5)
9700 IF(PTKD-X)23,24,24
9710 24 DO 28 J=1,NWL
9720 NWU=NWU+1
9730 X=DRAND(5)
9740 IF(DLNK(LD,14)-X) 28,27,27
9750 27 KDMGE=3
9760 CALL DAMAGE
9770 GO TO 31
9780 28 CONTINUE
9790 31 NWL=NWL-NWU
9820 IF(NWL)2,25,23
9830 23 RAC=RAC-DLNK(LD,5)
9860 GO TO (29,30),NDR
9870 29 FDIST=DLNK(LD,5)+GRID(LD,6)+(.05*ACS)
9880 NDR=2
9890 IF(RAC-FDIST)25,25,19
9900 30 FDIST=DLNK(LD,5)+GRID(LD,7)+(.05*ACS)
9910 NDR=1
9920 IF(RAC-FDIST)25,25,19
9930 19 KACAT(LBAT,5)=NWL
9940 AATRIB(1)=TTNOW+(DLNK(LD,5)/ACS)+.05
9950 CALL FILEM(1)
9951 AC=NWL/2.
9952 MAC=NWL/2
9953 IF(AC-MAC)40,40,41
9954 40 MAC=MAC+1
9970 41 KACAT(LBAT,3)=MAC
9980 KACAT(LBAT,6)=RAC
9990 KACAT(LBAT,7)=NDR
10000 GO TO 25
10010 2 IF(KACAT(I,4).LT.0) KODE=6
10020 IF(KACAT(I,1).LT.0) KODE=7
10030 IF(NAC.LT.0) KODE=8
10040 IF(NTK.LT.0) KODE=9
10050 IF(NWL.LT.0) KODE=10
10060 CALL UERR(KODE)
10070 25 RETURN
10080 END
```

SUBROUTINE DAILYOPS

```
10090 SUBROUTINE DAILYOPS
10100$:SELECTA:GRADLIB/G4SUBCMN,R
10110$:SELECTA:77A59/USERM,R
10120C
10130C PERFORM DAILY SCHEDULING AND COMPUTE STATS
10140C
10150 AATRIB(1)=TTNOW+24.
10160 AATRIB(2)=2.
10170 CALL FILEM(1)
10180 IF(NDAY)3,2,3
10190 3 MTSINK=MTSINK+NDTSINK
10200 TFLOW=TFLOW+SS(2)
10210 DAYDATA(NDAY,15)=SS(2)
10220 DO 251 I=1,IRU
10230 MTSINK=MTSINK+IPILE(I,2)
10240 251 IPILE(I,2)=0
10250 TRKUSE=MTSINK*VTRKUSE
10260 NDTSINK=MTSINK/5
10265C
10270C # OF USABLE TRUCKS
10275C
10280 MTSINK=MTSINK-NDTSINK
10285C
10290C   # OF TRUCKS AT SOURCE
10295C
10300 MTSOR=MTSOR+NDTSOR
10310 DO 252 I=1,IRU
10320 MTSOR=MTSOR+IPILE(I,1)
10330 252 IPILE(I,1)=0
10340 NDTSOR=MTSOR/5
10350 MTSOR=MTSOR-NDTSOR
10351 IF((TRKUSE+ADU)-SS(1))402,402,401
10352 401 USE=USE-(TRKUSE+ADU-SS(1))
10353 SS(1)=0.
10354 GO TO 403
10360 402 SS(1)=SS(1)-(TRKUSE+ADU)
10370 403 DUSE=USE+TRKUSE+ADU
10380 DAYDATA(NDAY,16)=DUSE
10390 DAYDATA(NDAY,17)=USE
10400 DAYDATA(NDAY,18)=TRKUSE
10410 DAYDATA(NDAY,19)=ADU
10420 ATI=SS(2)/RTH
10430 DAYDATA(NDAY,12)=ATI
10440 TUSE=TUSE+DUSE
10450 NACL=NACP+NAC1+NAC2+NAC3
10460 TACD=TACD+NACP
10470 DAYDATA(NDAY,2)=NACL
10480 PRINT 100,SS(2),DUSE,USE
10490 100 FORMAT(/1X,"THRUPUT=",1X,F8.2,5X,"TOTAL SUPPLY ",
```

```
10500&"USE=",1X,F8.2,5X,"TROOP SUPPLY USE=",1X,F8.2)
10510 PRINT 101,TRKUSE,ADU,ATI
10520 101 FORMAT(/1X,"TRUCK SUPPLY USE=",1X,F8.2,5X,"AAA ",
10525&"SUPPLY USE=",1X,
10530&F8.2,5X,"ACHIEVED DAILY THRUPUT INDEX=",1X,F6.3)
10540 ITRK=ITRK-(NTKD-NTR)
10550 PRINT 102,NTKD,NTR
10560 DAYDATA(NDAY,22)=NTKD
10570 DAYDATA(NDAY,23)=NTR
10580 DAYDATA(NDAY,24)=NTKD-NTR
10590 102 FORMAT(/1X,"TRUCKS DAMAGED TODAY=",1X,I3,5X,
10600&"NO. DAMAGED TRUCKS REPAIRABLE=",1X,I3)
10610 PRINT 103,NACL,NAC1,NAC2,NAC3,NACP
10620 103 FORMAT(/1X,"DAILY TOTAL AC DAMAGE=",1X,I3,5X,
10630&"AC REQ 1 DAY REPAIR=",1X,I3,/1X,"AC REQ 2 DAY ",
10635&"REPAIR=",1X,I3,
10640&5X,"AC REQ 3 DAY REPAIR=",1X,I3,/1X,"AC NOT",1X,
10645&"REPAIRABLE=",1X,I3)
10650C CALCULATING AC NEEDED FOR NEXT DAY
10660 ITAC=ITAC+MAC1-(NAC2+NAC3+NACP)
10670 MAC1=NAC2+MAC2
10680 MAC2=NAC3
10690 MTACL=MTACL+NACL
10700 TDTK=TDTK+NTKD
10720 DAYDATA(NDAY,3)=NAC1
10730 NAC1=0
10740 DAYDATA(NDAY,4)=NAC2
10750 NAC2=0
10760 DAYDATA(NDAY,5)=NAC3
10770 NAC3=0
10780 DAYDATA(NDAY,6)=NACP
10790 NACP=0
10800 NTKD=0
10810 NTR=0
10820 use=0.
10830 IF(NQQ.GT.2) GO TO 25
10840 2 NDAY=NDAY+1
10870 DAYDATA(NDAY,13)=SS(1)
10880 USERATE=ISUPPLY(NDAY)/24.
10890 IF(SS(1).LE.SUCP1) USERATE=MINUSE/24.
10900 SH=DSUPPLY+ISUPPLY(NDAY)-SS(1)
10910 SH=AMAX1(0.,SH)
10920 ORDER=ISUPPLY(NDAY+1)+SH+ADU+TRKUSE
10925 VORDER=ORDER-1.
10930 RTH=ADU+TRKUSE+ISUPPLY(NDAY+1)
10940 DAYDATA(NDAY,14)=ORDER
10950 TORDER=TORDER+ORDER
10955 VT=9.
10960 ADU=0.
10965 SS(2)=0.
10970 TRKUSE=0.
10980 ITRKMAX=MTSOR+MTSINK
```

```
10990 DAYDATA(NDAY,21)=ITRKMAX
10995C
11000C COMPUTE INDEXES FOR TODAY
11005C
11010 USI=SS(1)/DSUPPLY
11020 DAYDATA(NDAY,7)=USI
11040 PSI=SS(1)/(ISUPPLY(NDAY)+ISUPPLY(NDAY+1)+ISUPPLY(NDAY+
11050 DAYDATA(NDAY,8)=PSI
11060 AMSI=SS(1)/SUCP1
11070 DAYDATA(NDAY,9)=AMSI
11080 DCI=SS(1)/MAXUSE
11100 IF(DCI.LT.0) DCI=0.
11110 DAYDATA(NDAY,10)=DCI
11120 DMOI=SS(1)/MINUSE
11130 DAYDATA(NDAY,11)=DMOI
11150 PRINT 104,NDAY,USI,PSI,AMSI,DCI,DMOI,SS(1)
11160 104 FORMAT(1H1,/1X,"DAY",1X,I3,/1X,"UNRESTRICTED ",
11165&"SUPPLY INDEX=",
11170&1X,F6.3,5X,"PROGRAMMED SUPPORT INDEX=",1X,F6.3,/1X,
11180&"MINIMUM SUPPORT INDEX=",1X,F6.3,"DAILY COMBAT ",
11185&"INDEX=",
11190&1X,F6.3,/1X,"DAILY MINIMUM OPERATION INDEX=",1X,F6.3,5
11200&5X,"SUPPLIES ON HAND=",1X,F9.1)
11210 PRINT 105,ORDER
11220 GO TO (201,202),NQQ
11230 202 PRINT 300,ITAC
11240 PRINT 162,NLA
11250 162 FORMAT(1X,"NUMBER OF LINKS TO BE ATTACKED=",I3)
11260 DAYDATA(NDAY,1)=ITAC
11270 105 FORMAT(/1X,"DAILY SUPPLY ORDER=",1X,F9.1)
11280 CALL THRUPUT
11290 CALL TRKASG
11300 IAAC=ITAC
11310 IF(NLA)91,91,92
11320 92 CALL ACSCHED
11330 IF(NATK)31,31,32
11340 31 PRINT,"NO AC ATTACKS SCHEDULED AGAINST LINKS"
11350 GO TO 201
11360 32 PRINT 1003
11370 1003 FORMAT(//10X,"AIRCRAFT ATTACK PLAN FOR LINK ",
11375&"ATTACKS")
11380 PRINT 1004
11390 1004 FORMAT(/2X,"ATTACK NO."5X,"TYPE OF ATTACK",5X,
11400&"LINK",5X,"ATTACK AIRCRAFT",5X,"DEFENSE SUPPRESSION ",
11405&"AIRCRAFT")
11410 DO 90 I=1,NATK
11420  PRINT 1005,I,KACAT(I,1),KACAT(I,2),KACAT(I,3),
11421&KACAT(I,4)
11425 1005 FORMAT(/5X,I2,13X,I2,13X,I2,11X,I3,23X,I4)
11430 AATRIB(3)=I
11440 CALL ACATK
11450 90 CONTINUE
```

```
11460 201 CALL THRUPUT
11470 CALL TRKASG
11480 91 DO 117 I=1,NRU
11490C
11500C IT = NUMBER OF TRKS AT THE SINK AT THE BEGINNING
11510C OF THE DAY ASSIGNED TO A PARTICULAR ROUTE
11520C
11530 IT=NTAR(I)/2
11540C
11550C
11560C ASSIGNED TO A PARTICULAR ROUTE AT THE BEGINNING
11570C OF THE DAY
11580 IS=NTAR(I)-IT
11590 IF(MTSOR-IS)7,8,8
11600C
11610C IDSO = NUMBER OF TRKS THAT ARE SHORT AT THE SOURCE
11620C
11630 7 IDSO=IS-MTSOR
11640 GO TO 9
11650 8 IDSO=0
11660 9 IF(MTSINK-IT) 12,13,13
11670C
11680C IDSI = NUMBER OF TRKS THAT ARE SHORT AT THE SINK
11690C
11700 12 IDSI=IT-MTSINK
11710 GO TO 14
11720 13 IDSI=0
11730C
11740C IF THERE ARE ENOUGH TRKS AVAILABLE TO FILL A ROUTE IN
11750C BOTH DIRECTIONS, WE ASSIGN THAT NUMBER OF TRKS TO
11760C EACH IPILE
11770C
11780 14 IF((IDSO.LE.0).AND.(IDSI.LE.0)) GO TO 15
11790C
11800C ENOUGH TRUCKS AT SOURCE, BUT WE ARE SHORT
11805C TRUCKS AT THE SINK- ASSIGN TRUCKS AT SINK
11810C AND TRY TO MAKE UP SHORTAGE OF TRUCKS
11820C AT THE SOURCE
11830C
11840 IF((IDSO.LE.0).AND.(IDSI.GT.0)) GO TO 16
11850C
11860C ENOUGH TRKS AT SINK BUT SHORT AT THE SOURCE
11870C
11880 IF((IDSO.GT.0).AND.(IDSI.LE.0)) GO TO 17
11890C
11900C SHORTAGE OF TRKS AT BOTH ENDS
11910C
11920 GO TO 40
11930C
11940C NO SHORTAGE OF TRKS AT EITHER END ; ASSIGN REQUIRED
11950C NUMBER OF TRKS AT EITHER END
11960C
```

```
11970 15 IPILE(I,1)=IS
11980 MTSOR=MTSOR-IS
11990 IPILE(I,2)=IT
12000 MTSINK=MTSINK-IT
12010 GO TO 117
12020C
12030C SHORT TRUCKS AT THE SINK MAKE UP THE
12035C DIFFERENCE AT THE SOURCE
12040C
12050 16 IS=IS+IDSI
12060 IPILE(I,2)=MTSINK
12070 MTSINK=0
12080 IF(MTSOR-IS) 19,20,20
12090 19 IS=MTSOR
12100 20 IPILE(I,1)=IS
12110 MTSOR=MTSOR-IS
1212C GO TO 117
12130C
12140C SHORT TRKS AT SOURCE , MAKE UP DIFFERENCE AT THE SINK
12150C
12160 17 IT=IT+IDSO
12170 IPILE(I,1)=MTSOR
12180 MTSOR=0
12190 IF(MTSINK-IT)21,22,22
12200 21 IT=MTSINK
12210 22 IPILE(I,2)=IT
12220 MTSINK=MTSINK-IT
12230 GO TO 117
12240 40 IPILE(I,1)=MTSOR
12250 IPILE(I,2)=MTSINK
12260 MTSOR=0
12270 MTSINK=0
12280 117 CONTINUE
12290 PRINT 161,ITRK,ITRKMAX
12300 161 FORMAT(//1X,"NO. OF TRUCKS IN THE SYSTEM=",1X,I4,
12310&1X,"TRUCKS USEABLE=",1X,I4)
12320 DAYDATA(NDAY,20)=ITRK
12330 PRINT 145
12340 145 FORMAT(//11X,"TRUCK ASSIGNMENTS")
12350 PRINT 160,TRKCAP
12360 160 FORMAT(/11X,"CAPACITY USED=",F9.2,1X,"TONS/DAY")
12370 PRINT 150
12380 150 FORMAT(11X,"ROUTES USED",12X,"TONS PER DAY")
12390 DO 28 I=1,NRU
12410 81 PRINT 155,(IFRUT(IRUTUSE(I),L),L=1,K),UCAP(I)
12420 155 FORMAT(/1X,8I3,7X,F9.2)
12430C 155 FORMAT(/1X,10I3,7X,F9.2)
12440 28 CONTINUE
12460 CALL TRANSYS
12470 DO 350 I=1,NRU
12480 350 PRINT 351,I,IPILE(I,1),IPILE(I,2)
12490 351 FORMAT(//1X,"NO. OF TRUCKS ASSIGNED TO ROUTE",
```

AD-A045 212 AIR FORCE INST OF TECH WRIGHT-PATTERSON AFB OHIO SCHO--ETC F/G 15/7
AN APPLICATION OF GASP IV TO DETERMINE THE EFFECT OF A LIMITED --ETC(U)
JUN 77 J W GEITH, P A OPENHYM
UNCLASSIFIED AFIT-LSSR-14-77A NL

3 OF 3
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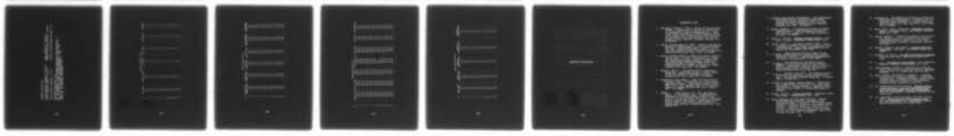

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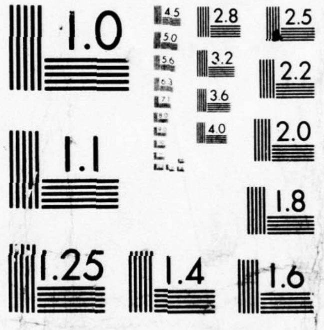

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

```
12500&1X,I2,1X,"TRUCKS AT THE SOURCE=",1X,I4,2X,
12510&"TRUCKS AT THE SINK=",1X,I4)
12520 300 FORMAT(/1X,"AIRCRAFT AVAILABLE=",1X,I4)
12530 DO 500 I=1,NRU
12540 AATRIB(1)=TTNOW
12550 AATRIB(2)=4.
12560 AATRIB(3)=I
12570 CALL TRKSCH
12580C SCHEDULE TERM OF TRK INPUT FOR 12 HR PERIOD
12590 AATRIB(1)=TTNOW+(VTIMOP-ONEWAYT(IRUTUSE(I)))
12600 AATRIB(2)=5.
12610 AATRIB(3)=I
12620 CALL FILEM(1)
12630 500 CONTINUE
12640 GO TO(25,203),NQQ
12650 203 CALL ACSCHED
12660 IF(NATK)25,33,34
12670 33 PRINT,"NO AC ATTACKS SCHEDULED AGAINST TRUCKS"
12680 GO TO 25
12690 34 PRINT 175
12700 175 FORMAT(//10X,"AIRCRAFT ATTACK PLAN FOR TRUCK ",
12705&"ATTACKS")
12710 PRINT 180
12720 180 FORMAT(/2X,"ATTACK NO.",5X,"TYPE OF ATTACK",5X,
12730&"LINK",5X,"ATTACK AIRCRAFT",5X,"DEFENSE SUPPRESSION ",
12731&"AIRCRAFT",5X,"NUMBER OF WEAPONS")
12740 DO 61 I=1,NATK
12750 IF(KACAT(I,3)) 82,25,82
12760 82 PRINT 171,I,KACAT(I,1),KACAT(I,2),KACAT(I,3),
12770&KACAT(I,4),KACAT(I,5)
12780 171 FORMAT(/5X,I2,13X,I2,13X,I2,11X,I3,23X,I4,25X,I4)
12790 61 CONTINUE
12800 25 RETURN
12810 END
```

SUBROUTINE DAMAGE

```
12820 SUBROUTINE DAMAGE
12830$:SELECTA:GRADLIB/G4SUBCMN,R
12840$:SELECTA:77A59/USERM,R
12870 DA=AATRIB(1)
12880 DB=AATRIB(2)
12890 DC=AATRIB(3)
12900 DE=AATRIB(4)
12910 GO TO (1,2,3,40),KDMGE
12915C
12920C AIRCRAFT DAMAGE
12925C
12930 1 X=DRAND(4)
12940 NX=4.*X+1.
12950 GO TO (4,5,6,7),NX
12960 5 NAC2=NAC2+1
12970C PRINT 712,NAC2
12980C 712 FORMAT(/1X,"NAC2",2X,I3)
12990 GO TO 25
13000 6 NAC3=NAC3+1
13010C PRINT 713,NAC3
13020C 713 FORMAT(/1X,"NAC3",2X,I3)
13030 GO TO 25
13040 7 NACP=NACP+1
13050C PRINT 714,NACP
13060C 714 FORMAT(/1X,"NACP",2X,I3)
13070 GO TO 25
13080 4 NAC1=NAC1+1
13110 GO TO 25
13115C
13120C LINK DAMAGE
13125C
13130 2 AATRIB(1)=TTNOW+(24.*DLNK(LD,8)-5.)
13140 AATRIB(2)=7.
13150 AATRIB(3)=LD
13160 AATRIB(4)=0.
13170 CALL FILEM(1)
13180 DLNK(LD,16)=DLNK(LD,6)-(DLNK(LD,6)*DLNK(LD,7))
13190 DLNK(LD,15)=DLNK(LD,16)/DBT
13200 IF(0-MD)15,25,25
13210 15 AATRIB(3)=MD
13220 CALL FILEM(1)
13230 DLNK(MD,16)=DLNK(LD,16)
13240 DLNK(MD,15)=DLNK(LD,15)
13250 GO TO 25
13255C
13260C TRUCK DAMAGE
13265C
13270 3 X=DRAND(6)
13280 STR=0.
```

```
13290 DO 811 I=1,NRU
13300 STR=STR+MTKR(I)
13310 TR=STR/NTK
13320 IF(TR-X) 811,812,812
13330 812 ILD=I
13340 GO TO 813
13350 811 CONTINUE
13360 813 STKE=NTKE(ILD)
13370 TE=STKE/MTKR(ILD)
13380 X=DRAND(5)
13390 NTKD=NTKD+1
13400C IF(LBAT.EQ.3) PRINT 333,TE,X
13410 333 FORMAT(1X,"TE=",1X,F9.5,2X,"X=",1X,F9.5)
13420 IF(TE-X)12,13,13
13430 13 X=DRAND(5)
13440 MTK=X*NTKE(ILD)+1
13470 MTT=2
13480 ATT=2.
13490 LNE=NTSTE(ILD)
13500 GO TO 33
13510 12 X=DRAND(5)
13520 MTK=X*NTKW(ILD)+1
13525 SS(2)=SS(2)-4.
13550 MTT=1
13560 ATT=1.
13570 LNE=NTSTW(ILD)
13580 33 X=DRAND(7)
13590 IF(.6-X)10,11,11
13600 10 MTT=0
13610 GO TO 38
13620 11 NTR=NTR+1
13630 38 I=0
13640 BLD=ILD
13650 34 IF(QSET(LNE+2).NE.1.) GO TO 32
13660 IF(QSET(LNE+3).NE.BLD) GO TO 32
13670 IF(QSET(LNE+4).NE.ATT) GO TO 32
13680 I=I+1
13690 IF(MTK-I)35,35,32
13700 32 LNE=NSET(LNE+5)
13710 IF(QSET(LNE+1).GE.(TTNOW+12.)) GO TO 331
13720 GO TO 34
13730 331 PRINT,"ERROR-CANNOT FIND DAMAGED TRUCK"
13740 GO TO 25
13750 35 IF(MTT)25,36,37
13760 37 NTRY=LNE
13770 CALL CANCL(NTRY)
13775 AATRIB(1)=TTNOW+8.0
13780 IF(AATRIB(4).EQ.1.) AATRIB(4)=3.
13790 IF(AATRIB(4).EQ.2.) AATRIB(4)=4.
13800 CALL FILEM(1)
13810 GO TO 25
13820 36 NTRY=LNE
```

```
13830 CALL CANCL(NTRY)
13860 GO TO 25
13870C
13880C AAA DAMAGE
13890C
13900 40 AATRIB(1)=TTNOW+.5
13910 AATRIB(2)=6.
13920 AATRIB(3)=LD
13940 CALL FILEM(1)
13950 DLNK(LD,17)=0.
13960 IF(0-MD)16,25,25
13990 16 DLNK(MD,17)=DLNK(LD,17)
14010 25 AATRIB(1)=DA
14020 AATRIB(2)=DB
14030 AATRIB(3)=DC
14040 AATRIB(4)=DE
14050 RETURN
14060 END
```

SUBROUTINE MISEVT(IX)

```
14070 SUBROUTINE MISEVT(IX)
14080$:SELECTA:GRADLIB/G4SUBCMN,R
14090$:SELECTA:77A59/USERM,R
14100C
14110C THIS ROUTINE HANDLES SEVERAL EVENTS
14115C
14120 LU=AATRIB(3)
14130 IR=IX-4
14140 GO TO(5,6,7,8,25,9),IR
14145C
14150C THIS EVENT CANCELS TRK SCHEDULING ON ROUTE #
14160C CONTAINED IN AATRIB(3)
14165C
14170 5 MPT=MMFE(1)
14180 1 IF(QSET(MPT+2).NE.4.) GO TO 20
14190 IF(QSET(MPT+3).NE.AATRIB(3)) GO TO 20
14200 NTRY=MPT
14210 CALL CANCL(NTRY)
14220 GO TO 25
14230 20 IF(QSET(MPT+1).GT.(TTNOW+10.)) GO TO 25
14250 MPT=NSET(MPT+5)
14260 GO TO 1
14265C
14270C AAA BECOMES OPERATIONAL FOLLOWING A DEFENSE
14280C SUPPRESSION ATTACK
14285C
14290 6 DLNK(LU,17)=1-(1-DLNK(LU,11))**DLNK(LU,10)
14292 LW=IALTLINK(LU,2)
14293 IF(LW.GT.0)DLNK(LW,17)=DLNK(LU,17)
14300 GO TO 25
14310C LINK REPAIR
14320 7 DLNK(LU,16)=DLNK(LU,6)
14330 DLNK(LU,15)=DLNK(LU,16)/DBT
14340 GO TO 25
14345C
14350C THIS EVENT SETS THE POINTER NQQ TO START
14360C THE INTERDICTION CAMPAIGN
14365C
14370 8 NQQ=2
14371 GO TO 25
14372C
14373C CHANGE RANDOM NUMBER SEED
14374C
14375 9 NRNS=AATRIB(3)
14376 IISEED(NRNS)=AATRIB(4)
14380 25 RETURN
14390 END
```

SUBROUTINE TRKSCH

```
14400 SUBROUTINE TRKSCH
14410$:SELECTA:GRADLIB/G4SUBCMN,R
14420$:SELECTA:77A59/USERM,R
14450C
14460C DETERMINES WHEN THE SCHEDULER WILL CHECK TO SEE IF
14470C A TRUCK IS AVAILABLE TO BE SENT OUT INTO THE NETWORK
14480C
14490 MMMM=JSUMCAP(AATRIB(3))
14500 AATRIB(1)=TTNOW+(1./MMMM)
14510 CALL FILEM(1)
14520C
14530C CHECKS TO SEE IF THERE IS A TRUCK AVAILABLE TO SEND
14540C FROM SOURCE TO SINK ON APPROPRIATE ROUTE
14550C
14555 IF(VT)26,25,2
14560 2 IF(IPILE(AATRIB(3),1).LT.1) GO TO 26
14570C
14580C SCHEDULE TRUCK ARRIVAL AT THE SINK
14590C
14600 AATRIB(1)=TTNOW+ONEWAYT(IRUTUSE(AATRIB(3)))+1.
14610 AATRIB(2)=1.
14620 AATRIB(4)=1.
14630 CALL FILEM(1)
14640C
14650C REDUCE# OF READY TRUCKS AT SOURCE ASSIGNED TO ROUTE
14660C
14670 IPILE(AATRIB(3),1)=IPILE(AATRIB(3),1)-1
14675 SS(2)=SS(2)+4.
14680C
14690C CHECK TO SEE IF THERE IS A TRUCK AVAILABLE TO SEND
14700C FROM SINK TO SOURCE ON APPROPRIATE ROUTE
14710C
14720 26 IF(IPILE(AATRIB(3),2).LT.1) GO TO 25
14730C
14740C SCHEDULE TRUCK ARRIVAL AT SOURCE
14750C
14760 AATRIB(1)=TTNOW+ONEWAYT(IRUTUSE(AATRIB(3)))+1.
14770 AATRIB(2)=1.
14780 AATRIB(4)=2.
14790 CALL FILEM(1)
14800C
14810C REDUCE # OF READY TRUCKS AT SINK ASSIGNED TO ROUTE
14820C
14830 IPILE(AATRIB(3),2)=IPILE(AATRIB(3),2)-1
14840 25 RETURN
14850 END
```

SUBROUTINE TRKARL

```
14860 SUBROUTINE TRKARL
14870$:SELECTA:GRADLIB/G4SUBCMN,R
14880$:SELECTA:77A59/USERM,R
14900 KTRK=AATRIB(4)
14910 GO TO (1,2,3,4),KTRK
14920C
14930C FULL TRUCK ARRIVES AT SINK- ACCOUNT FOR LOAD
14950C SS(1) = SUPPLIES ON HAND AT FEBA
14960C
14970 1 SS(1)=SS(1)+4.
14990 IPILE(AATRIB(3),2)=IPILE(AATRIB(3),2)+1
15000 GO TO 25
15010C
15020C EMPTY TRUCK ARRIVES AT SOURCE--LOAD AND ADD
15030C TO GROUP OF READY TRUCKS
15040C
15050 2 IPILE(AATRIB(3),1)=IPILE(AATRIB(3),1)+1
15060 GO TO 25
15070C
15080C DAMAGED TRUCK ARRIVES AT SINK
15090C
15100 3 NDTSINK=NDTSINK+1
15110 GO TO 25
15120C
15130C DAMAGED TRUCK ARRIVES AT SOURCE
15140C
15150 4 NDTSOR=NDTSOR+1
15160 25 RETURN
15170 END
```

SUBROUTINE STATE

```
15180 SUBROUTINE STATE
15190$:SELECTA:GRADLIB/G4SUBCMN,R
15200$:SELECTA:77A59/USERM,R
15220C
15230C PUSE EQUALS POTENTIAL SUPPLY USE SINCE THE
15240C LAST EVENT
15250C SS(1) EQUALS THE SUPPLIES ON HAND AT FRONT
15260C
15270 PUSE=DDTNOW*USERATE
15330C
15340C IF PUSE GREATER THAN SUPPLIES ON HAND PUSE IS
15350C REDUCED TO TOTAL SUPPLIES AVAILABLE
15360C
15370 16 IF(PUSE.GT.SS(1)) PUSE=SS(1)
15380 SS(1)=SS(1)-PUSE
15490 18 RETURN
15500 END
```

SUBROUTINE SCOND

```
15510 SUBROUTINE SCOND
15520$:SELECTA:GRADLIB/G4SUBCMN,R
15530$:SELECTA:77A59/USERM,R
15550 LLFLAG(1)=KROSS(1,0,0.,SUCP1,-1,10.)
15560 LLFLAG(2)=KROSS(1,0,0.,SUCP1,1,10.)
15570 LLFLAG(3)=KROSS(2,0,0.,ORDER,1,5.)
15571 LLFLAG(4)=KROSS(2,0,0.,VORDER,-1,5.)
15580 RETURN
15590 END
```

SUBROUTINE OTPUT

```
15600 SUBROUTINE OTPUT
15610$:SELECTA:GRADLIB/G4SUBCMN,R
15620$:SELECTA:77A59/USERM,R
15625 CALL SUPUSE
15630 NQQ=5
15640 CALL DAILYOPS
15650 PRINT 10
15660 10 FORMAT(//1X,"SUMMARY STATISTICS")
15670 PRINT 150,TORDER,TFLOW,TUSE,SS(1)
15680 150 FORMAT(/1X,"TOTAL SUPPLIES ORDERED=",1X,F9.1,
15690&5X,"TOTAL THRUPUT=",1X,F9.1,/1X,"TOTAL SUPPLIES USED",
15700&"=",1X,F9.1,2X,"SUPPLIES ON HAND AT END=",1X,F9.1)
15710 PRINT 151,TDTK,ITRK
15720 151 FORMAT(/1X,"TOTAL TRUCKS DAMAGED=",1X,F5.1,5X,
15730&"TRUCKS IN THE SYSTEM AT END=",1X,I4)
15740 PRINT 152,ITAC,MAC1,MAC2,MTACL,TACD
15750 152 FORMAT(/1X,"AIRCRAFT OR AT END=",1X,I4,/1X,
15760&"NO. OF AIRCRAFT IN MAINTENANCE REQUIRING ONE DAYS ",
15765&"WORK=",
15770&I4,/1X,"NO OF AIRCRAFT IN MXT AT END REQUIRING 2 ",
15775&"DAYS WORK=",
15780&I4,/1X,"TOTAL NO. OF AIRCRAFT DAMAGED/DESTROYED=",I4,
15790&/1X,"TOTAL NO. OF AIRCRAFT DESTROYED=",1X,F4.0)
15800 PRINT 160
15810 160 FORMAT(1H1,//40X,"AIRCRAFT STATISTICS BY DAY")
15820 PRINT 161
15830 161 FORMAT(/1X,"DAY",5X,"OR AIRCRAFT",5X,
15840&"AIRCRAFT DAMAGED",5X,"1 DAY REPAIR",5X,
15850&"2 DAY REPAIR",5X,"3 DAY REPAIR",5X,"DESTROYED")
15860 DO 11 I=1,NDAY
15870 11 PRINT 162,I,(DAYDATA(I,J),J=1,6)
15880 162 FORMAT(/1X,I3,8X,F4.0,14X,F4.0,17X,F4.0,13X,
15890&F4.0,13X,F4.0,11X,F4.0)
15900 PRINT 163
15910 163 FORMAT(1H1,//40X,"SUPPORT INDICIES BY DAY")
15920 PRINT 164
15930 164 FORMAT(/1X,"DAY",4X,"UNRESTRICTED",6X,
15935&"PROMGAMMED",
15940&8X,"MINIMUM",10X,"DAILY",9X,"DAILY MINIMUM",8X,
15945&"ACHIEVED")
15950 PRINT 165
15960 165 FORMAT(7X,"SUPPORT  INDEX",3X,"SUPPORT  INDEX",3X,
15970&"SUPPORT INDEX",3X,"COMBAT  INDEX",3X,"OPERATIONS ",
15980&"INDEX",3X,"THRUPUT INDEX")
15990 N=6
16000 DO 12 I=1,NDAY
16010 12 PRINT 166,I,(DAYDATA(I,(J+N)),J=1,6)
16020 166 FORMAT(/1X,I3,8X,F6.3,11X,F6.3,10X,F6.3,10X,F6.3,
16021&12X,F6.3,11X,F6.3)
```

```
16030 N=12
16040 PRINT 167
16050 167 FORMAT(1H1,//40X,"SUPPLY STATISTICS BY DAY")
16060 PRINT 168
16070 168 FORMAT(/1X,"DAY",6X,"SUPPLIES ON HAND",2X,
16080&"DAILY ORDER",6X,"THRUPUT",4X,"TOTAL SUPPLY USE",
16090&2X,"TROOP USE",7X,"TRUCK USE",3X,"AIR DEFENSE USE")
16100 DO 14 I=1,NDAY
16110 14 PRINT 169,I,(DAYDATA(I,(J+N)),J=1,7)
16120 169 FORMAT(/1X,I3,9X,7(F9.2,6X))
16130 N=19
16140 PRINT 170
16150 170 FORMAT(1H1,//40X,"TRUCK STATISTICS BY DAY")
16160 PRINT 171
16170 171 FORMAT(/1X,"DAY",5X,"TOTAL NUMBER",7X,"NUMBER OF",
16180&10X,"NUMBER OF",12X,"NUMBER OF",12X,"NUMBER OF")
16190 PRINT 172
16200 172 FORMAT(11X,"OF TRUCKS",6X,"USEABLE TRUCKS",5X,
16210&"TRUCKS DAMAGED",5X,"TRUCKS REPAIRABLE",5X,
16220&"TRUCKS DESTROYED")
16230 DO 16 I=1,NDAY
16240 16 PRINT 173,I,(DAYDATA(I,(J+N)),J=1,5)
16250 173 FORMAT(/1X,I3,9X,F5.0,11X,F5.0,15X,F5.0,14X,F5.0,
16255&17X,F5.0)
16260 RETURN
16270 END
```

SUBROUTINE EVNTS(IX)

```
16280 SUBROUTINE EVNTS(IX)
16290$:SELECTA:GRADLIB/G4SUBCMN,R
16300$:SELECTA:77A59/USERM,R
16310 CALL SUPUSE
16370 GO TO(1,2,3,4,5,5,5,5,9,5),IX
16380 1 CALL TRKARL
16390 GO TO 25
16400 2 CALL DAILYOPS
16410 GO TO 25
16420 3 CALL ACATK
16430 GO TO 25
16440 4 CALL TRKSCH
16450 GO TO 25
16460 5 CALL MISEVT(IX)
16470 GO TO 25
16480C
16490C IX=11 STATE EVNT HAS OCCURRED
16500C
16510C IF LLFLAG(1)<0. SUPPLIES ON HAND ARE<SUCP1
16520C
16530 9 IF(LLFLAG(1).LT.0) USERATE=MINUSE/24.
16540C
16550C IF LLFLAG(2)>0. SUPPLIES ON HAND HAVE INCREASED TO
16560C >3*MINUSE
16570C
16580 IF(LLFLAG(2).GT.0) USERATE=ISUPPLY(NDAY)/24.
16590C
16600C LLFLAG(3)>0 MEANS TODAY'S THRUPUT=ORDER-STOP TRUCKS
16610C
16680 IF(LLFLAG(3).GT.0) VT=-7.
16682C
16683C LLFLAG(4)<0, THRUPUT<ORDER-SCHEDULE TRUCKS
16684C
16685 IF(LLFLAG(4).LT.0) VT=9.
16750 25 RETURN
16760 END
```

SUBROUTINE UERR(KODE)

```
16770 SUBROUTINE UERR(KODE)
16780$:SELECTA:GRADLIB/G4SUBCMN,R
16790$:SELECTA:77A59/USERM,R
16800 GO TO (1,2,3,4,5,6,7,8,9,10,11,12),KODE
16810 1 PRINT,"SUBSCRIPT FOR MAX LINKS USED IN
16820&FEASIBLE ROUTE HAS BEEN EXCEEDED-REDIMENSION BEFORE
16830&RERUN"
16840 GO TO 50
16850 2 PRINT,"ERROR SUBROUTINE ACSCHED-NEG. TRK DENSITY"
16860 GO TO 50
16870 3 PRINT,"ERROR SUBROUTINE ACSCHED-NEG. PULINK(IW)"
16880 GO TO 50
16890 4 PRINT,"ERROR-SUBROUTINE ACSCHED-NETREDUC(LINKX) IS
16900&NEG-NEG VALUE GENERATED IN SUBROUTINE THRUPUT"
16910 GO TO 50
16920 5 PRINT,"ERROR-SUBROUTINE ACREQ-DLNK(I,10) CONTAINS
16930&A NEG VALUE"
16940 GO TO 50
16950 6 PRINT,"ERROR-SUBROUTINE ACATK-NEG NUMBER FOR NUMBER
16960&OF DEFENSE SUPRESSION AIRCRAFT"
16970 GO TO 50
16980 7 PRINT,"ERROR-SUBROUTINE ACATK-ZERO OR NEG NUMBER FOR
16990&TYPE OF ATTACK"
17000 GO TO 50
17010 8 PRINT,"ERROR-SUBROUTINE ACATK-NAC<0"
17020 GO TO 50
17030 9 PRINT,"ERROR-SUBROUTINE ACATK-NTK<0"
17040 GO TO 50
17050 10 PRINT,"ERROR-SUBROUTINE ACATK-NWL<0"
17060 GO TO 50
17070 11 PRINT,"ERROR-SUBROUTINE THRUPUT-NEGATIVE ROUTE CAP"
17080 GO TO 50
17090 12 PRINT,"ERROR - SUBROUTINE ROUTE LABEL 12"
17100 50 STOP
17110 END
```

SUBROUTINE SUPUSE

```
17120 SUBROUTINE SUPUSE
17130$:SELECTA:GRADLIB/G4SUBCMN,R
17140$:SELECTA:77A59/USERM
17150C
17160C USE EQUALS CUMULATIVE SUPPLY USE FOR THE CURRENT DAY
17170C
17180 PUSE=(TTNOW-TLAST)*USERATE
17190C
17200C IF PUSE > SS(1); REDUCE PUSE TO = SS(1)
17210C
17220 IF(PUSE.GT.SS(1)) PUSE=SS(1)
17230 USE=USE+PUSE
17240 IF(NDAY.LT.2) GO TO 3
17280 3 TLAST=TTNOW
17290 RETURN
17300 END
```

APPENDIX D

SAMPLE OUTPUT

```
                         GFITH-OPENHYM AFIT/SLG-77A
                     ---------------------------------------

                     DATE -- 05/17/77            TIME --  9:35

                  GASP IV - AFIT SCHOOL OF SYSTEMS AND LOGISTICS
                             VERSION A -- 31 JANUARY 1975

              LLSUP=00022220000000022          ' RUN NUMBER   1 OF    1

                                     DATA ECHO CHECK
                                     ---------------

NNCLT=      0    NNSTA=      0    NNHIS=     0    NNPRM=      5    NNPLT=      0    NNSTR =     7    NNTRY=    900
NNATR=      4    NNFIL=      1    NNSET=  5500    NNEQD=      0    NNEQS=      2    NNFLAG=     4

KKRNK =(    1)

IINN  =(    1)

IIFVT =     0    LLERR=      0    AAERR =         0.1000E 01            RRERR=     0.4000E 01
DDTMIN=     0.1000E-02            DDTMAX=         0.1000E 01            DDTSAV=     0.1000E 01

PARAMETER SET        1 =     0.2000E 04     0.0000E 03      0.7200E 04     0.6000E 04
PARAMETER SET        2 =     0.5000E 03     0.1000E 01      0.2400E 04     0.1250E 00
PARAMETER SET        3 =     0.1000E 03     0.6000E 03      0.5000E 03     0.2000E 01
PARAMETER SET        4 =     0.2000E 01     0.1200E 02      0.1000E 01     0.6000E 00
PARAMETER SET        5 =     0.2000E 03     0.1200E 03      0.7000E 02     0.3000E 02

MMSTOP=     1    JJCLR=      1    JJBEG=     1    IICRD=      1    TTBEG=     0.              TTFIN=      0.3600E 03
JJFIL =     1
IISEED=     1274321           342761           5317425           523416            1463257            1946073
IISEED=     4567892

NUMBER OF INITIAL ENTRIES FILED IN QSET (BY DATIN)  =    16
```

```
                 **GASP FILE STORAGE AREA DUMP AT TIME 0.

             MAXIMUM NUMBER OF ENTRIES IN FILE STORAGE AREA = 16

                         PRINTOUT OF FILE NUMBER 1
                               TTNOW = 0.
                               QQTIM = 0.

                               FILE CONTENTS
ENTRY  1 = 0.1000E 01        0.2000E 01        0.                0.
ENTRY  2 = 0.1200E 03        0.9000E 01        0.1000E 01        0.9877E 07
ENTRY  3 = 0.1200E 03        0.9000E 01        0.2000E 01        0.8237E 06
ENTRY  4 = 0.1200E 03        0.9000E 01        0.3000E 01        0.4328E 07
ENTRY  5 = 0.1200E 03        0.9000E 01        0.4000E 01        0.7311E 06
ENTRY  6 = 0.1200E 03        0.9000E 01        0.5000E 01        0.5238E 07
ENTRY  7 = 0.1200E 03        0.9000E 01        0.6000E 01        0.4241E 07
ENTRY  8 = 0.1200E 03        0.9000E 01        0.7000E 01        0.1136E 07
ENTRY  9 = 0.2400E 03        0.9000E 01        0.1000E 01        0.4247E 07
ENTRY 10 = 0.2400E 03        0.9000E 01        0.2000E 01        0.6580E 07
ENTRY 11 = 0.2400E 03        0.9000E 01        0.3000E 01        0.3429E 08
ENTRY 12 = 0.2400E 03        0.9000E 01        0.4000E 01        0.2337E 07
ENTRY 13 = 0.2400E 03        0.9000E 01        0.5000E 01        0.8795E 07
ENTRY 14 = 0.2400E 03        0.9000E 01        0.6000E 01        0.6515E 07
ENTRY 15 = 0.2400E 03        0.9000E 01        0.7000E 01        0.2573E 08
ENTRY 16 = 0.3600E 03        0.8000E 01        0.                0.
```

```
                  INPUT BLNK VALUES
 IN=  27  K=  10  LS=   4
  1.   1.   2.   0.  25.  50.   0.100   1.000   0.300   2.000   0.050   0.125   0.500   0.700
  2.   1.   4.   0.  30.  40.   0.100   1.000   0.250   2.000   0.050   0.125   0.500   0.700
  3.   1.   3.   0.  33.  35.   0.100   1.000   0.250   2.000   0.050   0.125   0.500   0.700
  4.   2.   6.  25.  50.  40.   0.100   1.000   0.150   2.000   0.050   0.125   0.500   0.700
  5.   2.   4.  19.  25.  30.   0.150   1.000   0.300   0.      0.050   0.125   0.300   0.700
  6.   4.   5.  21.  19.  25.   1.000   5.000   0.000   5.000   0.050   0.125   0.300   0.700
  7.   3.   5.  27.  31.  30.   0.150   1.000   0.250   0.      0.050   0.125   0.300   0.700
  8.   3.   8.  27.  40.  50.   0.100   1.000   0.200   2.000   0.050   0.125   0.500   0.700
  9.   6.   7.  26.  33.  30.   0.150   1.000   0.250   0.      0.050   0.125   0.300   0.700
 10.   4.   7.  20.  35.  40.   0.100   1.000   0.250   2.000   0.050   0.125   0.500   0.700
 11.   5.   7.  24.  28.  30.   0.150   1.000   0.300   0.      0.050   0.125   0.300   0.700
 12.   5.   8.  23.  17.  30.   0.150   1.000   0.300   2.000   0.050   0.125   0.300   0.700
 13.   6.  10.   0.  39.  35.   0.100   1.000   0.200   2.000   0.050   0.125   0.500   0.700
 14.   7.  10.   0.  25.  40.   0.100   1.000   0.300   2.000   0.050   0.125   0.500   0.700
 15.   8.  10.   0.  46.  50.   1.000   2.000   0.000   6.000   0.050   0.125   0.300   0.700
 16.   8.   9.   0.  26.  35.   0.100   1.000   0.170   2.000   0.050   0.125   0.500   0.700
 17.   1.   5.   0.  43.  30.   0.100   1.000   0.200   2.000   0.050   0.125   0.500   0.700
 18.   9.  10.   0.  27.  35.   0.100   1.000   0.170   2.000   0.050   0.125   0.500   0.700
 19.   4.   2.   5.  25.  30.   0.150   1.000   0.300   0.      0.050   0.125   0.300   0.700
 20.   7.   4.  10.  35.  40.   0.100   1.000   0.250   2.000   0.050   0.125   0.500   0.700
 21.   5.   4.   6.  19.  25.   1.000   5.000   0.000   5.000   0.050   0.125   0.300   0.700
 22.   8.   3.   8.  40.  35.   0.100   1.000   0.200   2.000   0.050   0.125   0.500   0.700
 23.   8.   5.  12.  17.  30.   0.150   1.000   0.300   2.000   0.050   0.125   0.300   0.700
 24.   7.   5.  11.  28.  30.   0.150   1.000   0.300   0.      0.050   0.125   0.300   0.700
 25.   6.   2.   4.  50.  35.   0.100   1.000   0.150   2.000   0.050   0.125   0.500   0.700
 26.   7.   6.   9.  33.  30.   0.150   1.000   0.250   0.      0.050   0.125   0.300   0.700
 27.   5.   3.   7.  31.  30.   0.150   1.000   0.250   0.      0.050   0.125   0.300   0.700

    INPUT PARAMETERS

    MINIMUM DISTANCE BETWEEN TRUCKS =  1.00
    NO. OF TRUCKS AT THE BEGINNING OF THE SIMULATION =   500
    PROBABILITY OF KILL PER AIR DEFENSE SUPPRESSION SORTIE = 0.400
    NO. OF AIRCRAFT AT THE BEGINNING OF THE SIMULATION =   100
    NO. OF LINKS BEING ATTACKED = 1
    DEFENSE SUPPRESSION CAPABILITY = 1
    AIRCRAFT FLYING RANGE IN TOTAL NO. OF MILES =   600.0
    AIRCRAFT SPEED =   500.0
    MAXIMUM DAILY SUPPLY USE BY COMBAT TROOPS =  2000
    MINIMUM DAILY SUPPLY USE BY COMBAT TROOPS =   800
    SUPPLIES ON HAND AT FEBA =  7200.000
```

```
  69  FEASIBLE ROUTES                        ROUND TRIP TIMES          ROUTE DISTANCE

   1    4   13    0    0    0    0    0    0    0              8.1286              122.0000
   2   19    4   13    0    0    0    0    0    0             10.2952              152.0000
  17   21   19    4   13    0    0    0    0    0             13.1819              184.0000
   3    7   21   19    4   13    0    0    0    0             14.2676              205.0000
   3    8   23   21   19    4   13    0    0    0             14.9343              231.4000
  17   11   20   19    4   13    0    0    0    0             15.2786              228.0000
   3    7   11   20   19    4   13    0    0    0             16.3643              249.0000
   3    8   23   11   20   19    4   13    0    0             17.0310              275.0000
   2   10   26   13    0    0    0    0    0    0              9.6786              137.0000
   1    5   10   26   13    0    0    0    0    0             10.8452              157.0000
  17   21   10   26   13    0    0    0    0    0             12.5652              169.0000
   3    7   21   10   26   13    0    0    0    0             13.6510              190.0000
   3    8   23   21   10   26   13    0    0    0             14.3176              216.0000
  17   11   26   13    0    0    0    0    0    0             11.1619              143.0000
   3    7   11   26   13    0    0    0    0    0             12.2476              164.0000
   2    6   11   26   13    0    0    0    0    0             11.3152              149.0000
   1    5    6   11   26   13    0    0    0    0             12.4819              169.0000
   3    8   23   11   26   13    0    0    0    0             12.9143              190.0000
   2   10   14    0    0    0    0    0    0    0              6.5000               90.0000
   1    5   10   14    0    0    0    0    0    0              7.6667              110.0000
  17   21   10   14    0    0    0    0    0    0              9.3867              122.0000
   3    7   21   10   14    0    0    0    0    0             10.4724              143.0000
   3    8   23   21   10   14    0    0    0    0             11.1390              169.0000
  17   11   14    0    0    0    0    0    0    0              7.9833               96.0000
   3    7   11   14    0    0    0    0    0    0              9.0690              117.0000
   2    6   11   14    0    0    0    0    0    0              8.1367              102.0000
   1    5    6   11   14    0    0    0    0    0              9.3033              122.0000
   3    8   23   11   14    0    0    0    0    0              9.7357              143.0000
   1    4    9   14    0    0    0    0    0    0              9.3500              141.0000
```

```
 2 19  4  9 14  0  0  0  0  0          11.5167          171.0000
17 21 19  4  9 14  0  0  0  0          14.4033          203.0000
 3  7 21 19  4  9 14  0  0  0          15.4890          224.0000
 3  8 23 21 19  4  9 14  0  0          16.1557          250.0000
 3  8 15  0  0  0  0  0  0  0           7.3257          119.0000
17 27  8 15  0  0  0  0  0  0          10.3733          160.0000
 2  6 27  8 15  0  0  0  0  0          10.5267          166.0000
 1  5  6 27  8 15  0  0  0  0          11.6933          186.0000
 1  4  9 20  6 27  8 15  0  0          16.8767          287.0000
 2 10 24 27  8 15  0  0  0  0          12.6233          210.0000
 1  5 10 24 27  8 15  0  0  0          13.7900          230.0000
 1  4  9 24 27  8 15  0  0  0          15.4733          261.0000
 2 19  4  9 24 27  8 15  0  0          17.6400          291.0000
17 12 15  0  0  0  0  0  0  0           7.8400          106.0000
 3  7 12 15  0  0  0  0  0  0           8.9257          127.0000
 2  6 12 15  0  0  0  0  0  0           7.9933          112.0000
 1  5  6 12 15  0  0  0  0  0           9.1600          132.0000
 1  4  9 20  6 12 15  0  0  0          14.3433          233.0000
 2 10 24 12 15  0  0  0  0  0          10.8900          156.0000
 1  5 10 24 12 15  0  0  0  0          11.2567          176.0000
 1  4  9 24 12 15  0  0  0  0          12.9400          207.0000
 2 19  4  9. 24 12 15  0  0  0          15.1867          237.0000
 3  8 16 18  0  0  0  0  0  0           8.5143          126.0000
17 27  8 16 18  0  0  0  0  0          11.5619          167.0000
 2  6 27  8 16 18  0  0  0  0          11.7152          173.0000
 1  5  6 27  8 16 18  0  0  0          12.8819          193.0000
 1  4  9 20  6 27  8 16 18  0          18.0652          294.0000
 2 10 24 27  8 16 18  0  0  0          13.8119          217.0000
 1  5 10 24 27  8 16 18  0  0          14.9786          237.0000
 1  4  9 24 27  8 16 18  0  0          16.6619          268.0000
```

```
 2 19  4  9 24 27  0 16 18  0          10.8286             290.0000
17 12 16 18  0  0  0  0  0  0           9.0286             113.0000
 3  7 12 16 18  0  0  0  0  0          10.1143             134.0000
 2  6 12 16 10  0  0  0  0  0           9.1019             119.0000
 1  5  6 12 16 18  0  0  0  9          10.3486             139.0000
 1  4  9 20  6 12 16 18  0  0          15.5319             240.0000
 2 10 24 12 16 18  0  0  0  0          11.2786             163.0000
 1  5 10 24 12 16 18  0  0  0          12.4452             183.0000
 1  4  9 24 12 16 18  0  0  0          14.1286             214.0000
 2 19  4  9 24 12 16 18  0  0          16.2952             244.0000
```

```
              INPUT GRID VALUES

     1.000   25.000  185.000   45.000  200.000

     2.000   45.000  170.000   45.000  200.000

     3.000   75.000  185.000   45.000  200.000

     4.000   15.000  136.000   25.000  185.000

     5.000   45.000  170.000   25.000  185.000

     6.000   59.000  150.000   45.000  170.000

     7.000   59.000  150.000   75.000  185.000

     8.000   75.000  145.000   75.000  185.000

     9.000   45.000  135.000   15.000  136.000

    10.000   45.000  135.000   45.000  170.000

    11.000   45.000  135.000   59.000  150.000

    12.000   75.000  145.000   59.000  150.000

    13.000   45.000  110.000   15.000  136.000

    14.000   45.000  110.000   45.000  135.000

    15.000   45.000  110.000   75.000  145.000

    16.000   70.000  120.000   75.000  145.000

    17.000   59.000  150.000   45.000  200.000

    18.000   45.000  110.000   70.000  120.000

    19.000   45.000  170.000   25.000  185.000
```

```
 20.000   45.000  135.000   45.000  170.000

 21.000   59.000  150.000   45.000  170.000

 22.000   75.000  145.000   75.000  185.000

 23.000   75.000  145.000   59.000  150.000

 24.000   45.000  135.000   59.000  150.000

 25.000   15.000  136.000   25.000  185.000

 26.000   45.000  135.000   15.000  136.000

 27.000   59.000  150.000   75.000  185.000

*** FROM TO MATRIX IS ***

  0  1  3  2 17  0  0  0  0  0
  0  0  0  5  0  4  0  0  0  0
  0  0  0  0  7  0  0  0  0  0
  0 19  0  0  6  0 10  0  0  0
  0  0 27 21  0  0 11 12  0  0
  0 25  0  0  0  0  9  0  0 13
  0  0  0 20 24 26  0  0  0 14
  0  0 22  0 23  0  0  0 16 15
  0  0  0  0  0  0  0  0  0 18
  0  0  0  0  0  0  0  0  0  0
```

AIRCRAFT REQUIRED TO ATTACK EACH LINK

LINK	AIRCRAFT ATTACKING LINK	DEFENSE SUPPRESSION AIRCRAFT
1	7	3
2	9	3
3	9	3
4	15	3
5	7	0
6	2	4
7	9	0
8	11	3
9	9	0
10	9	3
11	7	0
12	7	3
13	11	3
14	7	3
15	2	4
16	13	3
17	11	3
18	13	3
19	7	0
20	9	3
21	2	4
22	11	3
23	7	3
24	7	0
25	15	3
26	9	0
27	9	0

```
DAY  14
UNRESTRICTED SUPPLY INDEX=  0.332      PROGRAMMED SUPPORT INDEX=  0.362
MINIMUM SUPPORT INDEX=  0.031DAILY COMBAT INDEX=  0.997
DAILY MINIMUM OPERATION INDEX=  2.492            SUPPLIES ON HAND=    1993.7

DAILY SUPPLY ORDER=    0048.4

AIRCRAFT AVAILABLE=   63
NUMBER OF LINKS TO BE ATTACKED=  2

          AIRCRAFT ATTACK PLAN FOR LINK ATTACKS

 ATTACK NO.      TYPE OF ATTACK       LINK      ATTACK AIRCRAFT      DEFENSE SUPPRESSION AIRCRAFT

     1                 1                2              9                         3

     2                 1                6              9                         3

NO. OF TRUCKS IN THE SYSTEM=  242 TRUCKS USEABLE=  195

           TRUCK ASSIGNMENTS

           CAPACITY USED=  1022.09 TONS/DAY
           ROUTES USED                TONS PER DAY

  2  6  9  0  0  0  0  0              1017.00

  1  4  0  0  0  0  0  0                 5.09

NO. OF TRUCKS ASSIGNED TO ROUTE  1 TRUCKS AT THE SOURCE=   90  TRUCKS AT THE SINK=   96

NO. OF TRUCKS ASSIGNED TO ROUTE  2 TRUCKS AT THE SOURCE=    1  TRUCKS AT THE SINK=    0

          AIRCRAFT ATTACK PLAN FOR TRUCK ATTACKS

 ATTACK NO.      TYPE OF ATTACK       LINK      ATTACK AIRCRAFT      DEFENSE SUPPRESSION AIRCRAFT      NUMBER OF WEAPONS

     1                 2                2              4                         3                             0

     2                 2                6              4                         3                             0

     3                 2                9              4                         3                             0

     4                 2                2              4                         3                             0

     5                 2                6              4                         3                             0

     6                 2                9              4                         3                             0
```

```
THRUPUT=   836.00      TOTAL SUPPLYUSE=   827.75      TROOP SUPPLY USE=   800.00

TRUCK SUPPLY USF=     14.50      AAA SUPPLY USE=     13.25      ACHIEVED DAILY THRUPUT INDEX=  0.409

TRUCKS DAMAOED TODAY=  35    NO. DAMAOFD TRUCKS REPAIRABLE=  25

DAILY TOTAL AC DAMAGE=   5    AC REQ 1 DAY REPAIR=   2
AC REQ 2 DAY RFPAIR=   1   AC REQ 3 DAY REPAIR=   1
AC NOT REPAIRABLE=   1
```

```
SUMMARY STATISTICS

TOTAL SUPPLIES ORDERED = 75202.9     TOTAL THRUPUT = 17804.0
TOTAL SUPPLIES USED = 23041.6        SUPPLIES ON HAND AT END = 1962.4

TOTAL TRUCKS DAMAGED = 719.0         TRUCKS IN THE SYSTEM AT END = 217

AIRCRAFT OR AT END = 72
NO. OF AIRCRAFT IN MAINTENANCE REQUIRING ONE DAYS WORK = 1
NO. OF AIRCRAFT IN MXT AT END REQUIRING 2 DAYS WORK = 0
TOTAL NO. OF AIRCRAFT DAMAGED/DESTROYED = 134
TOTAL NO. OF AIRCRAFT DESTROYED = 27.
```

AIRCRAFT STATISTICS BY DAY

DAY	OR AIRCRAFT	AIRCRAFT DAMAGED	1 DAY REPAIR	2 DAY REPAIR	3 DAY REPAIR	DESTROYED
1	100.	13.	3.	3.	4.	3.
2	90.	7.	3.	1.	1.	2.
3	89.	15.	2.	4.	4.	5.
4	81.	5.	0.	0.	3.	2.
5	81.	2.	0.	1.	0.	1.
6	83.	8.	3.	4.	1.	0.
7	82.	12.	4.	1.	6.	1.
8	78.	16.	2.	6.	6.	2.
9	66.	10.	1.	3.	4.	2.
10	69.	1.	1.	0.	0.	0.
11	78.	11.	4.	1.	4.	2.
12	75.	15.	7.	2.	3.	3.
13	68.	12.	1.	6.	3.	2.
14	63.	5.	2.	1.	1.	1.
15	69.	2.	1.	0.	0.	1.

SUPPORT INDICIES BY DAY

DAY	UNRESTRICTED SUPPORT INDEX	PROGRAMMED SUPPORT INDEX	MINIMUM SUPPORT INDEX	DAILY COMBAT INDEX	DAILY MINIMUM OPERATIONS INDEX	ACHIEVED THRUPUT INDEX
1	1.200	1.636	3.000	3.600	9.000	1.000
2	1.194	1.378	2.985	3.582	8.956	0.778
3	1.292	1.292	3.130	3.756	9.389	0.781
4	1.176	1.176	2.940	3.520	8.819	0.703
5	1.076	1.076	2.691	3.229	8.073	0.687
6	0.978	1.058	2.424	2.909	7.273	0.610
7	0.830	1.005	2.695	2.513	6.284	0.800
8	0.781	0.935	1.753	2.104	5.259	0.773
9	0.644	0.773	1.610	1.932	4.829	0.826
10	0.600	0.655	1.500	1.800	4.500	0.574
11	0.539	0.539	1.348	1.617	4.043	0.498
12	0.382	0.382	0.955	1.145	2.864	0.466
13	0.337	0.337	0.843	1.011	2.528	0.437
14	0.332	0.362	0.831	0.997	2.492	0.409
15	0.334	0.400	0.834	1.001	2.502	0.513

SUPPLY STATISTICS BY DAY

DAY	SUPPLIES ON HAND	DAILY ORDER	THRUPUT	TOTAL SUPPLY USE	TROOP USE	TRUCK USE	AIR DEFENSE USE
1	7200.00	1200.00	1200.00	1235.75	1200.00	7.75	27.50
2	7164.75	2070.50	1504.00	1237.50	1200.00	22.50	15.00
3	7511.25	2526.25	1592.00	2048.13	2000.00	23.00	25.13
4	7055.12	2993.00	1440.00	2036.63	2000.00	22.13	14.50
5	6450.50	3570.13	1400.00	2040.00	2000.00	22.13	17.88
6	5818.50	4221.50	1244.00	2035.63	2000.00	21.63	14.00
7	5026.07	4508.76	1228.00	2047.75	2000.00	17.75	30.00
8	4207.12	4840.63	1196.00	1539.75	1500.00	19.00	20.75
9	3863.37	5176.38	1272.00	1535.[illegible]	1500.00	17.00	17.50
10	3599.99	5935.38	1140.00	1533.50	1500.00	17.50	16.00
11	3234.49	6799.01	1012.00	1955.63	1912.00	17.13	26.50
12	2290.07	7752.76	952.00	1220.86	1172.49	15.38	33.00
13	2027.01	8026.37	896.00	924.30	882.10	14.88	27.25
14	1993.71	8848.42	836.00	827.75	800.00	14.50	13.25
15	2081.96	7925.79	784.00	823.99	799.97	13.63	10.00

TRUCK STATISTICS BY DAY

DAY	TOTAL NUMBER OF TRUCKS	NUMBER OF USEABLE TRUCKS	NUMBER OF TRUCKS DAMAGED	NUMBER OF TRUCKS REPAIRABLE	NUMBER OF TRUCKS DESTROYED
1	500.	400.	70.	42.	28.
2	472.	370.	75.	48.	27.
3	445.	356.	63.	29.	34.
4	411.	330.	69.	44.	25.
5	386.	310.	71.	37.	34.
6	352.	282.	50.	34.	16.
7	336.	270.	48.	30.	18.
8	318.	295.	47.	24.	23.
9	295.	237.	13.	11.	2.
10	293.	235.	18.	10.	8.
11	285.	220.	43.	28.	15.
12	270.	217.	43.	25.	18.
13	252.	203.	30.	20.	10.
14	242.	195.	35.	25.	10.
15	232.	186.	36.	21.	15.

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