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TECHNICAL REPORT T.R.9-71

SURVEILLANCE, TARGET ACQUISITION AND NIGHT OBSERVATION (STANO) PHASE I SYSTEM ASSESSMENT MODEL (SAM)

(Short Title: STANO PHASE I SAM)

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UNITED STATES ARMY
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13. ABSTRACT

The STANO Phase I SAM is designed to simulate a brigade or smaller STANO System in a low-intensity conflict. The model will permit the establishment and evaluation of numerous effectiveness criteria for individual STANO sensors and subsystems. It will facilitate the formation of improved candidate STANO Systems, through better understanding of shortcomings in organization, materiel and concepts of employment. It has the capability of producing information permitting scientifically supportable evaluations and judgments of interface requirements and trade-off options of STANO subsystems. The model can be used for parametric analysis, trade-off analysis, and system performance sensitivity tests. (U)

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Sensors						
Detection						
Systems analysis						
Sensitivity tests						
Performance						
Night operations						
Intelligence						

TABLE OF CONTENTS

Section 4

INTERACTION ELEMENTS

4.1 INTRODUCTION

This section describes the following elements of the PRERUN portion of the Systems Assessment Model:

(1) Equipment deployment and failures, including the representation of sensing missions, emplacement and re-emplacement of remote sensor system equipments, and equipment maintenance and repair. (Steps 1, 2, and 4 of the model PRERUN).

(2) Determination of ground truth positions for stationary sensing equipments, and determination of navigation errors for moving sensing systems. (Steps 3 and 4 of PRERUN).

(3) Determination of game time periods for each sensor during which the sensor is so exposed to either a red or blue target that (given certain other necessary conditions) detection may occur. (Step 8 of PRERUN).

(4) Computation of false alarms and sensor parameter changes resulting from variations of noise level within the environment. (Step 7 of PRERUN).

(5) Determination of line-of-sight conditions for those sensor-target combinations for which time and space unions have been established in Step 8 of PRERUN. (Step 9 of PRERUN).

The principal objective of the discussions presented in this section is to describe just what processes and procedures are simulated in the corresponding portions of the model, the assumptions underlying their method of representation and the degree of detail in which they are represented.

4.2 EQUIPMENT DEPLOYMENT AND FAILURES

4.2.1 Remote Unattended Sensors and Related Equipments.

The remote unattended sensor systems are represented as consisting of the remote sensors *per se*, one or more monitors to which each remote sensor array is intended to report, and (in cases where sensor-to-monitor range and/or terrain characteristics so dictate) one or two intermediate data link relays between sensor array and monitor. Emplacements, failures and re-emplacements of the remote sensors are simulated in subroutine RUSUP. Deployments, failures and repair/replacements of the remote sensor monitors are simulated in subroutine READUP. Emplacements, failures and repair/replacements of the data link relays are simulated in subroutine COMMUP. The material that follows describes each of these subroutines in turn.

4.2.1.1 RUSUP

The purpose of subroutine RUSUP is to determine, for each remote unattended sensor involved in the game, the period or periods of time (if any) during which the sensor is emplaced and operable. The subroutine produces two records whose indices are in register: the first record contains for each sensor the game times at which changes of status occur; the second record contains for each sensor a status code denoting the status assumed by the sensor at the corresponding game time. The status codes are described in Table 4.2-I.

For the purpose of the processing accomplished by this subroutine each sensor is treated as belonging to an array of sensors. A sensor array may consist of a single sensor. Dimensions provided in the program limit the maximum number of sensors in an array to ten. Sensors belonging to a given array are considered to be of such proximity as to share a common emplacement time. Criteria governing re-emplacement of failed sensors are based on sensor array operability level.

A macro-flow chart for RUSUP is given in Figure 4.2-1. For each sensor array the following general sequence of processing events is followed by the subroutine:

(1) Determine tentative initial emplacement time.

(2) If applicable (i.e., if emplacement is by a method other than artillery or mortar), determine whether or not an emplacement mission abort occurs.

(3) If mission does not abort and if applicable (i.e., if emplacement is by a method other than hand-emplaced). determine which sensors of the array survive emplacement and which are destroyed in the emplacement process.

(4) For sensors successfully emplaced, determine for each the time at which a failure (either reliability or life failure) will occur. In the case of sensor arrays for which the planner has not specified re-emplacement criteria, the following additional general sequence of processing events ensues.

Table 4.2-I
SUBROUTINE RUSUP STATUS CODES

Code	Status Indicated
-8	Sensor is down because the array to which it belongs has fallen below criterion strength and attempt to re-emplace did not bring array up to criterion strength.
-9	Sensor is down because the array to which it belongs has fallen below criterion strength.
-10	Sensor is up following a maintenance check.
-11	Sensor is down because the planner has specified that it should be down at this point in game time.
-12	Sensor is up following an emplacement for the array of which it is a part.
-13	Sensor is down as a consequence of a mission abort.
-14	Sensor is down as a consequence of a reliability failure.
-15	Sensor is down as a consequence of a life (battery) failure.
-16	Sensor is down because the sensor with which it reported in a primary/auxiliary relationship has failed.
-17	Sensor is down because it failed to survive impact.
-18	Sensor is down because its emplacement time was equal to or greater than its planned down game time.

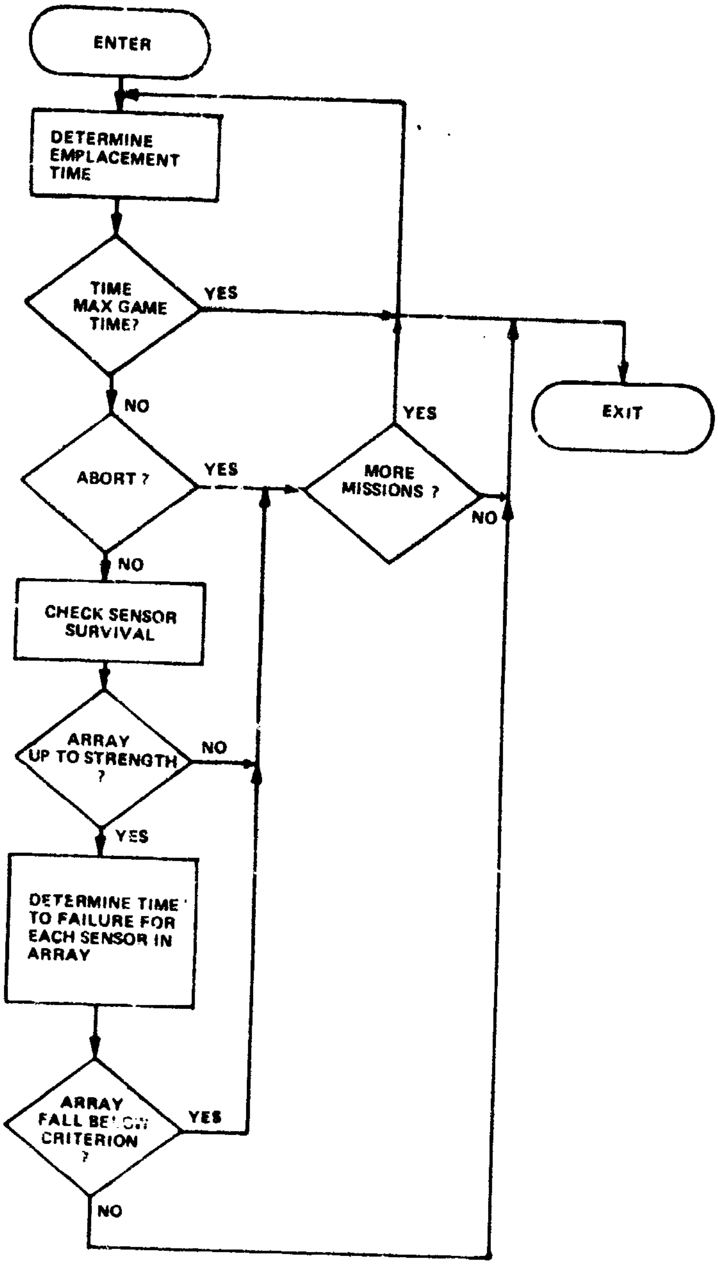

Figure 4.2-1 RUSUP MACROFLOW

(5) Determine the game time at which the sensor array no longer conforms to the level of operability criterion specified by the planner. Using this time as a reference (and provided that the number of emplacement missions previously undertaken for the array is less than the maximum number of emplacement missions specified by the planner), determine the tentative time at which re-emplacement of the array is to occur.

(6) Steps (2), (3), (4), and (5) above are repeated in sequence until one of two conditions exists:

a. The number of emplacement missions undertaken for the array is equal to the maximum number of such missions specified by the planner, or

b. A tentative re-emplacement time is determined that is equal to or greater than the end of game time.

4.2.1.1.1 Description of RUSUP Inputs. The inputs described here are identified by the names by which they are represented in the RUSUP program listing. Some of these inputs apply to the entire sensor array; others apply to individual sensors within the array. The input descriptions include mention of applicability in this regard.

(1) Inputs Defining Array Composition

Input Name	Input Description
N (I, 4)[*]	This is the total number of sensors in the array in question when the array is at full strength. N may be assigned any value from one through ten (dimensions provided in the program imposing the upper limit on its value). N, of course, applies to the entire array.
ICR (I, 26)	This is the operability level criterion specified by the game planner for the array. For example, the planner may specify that the total number of sensors (N) in a given sensor array is to be five and that the value of ICR for that

---

[*] These parenthetical designations reference data input descriptions presented in Appendix F of Volume II. The roman numeral indicates the data set in Appendix F; the arabic numeral indicates the entry within the data set.

array is three. This means that as long as three or more sensors remain operable in the array no re-emplacement will be undertaken, but that failures occur such that fewer than three sensors remain operable in the array re-emplacement will be undertaken. (This definition will be further qualified in a subsequent description of an input governing the number of re-emplacement missions to be undertaken for a given sensor array.) ICR applies to the entire sensor array.

MPL (I, 11)	This is a code indicating the technique of emplacement specified by the planner for a given sensor array. For MPL = 1, the array is hand-emplaced. For MPL = 2, the array is air-dropped. For MPL = 3, the array is array is artillery or mortar emplaced.
PS (IV, 9)	This is the probability that a given artillery/mortar-emplaced or air-dropped sensor will be operable after impact. This value is assumed to be unity for hand-emplaced sensors. PS applies to the individual sensor.
SD (I, 27)	This is a code indicating whether or not a sensor self-destructs when its batteries become exhausted. SD = 1 indicates self-destruct; SD = 0 indicates no self-destruct. This input applies to the individual sensor.
AUX (IV, 8)	This is a code indicating whether or not a sensor is operating as an auxiliary to another sensor. AUX = 1 indicates an auxiliary sensor; AUX = 0 indicates a primary sensor. This input applies to the individual sensor.

(2) Inputs Defining Time Distributions

Name	Input Description
XMUF (IV, 4)	This is the mean time between failures (MTBF) for a given sensor. XMUF defines the reliability failure distribution. This input applies to the individual sensor.
XMUL (IV,5)	This is the mean battery life of a given sensor. It applies to the individual sensor.
SIGL (IV, 6)	This is the standard deviation of the battery life of a given sensor. It applies to the individual sensor.
XMUE (I, 9)	This is the nominal game time at which the planner specifies a given sensor array is to be emplaced. This input applies to the entire sensor array.
SIGE (I, 28)	This is the standard deviation of the distribution of times about XMUE. This input applies to the entire sensor array.

Rather than being specified directly by the planner, this standard deviation value is determined by a code input by the planner. The implications of the value assigned this code are as follows:

Code	Value of Standard Deviation (hours)
0	zero
1	0.25
2	0.75
3	2

XMUR (I, 29)	This is the mean time required to execute a re-emplacement mission for a given sensor array. This value should be interpreted as including not only the time required for the actual re-emplacement mission, but also the time required to recognize that the sensor array in question has fallen below its operability level criterion and that re-emplacement is required. This input applies to the entire sensor array.
SIGR (I, 30)	This is the standard deviation of the distribution of times about XMUR. This input applies to the entire sensor array.

The value of this standard deviation is determined (as in the case of SIGE, previously discussed) by the value assigned to a (0, 1, 2, 3) code by the game planner. Specifically, the following values are assigned by designer input:

Code	Value of Standard Deviation (hours)
0	zero
1	0.25
2	0.75
3	2

XMUM (I, 31)	This is the mean interval between scheduled maintenance checks (i.e., battery replacement) for the sensors in a given array. This input applies to the entire sensor array.
SIGM (I, 32)	This is the standard deviation of the distribution of times about XMUM. It applies to the entire sensor array.

Rather than being specified directly by the planner, the value of this standard deviation is controlled by a two-value code whose value is assigned by the planner. Specifically, the following values are assigned by designer input.

Code	Standard Deviation Value
0	0
1	1 day

(3) Inputs Governing Sensor Emplacement Missions

Name	Input Description
NMC (I, 25)	This is the total number of emplacement missions specified by the planner that are to be undertaken (if necessary) to maintain a given sensor array at or above its operability level criterion (i.e., the ICR value previously described). Thus, the inputs NMC and ICR together tend to determine the level of re-emplacement activity for a given sensor array during the game. Any time the number of operable sensors within a given array falls below the ICR value specified for that array, re-emplacement will be undertaken if, and only if, the number of emplacement missions previously undertaken for that array is less than the value of NMC. This input applies to the entire sensor array.
NPC (I, 24)	This is the number of emplacement attempts specified by the planner to make (if necessary) during a given emplacement (or re-emplacement) mission for a given sensor array. For example, during an air-drop emplacement mission for an array having an ICR value of three and an NPC value of two, if five sensors are dropped during the first pass over the intended emplacement location and only two survive impact, a second pass over the emplacement location will be undertaken.
PA (I, 23)	This is the probability that an emplacement (or re-emplacement) mission for a given sensor array will abort. This input applies to the entire sensor array.
TMAX (I,10)	Planned Down Time. It is the game time specified by the planner at which he desires that particular array to cease being played in the game. This input applies to the entire array.

4.2.1.1.2 Simulation of Remote Sensor Emplacement, Failure and Re-emplacement. In determining game times of sensor emplacement and re-emplacement RUSUP treats sensors within the context of the array to which they belong rather than in isolation. Considerations leading to this feature of the RUSUP design are discussed briefly here.

For the purpose of the RUSUP design, it was assumed that the sensors included in any given array would be located in relatively near proximity to one another.* Under this assumption it appears likely that, within an actual operational environment, all of the sensors making up a given array would become operative at essentially the same time. It was believed desirable in modeling the sensor emplacement process to provide for some randomness in the time of emplacement. At the same time it was apparent that to permit such randomness in the emplacement time of each sensor of a given array would, in many cases, lead to operationally implausible situations; for example, it could result in widely disparate emplacement times for sensors making up a single array and located only a few meters apart. Likewise the treatment of sensor re-emplacement strictly on an individual basis without regard for the array context would lead to implausible results. For example, cases would be expected to occur where a single failed sensor was re-emplaced although other sensors located within a few meters of it required re-emplacement at the same time.

Although the RUSUP design provides for the treatment of emplacement and re-emplacement times within the context of the array as a whole, this feature need not of course, be used. If for any reason the game planner wishes emplacement and re-emplacement times to apply strictly to individual sensors, he need only specify arrays consisting of a single sensor each.

The succeeding paragraphs of this section discuss underlying assumptions and rationale which influenced the design of RUSUP but which are not necessarily apparent from an examination of the program listing.

(1) Determination of Initial Emplacement Time

RUSUP provides for Monte Carlo determination of initial emplacement time for each sensor array. It is expected that in an operational environment the actual emplacement times will deviate in varying degrees from any pre-planned sensor deployment schedule. Such

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*As discussed elsewhere in this report, the assumption of the near proximity of the sensors within a given array is also pertinent to the treatment of propagation line of sight for the sensor reporting link.

deviation might be trivial in the case of sensor deployment for close-in intrusion detection, but could be quite substantial when sensors are emplaced in remote locations, particularly when unfavorable terrain and/or hostile encounters are involved. Such deviations are treated in RUSUP as being normally distributed about the preplanned or scheduled emplacement time.* The variance of this distribution is determined by input. When a Monte Carlo sample is drawn such that the resulting emplacement time would be less than half the nominal or scheduled emplacement time, the sample is rejected and resampling occurs. In the case of determining initial emplacement time, this sampling procedure has the effect of avoiding emplacement times having a negative game time value.

(2) Determination of Emplacement Mission Aborts

The emplacement time whose method of determination was discussed in the previous paragraph is tentative in cases where the input value for probability of emplacement mission abort is greater than zero. That is, the time determined is the time at which emplacement will occur provided the emplacement mission does not abort. In the case of sensor arrays for which a non-zero value of probability of mission abort is input, determination of whether or not an abort occurs is accomplished by comparison of this value with a uniform random number (0, 1). If the sample value is equal to or less than the input probability value, the mission is assumed to have aborted. Treatment of the array after a mission abort is covered in the subsequent discussion of sensor re-emplacement missions (see paragraph 4.2.1.1.2(5)).

(3) Determination of Whether Sensors Survive Impact

In the case of air-dropped and artillery/mortar-emplaced sensor arrays provisions are made for determining which sensors are operable after impact. Representation of this portion of these missions involves several counting operations and comparisons as illustrated in the logic flow chart presented in Figure 4.2-2. For the present discussion of the process depicted in Figure 4.2-2 it is assumed that an air-drop sensor emplacement mission is in progress. The value N is the number of sensors in the array when the array is up to full strength (as discussed previously in the description of RUSUP inputs.) K is the number of sensors that must be emplaced in order to bring the array up to full strength; for the initial emplacement mission for a given array, of course, K = N. The counter NPM counts the number of passes made over the drop site by the emplacement aircraft, which drops K sensors during each such pass. As each sensor is dropped its probability of survival value (PS), previously discussed in the description of inputs, is compared with a uniform random number (0, 1) to determine whether the sensor survives. The counter I counts the sensors that survive impact. The counter J counts all sensors dropped and when J = K the pass is complete. At this point the number of operable sensors in the array is compared with the operability level criterion (ICR) for the array. If the array is up to specified minimum strength, the emplacement mission ends. If not and if the number of passes made during this emplacement mission is equal to the NPC value for this array (previously dis-

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* In the absence of data reflecting actual experience or experimental results, the normal distribution was intuitively judged to be appropriate for this application.

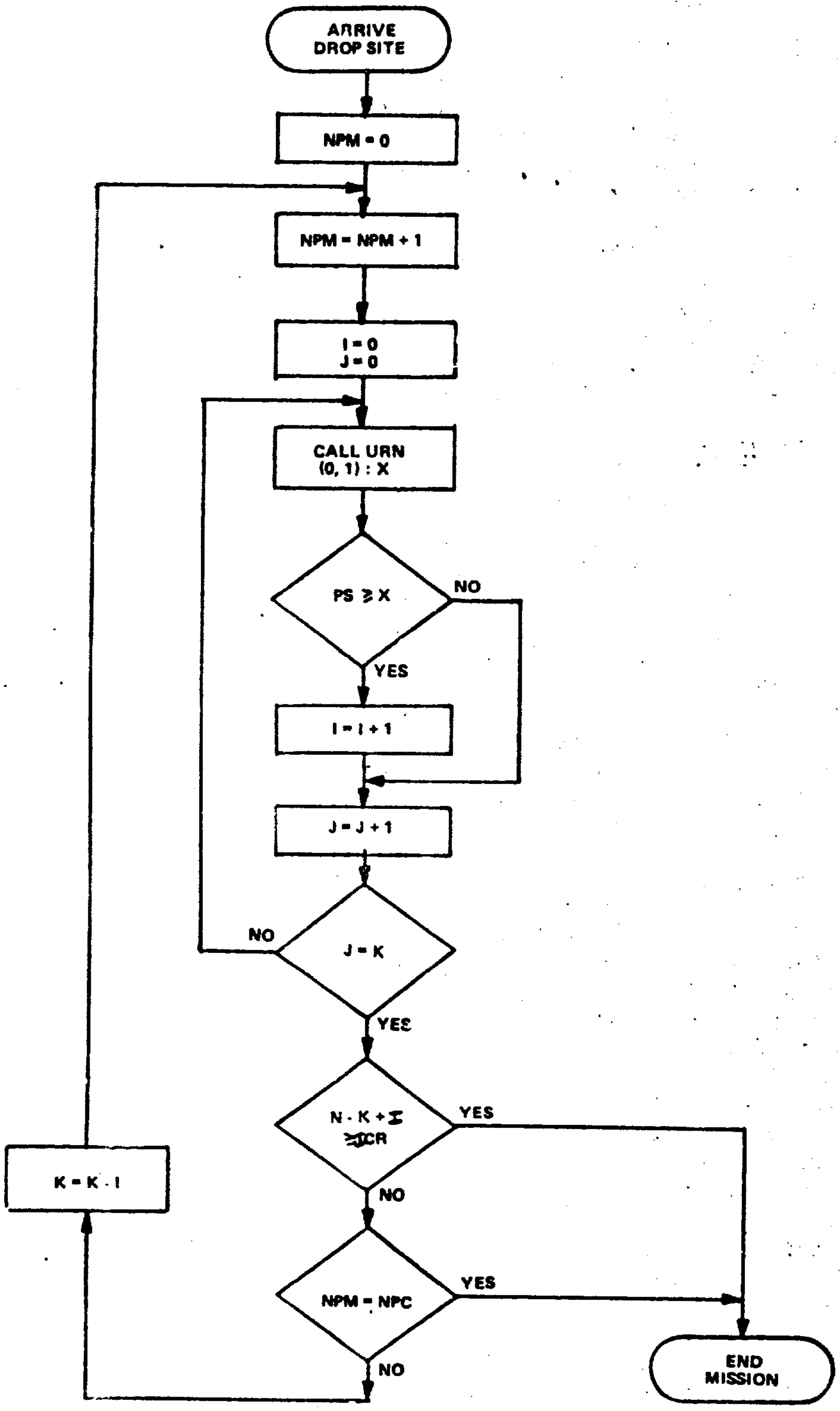

Figure 4.2-2 DETAIL OF AIR-DROP SENSOR EMPLACEMENT MISSION

cussed in the description of inputs) the mission ends. If, however, the number of passes made during this mission is smaller than the value of NPC, the value of K is adjusted (as required) and another pass over the emplacement site is undertaken.

(4) Determination of Sensor Failure Times

The remote unattended sensors are treated in RUSUP as being subject to both reliability failures and life failures (that is, failures resulting from exhaustion of the sensor batteries). The reliability failures are treated as a Poisson distribution whose defining parameter is the MTBF value applicable to the equipment in question. The life failures are treated as occurring, on the average, at some specified elapsed time after emplacement and as varying about this mean value as a normal distribution. Provisions are made to permit input of a sensor maintenance schedule which is interpreted to mean that batteries of emplaced sensors are replaced at more or less regular intervals. Thus, if, for a given sensor array, a maintenance check is determined to occur at an earlier game time than a life failure, the life failure is interpreted as having been prevented.

Time to failure for each sensor in a given sensor array is determined as indicated in the logic flow chart shown in Figure 4.2-3. Time to reliability failure, TRF, is compared to the time to life failure, TLF (that is, the first life failure not forestalled by a previous maintenance check). If the reliability failure occurs first, its time is taken to be the time of sensor failure. If the life failure occurs first, its time is taken to be the time of sensor failure; however, if the sensor does not self-destruct upon life failure (i.e., ISD = 0), the projected reliability failure time is stored and this failure may occur subsequently in the game following replacement of the batteries of the sensor in question. Any sensor (whether primary or auxiliary) which is paired with another sensor and reporting in a primary/auxiliary relationship is treated as failing at the time of failure of the sensor with which it is paired.

(5) Sensor Re-Emplacement

At any time that a sensor array falls below the minimum operability level specified by input (or at any time a sensor emplacement mission aborts) and provided that additional emplacement missions remain to be expended in the interest of keeping the sensor array in question up to minimum specified strength, sensor re-emplacement for the array involved is initiated. Following a mission abort the game time reference for re-emplacement initiation is the time at which the abort occurred, which in turn is taken to be the time that emplacement would have been accomplished had the mission not aborted. When re-emplacement becomes necessary because of failures of emplaced sensors, the game time reference is determined by rank ordering the failure times of the sensors in the array and selecting the game time of failure of the sensor whose failure left the array no longer in conformance with the specified minimum operability level.

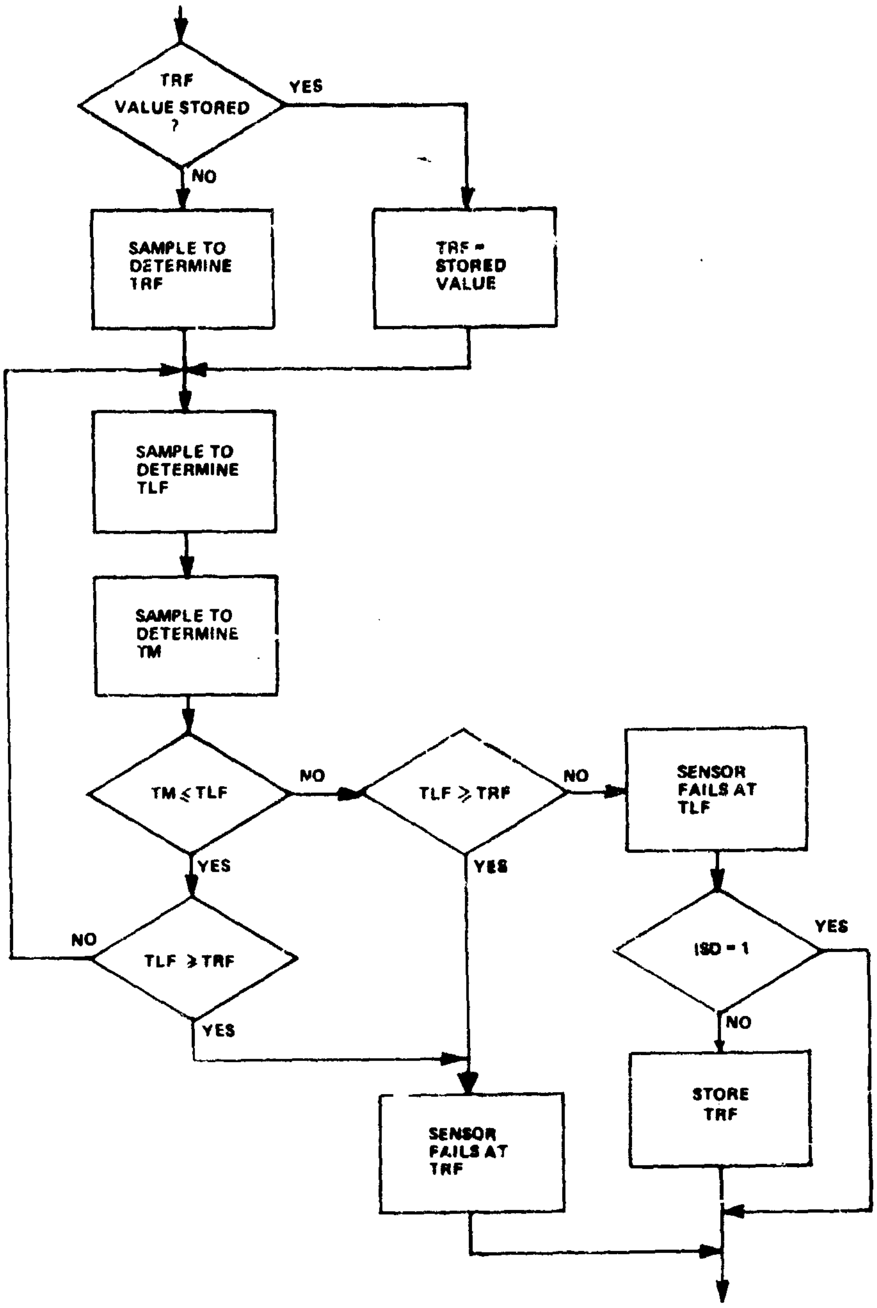

Figure 4.2-3 DETERMINATION OF TIME OF SENSOR FAILURE

Once this game time reference is established the game time at which re-emplacement will occur is determined by adding the mean replacement time value for the array (XMUR) to a random sample from a normal distribution whose variance is defined by input (SIGR) and adding this sum to the game time reference. When a sample is drawn such that the elapsed time to re-emplacement would be less than half the mean time to re-emplace, the sample is rejected and resampling occurs. In the case of determining sensor re-emplacement time, this sampling procedure has the effect of avoiding re-emplacement times that occur earlier in game time than do the corresponding sensor failure times.

4.2.1.2 Subroutine READUP

The purpose of subroutine READUP is to determine, for each remote unattended sensor monitor equipment involved in the game, the game times during which the equipment is operating. READUP produces, for each monitor equipment, a record of game times. The first entry in this record is the first game time up, the second entry is the first game time down, the third entry the second game time up, and so on.

4.2.1.2.1 Description of READUP Inputs

(1) Planned Up and Down Times for Each Monitor
A record containing planned up and down times for each monitor constitutes a part of the input to subroutine READUP. The total number of entries in this record for each monitor (NK in the program) is also input.

(2) Parameters Defining Failure and Repair Time Distributions

Name	Description
FMUF (VII, 3)*	This is the mean time between failures (MTBF) value for the monitor equipment.
FMUR (VII, 4)	This is the mean time required to repair (or replace) the monitor equipment.
SIGR (VII, 5)	This is the standard deviation of the distribution of repair/replacement times about FMUR.
T(1) (VII, 6)	Planned up game time.
T(2) (VII, 7)	Planned down game time.

---

*The roman numeral in these parenthetical designations indicate a particular data set in Appendix F of Volume II of this report. The arabic numerals refer to a particular entry within the data set.

4.2.1.2.2 Processing to Determine Monitor Up and Down Times. A macroflow for subroutine READUP is shown in Figure 4.2-4. The index I used in the flow chart denotes a set of one or more planned up periods for the monitor in question during the course of the game. Planner input defines each such period by means of a specified planned up time and a specified planned down time. READUP compares these planned up times with periods of monitor availability (i.e., periods during which the monitor is operable), and produces an output record of monitor up times for those periods during which the monitor is both planned to be up and is operable.

The assumption is made that, for the initial planned up period for a given monitor during the game, the monitor is operable at the beginning of the planned up period. This assumption is not made for any subsequent planned up period or periods for the monitor in question.

The monitors are not represented in READUP as subject to life (or battery exhaustion) failures. The monitors are manned equipments, and even though some of these equipments may be powered by batteries it is assumed that timely replacement of batteries will forestall life failures. The monitors are, however, treated as subject to reliability failures. Operating time to reliability failure is determined by random entry into a Poisson distribution defined by the mean time between failures value applicable to the monitor (this is the FMUF input value previously described for READUP). It should be noted that this time to failure is construed to be <u>operating time to failure</u>; that is, any period or periods during which the equipment is planned down are not interpreted as contributing to elapsed time to failure.

A brief discussion of Figure 4.2-4 should serve to convey an understanding of the processes simulated by READUP.

For a given monitor, the first processing accomplished by READUP is the determination of an operating time to failure; this is accomplished as described above.

The incrementing of I in the macroflow indicates simply that a new planned up period from game planner input is being considered at this point in the processing. The branch immediately following the incrementing of I is intended to pose the following question: is this monitor operable at any time during the planned up period currently being considered? If the answer here is yes, an up time entry is made in the READUP output record; this time is either the planned up time or the time at which the monitor becomes operable, whichever is later in game time. If the answer is no (and the input record of planned up periods is not exhausted), the next planned up period is considered and the question posed again.

The next branch in the macroflow is intended to pose the following question: does this monitor fail at any time during the current planned up period? If the answer here is no, the READUP output record receives the planned down time for the monitor. If the answer is yes, the

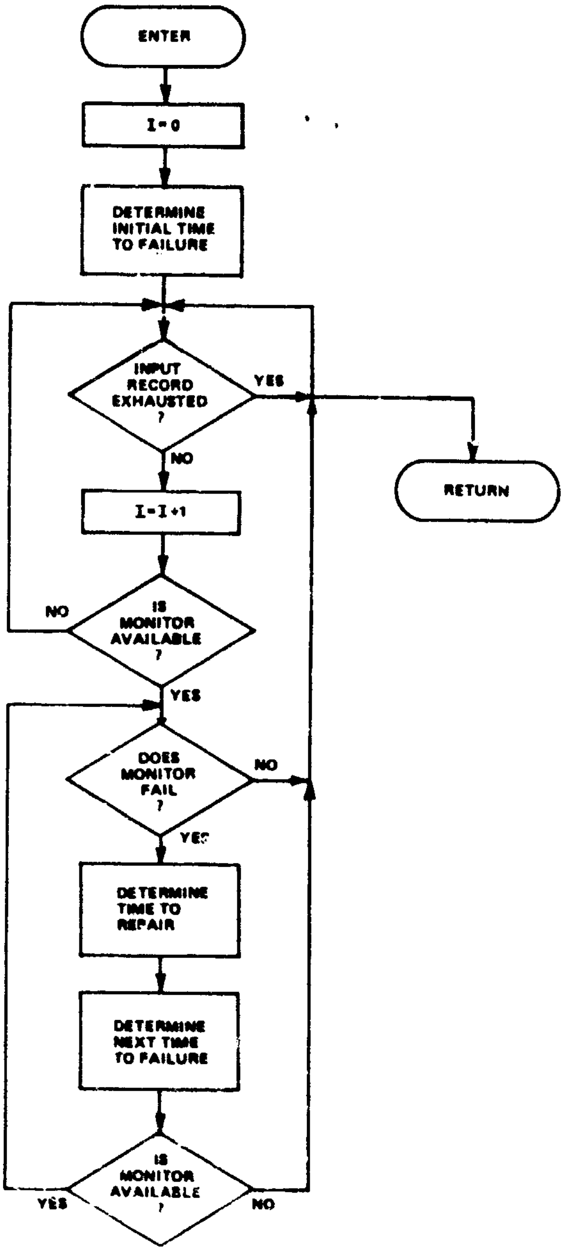

Figure 4.2-4 READUP MACROFLOW

time to repair is taken to be the algebraic sum of the average repair time (TMUR) and a random sample drawn from a normal distribution whose standard deviation is SIGR. (Here again, if the resulting time to repair is less than half the mean time to repair, the sample is rejected and re-sampling occurs.) A new operating time to failure is also determined; this is accomplished as previously described.

Finally, the equipment operability check is again made. If the repair is to be completed before the planned down time, the failure check is made again, this time against the new time to failure, and so on. If the repair is not to be completed before the planned down time (and if the input record of planned up periods has not been exhausted), the next planned up period for the monitor is considered.

The effect of the READUP processing to determine game up times for a monitor is illustrated in Figure 4.2-5.

4.2.1.3 Subroutine COMMUP

The purpose of subroutine COMMUP is to determine, for each remote unattended sensor data link relay involved in the game, the game times during which the relay is emplaced and operable. A macroflow chart of COMMUP is shown in Figure 4.2-6.

4.2.1.3.1 Description of COMMUP Inputs

Name	Input Description
XMUE (VIII, 7)*	This is the game time at which the game planner has specified the relay is to be emplaced.
SIGE (VIII, 9)	This is the standard deviation of the distribution (treated as a normal) of times about XMUE.

Rather than being specified directly by the planner, this standard deviation value is determined by a code input by the planner. The implications of the value assigned this code are as follows:

Code	Value of Standard Deviation (hours)
0	zero
1	0.25
2	0.75
3	2

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*The roman numeral in these parenthetical designations refer to a data set in Appendix F of Volume II of this report. The arabic numeral refers to a particular entry within the data set.

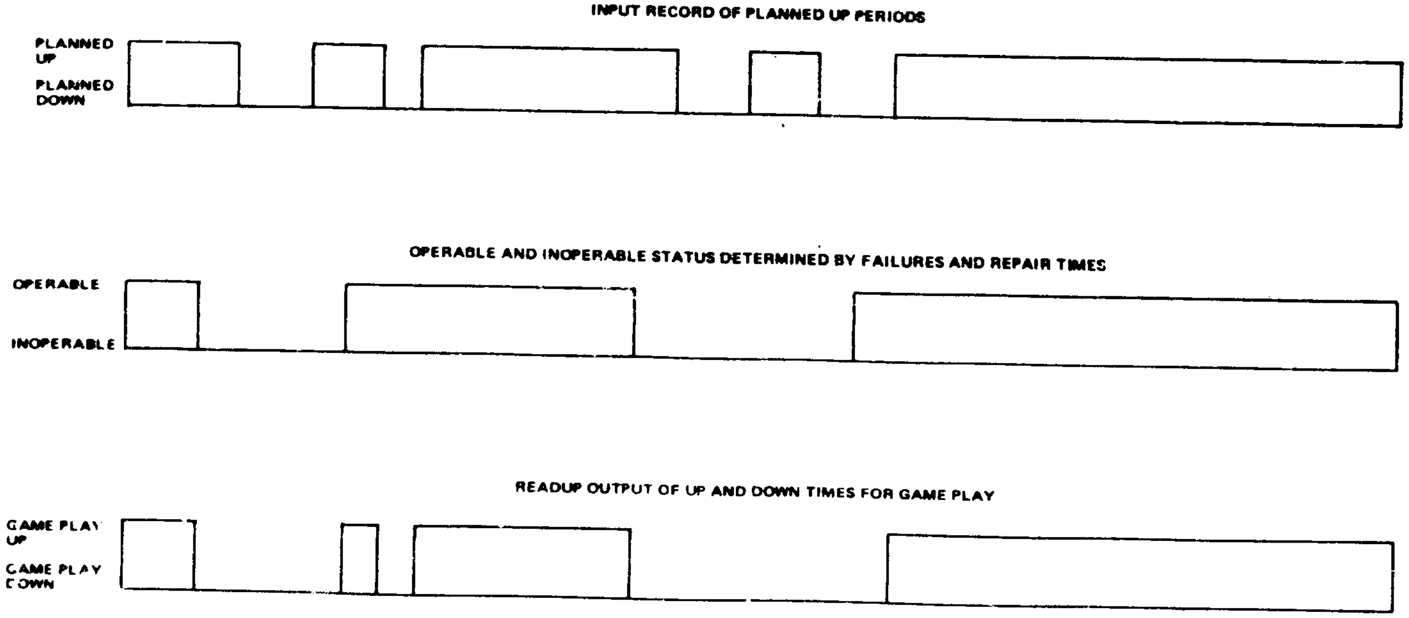


Figure 4.2-5 EFFECT OF READUP PROCESSING TO DETERMINE GAME PLAY UP AND DOWN TIMES FOR REMOTE UNATTENDED SENSOR MONITORS

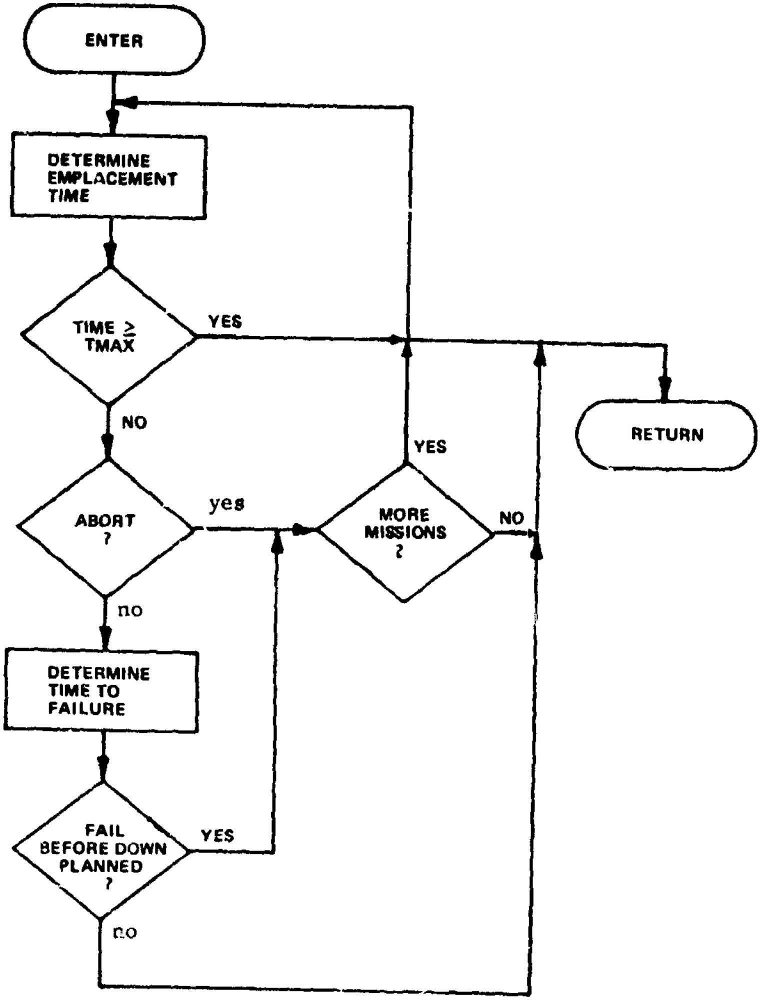


Figure 4.2-6 SUBROUTINE COMMUP MACROFLOW

TMAX (VIII, 10)	This is the planned down time for the relay.
XMUF (IX, 3)	This is the mean time between failures value applicable to the relay.
XMUL (IX, 4)	This is the average battery life for the relay.
SIGL (IX, 5)	This is the standard deviation of the distribution (treated as normal) of times about XMUL.
XMUM (VIII, 11)	This is the average time interval between maintenance checks for the relay.
SIGM (VIII, 12)	This is the standard deviation of the distribution (treated as normal) of the times about XMUM.

Rather than being specified directly by the planner, the value of this standard deviation is controlled by a two-value code whose value is assigned by the planner. Specifically, the following values are assigned bv designer input:

Code	Standard Deviation Value
0	0
1	1 day

XMUR (VIII, 13)	This is the average time required to repair/re-emplace the relay.
SIGR (VIII, 14)	This is the standard deviation of the distribution (treated as normal) of times about XMUR.

The value of this standard deviation is determined by the value assigned to a (0, 1, 2, 3) code by the game planner. Specifically, the following values are assigned by designer input:

Code	Value of Standard Deviation (hours)
0	zero
1	0.25
2	0.75
3	2

NMC (VIII, 15)	This is the maximum number of emplacement missions specified by the game planner in the interest of keeping the relay operable until its planned down time.

PA (VIII, 10)	This is the probability that an emplacement (or re-emplacement) mission for a given relay installation will abort.
ISD (IX, 6)	This is a code indicating whether or not the relay will self-destruct when its batteries are exhausted (ISD = 1 indicates self-destruct; ISD = 0 indicates no self-destruct).

4.2.1.3.2 Simulation of Relay Emplacement, Failure and Re-Emplacement. Much of the processing in COMMUP is quite similar to portions of that described previously for subroutine RUSUP. The present discussion, then, will trace briefly through the macroflow shown in Figure 4.2-6, with cross-reference to specific portions of the RUSUP description, as appropriate.

Initial relay emplacement time is treated as being normally distributed (with a sigma value of SIGE) about a point in game time (XMUE) specified by the planner, and is determined by Monte Carlo sampling. If the resulting emplacement time is less than half the value of XMUE the sample is rejected and resampling occurs; this sampling procedure has the effect of avoiding negative emplacement times.

If the above emplacement time is less than the planned down time for the relay, a check is made for mission abort. This is done by comparison of the input probability of mission abort (PA) with a uniform random number (0, 1). If the mission aborts, it is considered to have done so at the previously determined emplacement time. If more missions remain to be undertaken in the interest of keeping this relay installation operable (depending on the input value for NMC), a new tentative emplacement time is determined, but using inputs XMUR and SIGR rather than XMUE and SIGE. If no missions remain, the relay remains down for the remainder of the game.

If an abort is not determined to occur in the above comparison, a time to failure is determined for the relay. This time to failure is determined as indicated in the previous Figure 4.2-3 and the accompanying discussion. (The final remarks of that discussion concerning auxiliary failures do not, of course, apply to the present case.) If the time to failure is such that the relay will not fail before its planned down time, then the processing of this relay through COMMUP is complete. Otherwise, re-emplacement will be undertaken, provided additional emplacement missions remain to be expended in the interest of keeping this relay installation operable until its planned down time.

The output record from COMMUP contains not only the game times at which up/down changes of state occur for the relay, but also status codes indicating the status assumed by the relay at each game time entry.

These status codes are defined in Table 4.2-II.

Table 4.2-II - RELAY STATUS CODES

Code	Status Indicated
-1	Relay becomes operable as a result of re-emplacement
-2	Relay becomes operable for first time in game
-3	Relay down because of mission abort
-4	Relay down because of reliability failure
-5	Relay down because of life (battery) failure
-6	Relay down because planned down

4.2.2 Deployment and Failures of Manned Stationary Sensors

The determination of up and down game time periods for manned stationary sensors is accomplished by processing these sensors through subroutine RUSUP. These sensors (referred as STASCAN sensors in the program) include ground radars, night observation devices, low light level TV, and any other manned sensing equipments that may be represented as performing the sensing function while occupying a fixed position and for which it is considered desirable to play failure and repair events.

Special attention should be paid to the assignment of RUSUP input values when STASCAN type sensors are to be processed through that subroutine. The following material is referenced to Section 4.2.1.1.1 (Description of RUSUP Inputs), and offers comments on the interpretation of RUSUP inputs as applicable to the manned stationary sensors.

(I) Inputs Defining Array Composition

Input Name	Comment
N (XIX, 4)*	Number of sensors in this array. All sensors in a STASCAN array must be of same type (e.g., radar).

---

*The roman numeral in these parenthetical designations refers to a particular data set in Appendix F of Volume II of this report. The arabic numeral refers to a particular entry within the data set.

ICR (I, 26)	If any repair/replacement is desired for a STASCAN sensor in the event of failure, ICR should be assigned a value of one. Otherwise, ICR should be assigned a value of zero.
MPL (XIX, 11)	Each STASCAN sensor should be defined as a hand-emplaced sensor.
PS (IV, 9)	By implication, this value will be unity, since the STASCAN sensor is treated as hand-emplaced.
SD (I, 27)	Since the STASCAN sensors are, by definition, manned it is doubtful that life (i.e., battery) failures would be played for them. In any case, these sensors would be represented as not having the self-destruct feature.
AUX (IV, 8)	Each STASCAN sensor should be represented as a primary sensor. This value should input as zero.

(2) Inputs Defining Time Distributions

Input Name	Comment
XMUF (IV, 4)	This is the mean time between failure for the particular type STASCAN sensor being contemplated.
XMUL (IV, 5)	Since these sensor types are manned, it probably will not be desired to play life (battery) failures. In such case, XMUL should be a value equal to maximum game time.
SIGL (IV, 6)	If XMUL is assigned a value equal to maximum game time, SIGL should be assigned a value of zero (to prevent the occurrence of life failures).
XMUE (XIX, 9) SIGE (XIX, 15) XMUR (XIX, 16) SIGR (XIX, 17)	The same considerations apply to these inputs for the STASCAN sensors that would apply in the case of the remote unattended sensors. (pages 4-7,4-8)*
XMUM (XIX, 18)	This input has an entirely different meaning in the case of the STASCAN sensors than in the case of the remote unattended sensors. In the present case it is to be interpreted as the mean time required to repair the STASCAN sensor in question.

---

*In the case of STASCAN sensors, however, XMUR can be interpreted as the mean time to repair (or if desired the mean time to replace) and SIGR as the corresponding standard deviation.

SIGM (XIX, 19) This is the standard deviation of a distribution of times about XMUM.

Rather than being specified directly by the planner, the value of this standard deviation is controlled by a two-value code whose value is assigned by the planner. Specifically, the following values are assigned by designer input:

Code	Standard Deviation Value
0	0
1	1 day

(3) Inputs Governing Sensor Emplacement Missions

Input Name	Comment
NMC (I, 25)	NMC is assigned a value of one when processing STASCAN type sensors through subroutine RUSUP.
NPC (I, 24)	NPC is assigned a value of one for the STASCAN sensors.
PA (I, 23)	PA is assigned a value of zero for a STASCAN sensor.

4.2.3 Moving Sensor System Missions and Equipment Failures

Moving sensor system missions and equipment failures associated with such missions are simulated in subroutine MVS (Step #4 of PRERUN).* MVS determines, for each moving sensor planned for play in the game, the game time during which the sensor is operating. The subroutine is used to process both moving sensor systems represented as moving on the ground and those represented as airborne. A moving sensor system may be represented in the subroutine as including as many as three sensing equipments.

4.2.3.1 Description of Inputs

The following inputs are required:

(XXI, 6) (1) The game time at which the moving sensor system mission is intended to begin.

---

*Subroutine MVS is also used to determine navigation errors for moving sensor system missions, as discussed in Section 4.3.2.

(XXI, 9) (2) The ground track of the entire mission.

(XXI, 11) (3) The speed of the vehicle or platform associated with the mission.

(XX, 4) (4) The number of sensing equipments included in the mission.

(IV, 4) (5) For each sensing equipment included in in the mission, its mean time between failures.

(XX, 10) (6) Specification of whether the mission must be accomplished during daylight, must be accomplished during night time, or is insensitive to day/night conditions.

(XX, 12) (7) Minimum visibility under which the mission can begin, and, having begun, continue.

(XX, 11) (8) Minimum ceiling under which the mission can begin, and, having begun, continue.

(XX, 9) (9) Probability of mission abort.

4.2.3.2 Processing to Determine Up Times for Moving Sensors

A macroflow of that portion of subroutine MVS concerned with determining up times for moving sensors is shown in Figure 4.2-7. In the design of this subroutine the assumption was made that in some cases the moving sensor system missions would require certain minimum meteorological and day/night conditions in order to be undertaken and completed; an airborne radar surveillance mission, for example, might represent such a case. As shown in Figure 4.2-7, for each planned moving sensor system mission the conditions necessary for its accomplishment must exist before it can be undertaken. Existing conditions as a function of time are determined by searching the ATMENV table (an array of data reflecting time-ordered changes in atmospheric, environmental and ephemerus conditions). ATMENV is searched, in turn, for suitable day/night conditions, suitable visibility and suitable ceiling conditions to begin the mission. If a game time cannot be found at which all of these conditions are suitable, the mission is abandoned. If such a game time can be found in ATMENV that is equal to or later than the input time for the initiation of the mission, that time is taken to be the tentative mission initiation time. Then ATMENV is searched to determine how long suitable conditions for the mission endure. If one or more of the necessary conditions ceases to exist during the period of time it would require to accomplish the mission, the mission is abandoned. Otherwise, the sensors included in the mission are recorded as being up and operable at the previously determined time for mission initiation.

Operating time to failure for each sensor included in the mission is then determined by random entry into a Poisson distribution whose defining parameter is the MTBF value applicable to the sensor in question.

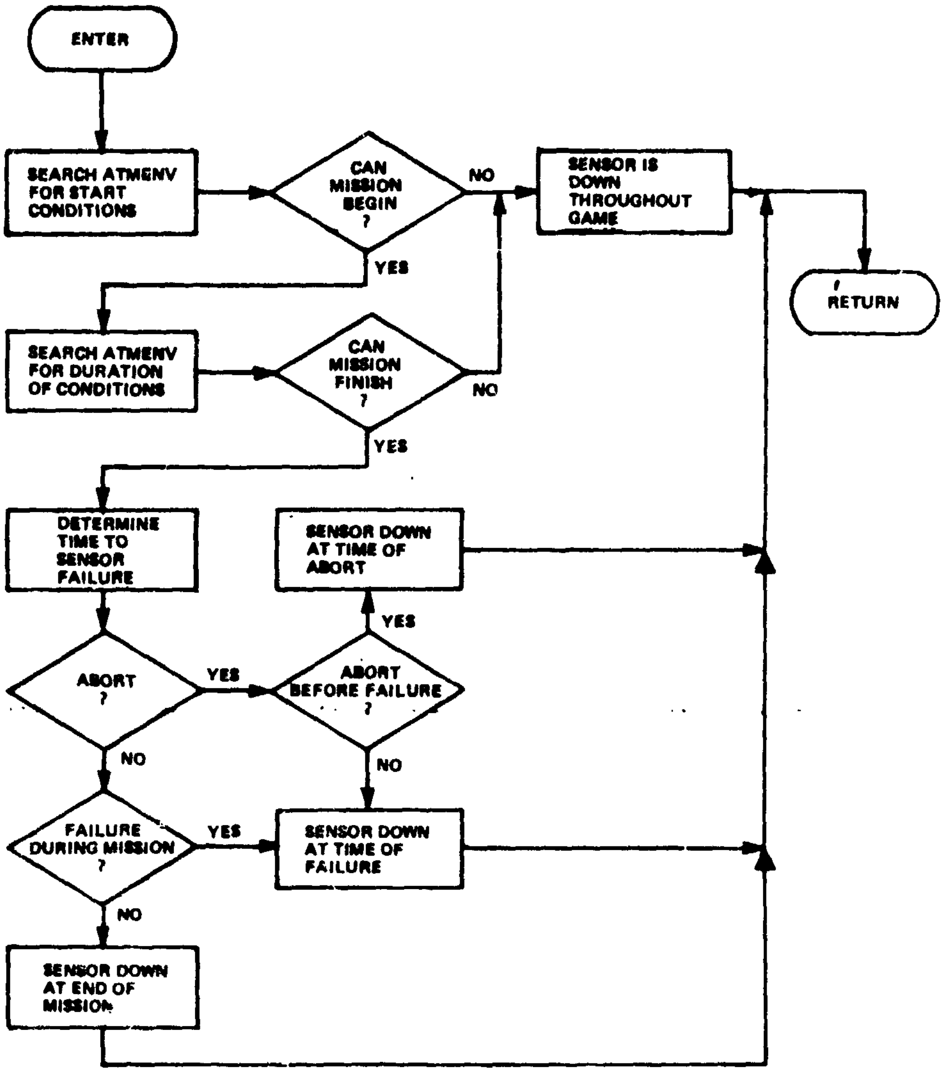


Figure 4.2-7 MOVING SENSOR MISSION AND EQUIPMENT FAILURE REPRESENTATION

Whether or not the mission aborts is determined by comparison of the input probability of mission abort with a uniform random number (0, 1). If mission abort occurs, its time is determined by uniform sampling across the mission duration period.

The down time for each sensor included in the mission is determined as follows. If an abort occurs, the sensor is recorded as down at its reliability failure time or at the time or abort, whichever comes earlier in game time. If no abort occurs, the sensor is recorded as down at its reliability failure time or at the end of mission time, whichever comes earlier in game time.

4.3 POSITION AND NAVIGATION ERRORS

Ground truth positions for stationary sensors played in the game and navigation errors for moving sensors played in the game are determined in Steps 3 and 4 of the PRERUN program. Position errors for both the remote unattended sensors and for the manned stationary ground sensors are calculated by means of subroutine SNPGT (Step 3 of PRERUN). Navigation errors for both airborne sensors and those represented as moving on the ground are calculated by means of subroutine MVS. Four called subroutines are used in conjunction with both SNPGT and MVS. These are:

(1) Subroutine DOPLER for use when a sensor platform or vehicle used for sensor emplacement missions is represented as being equipped with a doppler navigation system.

(2) Subroutine RHOTHE, for use when a sensor platform or vehicle used for sensor emplacement missions is represented as making use of a rho-theta radar tracking navigation system.

(3) Subroutine HYPERB, for use when a sensor platform or vehicle used for sensor emplacement missions is represented as supported by a hyperbolic navigation system.

(4) Subroutine NORMER, for use in sensing missions and sensor emplacement missions wherein position location is represented as being determined in open terrain from maps and visual sightings.

4.3.1 Subroutine SNPGT

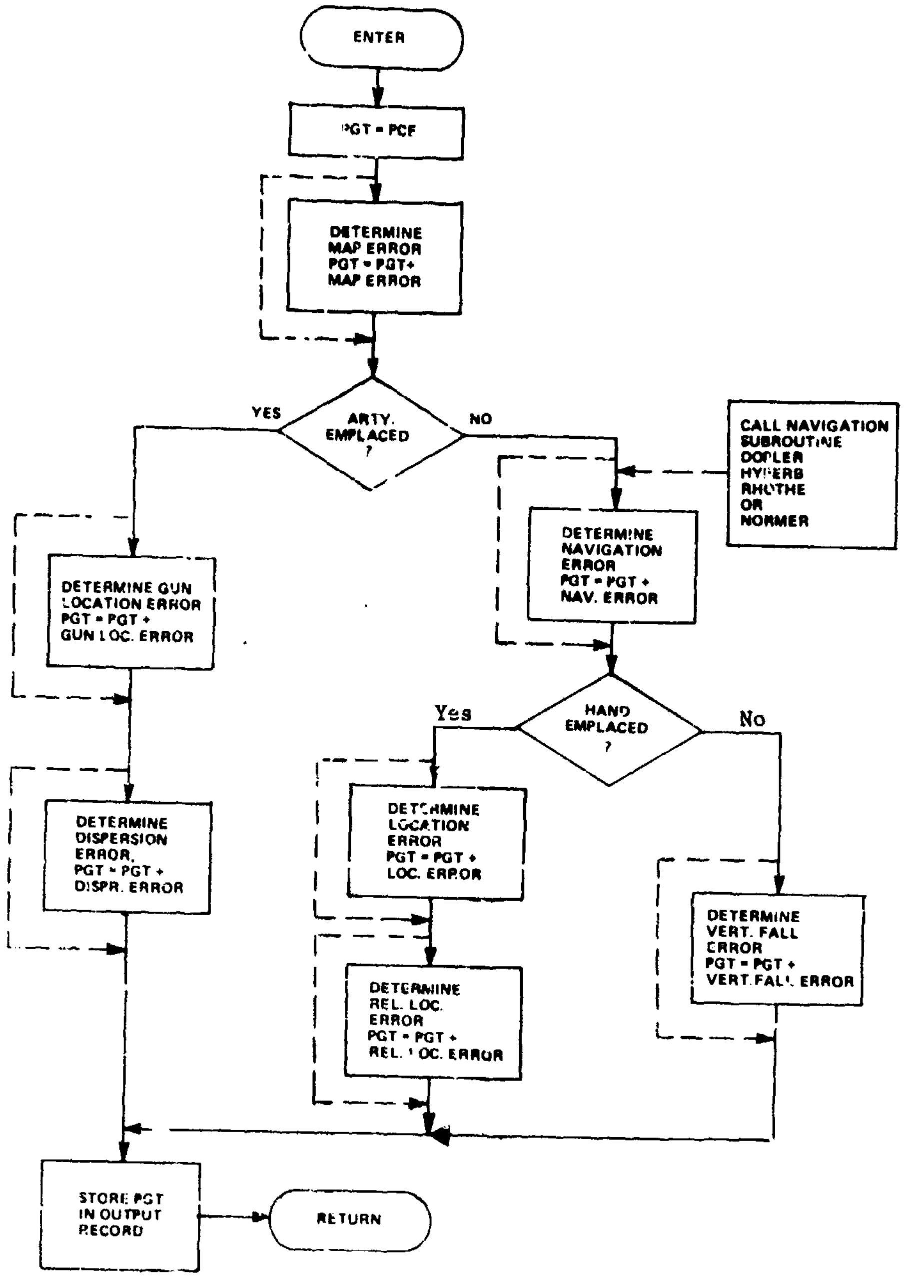
The purpose of subroutine SNPGT is to determine, for each stationary ground sensor (i.e., both remote unattended sensors and manned sensing equipments) played in the game, the ground truth position coordinates of the sensor for each game time period during which the sensor is represented as operating.

4.3.1.1 Description of SNPGT Processing

A macroflow of subroutine SNPGT is shown in Figure 4.3-1. One of the principal objectives in the design of this subroutine was to provide maximum flexibility for the examination of the influence on system performance of the disparity between planner-specified sensor position and actual ground truth sensor position, as determined by the introduction of errors from one or more of several error sources. For each sensor to be deployed in the course of the game, a position is specified by planner input. This position is referred to in Figure 4.3-1 as PCE (that is, the Commander's Estimate of the Position of the sensor). For the purpose of any intelligence inferences drawn from any target detections by the sensor during the game, PCE is treated as though it were the actual ground truth position of the sensor; that is, the estimated sensor position is attributed the same significance that would be the case in actual operations. If the game planner does not desire to play location errors for stationary ground sensors, then PCE and the Ground Truth Position (PGT in the macroflow) are identical. If, however, the planner wishes to play one or more of the error sources, the ground truth position is derived by incorporating, in turn, errors from each of the error sources designated by the planner to be played in the game. The paragraphs that follow discuss the treatment in SNPGT of the several error sources shown in Figure 4.3-1.

(1) Map Error. Map error is treated in subroutine SNPGT in the familiar operational sense of the term. That is, it is construed to mean the distribution of differences that would be observed if the distances and directions among features as represented on the map were compared with the results of arbitrarily accurate measurements among the corresponding features as they actually exist on the terrain. The dashed line by-pass indicated in the macroflow indicates that whether or not map error is to be played is a matter of planner option; this is also true of all other error sources depicted in Figure 4.3-1. In cases where two or more sensors are so emplaced or deployed that they would logically share a common map error (i.e., assuming map error is to be played), Monte Carlo sampling to determine map error is done only once, and the sample value is taken as applicable to all of the sensors involved. For example, in the representation of the emplacement of an array of three remote unattended sensors fifty meters apart at some nominal location within the scenario terrain, the same map error sample would apply to all three sensors, although a relative location error (to be discussed presently) might apply to the individual sensors in the array.

(2) Sensor Emplacement by Artillery and Mortars. As indicated in the macroflow, SNPGT provides for the play of two error sources (in addition, that is, to map error previously discussed) for artillery/mortar-emplaced sensors: weapon location error, and weapon dispersion error. In the case of unobserved fire, all sensors fired from a given weapon position are treated as receiving the same weapon location error component in their overall position error. In the case of observed fire, the weapon location



4.3-1 MACROFLOW OF SNPGT

error is by-passed. When the planner elects to play weapon dispersion error, Monte Carlo sampling occurs each time a sensor is fired and the sample is incorporated into the sensor's overall position error. When artillery/mortar-emplaced sensors are represented as being re-emplaced, resampling occurs to determine the new sensor position. If fired from the same weapon position as in their previous emplacement, sensors are attributed the previously determined component of weapon location error; but in any case resampling occurs to determine weapon dispersion error for each such sensor.

(3) Sensor Emplacement by Air-Drop. For sensors represented as air-drop-emplaced, SNPGT provides for two error sources (in addition to map error); these are navigation error and vertical fall error. If navigation error is to be played, the subroutine representing the specified type of navigation system (DOPLER, RHOTHE, HYPERB or NORMER) is called and the navigation error returned to SNPGT. Vertical fall error is intended as the dispersion that might be expected to occur when sensors are dropped from an airborne platform with an intended impact point at or near some terrain feature. When this error source is played, Monte Carlo sampling occurs each time a sensor is dropped. As in the case of artillery/mortar-emplaced sensors, resampling is done to determine re-emplacement positions for air-drop sensors.

(4) Hand-Emplaced Unattended Sensors and Manned Stationary Sensors. Hand-emplaced remote unattended sensors and manned stationary sensors may be specified by the planner as being subject to map error as regards ground truth position. In addition, such sensors may be subject to one or the other of two error sources: the error source referred to in the macroflow as location error or that referred to as relative location error. All manned stationary sensors and all remote unattended sensors that are either the first or the only sensor in the array are treated as subject to location error. All remote unattended sensors that are the second or subsequent sensor in the array are treated as subject only to relative location error. That is, relative location error is the random error that would occur in positioning sensors with respect to one another within a single array of sensors. Typically, the distribution of relative location errors would have a considerably smaller variance than would the distribution of location errors.

Special provisions are made in subroutine SNPGT for hand-emplaced remote unattended sensors and manned stationary sensors that are specified to be emplaced adjacent to trails or other clearly defined terrain features. Clearly it is not plausible that operational personnel intending to hand-emplace a sensor beside a trail would inadvertently emplace the sensor fifty or a hundred meters away from the trail. On the other hand, a distribution of errors would be expected to exist along the trail. In such cases, therefore, SNPGT rejects the component of error (as determined by Monte Carlo sampling) perpendicular to the trail and represents only that component parallel to the trail as reflected in the ground truth position of the sensor.

4.3.1.2 Description of SNPGT Inputs

In the following descriptions of SNPGT planner inputs the parenthetical designation following the input description indicates the location of the corresponding entry in Appendix F of Volume II of this report. The first element in each designation (roman) refers to a particular Appendix F data set; the second element (arabic) in each designation refers to a particular entry in the aforesaid data set.

(III, 1) (1) Sensor ID number.

(I, 11) (2) Technique of sensor emplacement. The following codes are used:

1 indicates hand emplacement

-2 indicates air drop without visual observation

2 indicates air drop with visual observation

-3 indicates artillery/mortar emplacement, unobserved fire

3 indicates artillery/mortar emplacement, observed fire.

(3) Standard deviation of map error. At the present time this value is not determined by planner input but is entered in the program as a constant (zero).*

(II, 3) (4) Standard deviation of location error. This error is applicable (at the planner's option) to artillery/mortar-emplaced and hand-emplaced sensors. For artillery/mortar emplacement, it represents the uncertainty as regards the true position of the firing weapon.

(II, 4) (5) Relative location error. This error applies (at the planner's option) to all second and subsequent sensors in a hand-emplaced array and is used (if at all) in lieu of all other errors. It is the standard deviation of the relative position errors among sensors within a given array.

(II, Air Drop 3) (6) Navigation system. This is a two-digit code. The first digit of this code is to be interpreted as follows:

0	Perfect navigation (i.e., no navigation error)
1	Hyperbolic navigation system.
2	Rho-Theta navigation.

---

* See listing for PRERUN Job Step 0, Executive Subroutine INMAIN, statement sequence 0021; i.e., ZMAP = 0.

3	Doppler navigation system.
4	No physical type of navigation system specified, but Gaussian errors randomly played using designer values for standard deviation.

The second digit in the code is to be interpreted as follows: the digits 1, 2, 3 and 4 indicate different versions (in ascending order of quality of performance) of each of the four generic navigation system types.

(II, Arty/Mort

(7) Weapon Code. Planner input codes for designating weapon type for weapon-emplacement of sensors are as follows:

155	155 mm howitzer
105	105 mm howitzer
8	8 inch howitzer
81	81 mm mortar
42	4.2 inch mortar

(II, Arty/Mort 5)

(8) This is the x coordinate of the position of the weapon used for weapon-emplacement of sensors.

(II, Arty/Mort 10)

(9) This is the y coordinate of the position of the weapon used for weapon-emplacement of sensors.

(III, 5, 6, 7)

(10) Coordinates of intended sensor emplacement position. Entries define the conventions adopted for treating this input, which are as follows:

Input Entry No.	Sensor in Open	Sensor by Path
5	0	ID of route
6	X (meters)	Leg Number
7	Y (meters)	Distance along leg

(II, Air Drop 4)

(11) Aircraft Type. The planner input code used is as follows:

1 indicates helicopter

2 indicates fixed-wing prop type

3 indicates fixed-wing jet type

(II, Air Drop 7) (12) Drop speed. This is the speed of the aircraft at the time of sensor deployment.

(II, Air Drop 8) (13) Drop altitude. This is the altitude of the aircraft at the time of sensor deployment.

(II, Air Drop 3) (14) Specification of the particular version of the previously designated generic type of navigation system (see item 6 above.

Designer Input Tables Used in SNPGT

Three designer input tables* are used in subroutine SNPGT. These are:

(1) Table ATMOE (designated Table 4.3-I in the present report) which provides firing table data defining range dispersion and deflection dispersion for the weapons used in the weapon-emplacement of remote unattended sensors.

(2) Table ADROP1 (designated Table 4.3-II in the present report) which provides standard deviation values for along track and across track dispersion of sensors dropped from helicopters, as a function of helicopter velocity and altitude.

(3) Table ADROP2 (designated Table 4.3-III in the present report) which provides standard deviation values for along track and cross track dispersion for sensors dropped from fixed-wing aircraft, as a function of aircraft velocity and altitude.

4.3.2 Moving Sensor Position Errors

Moving sensor position errors as a function of time are determined by subroutine MVS (Step 4 of pre-run) which in turn calls (as required) one of the four navigation subroutines: DOPLER, RHOTHE, HYPERB or NORMER. Subroutine MVS determines ground truth position coordinates, elapsed movement and time and average movement velocity for each moving sensor platform played in the game. The subroutine calculates these data for the initial point of each segment of the movement route and for the movement termination point. Ground truth position reflects the effects of all location errors played. Elapsed time data are dependent upon velocity specified by input. If the sensor platform is constrained to follow a prominent route, elapsed time is adjusted to allow for navigation and map error while the coordinates of each path segment are adjusted only for map error.

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*See also Volume II, Appendix I, Tables I-4, I-5 and I-6

Table 4.3-I

ATMOE DESIGNER INPUT DATA

BALLISTIC DISPERSION OF SENSOR EMPLACEMENT WEAPONS*

RANGE INTERVAL		155MM HOW σ RANGE	155MM HOW σ DEFL	105MM HOW σ RANGE	105MM HOW σ DEFL	8-IN. HOW σ RANGE	8-IN. HOW σ DEFL
0	500						
500	1000						
1000	1500						
1500	2000						
2000	2500			39	22		
2500	3000			48	22		
3000	3500	74	15	54	44		
3500	4000	86	15	59	60		
4000	4500	86	15	68	60	92	37
4500	5000	101	15	71	82	104	37
5000	5500	98	22	86	67	116	37
5500	6000	107	22	68	74	118	44
6000	6500	101	30	74	74	131	37
6500	7000	110	[illegible]	83	74	128	44
7000	7500	119		77	37	140	44
7500	8000	119		83	37	134	52
8000	8500	128	37	89	30	142	52
8500	9000	134	37	85	44	151	44
9000	9500	143	37	89	44	140	52
9500	10000	128	44	95	44	148	52
10000	10500	137	44	108	37	157	52
10500	11000	143	44	92	37	166	44
11000	11500	148	44	128	37	146	52
11500	12000	157	60			154	52
12000	12500	131	60			160	52
12500	13000	137	52			169	52
13000	13500	145	52			178	52
13500	14000	151	52			156	60
14000	14500	160	44			152	60
14500	15000	170	44			157	60
15000	15500					164	60
15500	16000					170	56
16000	16500					179	52
16500	17000					187	52

RANGE INTERVAL		81MM MORT σ RANGE	81MM MORT σ DEFL	4.2-IN. MORT σ RANGE	4.2-IN. MORT σ DEFL
0	200				
200	400	10	27		
400	600	16	27		
600	800	23	43		
800	1000	31	41	38	14
1000	1200	42	61	43	14
1200	1400	49	61	54	20
1400	1600	56	54	60	20
1600	1800	64	74	68	20
1800	2000	73	68	76	27
2000	2200	78	68	84	34
2200	2400	87	61	69	34
2400	2600	89	54	97	34
2600	2800			106	41
2800	3000			114	41
3000	3200			119	47
3200	3400			125	47
3400	3600			136	47
3600	3800			141	47
3800	4000			146	54
4000	4200			154	54
4200	4400			160	54
4400	4600			165	61
4600	4800			171	61
4800	5000			176	67
5000	5200			184	68
5200	5400			190	68
5400	5600			195	68

*All data represent one standard deviation of a normal error distribution.

Table 4.3-II

ADROP1 DESIGNER INPUT DATA

A/C ALTITUDE (ABOVE MSL, METERS)	VELOCITY (M/SEC)			
	0-25		25-50	
	σ ALONG TRACK	σ CROSS TRACK	σ ALONG TRACK	σ CROSS TRACK
0-150	60	20	80	25
150-300	60	20	80	25
300-450	70	20	90	25
450-600	70	20	90	30
600-750	80	20	100	30
750-900	95	25	115	30
900-1050	100	25	125	35
1050-1200	100	25	140	35
1200-1350	100	25	160	40
1350-1500	100	25	175	40

Table 4.3-III

ADROP2 DESIGNER INPUT DATA

A/C ALTITUDE (ABOVE MSL, METERS)	A/C VELOCITY (M/SEC)					
	100-150		150-200		200-250	
	σ ALONG TRACK	σ CROSS TRACK	σ ALONG TRACK	σ CROSS TRACK	σ ALONG TRACK	σ CROSS TRACK
0-150	100	25	110	30	100	25
150-300	110	25	110	30	110	25
300-450	110	25	120	30	120	30
450-600	120	30	120	30	130	30
600-750	120	30	130	35	140	35
750-900	130	30	130	35	150	35
900-1050	130	35	140	40	150	40
1050-1200	140	35	140	40	160	40
1200-1350	140	35	150	40	180	45
1350-1500	140	35	150	40	180	45

4.3.2.1 Processing to Determine Moving Sensor Position Errors

A macroflow of the treatment of moving sensor position error as a function of time is shown in Figure 4.3-2.

If map error is to be played, the error parameter and error components are selected and added to path segment coordinates. Map error data used at the start of the movement is held to be played at the end of the movement if it is terminated at the starting point.

Velocity control factor (MFAC) used to vary the velocity on each movement leg is obtained and the leg velocity calculated.

If navigation error is not played, elapsed time data is calculated and stored. If navigation error is played, the appropriate navigation system error subroutine is called.

If the sensor platform is not constrained to follow a trail, navigation system error is combined with path segment coordinates which are then used to calculate elapsed time data. The coordinates and time data are then stored. If the sensor platform does follow an established route, then navigation system error is used to adjust the time required (elapsed time) for the platform to reach the starting point of the path leg under consideration. If this error vector is oriented within 90° of the direction of movement, the elapsed time is reduced indicating that the error in determining position along the trail caused early arrival at that point of the trail. If the opposite is true, the time is decreased. If neither case is true, the time is not changed.

4.3.2.2 Description of Inputs

The following are descriptions of planner inputs required for those portions of subroutine MVS that determine ground truth position of moving sensors in the game. The parenthetical designations for each input description reference the corresponding entries in the master input table description given in Appendix F of the User's Manual (Volume II of this report). The first element in each such designation (the roman numeral) references a data set in Appendix F; the second element (the arabic numeral) references a particular entry in the aforesaid data set.

(XX, 6) (1) ID number of the moving sensor system of which this sensor is a part.

(XX, 4) (2) Number of sensors included within the moving sensor system of which this sensor is a part.

(XX, 5) (3) ID number of first sensor of the moving sensor system of which this sensor is a part.

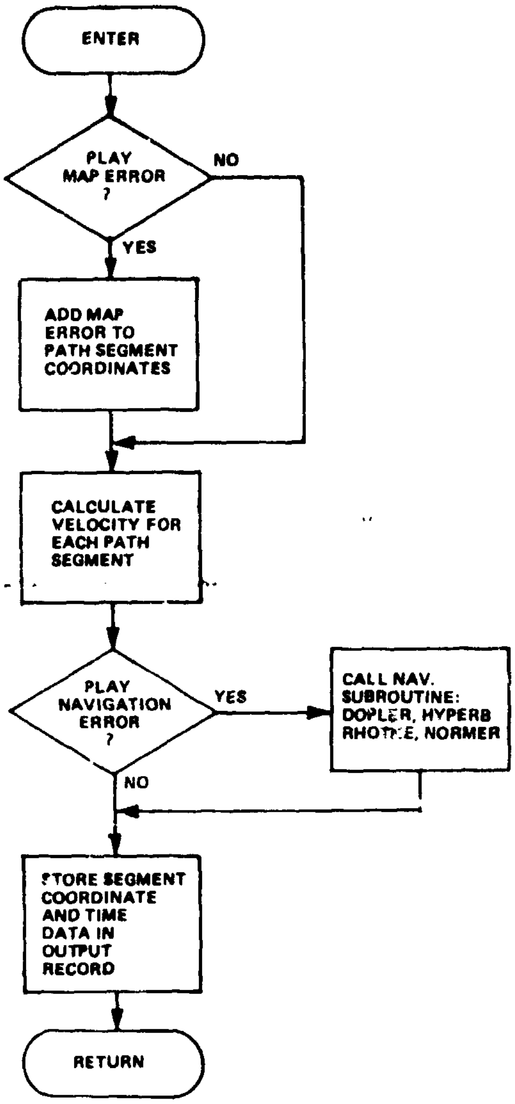


Figure 4.3-2 MOVING SENSOR POSITION ERROR MACROFLOW

(II, 3) (4) Type of navigation system specified for this moving sensor system. Planner input codes are interpreted as follows:

0	Perfect navigation system (i.e., no navigation error)
1	Hyperbolic navigations system
2	Rho Theta type navigation
3	Doppler Navigation system
4	No specific type navigation system specified, but Gaussian errors played, determined by designer input standard deviation value.

(XX, 8) (5) Specification of particular version of selected generic type of navigation system. Code (1, 2, 3, 4) that indicates which version is applicable to this moving sensor system; planner inputs appropriate data sets XV, XVI, XVII, XVIII. If Item (4) above is zero, the present input item is left blank.

(XX, 9) (6) Probability of mission abort due to causes other than day/night timing of mission, sensor failure, ceiling or visibility conditions.

(XX, 10) (7) Day/Night mission constraint code, as follows:

0 Mission can occur in daylight only
1 Mission can occur at night only
2 No day/night constraint on mission.

(XX, 11) (8) Minimum ceiling conditions under which mission can occur, meters to ceiling.

(XX, 12) (9) Minimum visibility conditions under which mission can occur, meters visibility.

(XXI, 6) (10) Planned game time of mission initiation.

(XXI, 10) (11) Node at which moving sensor system mission begins and node at which it ends.

(XXI, 9) (12) ID of route[*] specified by planner to be taken for the moving sensor system mission.

(XXI, 11) (13) Nominal speed of moving sensor mission in km/hr.

4.3.3. Subroutine DOPLER[**]

Subroutine DOPLER generates X and Y components of system error expected from a Doppler navigation system. This error is proportional to the time of flight and is, therefore, cumulative. The present simulation, however, provides for updating the Doppler system at a specified navigation checkpoint along the flight path and generates applicable updated system error components.

4.3.3.1 General Description of Processing

A macroflow for subroutine DOPLER is shown in Figure4.3-3. The sequence of processing is as follows:

1. (1) Navigation system error parameters and the factor for system up-dating are obtained from the DOPLER navigation parameter table.
2. (2) One standard deviation of error for registering the system at the take-off point is obtained at the start point of the second leg. The error distribution is assumed to be circular normal.
3. (3) Distance and time involved in traversing the leg are calculated.
4. (4) One standard deviation of along-track and cross-track components of Doppler error are calculated.
5. (5) Along track error and cross track error parameters are combined.
6. (6) The angular slope (Theta) of the flight path, measured from the positive X-axis, is derived. Random normal deviates of along-track and cross-track error components are selected.

---

[*] Detailed treatment of path input data for a designated route is described in data set XII presented in Appendix F of Volume II of this report.

[**] The mathematical relationships represented in the subroutine DOPLER are taken from "The Covariance of Position Location," Stanford Research Institute Project 5205, November 1968.

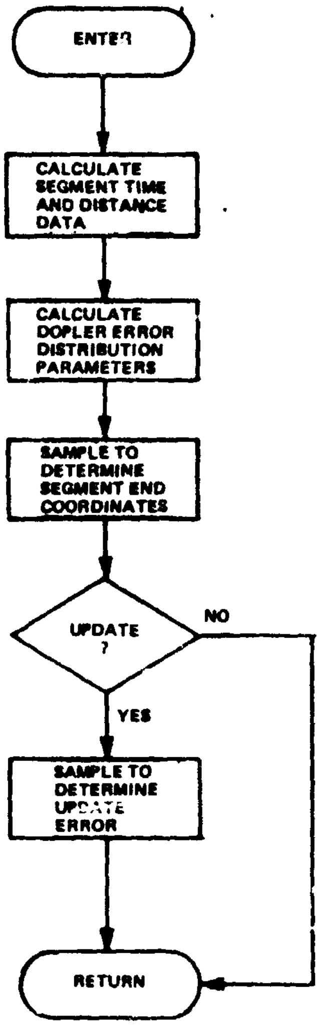


Figure 4.3-3 SUBROUTINE DOPLER MACROFLOW

(7) The X and Y components of along-track error and of cross-track error are calculated and added to obtain the desired output.

(8) The Doppler system updating is assumed to occur at the initial point of a flight path segment. If updating is called for then one standard deviation of the error distribution (assumed to be circular normal) is calculated from aircraft altitude and the error factor.

(9) Random normal deviates of updated system error are selected as output of the subroutine.

4.3.3.2 Description of Inputs to Subroutine DOPLER

The input structure for subroutine DOPLER is designed to accept a planner code (1, 2, 3, 4) specifying which of four input performance parameter sets is to be played. For a given equipment performance parameter set the following input values are required:*

(1) Standard deviation of error in registering system at movement initiation point (meters).

(2) Standard deviation of flight updating error (Percent/100 that is applied to altitude above ground.

(3) System Noise Bandwidth (1/microsecond).

(4) Standard deviation of along-track sensor error (meters).

(5) Standard deviation of along-track computer error (meters).

(6) Standard deviation of cross-track sensor error (meters).

(7) Standard deviation of cross-track computer error (meters).

4.3.4 Subroutine RHOTHE**

Subroutine RHOTHE generates X and Y components of error representative of a Rho-Theta radar tracking navigation system utilizing a barometric altimeter for independent altitude measurement.

---

*See Data Set XVII, Appendix F, Volume II. A designer input table is also currently included in model for these parameters containing one set of values to which the program will default if planner inputs not supplied. (See Vol. II, App. I, Table I-9)

**The mathematical relationships represented in the subroutine RHOTHE program are taken from "The Covariance of Position Location," Stanford Research Institute Project 5205, November 1968.

4.3.4.1 General Description of Processing

A macroflow diagram for subroutine RHOTHE is shown in Figure 4.3-4. The sequence of processing is as follows:

(1) Navigation system ground station location and one standard deviation value of system component errors are obtained from the PRNV2 (navigation parameter) table.

(2) The square of ground range (DD1) and of slant range (DD2) to the sensor platform are calculated.

(3) One standard deviation of the ground plane component of range error (GRRS) and azimuth error (GRAS) are calculated.

(4) Slope (THETA, measured from position X axis) of the line joining the ground station and the sensor's projected X, Y position is determined for use in computing X and Y components of range and azimuth error. Random normal deviates of range and azimuth error are selected. X and Y components of error are obtained.

(5) Range and azimuth error components are combined.

4.3.4.2 Description of Inputs to Subroutine RHOTHE

The input structure for subroutine RHOTHE is designed to accept a planner code (1, 2, 3, 4) specifying which of four input equipment performance parameter sets is to be played. For a given equipment performance parameter set the following input values are required:*

(1) Standard deviation of ground station location error (meters).

(2) Standard deviation of system direction resolution error (mils).

(3) Standard deviation of system range-resolution error (meters).

(4) Standard deviation of altitude-resolution error (meters).

(5) X-coordinate of ground station location (meters).

(6) Y-coordinate of ground station location (meters).

(7) Elevation above MSL of ground station location (meters).

---

*See Data Set XVI, Appendix F, Volume II. A designer input table (Vol. II, App. I, Table VII) is also currently included in model for checkout purposes. One set of values is included to which program will default if planner inputs not supplied. Since parameters are scenario dependent, designer table should not be used.

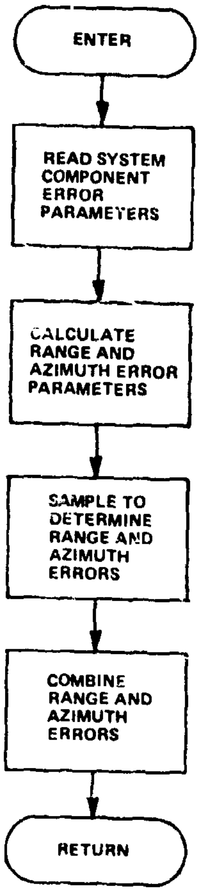


Figure 4.3-4 **SUBROUTINE** RHOTHE MACROFLOW

4.3.5 Subroutine HYPERB[*]

Subroutine HYPERB permits the planner to play navigation system error for a four-station (three slaves and one master) hyperbolic navigation system. Although typically used for airborne sensor platforms (or aerial vehicles used for sensor emplacement missions), HYPERB is also applicable to ground movements, either along prominent trails or over unrestricted routes. The subroutine derives the position error vector that results for each of the three station pair combinations, then selects the one of smallest magnitude for deriving the output error components of the subroutine.

4.3.5.1 General Description of Processing

A macroflow diagram for subroutine HYPERB is shown in Figure 4.3-5 .The processing sequence followed in the subroutine is as follows:

(1) System ground station location and error components are obtained from the navigation parameter (PRNV1) table.

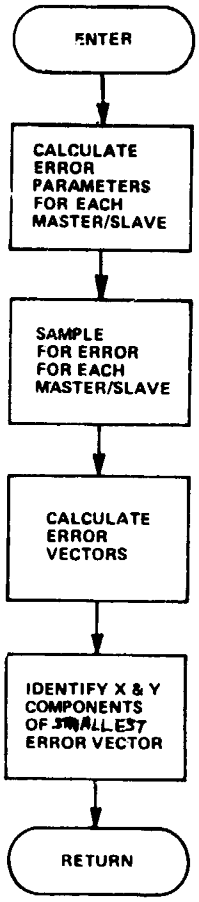
(2) Slope of the line (BETA, measured in the ground plane from positive X-axis) between ground stations and the platform is determined. The angle, ALPH, between the above mentioned line and a line of position to the platform is determined. The time difference from the particular master-slave combination under consideration.

(3) If one master-slave combination cannot be used, then error for the remaining two combinations are calculated. This error (SG) is one standard deviation of a lineal normal distribution oriented at right angles to the line of position. The slope of the line of position, (THET, measured clockwise from the positive X-axis) is also calculated. Random normal deviates of this error are selected.

(4) If all three master-slave combinations are useable, then three sets of error parameters described in Item (3) above are calculated. Random normal deviates of these errors are selected.

---

[*] Mathematical relationships represented in subroutine HYPERB are taken from the following sources: "The Covariance of Position Location," Stanford Research Institute Project 5205, November 1968; and LORAN," MIT Radiation Laboratory Series, 1948.



4.3-5 SUBROUTINE HYPERB MACROFLOW

(5) X and Y components of the selected error values are calculated.

(6) RERR is called to find the point of intersection of two lines, one passing thru the point E1X, E1Y and parallel to the line of position with slope THET1 and the other passing thru the point E2X, E2Y and parallel to the line of position with slope THET2. The vector from the sensor position to the above point of intersection is the navigation error vector for the station pair considered. All three possible error vectors are calculated.

(7) The smallest of the three error vectors is selected and its X-Y components identified.

(8) If the movement is not confined to a trail, the data referred to above ' provided as output of the subroutine representing hyperbolic navigation system error. If not, then the flow on sheet 4 projects the previously determined error vector on to the trail segments and determines the size of the along-trail component of error. If the direction of the error vector is within 90 degrees of the previous trail segment, then it is projected onto that segment. This procedure is followed also, if the vector has been determined for the end point of the trail (NSLEG=0). If the direction of the vector is within 90 degrees of the present trail segment, it is projected onto that segment. If the error vector's orientation does not fall into either of these two categories then the sensor

(9) Is assumed to be located at the junction of the two trail segments (identical to considering the error vector to have zero magnitude). The X and Y components of the projection of the error vector onto the trail segments are calculated and provided as output to the subroutine for movements confined to a trail.

4.3.5.2 Description of Inputs to Subroutine HYPERB

The input structure for subroutine HYPERB is designed to accept a planner code (1, 2, 3, 4) specifying which four equipment performance parameter sets is to be played. For a given equipment performance parameter set the following input values are required:*

---

*See Data Set XV, Appendix F, Volume II. A designer table (Vol. II, App. I, Table VII) is also currently included in model for checkout purposes. One set of values is included to which program will default if planner inputs not supplied. Since parameters are scenario dependent, designer table should not be used.

(1) Standard deviation of ground station location error (meters).

(2) Standard deviation of system time difference measurement error (microseconds).

(3) X-coordinate, Slave Station Number 1 (meters).

(4) Y-coordinate, Slave Station Number 1 (meters).

(5) X-coordinate, Slave Station Number 2 (meters).

(6) Y-coordinate, Slave Station Number 2 (meters).

(7) X-coordinate, Slave Station Number 3 (meters).

(8) Y-coordinate, Slave Station Number 3 (meters).

(9) X-coordinate, Master Station (meters).

(10) Y-coordinate, Master Station (meters).

4.3.6 Subroutine NORMER

Subroutine NORMER allows the game planner to play navigation error expected when position location is determined in open terrain from maps and visual sightings. This type of navigation may be used from ground positions or from aircraft. For the former use, the subroutine is designed to apply either when movement is constrained to follow a prominent trail (for which the planner must provide trail segment coordinates) or when it is not constrained to follow a trail.

4.3.6.1 Description of Processing

A macroflow for subroutine NORMER is shown in Figure 4.3-6. The following processing sequence is accomplished in the subroutine:

(1) One standard deviation of navigation location error is obtained from the input table. The error distribution is assumed to be circular normal.

(2) Random normal deviates are selected. These are the X and Y components of error provided when the movement does not follow a trail.

(3) When the movement follows a trail, a random normal deviate is selected to represent the navigation error vector. It is assumed to be oriented parallel to the trail segment. This vector is assumed to be directed

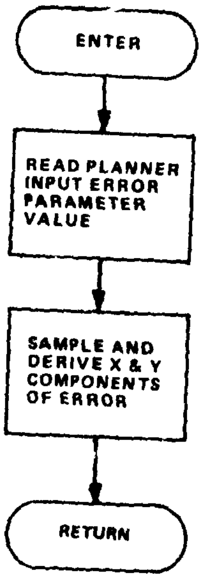


Figure 4.3-6 SUBROUTINE NORMER MACROFLOW

toward the starting point of the previous trail segment if the random deviate is negative, and toward the starting point of the next segment if positive. It is also assumed to be directed toward the starting point of the previous trail segment when the error for the end point (NSLEG = 0) of the trail is obtained.

(4) The angle, THETA, is derived for use in obtaining X and Y error components.

(5) The X and Y components of **NORMER** error are derived.

4.3.6.2 Description of Inputs to Subroutine NORMER

The input structure for subroutine NORMER is designed to accept a planner code (1, 2, 3, 4) specifying which of four navigation error standard deviation values is to be played in the game. When NORMER is exercised in the game, this standard deviation value is its sole input. NORMER inputs are described in Data Set XVIII, Appendix F, Volume II of this report.*

4.4 SUBROUTINE ELPDT

The purpose of subroutine ELPDT is to determine, for each sensor played in the game, the periods of game time during which one or more valid targets for the sensor (that is, targets of a type the sensor is designed to detect (see Table 4.4.I)for valid sensor/target combinations) are in such proximity to the sensor that sensor/target range and geometry alone would not necessarily prevent detection. Subroutine ELPDT (together with the sensor-to-target line-of-sight subroutine)**performs a screening function in order that the sensor performance subroutines need only be called in the Main Simulation Model during those game time periods within which sensor performance per se is the principal variable that will determine whether or not detection occurs.

4.4.1 Summary Description of ELPDT Processing

A macroflow diagram of subroutine ELPDT is presented in Figure 4.4-1. For each valid sensor/target combination, appropriate items of input data are compared to determine the answers to the following questions:

(1) Are both this sensor and this target simultaneously active in the game during one or more periods within total game time?

---

[*] A designer table (Vol. II, Appendix I, Table X) is also included in present model. This was used for checkout purposes and program defaults to it if planner inputs not supplied.

[**] Table 4.4-II shows sensor/target line-of-sight dependence as played in the game.

Table 4.4-I

DESIGN INPUT FOR VALID SENSOR TARGET COMBINATIONS

TARGET CATEGORY

GENERIC SENSOR TYPE	INDIV	SQD	PLAT	CO	SMVECH	HVYTRK	TANK	TRAIN	HELO	LTA/C	JETA/C	RAFT	OUTBRD	PTBOAT	LT AMMO	MD AMMO	HVY AMMO	SMANIM	LGANIM	CODE ***
SEISMIC	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	1
ACOUSTIC	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	2
MAGNETIC*	X	X	X	X	X	X	X	X											X	1
ARFBUOY	X	X	X	X	X	X	X												X	1
PASSIVIR	X	X	X	X	X	X	X	X				X	X	X					X	1
RADAR**	X	X	X	X	X	X	X	X				X	X	X					X	1
IMAGE	X	X	X	X	X	X	X	X				X	X	X					X	2
THERMVEW	X	X	X	X	X	X	X	X				X	X	X					X	2
BREAKWIR	X	X	X	X	X	X	X					X	X	X					X	1
																****				

---

* A valid target for a magnetic sensor must have ferrous metal present, indicated by A '1' in Item 2 in the Force Type Parameter Set Input (Appendix F - Data Set XIII).

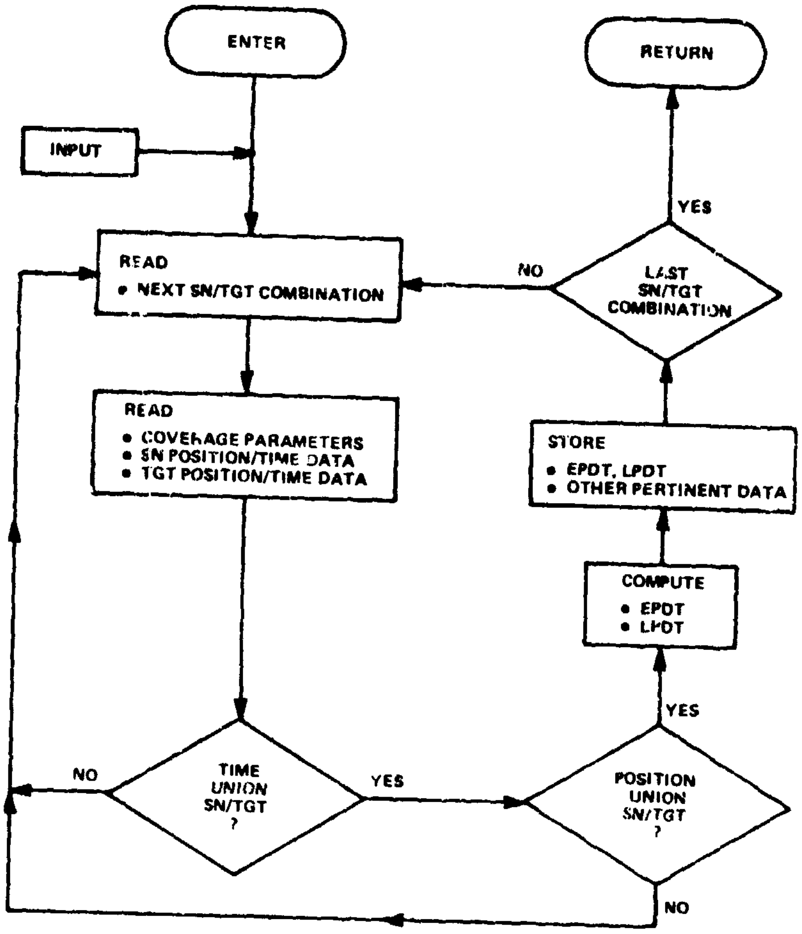
** RADARS in SAM-I are MTI-type thus targets with a nominal velocity less than half the MTI criterion are not valid targets. (A multiplier of two is used to account for forward and reverse speed factors that may be played.

*** 0 - Detects only stationary targets

1 - Detects only moving targets

2 - Detects both stationary and moving targets

**** The entries in these target categories are from CULTURE and BATTLE only; other target categories may be from either BLUE or RED Force inputs plus CULTURE or BATTLE as appropriate.



4.4-1 SUBROUTINE ELPDT MACROFLOW

Table 4.4-II

DESIGN INPUT FOR LOS DEPENDENCE

SEISMIC	NO
ACOUSTIC	NO
MAGNETIC	NO
ARFBUOY	NO
BREAKWIR	NO
PASSIVIR	ASSUMED
RADAR (STATIONARY)	YES
RADAR (MOVING/AIR)	YES
IMAGE (STATIONARY)	YES
IMAGE (MOVING/GROUND)	YES
IMAGE (MOVING/AIR)	YES
THERMVEW (STATIONARY)	YES
THERMVEW (MOVING/GROUND)	YES
THERMVEW (MOVING/AIR)	YES

(2) Assuming an answer in the affirmative to (1) above, do sensor/target geometrical relationships occur one or more times such that detection of the target by the sensor would not necessarily be impossible?

For cases where both of the above questions are answered in the affirmative, the subroutine calculates (for each sensor-to-target exposure) the earliest possible game time of detection and the latest possible game time of detection.

For the processing accomplished by subroutine ELPDT, all targets are assumed to be on straight-line paths and moving with a constant velocity.* The target position is given by specifying the x and y coordinates and the times for each of the end points of these path segments. The target may be stationary, in which case the coordinates of the end points are the same. Targets moving along more than one straight-line segment of a path are treated as separate targets, and the information given for each straight-line segment.

Sensors are assumed to have either rectangular coverage or circular sector coverage. Examples of circular sensor coverage are shown in Figure 4.4-2. Examples of rectangular sensor coverage are shown in Figure 4.4-3. Target straight-line path segments intersecting various sensor coverage patterns are shown in Figure 4.4-4. (Sensor number two depicted in Figure 4.4-4 is represented as having the coverage of a degenerate rectangle--that is, the sides of the rectangle parallel to the line of target movement are represented as having zero length. Sensors number one, three and four in the figure are represented as having forms of circular coverage.)

All moving sensors must have rectangular coverage in the present version of the model. Two of the sides of the coverage rectangle must be parallel to the line of sensor movement.

The coverage parameters for the circular type coverage are the minimum and maximum radii of the concentric circles (see Figure 4.4-2, and if sector coverage is to be represented the coverage angle and the orientation angle (the center of the sector) must be specified. The minimum radius may be zero (as in the case of a seismic sensor) or it may be equal to the maximum radius (as in the case of a breakwire deployed in the form of a circle). The sector coverage angle may be zero or may be 360°. If circular coverage (i.e., complete circle) is to be represented, it is specified by using a coverage angle equal to or greater than 6.28 radians.

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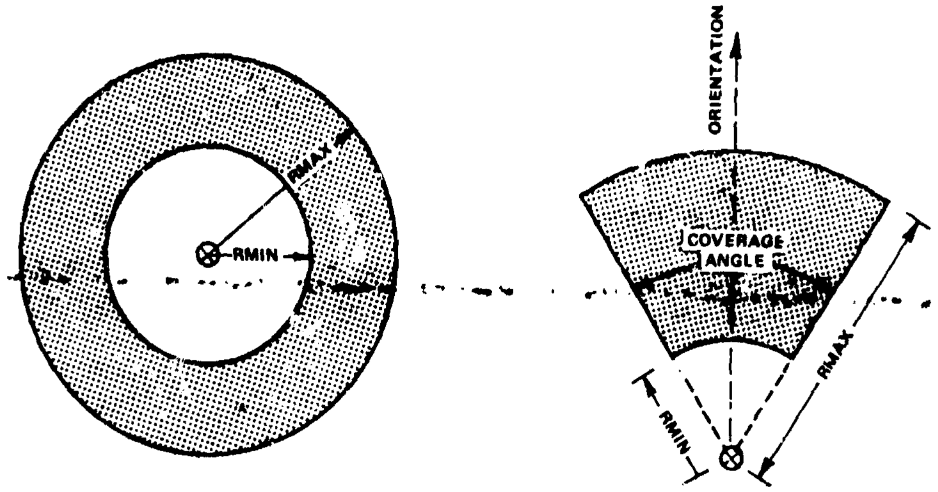
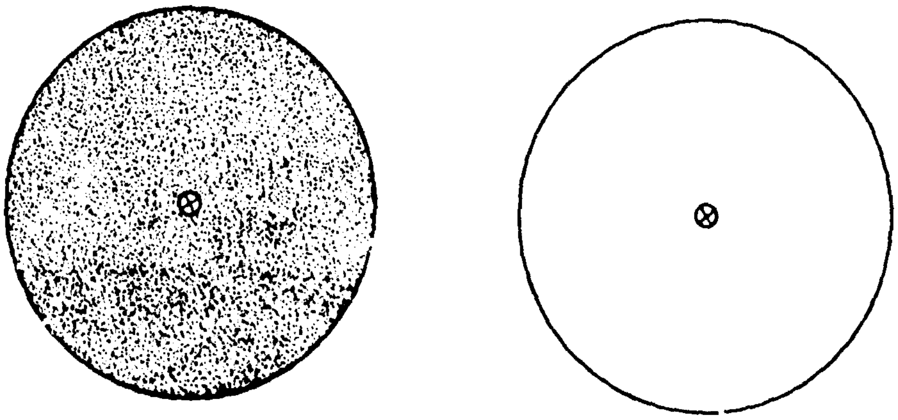
[*] Sensor movement representation is identical to that of target movement.



RMIN ≠ RMAX (PPS-25 RADAR)

SECTOR COVERAGE (PPS-5 RADAR)



RMIN = 0 (SEISMIC SENSOR)

RMIN = RMAX (BREAKWIRE)

Figure 4.4-2 CIRCULAR COVERAGE GEOMETRIES

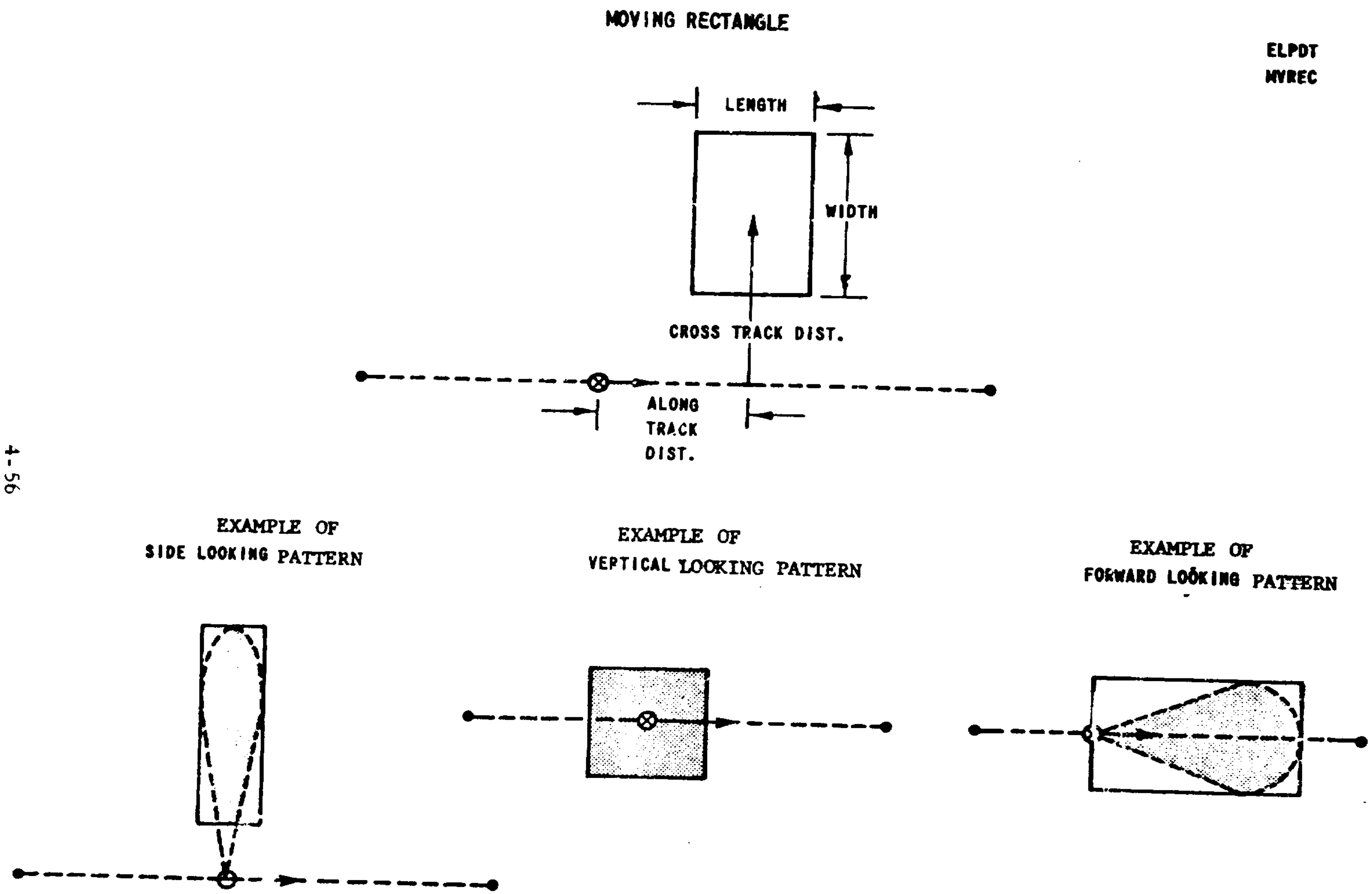


Figure 4.4-3 RECTANGULAR COVERAGE GEOMETRIES

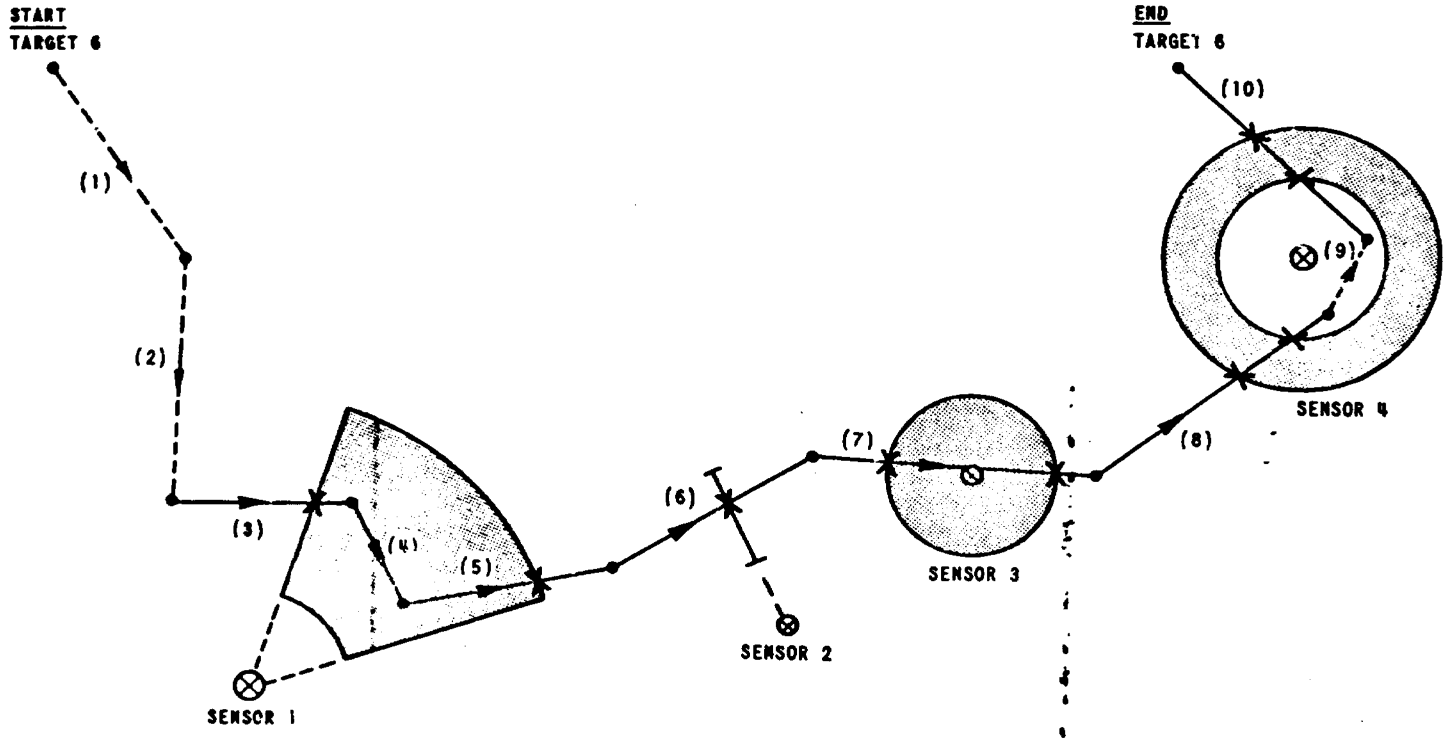


Figure 4.4-4 STATIONARY SENSOR COVERAGE vs MOVING TARGET

The coverage parameters for rectangular coverage are the orientation angle (must be parallel to the line of sensor motion in the case of moving sensors and parallel to the path segment in the case of stationary sensors located relative to a path); the location of the center of the rectangle relative to the sensor position, specified by the distance parallel to the path (and in the direction of the path) and perpendicular to the path (and to the left of the path); the length of the rectangle (parallel to the path) and the width of the rectangle (perpendicular to the path). The rectangle may have zero width and/or zero length.

Subroutine ELPDT treats one sensor at a time and computes possible detections by using the sector routine (SECT) or the rectangular routine (GREC). The (x, y) position of the sensor and the target are defined by a linear parametric form using time as a parameter.

Valid sensor/target combinations (see Table 4.4-I), line-of-sight dependence (see Table 4.4-II and type of target (used to select the proper maximum and minimum radii or the coverage rectangle dimensions) are determined by use of subroutine VALID.

4.4.2 Summary of Inputs to Subroutine ELPDT

Tables 4.4-III and 4.4-IV summarize the sensor-related and target-related inputs, respectively, required for subroutine ELPDT.

Table 4.4-III

SENSOR-RELATED INPUTS TO SUBROUTINE ELPDT

STATIONARY SENSORS	MOVING SENSORS
SENSOR ID NUMBER	SENSOR ID NUMBER
SENSOR GROUND TRUTH POSITON	GROUND TRUTH PATH AND PATH SEGMENT END POINTS
SENSOR ORIENTATION	PATH SEGMENT INITIAL TIMES
SENSOR "UP" GAME TIMES	PATH SEGMENT END TIMES
SENSOR "DOWN" GAME TIMES	

Table 4.4-IV

TARGET-RELATED INPUTS TO SUBROUTINE ELPDT

STATIONARY TARGETS	MOVING TARGETS
TARGET ID NUMBER	TARGET ID NUMBER
TARGET (X'Y) COORDINATES	TARGET MOVEMENT PATH AND PATH SEGMENT END POINTS
TARGET "UP" GAME TIMES	PATH SEGMENT INITIAL GAME TIMES
TARGET "DOWN" GAME TIMES	PATH SEGMENT END GAME TIMES

4.5 FALSE ALARMS

In the System Assessment Model (SAM), random false alarms are explicitly simulated for five generic types of sensors: seismic, acoustic, passive IR, airbuoy and breakwire. In terms of program sequencing, false alarm time histories are generated for each sensor in these five categories within PRERUN Job Step 7. Within this job step, a special purpose random number generator, FAINTV, is invoked to provide random time intervals with the statistical properties appropriate to (a) sensor type and (b) environment-dependent input argument that controls the mean time between false alarms.

The corresponding events, temporarily stored on disk, are subsequently merged into time sequence with all other simulation events, and passed to MSM for final processing.

In the overall model, "false alarms" are distinguished from "false targets", even though in some cases the final effects might appear similar in the sensor output histories. Detailed discussion of the distinction would eventually require a separation by sensor type. But in general, false alarms differ from false target alarms by the following criteria:

(a) false alarms from one sensor are statistically independent of false alarms from any other sensor*

---

* False or real targets generally cause sensor reports to be correlated, if the sensors are sufficiently close to one another. A munitions explosion, for example, excites seismic or acoustic sensors in an array at nearly the same time. Vehicle, personnel or most large-animal movements tend to excite sensors in a definite time sequence, depending upon sensor placement geometries relative to path of motion.

(b) a specific false alarm cannot be keyed to any external "thing" that is controlled by the planner, or that can be explicitly identified as to identity, position and time.

In practice, the dichotomy between false alarms and false targets has been modeled with no significant ambiguity. Some examples of resolution might be:

(a) Rain, wind: Detailed variations not controlled and not identifiable as to exact locations and times. Sensor responses classified as false alarms.

(b) Battlefield activity: Produces both false targets and false alarms. For effects that can be associated with definite times and positions (e.g., munitions firing or impact, personnel, casual military aircraft flights, vehicles), corresponding sensor responses are considered to be caused by targets. However, the general background noise (seismic and acoustic) caused by, say, munitions fire affects sensor background noise levels, and may cause or affect false alarms.

(c) Cultural activity: Comments are similar to those for battlefield activity. Definite civilian traffic, for example, generates false targets. General background noise level caused, for example, by activity within a village or city, affects false alarms.

4.5.1 False Alarm Statistics

The physical and logical mechanisms of false alarms differ among the five generic sensor types considered:

For ARFBUOY sensors, a false alarm corresponds to a dislodgment of a bomblet or bomblets by something too indefinite to be considered a target. These dislodgments occur most frequently during heavy rains and/or winds. An exponential distribution of times between false alarms was assumed.

For breakwire sensors, breakage in a target free environment tends to be infrequent, except when moderate to heavy winds occur (especially if local vegetation can be blown against the wire). For a fixed environment, the time to breakage was simulated as a random variable with exponential distribution .

Seismic, acoustic and passive IR sensors have a somewhat common logic. First, transducers convert physical signals (e.g., seismic vibrations) into internal voltage signals. Second, internal voltages are compared with a reference or threshold voltage; when the voltage exceeds the reference, a so-called "threshold crossing" is said to exist. Third, a single threshold crossing does not generate an alarm. Rather, an alarm is defined by logic of the form: alarm occurs if N threshold crossings occur within a time interval of T seconds. Specific values (designer values) for N and T are:

	N	T
Seismic	4	6.
Acoustic	4	6.
Passive IR	2	1.5

And fourth, for these sensors there is a period of sensor deactivation -- a dead zone -- following any alarm. The value of this dead time interval is 15 seconds for seismic and acoustic, 1.5 seconds for passive IR.

Simulation of the constant dead times is trivial, so consider the random component of the time between false alarms. The general theory of noise signals makes it a reasonable assumption that threshold crossing times are exponentially distributed (equivalently, the number of threshold crossings per fixed time interval is Poisson distributed). It does not, however, follow rigorously that the corresponding times between false alarms are also exponentially distributed.

Indeed, the exact theory of false alarm time intervals proved extremely difficult. Fortunately, an approximate theory valid in the range of practical sensor sensitivity (threshold) settings was found, and was verified by comparison with "exact" simulations*. This theory not only indicated that an exponential distribution fitted false alarm times (ignoring the constant dead time), but it also provided estimates of the parameter (mean time between false alarms) in terms of known parameters. A summary of these results is given in Figure 4.5-1.

4.5.2 Subprogram FAINTV

A special purpose random number generator was coded to provide random inter-false-alarm time intervals for the five types of sensors. The name, FAINTV, is an acronym for False Alarm INTerVal. A function-type subprogram, it supplies at each call a random time interval value that (a) is independent of all previous values, (b) gives a value that is the sum of a constant value (dead time) plus a random expo-

---

* Initially, it was planned to simulate false alarm time intervals using the brute-force "exact" simulation program. Although the final version program is far superior in terms of speed, the initial program proved useful for numerical verification of validity of the approximations.

Threshold crossings:	Assumed exponential distribution for times between crossings, with parameter (average time) τ_0
False alarms:	Generated whenever N threshold crossings occur within T seconds.
Distribution of false alarm times:	For the practical cases of sensor settings, τ_0 is larger than T. In such cases, the time t between false alarms is very nearly exponentially distributed. The corresponding parameter (mean time between false alarms), $\bar{t}$, is closely approximated by the formula below.

$$\bar{t} \cong T\,(N-1)!\; e^{\frac{N}{2\tau_0}} \left(\frac{\tau_0}{T}\right)^{N} + T$$

For seismic and acoustic sensors (N = 4, T = 6):

$$\bar{t} \cong \frac{e^{4.66/\tau_0}\ \tau_0^{4}}{36} + 6$$

For passive infrared sensors (N = 2, T = 1.5):

$$\bar{t} \cong \frac{e^{2.33/\tau_0}\ \tau_0^{2}}{1.5} + 1.5$$

Because theory is only approximate, numerical experimentation using exact simulations was used to verify both the shape of the distribution, and the estimates of parameters. Agreement was verified for the specific cases (seismic, acoustic and passive infrared) of interest.

Figure 4.5-1

SUMMARY OF FALSE ALARM STATISTICAL THEORY nentially distributed variate. The input parameters are (a) sensor type code, and (b) mean time between threshold crossings. The COMMENTS portion of the program listing, reproduced in Fig. 4.5-2, summarizes its basic features as a subprogram.

As mentioned, FAINTV is used within PRERUN Job Step 7. The input argument (b) (mean time between threshold crossings) is determined on a time varying basis by sensor background routines, and reflects changes in atmospheric, battlefield and cultural environment.

```
C************************************ FAINTV ****************************
C*                                                                      *
C*                            FUNCTION FAINTV                           *
C*                                                                      *
C*    PURPOSE                                                           *
C*        SPECIAL PURPOSE RANDOM NUMBER GENERATOR.  PROVIDES            *
C*        RANDOM FALSE ALARM TIME INTERVALS FOR 5 TYPES OF              *
C*        SENSORS, WITH STATISTICS APPROPRIATE TO (A) SENSOR            *
C*        LOGIC AND (B) AN AVERAGE TIME PARAMETER SUPPLIED              *
C*        AS AN INPUT VARIABLE.                                         *
C*                                                                      *
C*    USAGE                                                             *
C*        TIME = FAINTV (AVGT, ITYPSN)                                  *
C*                                                                      *
C*    DESCRIPTION OF PARAMETERS                                         *
C*        ITYPSN   INTEGER CODE FOR SENSOR GENERIC TYPE.                *
C*                  VALID VALUES ARE 1 (SEISMIC), 2 (ACOUSTIC),         *
C*                 4 (ARFBUOY), 5 (PASSIVIR), AND 9 (BREAKWIR).         *
C*                                                                      *
C*        AVGT     FOR ARFBUOY AND BREAKWIR, = AVERAGE FALSE            *
C*                 ALARM TIME.  FOR OTHER SENSOR TYPES, = AVERAGE       *
C*                 THRESHOLD CROSSING TIME.                             *
C*                                                                      *
C*    REMARKS:                                                          *
C*        1. ALL FALSE ALARM TIME INTERVALS ASSUMED TO HAVE EXPO-       *
C*           NENTIAL PROBABILITY DISTRIBUTIONS (POISSON PROCESS).       *
C*           THE APPROPRIATE PARAMETER DEPENDS UPON SENSOR LOGIC.       *
C*           FORMULAS USED FOR THE NON-TRIVIAL CASES ARE APPROXI-       *
C*           MATE, BUT VERIFIED AGAINST EMPIRICAL RESULTS OF A          *
C*           PREVIOUS 'BRUTE FORCE' FAINTV ALGORITHM.                   *
C*                                                                      *
C*        2. THIS FAINTV ROUTINE REPLACES ALL PREVIOUS VERSIONS,        *
C*           THAT WERE LESS GENERAL AND/OR REQUIRED EXCESSIVE           *
C*           COMPUTATIONAL TIME.  NOTE THAT CALLING SEQUENCE            *
C*           DIFFERS FROM PREVIOUS VERSIONS.                            *
C*                                                                      *
C*        3. DESIGNER VALUES ARE USED IN PROGRAM FOR THE N AND T        *
C*           IN 'FALSE ALARM WHEN N THRESHOLD CROSSINGS IN T            *
C*           SECONDS', AND FOR THE DEAD TIME (SENSOR INACTIVATED)       *
C*           FOLLOWING A FALSE ALARM.  SPECIFICALLY...                  *
C*                                                                      *
C*                            N         T         DEAD TIME             *
C*                 SEISMIC    4     6 SECONDS    15 SECONDS             *
C*                 ACOUSTIC   4     6 SECONDS    15 SECONDS             *
C*                 PASSIVIR   2   1.5 SECONDS   1.5 SECONDS             *
C*                 ARFBUOY    1    IRRELEVANT    0 SECONDS              *
C*                 BREAKWIR   1    IRRELEVANT    0 SECONDS              *
C*                                                                      *
C*        4. ERROR PROTECTION FOR AN INVALID ITYPSN IN CALL.            *
C*           DIAGNOSTIC MESSAGE IS PRINTED, 'VERY LARGE' VALUE          *
C*           IS SUPPLIED AS FUNCTION VALUE, AND PROGRAM CONTINUES.      *
C*                                                                      *
C*    SUBROUTINE AND FUNCTION SUBPROGRAMS REQUIRED                      *
C*        URN      (UNIFORM RANDOM NUMBER GENERATOR)                    *
C*                                                                      *
C*        15 OCTOBER 1970                                               *
C*                                                                      *
C***************************                                          ***
```

Figure 4.5-2 COMMENTS FOR SUBPROGRAM FAINTV

4.6 LINE OF SIGHT

For those sensors that are line-of-sight (LOS*) dependent, the system model provides evaluations of line of sight. These evaluations are made in PRERUN Job Step 9, after initial screening has been completed for the nominal time and geometry intersections of targets with nominal sensor coverage patterns.

It was early established that the primary method of LOS evaluation would be based on direct calculation using digital terrain data of moderately high resolution. The scope of the storage problem was established then by: (a) maximum size scenario area, and (b) the final resolution chosen for terrain data. For the former, the design value specified at the beginning was 30 km by 30 km. For the latter, a nominal value of 100 meters** was jointly accepted by CAL and CDC/ISA as an acceptable compromise between conflicting storage and accuracy requirements.

Thus, a data base potentially including some 90,000 terrain height values became a major consideration in the design of the corresponding program structure. In particular, an otherwise desirable placement of LOS calculations in MSM, where each LOS calculation might be dynamically requested as needed, was judged completely infeasible in terms of core storage, access times to peripheral storage, and computing time.***

---

* In this section, "LOS" will refer to the phrase "line of sight;" it is also the specific name of the major line of sight subroutine. In context, the particular meaning will be self-evident.

** Actual value about 101.6 meters. See Section 5.3.1.

*** A design goal was to hold all major data storage areas to total of about 30,000 computer words. Final version of MSM uses over 20,000 words for data other than terrain heights.

Consequently, LOS calculations were assigned as a PRERUN task, and a distinct job step, so that:

(a) When LOS calculations are being made, all of available storage can temporarily be dedicated to terrain data and line of sight programs.

(b) Partly because of core-storage efficiencies implied by (a), and partly because sequencing of calculations could be organized efficiently (on a sensor-by-sensor basis, rather than by game time), accesses to tape or disk could be minimized, and computing time could be held to acceptable values.

This choice of program structuring, incidentally, provides complete flexibility for the introduction of alternative methods[*], as for example a probabilistic method. The basic LOS subroutine would be replaced; only one job step would be affected directly; and there would be no additional linkage problems to be resolved.

The remainder of this section is limited to a discussion of the basic line of sight computing method (i.e., the one based on digital terrain data), beginning at the level of the primary subroutine LOS. Incorporation of this subroutine into operational procedures of PRERUN is covered in the Users' Manual[**], and details not covered in the summary discussion below may be found in program listings and AUTOFLOWS of the appropriate subroutines. Figure 4.6-1 lists, for convenience, the secondary subroutines associated with subroutine LOS, and their basic roles.

---

[*] Two choices were provided in the initial model release: the detailed version based on digital terrain, and a "dummy LOS" package for which line of sight is always assumed to exist. These two represent probable extremes.

[**] Volume II, Description of PRERUN Job Step 9.

SUBROUTINE LOS

Primary line of sight subroutine, for point-to-point evaluations.

LOS calls the following subprograms:

SUBROUTINE TERANE

Called when necessary, to fetch terrain data from disk.

SUBROUTINE FOLAGE

Determines foliage (canopy) height

SUBROUTINE IUTEVL

Determines, from x,y coordinates, the "IUT" index for unit terrain type (IUT is used to access the appropriate UNTER table data)

SUBROUTINE MICTER

Makes probabilistic evaluation of local masking of target, due to fine structure of foliage/terrain.

4

Figure 4.6-1

BASIC LINE OF SIGHT SUBPROGRAMS

4.6.1 Information Available

Subroutine LOS is the primary program for determining whether line of sight exists between two given points, one considered the sensor position, the other the target position. The basic logic behind this subroutine's operations is summarized in Section 4.6.2. However, some prior discussion of the data base from which subroutine LOS works is given here partly to set the context of the computational problem, and partly because the details of the data base strongly affected the actual program logic.

4.6.1.1 Digital Terrain Data*

Digital terrain data, stored on a so-called operational tape, give terrain heights within the scenario area on a discrete set of (x,y) grid points. Nominal spacing between adjacent points (in either the x or the y direction) is 100 meters.

As discussed in Section 5.3.1, these terrain height data are reasonably accurate in reflecting the blockage or non-blockage of a potential line of sight ray. They do not necessarily provide comparable accuracy for the absolute altitude at a point, as for example would be implied in determining height of a sensor position from x,y coordinates. The distinction will be clarified in Section 4.6.2. The significance of the distinction depends upon the roughness of the terrain (within a 100 meter square).

---

* For additional information, see Section 5.3.1.

4.6.1.2 Foliage Data

Certain foliage data are available in the so-called UNTER (unit terrain) tables, described in Section 5.3.2. For line of sight calculations, the primary parameters used are canopy height and the estimates of upper and lower ground visibility limits.

Resolution in x and y for foliage data is 500 meters. That is, values given in the UNTER tables are, in any application, intended to be average or typical values for a 500 meter square block of terrain. Thus, relative to that for bare-earth terrain, resolution for foliage data is less by a factor of 5 (linear) or 25 (area).

4.6.1.3 Sensor Data

Information provided to subroutine LOS about the sensor includes: x,y coordinates; height above ground*; a parameter, RCLEAR, that gives a distance before the sensor that may be assumed clear of foliage**; and in the case of radar, a logical variable that specifies whether or not a foliage penetration capability is to be assumed for that radar.

4.6.1.4 Target Data

Logic and bookkeeping that distinguish extended targets from point targets are handled in PRERUN by the execu-

---

* Airborne sensors are allowed; for these, the height is the nominal aircraft height above ground as specified by the planner input data.

** Planner specifies RCLEAR values in scenario specification Data Set IV (Sensor Descriptor Parameters). See Volume II, PRERUN Step 0.

tive routine (main program). In the context of the present discussion, the relevant target parameters available are: x,y coordinates; and an indicator, KSECUR[*], that specifies whether or not the target is attempting to move with maximum concealment.

4.6.2 LOS Path Regions

The most general case of line of sight computations occurs for the larger distances between sensor and target. In these cases, the overall path between the two points is divided, for purposes of calculation, into three regions, as sketched in Fig. 4.6-2. These regions differ in certain significant physical attributes. Perhaps more important, they differ in the degree to which data base limitations affect accuracy and program logic. The three regions may be defined by:

Region A:	Segment of terrain near the sensor, within the cleared distance RCLEAR
Region B:	The central region
Region C:	Segment of terrain near target.

If the distance between sensor and target is in fact sufficiently large that all three regions exist, the following comments apply:

---

[*] Planner specifies KSECUR values for red and blue forces in scenario specification Data Set XIII (Force Type Parameters); see Volume II, PRERUN Step 0. False targets are assumed not moving for maximum security.

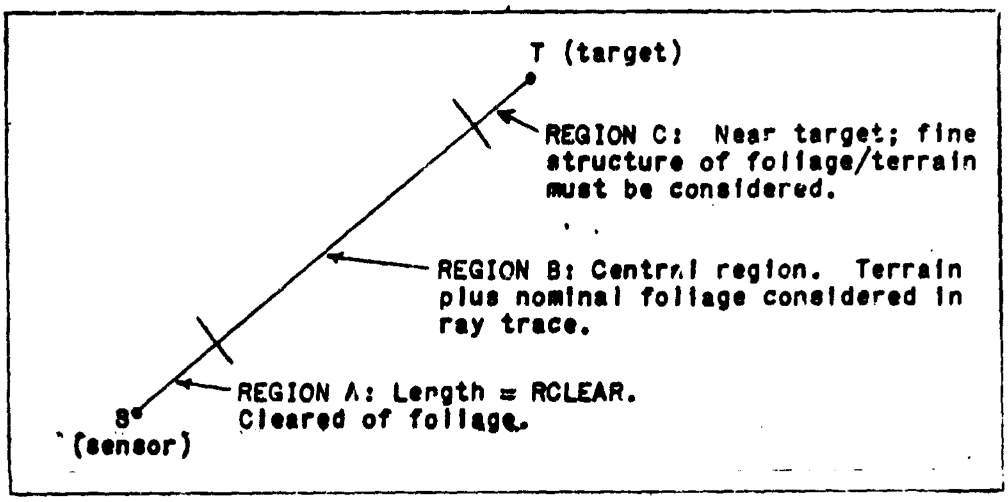


Figure 4.6-2a LOS PLAN VIEW. REGION DEFINITIONS.

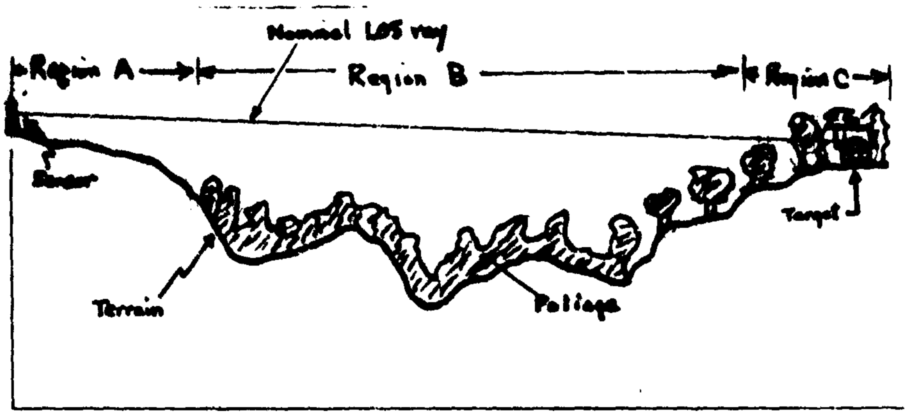


Figure4.6-2b LOS DETERMINED IN REGION B

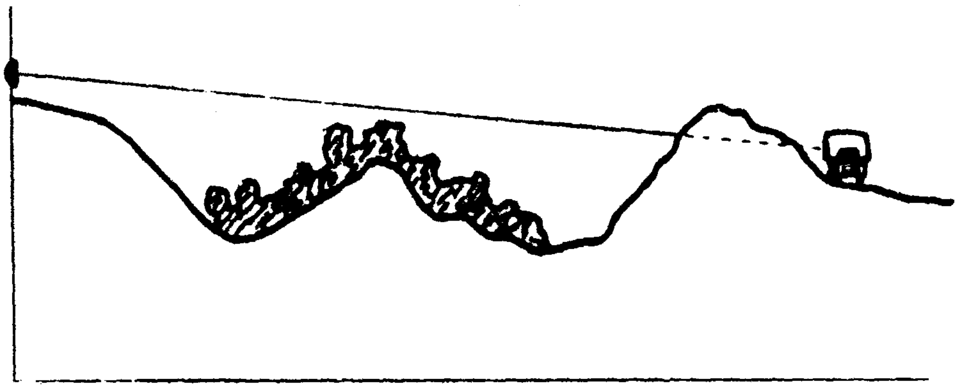


Figure 4.6-2c LOS DETERMINED DURING RAY TRACE

Region A. By definition, foliage is cleared in this region, so limitations of the foliage data base are irrelevant. Comments on bare-earth data are the same as for Region B.

Region B. Although limitations in foliage and bare-earth data can introduce errors in this region, results for this region are actually rather insensitive to these limitations.

The microstructure of terrain, for example, is unimportant. Only the maximum value of terrain over a quantum distance (~100 meters) can affect line of sight status, and terrain data are relatively accurate in defining maxima*.

Even though foliage is defined with coarse x,y resolution, the effect on line of sight in Region B does not derive from the fine structure (e.g., exact locations of individual clumps of vegetation). Provided that at least a part of a quantum distance has a sample of "typical" canopy height, the effect on line of sight status is determined on a valid basis.

Region C. In this region, any significant fine structure in foliage or bare-earth terrain would have a major effect on true line of sight, but the data base for computation does not provide sufficient resolution for this effect to be evaluated deterministically. Region C is assumed to be 250 meters or the distance between the target and the sensor minus Region A, whichever is less.

---

* See Section 5.3.1 ("Terrain Tape").

Consider foliage, for example. For two extreme cases -- uniformly dense vegetation, and open fields -- no particular problem arises. But if any clumping effect exists, then target movement over a clump size or clearing size region can completely change line of sight status. Indeed, for a small target (man), motion of a few feet may determine whether or not line of sight exists.

The microstructure of terrain is probably less significant than the fine structure of foliage, at least in a southeast Asian environment, considering the 5:1 better resolution for bare earth data.

The computational treatment for this region is discussed below in connection with subroutine MICTER.

4.6.3 Program Logic: Key Elements

4.6.3.1 Terrain Data Access and Storage

Major features in this aspect of the program are:

(a) If terrain data in storage adequately cover the sensor-to-target path, no request for terrain data is placed to the disk access subroutine.

(b) If terrain data are needed, the program distinguishes between a "short range" case (sensor range less than 5 km) and "long range" case (sensor range greater than 5 km.).

For the former, storage is adequate to hold a 10 km wide strip of terrain, centered (north-south) on the sensor; this strip is requested from disk. If the next call to subroutine LOS applies to the same sensor position (or nearly the same), terrain will already be resident in core storage, regardless of the target position.

(c) For the latter, complete coverage of the overall sensor coverage field cannot generally be held in storage. However, at least half of the sensor coverage area can be accommodated, and calls to disk tend to be minimal.

These features do not affect the final result. They do imply greater machine efficiency for sensors with at most 5 km maximum range than for longer range sensors.

4.6.3.2 Subroutine MICTER

After subroutine LOS has made some elementary validity (error checking) tests, it calls Subroutine MICTER. This subroutine makes a probabilistic evaluation of whether line of sight would exist, insofar as the fine structure of foliage in the vicinity of the target is an influence (Region C in the previous discussion).

This subroutine has one major branch, according as the nominal LOS ray comes from above (as for an airborne sensor) or is more nearly horizontal (most ground-to-ground cases).

For the former case, a probability of (local) line of sight is based on upper and lower limits of canopy closure (from UNTER tables), and a random sample with the indicated probability is drawn to define whether LOS exists for the particular call.

For the latter case, the concept of deriving a probability and basing the returned answer on a random sample is the same. However, the probability of (local) LOS is based upon: (a) upper and lower limits of ground visibility (from UNTER tables); (b) previous history for the same target, namely, the distance the target has moved since the last call to MICTER (with special logic for first such call); ~~and the KSEGUR value that specifies whether the target is~~ assumed to be trying for maximum concealment.

4.6.3.3 Ray Trace

If a 'false' answer is returned by MICTER, the question of line of sight is answered. Otherwise, subroutine LOS initiates a point by point trace of bare-earth effect from sensor to the end of Region A; then of bare-earth plus foliage to the end of Region B; then of bare-earth only to the target itself.[*] If, at any point along this trace, the pre-determined line from sensor to target is intercepted (blocked) by terrain (or terrain plus foliage, in Region B), line of sight is known not to exist; the trace is discontinued; and subroutine LOS returns a 'false' answer.

An interesting observation is that machine time tends to be much less for masked targets than for visible ones. For the latter, every operation including the lengthy ray trace must be executed to completion.

4.6.4 Foliage-Penetrating Radars

For radars that are designated as "foliage penetrating," line of sight calculations are partially performed within the basic LOS package (i.e., in PRERUN Step 9), and partially within the sensor routine itself (in RSM). Insofar as subroutine LOS operations apply, the primary differences

---

[*] By definition, foliage is cleared over Region A, and the effects of foliage (but not of major terrain variations) have already been accounted for by subroutine MICTER in Region C.

in computation are:

(a) Subroutine MICTER is bypassed

(b) Foliage is not added to terrain, when the ray trace is made.

Thus, LOS determines only whether or not the bare-earth profile would cause radar masking.

The sensor (RADAR) routine in MSM would not be called unless the LOS calculation has established bare-earth line of sight. The determination of signal loss in foliage, however, is done within the sensor routine .

4.6.5 LOS Summary

The discussion above of line of sight program operations is not, and is not intended to be, complete in all details. For these, reference is made to the program listings and AUTOFLOW diagrams supplied as Volume III of this report.

Section 5

ENVIRONMENTAL ELEMENTS

5.1 INTRODUCTION

The Systems Assessment Model has been designed to incorporate as realistically as practicable, those environmental effects present on the battlefield which will or are likely to affect STANO systems performance. This section presents a discussion of the major environmental elements included in terms of the specific programs and subroutines developed. Such environmental effects have been divided into four categories as follows:

- Atmospheric
- Terrain
- Battlefield
- Cultural

The atmospheric environment is taken care of by a separate submodel the output of which is a game history of specific parameters needed by the various subroutines in PRERUN and MSM. Sixteen parameters are specified extending from weather effects such as precipitation, wind, temperature, humidity, etc. to ephemeris parameters such as solar and moon parameters and irradiance effects due to natural light sources. The program is designed for extreme flexibility such that the planner need only specify the month, time of day, duration and location of game on which case the program will internally generate the complete atmospheric history required. On the other hand, the planner may choose to provide any or all of nine categories of the atmospheric history with the program computing the remainder. When planner desires to provide any of these categories, he has additional flexibility in how they will change during a game, e.g., keeping wind constant for entire game, changing it in step fashion, or in a smooth variable transition. The operation of this submodel together with all the logic and derivation of computation methods is presented in Section 5.2. Each subroutine is discussed separately in the order in which it is used in the overall program. The atmospheric model, as noted earlier, is an auxiliary, independent job step which is a prerequisite to running PRERUN and MSM but need only be run whenever a new game atmospheric history is desired.

The terrain environment effects are accounted for in two basically independent programs. The first, Make Sparse Terrain Tape, provides a digitized terrain description of the scenario area in approximately 100 meter increments. It is produced from finer grain digitized terrain tapes supplied by the U.S. Army Topographic Command and modified to be readable by IBM 360 series computers by the U.S. Army Institute for Systems Analysis of Combat Developments Command. The output of this auxiliary input submodel is required for use in the other auxiliary input submodels, Radar Contour Plot and RF Data Link Analysis and also in the PRERUN for Step 9 when sensor line of sight is played. It should be understood that this program need only be run once for a given map area, no matter how many different scenarios or games are run within this area. Terrain tape preparation is presented in Section 5.3.1. The second terrain environment program is TERAN and provides for the preparation of 500 meter square terrain description grid index numbers and values of nineteen terrain parameters for each type terrain index. These parameters are used in various other programs as a means of accounting for such characteristics as vegetation variations, background reflectances, soil moisture, and ground to ground visibility. The preparation of the terrain grid, assignment of unit terrain indices, and the terrain parameters are discussed in detail in Section 5.3.2.

Battlefield and Cultural effects are incorporated in the model during one of the PRERUN steps (Step 6). Battle effects include such red or blue force activities not directly played in the target detection flow of the model as firing of weapons, impact of all types of ordnance and non-game connected military aircraft and vehicles. Non-battle connected background noise sources (village, water noise, non-battle motor-caused effects) and various moving activities (fauna, rail traffic, and non-combat personnel) are played in a culture model. The Battlefield and Cultural activities produce background effects which in turn may effect sensor performance and also generate false targets or cause false alarms to be more readily generated. The above described type activities may be specifically input or generated randomly using frequency data supplied by the planner. The actual effects resulting from these activities (background levels, false target events, or illumination events) are determined based on both planner inputs and designer input tables contained in PRERUN Step 6 program. The detailed discussion of the culture and battle environment considerations is included in Section 5.4.

5.2 ATMOSPHERICS MODEL

5.2.1 MAIN PROGRAM - ATMOMN

5.2.1.1 Purpose

ATMOMN is the main program required to initiate generation of the atmospheric environment for the duration of the game. It is used as a vehicle for providing inputs to the simulation and therefore subject to alteration by the game planner. Because various portions of the PRERUN and Main Simulation Model require knowledge of the atmospheric environment, it is intended to be a stand-alone program executed prior to the PRERUN

5.2.1.2 Use and Description of Inputs

Although ATMOMN only calls Subroutine ATMOS, fourteen other supporting subroutines are required for execution. Fig. 5.2-1 presents a structure tree of the complete program.

The ATMOMN Program is used as a vehicle for providing inputs to ATMOS as well as the PRERUN and Main Simulation Model. Fig. 5.2-2 presents the thirteen Fortran statements which compose the program. This auxiliary program must be prepared each time ATMOS is to be executed. Lines 1, 2, 9, 10, 12 and 13 should appear exactly as shown. Lines 3 through 8 and line 11 are altered as required for the particular game being played. Lines 3 through 6 specify the content of four integer variables in the BASICT common area. Line 3 establishes ITODST, the time of day at the start of the game in seconds. In the example presented ITODST is equal to zero indicating that the start of the game is equal to 0000 hours. Line 4 sets ITDURN a variable describing the duration of the game in seconds. In the present example the duration is equal to three days. The maximum allowed duration is six weeks. Line 5 which sets the variable IDATE specifies the date of the start of the game. This is always a 6-digit integer with the first two digits being the day of the start of game, the next two digits the month and the last two digits the year. In the present example

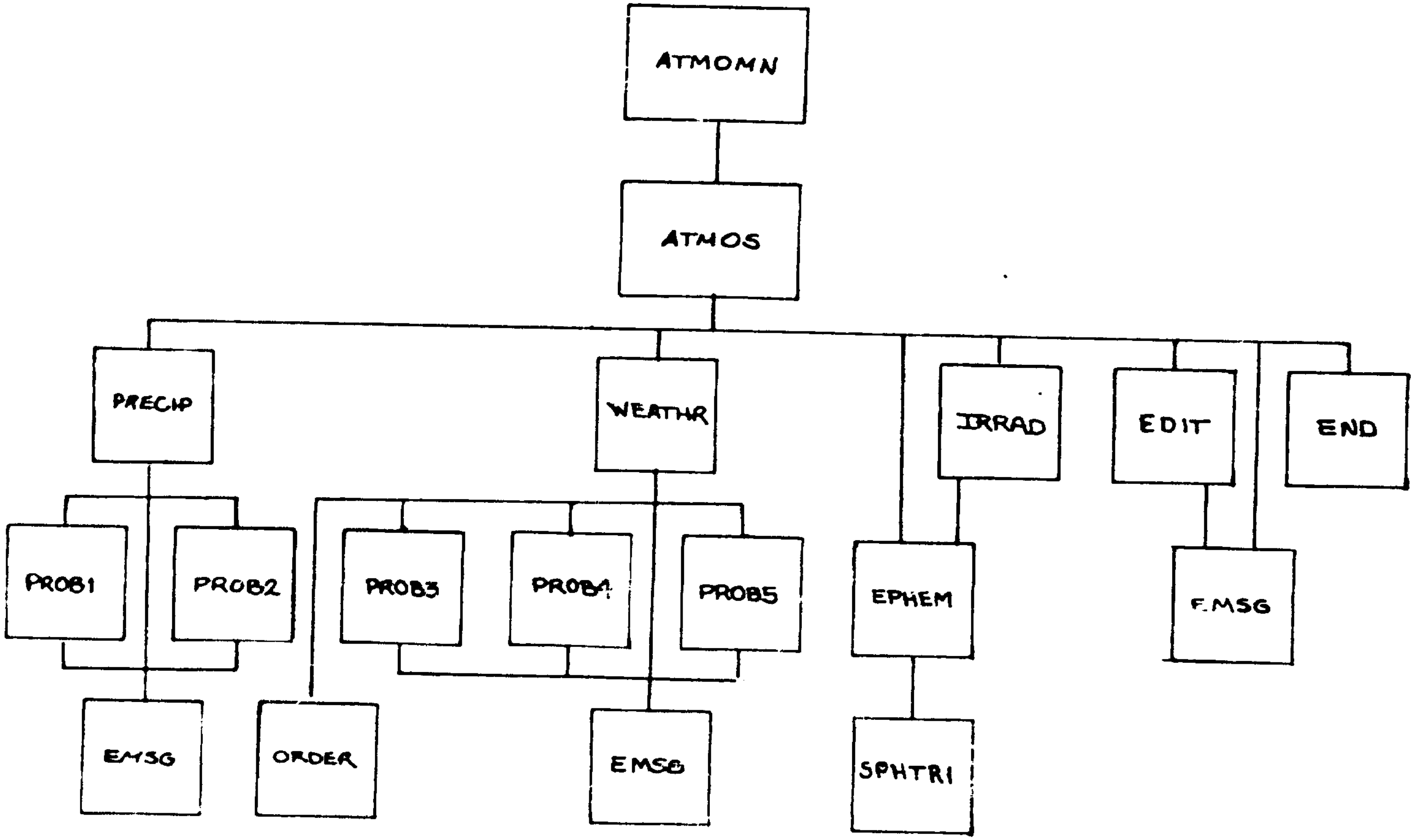


Figure 5.2-1 PROGRAM STRUCTURE TREE FOR GENERATING ATMOSPHERIC ENVIRONMENT

C-COMMENT NUMBER	CONT	FORTRAN STATEMENT	IDENTIFICATION

```
 1  CØMMØN/BASICT/ITIME,ITØD,ITØDST,ITDURN,IDATE,IDAREA
 2  LØGICAL PRØPT

 3  ITØDST=0
 4  ITDURN=259200
 5  IDATE=290569
 6  IDAREA=2

 7  IREFG=521341655
 8  IREFU=664345465

 9  CALL GRNØRG(IREFG)
10  CALL URNØRG(IREFU)

11  PRØPT=.TRUE.

12  CALL ATMØS(PRØPT)

13  END
```

Figure 5.2-2 FORTRAN STATEMENTS COMPOSING ATMOMN PROGRAM the game begins on May 29, 1969. Line 6 which establishes the value of IDAREA describing the scenario area where the game is to be played; 1 = Khe Sahn, South Vietnam, 2 = Hue, South Vietnam, and 3 = Fort Hood, Texas. In the present example the game is being played in the Hue scenario area. Lines 7 and 8 describe reference numbers for the origin of the gaussian and uniform random number generators. These variables can be set to any arbitrary nine-digit integer but must be changed between successive executions of ATMOS if different atmospheric environments are required. Line 11 sets the variable PROPT representing an output option available to the planner. If PROPT is set equal to .TRUE. the values in the ATMENV tables describing the environment will be printed out and recorded on magnetic tape. If this variable is set equal to .FALSE. the printed report will be deleted and the ATMENV Tables will only be recorded on magnetic tape.

In addition to the inputs which must be provided by the planner through the FORTRAN Statements composing ATMOMN, data must be supplied in an input data stream. Fig. 5.2-3shows the data sets which compose the ATMOMN input data stream. The planner input data set presents the meteorological variables that the planner has elected to supply in the form of a time history. The preparation of this data set is detailed in the description of Subroutine ATMOS. If no input is being supplied, this data set must consist of a blank data card. The remaining five data sets in the input data stream represent designer input data. These sets contain the parameters of the statistical distributions determined from recorded meteorological data. These data sets must be included in the input data stream regardless of the amount and type of planner inputed data. A limited number of these designer input data sets have been prepared during development of the model. Detailed descriptions of the preparation of these data sets is included with the description of the corresponding supporting subroutine. In placing the data sets into the input data stream one must take care to insure that they have the proper order and that the data sets selected agree with the month and scenario area of the game.

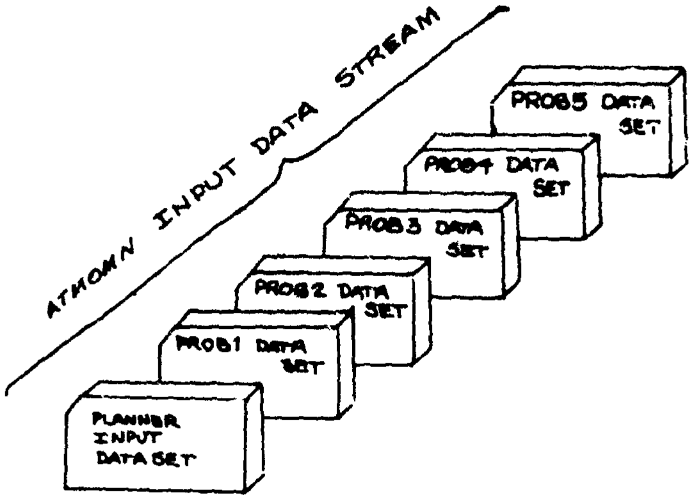


Figure 5.2-3 ATMOMN INPUT DATA STREAM

5.2.1.3 Description of Logic and Processing

See Section 2.

5.2.1.4 Sample Data Set

The FORTRAN Statements composing ATMOMN during the System Assessment Model checkout were identical to the example presented in Fig. 5.2-2. The six data sets in the input data stream are presented with the descriptions of the corresponding subroutines (i.e., ATMOS, PROB1, PROB2, PROB3, PROB4 or PROB5).

5.2.1.5 Sample Output

No output is produced directly by ATMOMN. A supporting subroutine, END, will generate a printed report of the time history of the atmospheric environment if this option is chosen by the planner (PROPT = .TRUE.). The reports generated during the checkout of the System Assessment Model are included in the description of Subroutine END.

5.2.2 SUBROUTINE ATMOS

5.2.2.1 Purpose

Subroutine ATMOS generates values for a number of meteorological factors which describe the atmospheric environment during the duration of the game. These factors compose the ATMENV Common Area as shown in Table 5.2-I. Because various portions of the PRERUN and Main Simulation Model require knowledge of the atmospheric environment, Subroutine ATMOS is intended to be part of a stand-alone program executed prior to the PRERUN.

5.2.2.2 Use and Description of Inputs

A main program, ATMOMN, and fourteen supporting subroutines must be employed with Subroutine ATMOS. The subroutines include EDIT, EMSG, END, EPHEM, IRRAD, ORDER, PRECIP, PROB1, PROB2, PROB3, PROB4, PROB5, SPHTRI and WEATHR in alphabetical order. The reader is referred to the descriptions of these programs in the following sections for detailed information. Subroutines descriptions are arranged in order of use by the program.

The planner may input data for one or more (or possibly all) of the variables which would otherwise be generated by Subroutine ATMOS using statistical procedures. The input data must be in the form of a time history which will be described in detail. This history is punched onto cards to form the Planner Input Data Set (see the input data stream in the description of ATMOMN main program (Section 5.2.1)) and read by Subroutine ATMOS. If no input is being supplied the data set must consist of a blank card.

There are nine categories in which the planner may elect to provide input. If he elects to provide any input at all, he must also provide time data. Table 5.2-II below lists these categories with their descriptions.

Note that in each of the first two categories, Emphemeris/Illumination Data and the Precipitation Data, the planner must specify more than one variable.

TABLE 5.2-I

CONTENTS OF ATMENV COMMON AREA

VARIABLE NAME	TYPE	DESCRIPTION	UNITS
ITEFF	Integer	Value of ITIME when ATMENV Table effective	Seconds
SOLALT	Real	Solar Altitude	Degrees
ALTLUN	Real	Lunar Altitude	Degrees
PHSLUN	Real	Lunar phase (civil)	Fraction
IPCODE	Integer	Precipitation code identifying type of precipitation 0 = No precipitation 1 = Thunderstorm 2 = Rain or drizzle 3 = Freezing rain or drizzle * 4 = Snow or sleet * 5 = Hail * 6 = Fog	-
PRATE	Real	Precipitation rate	mm/hr
PTOT24		Total precipitation during the last 24 hours	mm
H2ODEN	Real	Amount of water in the air	gm/cc
WSPEED		Wind speed	km/hr
CCOVER		Cloud cover	fraction
ATEMP		Air temperature	°C
PRESUR		Pressure	mm of mercury
HUMDTY		Relative humidity	%
VISIB		Meteorological visibility	meters
CEIL		Ceiling	meters
ASID	Real Array	ASID(1) = Amplitude of the spectral irradiance due to direct sunlight or direct moonlight ASID(2) = Amplitude of the spectral irradiance due to clear sky ASID(3) = Amplitude of the spectral irradiance due to air glow	watts/m^2
TCLOUD	Real	Transmission of cloud cover	-

*Not presently played in model

TABLE 5.2-II

TYPES OF PLANNER INPUT

CATEGORY	VARIABLE	DESCRIPTION/UNITS
Time	Day (INDAY)	A two-digit integer describing the day of the game, thus 00 is D-day, 05 D-day + 5, etc.
	Hour (INHR)	A four-digit integer equal to the military time, e.g., 0900, 1755 etc.
1. Ephemeris/ Illumination	Solar Altitude (SOLALT)	Local elevation of the sun in degrees. A negative value indicates that the sun is below the horizon (i.e., nighttime)
	Lunar Altitude (ALTLUN)	Local elevation of the moon in degrees. Negative value indicates moon below horizon.
	Lunar Phase (PHSLUN)	Expressed as a fraction, i.e., 0.00 = New Moon, 0.25 = 1st Quarter, 0.50 = Full Moon, 0.75 = 3d Quarter
2. Precipitation	Condition Code (IPKODE)	A one-digit integer code identifying the type of precipitation 0 = No precipitation 1 = Thunderstorm 2 = Rain or drizzle 3 = Freezing rain or drizzle* 4 = Snow or sleet* 5 = Hail* 6 = Fog
	Total Amount of Precipitation for Event (TOTP)	Total amount of rain (or snow) in inches for the event identified by the condition code
3. Wind Speed	(WSPEED)	Knots
4. Cloud Cover	(CCOVER)	Fraction 0.0 - 1.0
5. Dry Bulb Temperature	(ATEMP)	Degrees Fahrenheit
6. Pressure	(PRESUR)	Inches of Hg
7. Relative Humidity	(HUMDTY)	Percent 0 - 100
8. Meteorological Visibility	(VISIB)	Miles
9. Ceiling	(CEIL)	Feet

*Not presently played in model. For details about the sensor model's response to these codes the reader is referred to the corresponding descriptions of the sensor performance models.

For example, if he elects to input illumination information he must specify solar altitude, lunar altitude and lunar phase as a function of time for the total duration of the game being played. This does not restrict these time histories to be representative of the "real world." For example, the planner could play a game history of several days keeping the solar altitude constant or a three-day game with the phase of the moon changing from 1/4 to 1/2 to 3/4 on successive nights. Due to the extreme flexibility in the types of input accepted, overall compatibility of the input rests with the planner. He should not, for example, specify rain without cloud cover.

To assist the planner in preparing the input, a form has been prepared and is shown in Tab. 5.2-III. Its use has been illustrated employing the environmental data from a draft scenario shown in Tab. 5.2-IV. In the present case the planner elected to provide input in seven of the nine categories (pressure and visibility are left unspecified). As can be seen from this example, the preparation of the planner input could become tedious when the planner elects to provide input in a majority of the categories for games with extensive duration. To ease the burden one can change the variables in a discontinuous or step function fashion with time (in the present example this was done with solar altitude, lunar altitude, lunar phase, cloud cover, relative humidity and ceiling) or keep them constant (as done for wind speed). If a smoother transition is desired (as done for temperature), the preparation becomes more difficult and it is recommended that the planner use the statistical procedures "built-in" to Subroutine ATMOS.

The first entry in the table establishes the conditions at the beginning of the game (DAY = 00, HOUR = TIME AT THE START OF GAME, in the present example it was assumed to be midnight thus the HOUR = 0000). In addition, this entry allows the planner to specify the variables he does not want to provide for in his input data. The reader may note that all the variables except solar or lunar altitude and temperature do not normally have negative values. Thus by assigning any negative decimal number to the initial value of a variable, the planner can indicate that he will not provide input for that variable. Note

TABLE 5.2-III

PLANNER INPUT FORM

DAY	HOUR	SOLAR ALTITUDE (Degrees)	LUNAR ALTITUDE (Degrees)	LUNAR PHASE (Fraction)	IPKODE	AMOUNT OF PRECI-PITATION (In)	WIND SPEED (Knots)	CLOUD COVER (Fraction)	TEMP. (°F)	PRESSURE (Inches of Hg)	RELATIVE HUMIDITY (Percent)	VISI-BILITY (Miles)	CEILING (Feet)
*00	0000	-90.0	-90.0	0.0	0	0.0	5.0	0.0	72.0	-1.0	91.0	-1.0	20000.
00	0500	-90.0	-90.0	0.0	6	0.0	5.0	0.0	72.0		91.0		20000.
00	0635	90.0	-90.0	0.0	6	0.0	5.0	0.0	72.0		91.0		20000.
00	0800	90.0	90.0	0.25	6	0.0	5.0	0.0	74.0		91.0		20000.
00	0900	90.0	90.0	0.25	0	0.0	5.0	0.0	74.0		91.0		20000.
00	1400	90.0	-90.0	0.0	0	0.0	5.0	0.0	87.0		69.0		20000.
00	1800	90.0	-90.0	0.0	0	0.0	5.0	1.0	85.0		69.0		3000.
00	1905	-90.0	-90.0	0.0	0	0.0	5.0	1.0	81.0		69.0		3000.
01	0100	-90.0	90.0	0.50	2	0.45	5.0	1.0	75.0		91.0		3000.
01	0400	-90.0	90.0	0.50	0	0.0	5.0	1.0	72.0		91.0		3000.
01	0500	-90.0	90.0	0.50	0	0.0	5.0	0.0	72.0		91.0		20000.
01	0635	90.0	90.0	0.50	0	0.0	5.0	0.0	72.0		91.0		20000.
01	1300	90.0	-90.0	0.0	0	0.0	5.0	0.0	85.0		69.0		20000.
01	1905	-90.0	-90.0	0.0	0	0.0	5.0	0.0	80.0		69.0		20000.
01	2300	-90.0	90.0	0.75	0	0.0	5.0	0.0	72.0		69.0		20000.
02	0635	90.0	90.0	0.75	0	0.0	5.0	0.0	72.0		91.0		20000.
02	0900	90.0	-90.0	0.0	0	0.0	5.0	0.0	74.0		91.0		20000.
02	1905	-90.0	-90.0	0.0	0	0.0	5.0	0.0	81.0		69.0		20000.

*First Entry must represent conditions at start of the game.

TABLE 5.2-IV

Environmental Data of a Draft Scenario

1. General. The following data is provided to exercise the STANO equipment in various environmental conditions. The basic data was extracted from the Tactical Scale Study Hue and Vicinity, 14 June 1968, HQ United States Military Assistance Command, Vietnam. Climatic conditions for the month of April have been portrayed. Where deviations occur, it was for the convenience of the scenario.

2. Precipitation. There is only one instance of rain:

DAY	DURATION	TYPE
D+1	0100 to 0400	light to medium

3. Fog. The only instance of fog is during D-day from 0500 to 0900.

4. Ceiling. The ceiling will remain above 3000 ft. MSL during the entire period. The only instance of cloud cover will exist from D-day 1800 hrs. to D+1 0500 hrs.

5. Moon Data.

DAY	RISE	SET	PHASE
D	0800	1400	1/4
D+1	0100	1300	1/2
D+2	2300	0900	3/4

6. Light Data - (Mean for entire scenario)

BMNT	SUNRISE	SUNSET	EENT
0548	0635	1905	1952

7. Wind - The mean wind speed is 5 knots.

8. Temperature

Mean high - 87°F

Mean low - 72°F

9. Relative Humidity

Mean 0700 hrs. - 91%

Mean 1300 hrs. - 69%

that in the example shown, pressure and visibility are left unspecified and therefore have been assigned an initial value of -1.0. The time histories for these variables will be generated by the ATMOS Subroutine.

In the case of the Ephemeris/Illumination data, a negative value for the lunar phase indicates that values for these variables are not provided in the planner input and no entry need be made for solar and lunar altitude. For the precipitation data, only TOTP need be set equal to a negative number while IPKODE can be left blank. To indicate that temperature information is not part of the input data, an initial value less or equal to -50.0 degrees must be assigned.

After the initial entry is made, time is advanced until the next change occurs in the atmospheric environment. In the example a fog occurs on D-Day (DAY = 00) at HOUR = 0500. This is shown as the second entry or line in the table where the condition code ("IPKODE") has been changed from 0 to 6. The values of the other variables remain unchanged and are simply repeated. Note that no further entry is required for pressure or visibility. The third entry (line) in the table occurs at sunrise (DAY = 00, HOUR = 0635) where the solar altitude has been changed from -90.0 to +90.0 degrees. This step function change in solar altitude is, of course, unrealistic. A smoother transition to account for twilight and low altitude periods could be provided by the planner at the expense of additional time and calculation. If he chose not to input Ephemeris/Illumination Data, the time history generated automatically would be smooth and represent the solar altitude occurring during the reference year 1969. The fourth entry (DAY = 00, HOUR = 0800) occurs at moon rise and the lunar altitude is changed from -90.0 to +90.0 degrees and the lunar phase from 0.0 to 0.25 as specified in "5. Moon Data" in Table 5.2-IV. The previous discussion in regard to solar altitude similarly applies here. The fifth entry (DAY = 00, HOUR = 0900) allows the fog condition to be terminated by changing "IPKODE" from 6 back to 0. The remainder of the entries in the table correspond directly to events specified in the draft scenario described in Tab. 5.2-IV. For example, Entry 9 (DAY = 01, HOUR = 0100) corresponds to the rain shower on D-DAY + 1. The condition code is changed from 0 to 2 and the amount of precipitation during the 3-hour shower is set equal to 0.45 inches. In selecting this value, the following guideline was used:

Light Precipitation	Less than 0.1 inches/hour
Medium or Moderate Precipitation	0.1-0.3 inches/hour
Heavy Precipitation	Greater than 0.3 inches/hour

Thus the shower has an average rainfall rate of 0.15 inches/hour equal to a moderate precipitation rate. The reader should note that entry 10 is made to terminate the rain shower at HOUR = 0400.

Once the planner has prepared the input form, the data can be keypunched directly onto IBM cards. The FORTRAN Statement used in Subroutine ATMOS to read the planner input data is FORMAT (I2, I4, 2F5.0, F4.0, I2, 7F4.0, F6.0, 24X). A new card is used for each line or entry (See Table 5.2-III.) Thus the our example 18 data cards would be required for the planner input data. This number must be punched onto a separate data card in an I4, 76X format and placed before the data cards containing the detailed planner input. The last 76 spaces on this card are available to the planner for any identifying alpha/numeric information he may desire. A blank card will indicate that <u>no</u> atmospheric environment data will be provided by the planner for the game.

5.2.2.3 Description of Logic and Processing

Fig. 5.2-4 is a macroflow diagram describing the major steps in Subroutine ATMOS. The reading and processing of the planner input data is the first step executed. If there is no planner input data, this step is bypassed. If there is planner data the first entry (card) is read and

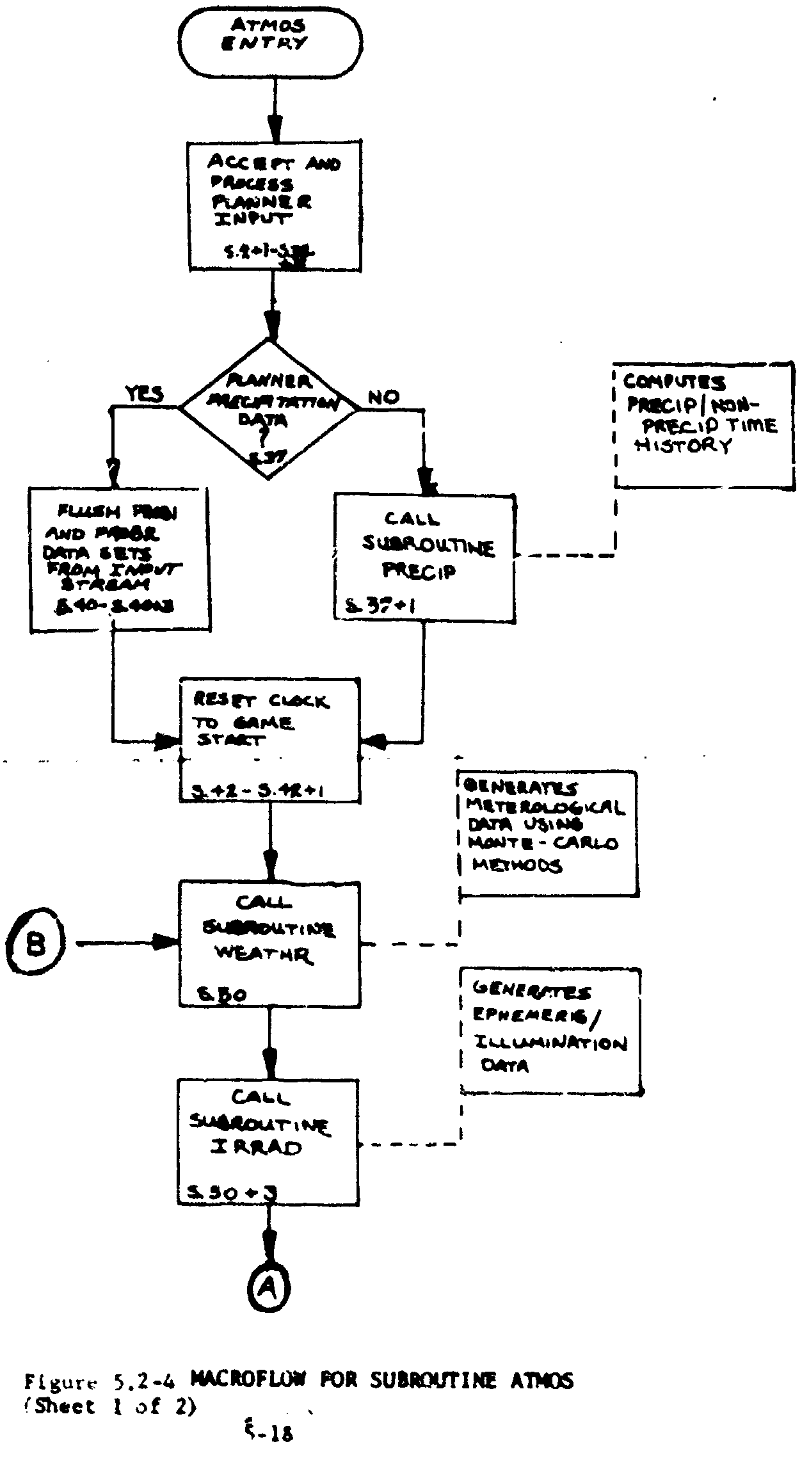


Figure 5.2-4 MACROFLOW FOR SUBROUTINE ATMOS
(Sheet 1 of 2)

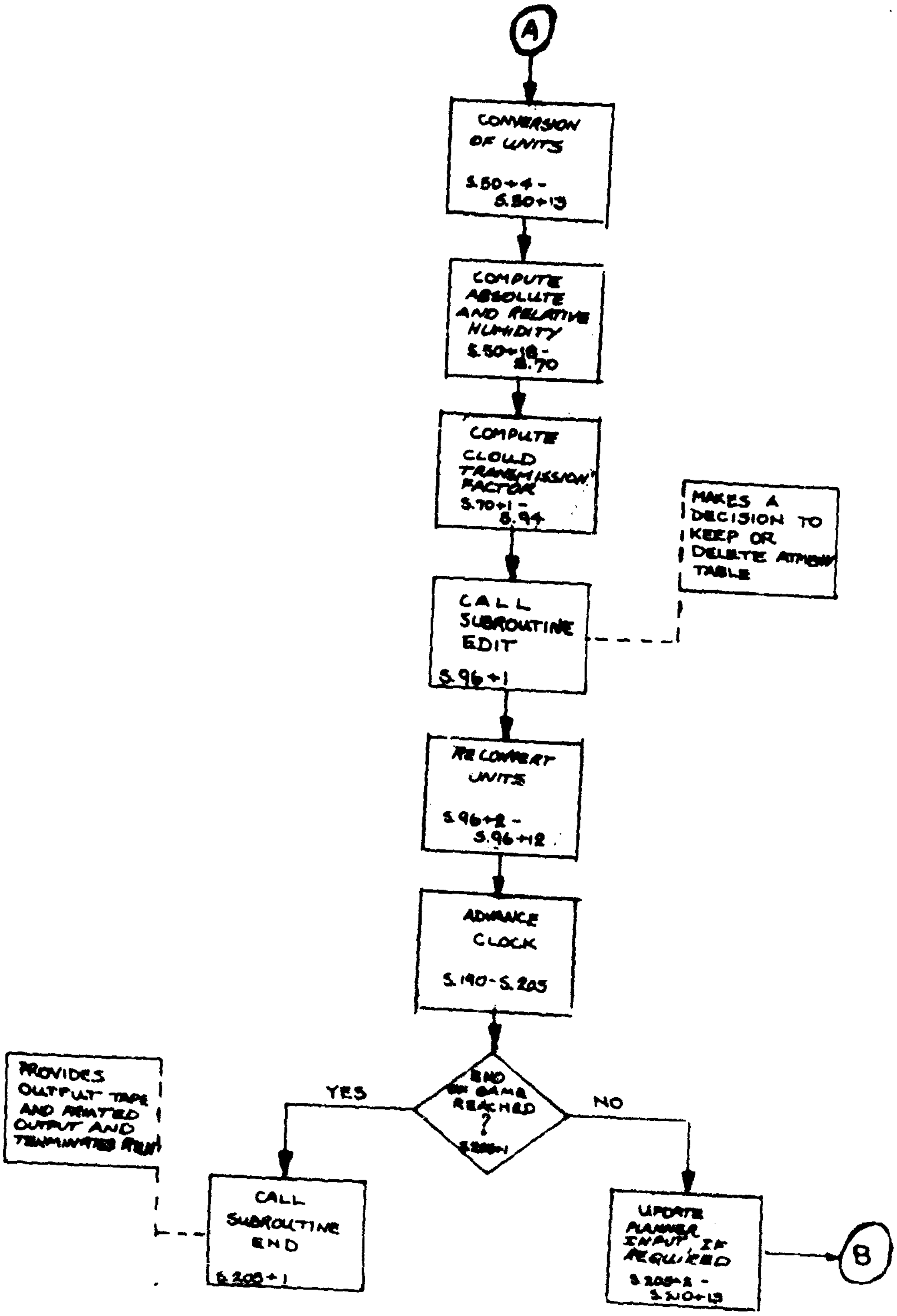


Figure 5.2-4 MACROFLOW FOR SUBROUTINE ATMOS
(Sheet 2 of 2)

the PLANIN logical array established. This array indicates whether the planner is providing data in each of nine categories available to him. It is used in the subsequent processing to bypass the calculations of parameters where input data has been provided. The remainder of the planner input data set is read and the complete set transferred into disk storage for future integration to the appropriate ATMENV Table. The next step is a call to Subroutine PRECIP which generates a precipitation/non-precipitation time history. If the planner has elected to include precipitation data in his input the call is bypassed and the PROB1 and PROB2 data sets are flushed from the input data stream. In the next step the internal clock is set equal to the start of the game and the detailed calculation of the contents of the ATMENV Tables is begun using the precipitation time history. The first step in this process is a call to Subroutine WEATHR which uses Monte-Carlo methods to generate values for meteorological factors which completely describe the atmospheric environment. This is followed by a call to Subroutine IRRAD which determines the ephemeris and illumination data required by the ATMENV Table. The next step is the conversion of the meteorological parameters to a consistent metric system. The ATMENV Table is completed by computing H2ODEN, the absolute humidity; HUMDTY, the relative humidity; and TCLOUD, a cloud transmission factor. The computation of absolute and relative humidity requires use of the relationship between temperature, T , and, ρ , the density of water vapor in the air at 100% saturation. Unfortunately no mathematical relationship exists. Algorithms were developed using empirical data published in the Handbook of Chemistry and Physics (Reference 1). For temperatures greater than 2°C the algorithm is

$$\rho = e^{\frac{T + 10.814}{0.072T + 12.17}}$$

For temperatures less than 2°C the algorithm becomes

$$\rho = e^{0.08312T + 1.58}$$

The next step is the computation of a value for the cloud transmission factor, TCLOUD. Algorithms for the computation of this factor were based upon empirical data obtained from Reference 2. These data are the measured decrease in total flux for several cloud types. By assigning typical altitudes to each cloud type the data was related to CEILING as shown in Figure 5.2-5. Simple algorithms (shown as dash lines in the figures were developed for several ranges of ceiling. The value of TCLOUD depends upon the value of ceiling as well as the value of solar or lunar altitude. Once the computation of this factor has been completed all of the parameters in the ATMENV Common Area have been determined and the next step in ATMOS is a call to subroutine EDIT. This subroutine examines the current values of the parameters and compares them to the previous values and decides to keep the current ATMENV Table only if a change has occurred in at least one of the parameters which would make a significant difference in the performance of the sensors employed in the model. After the return from EDIT the parameters are restored to their original units. This is necessary to insure that the planner input data is restored to its original form. The final step in the program is the advancement of the clock. If the value of time after the clock has been advanced exceeds the game duration time, Subroutine END is called to terminate the execution and provide the appropriate output. If the end of the game has not been reached, the planner input is updated if required and the execution is recycled to the call of Subroutine WEATHR to compute the next ATMENV Table.

5.2.2.4 Sample Data Set

The Planner Input Data Set used during the System Assessment Model checkout is shown in Fig. 5.2-6. This data set was prepared using the scenario presented previously in Tab. 5.2-IV and consequently is similar to the example Data Set in Table 5.2-III except that the planner has elected not to supply the Ephemeris/Illumination Data.

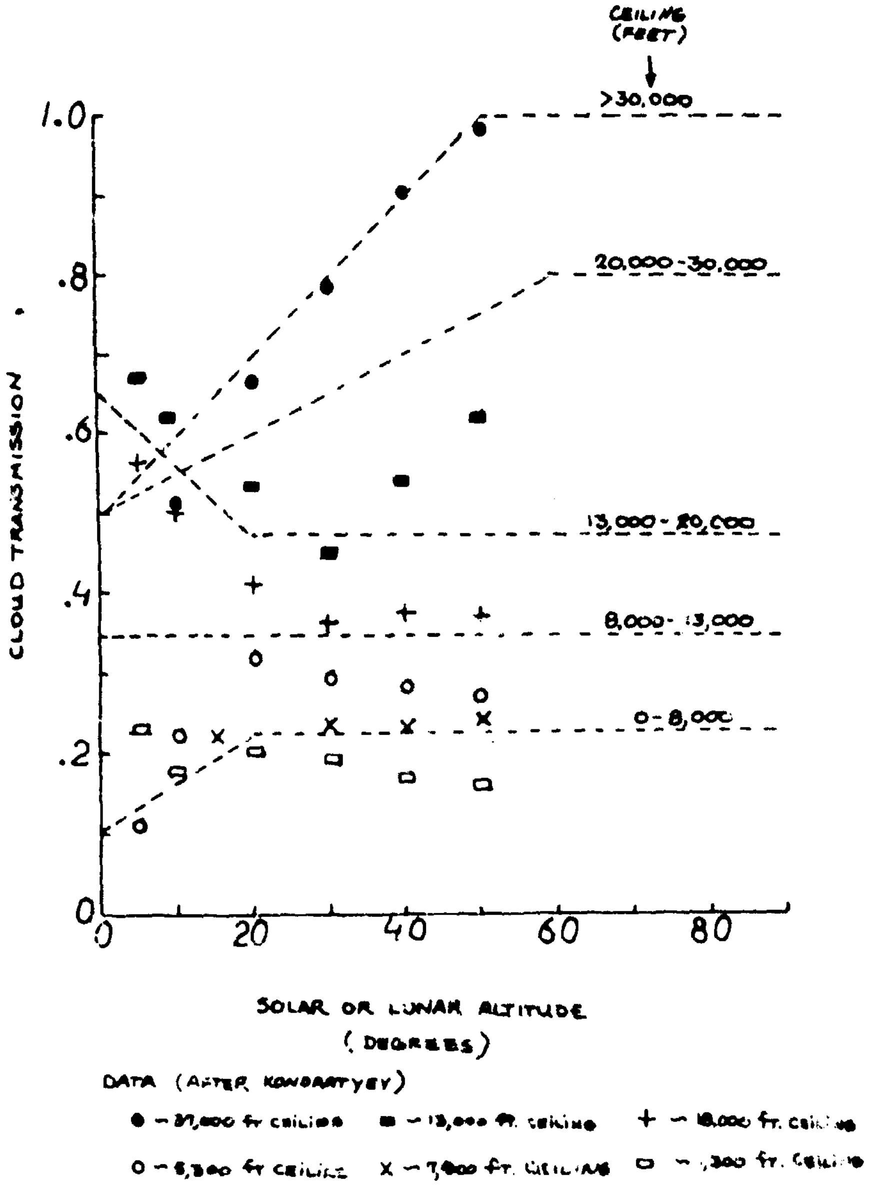
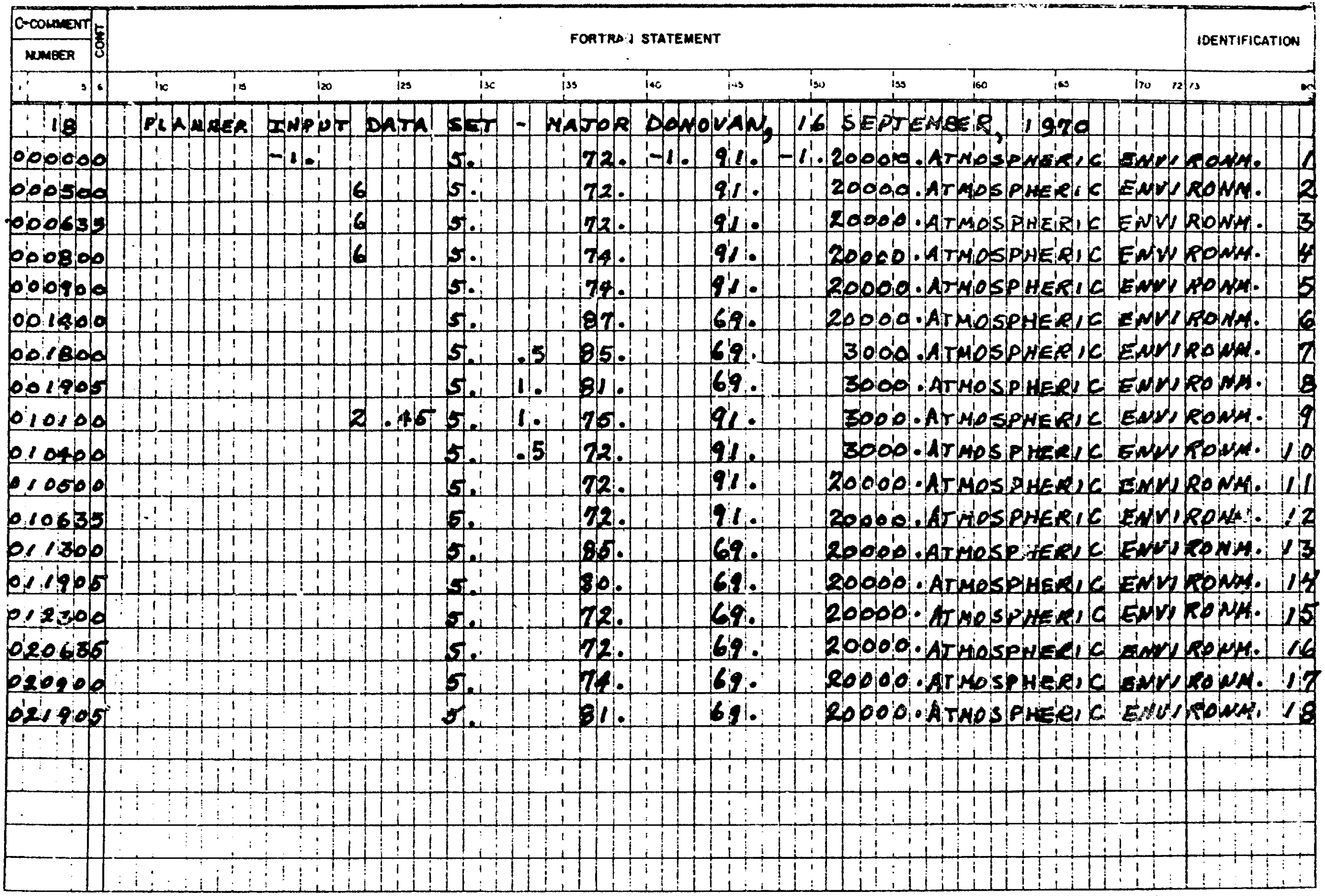


Figure 5.2-5 ALGORITHM FOR DETERMINING CLOUD TRANSMISSION FROM CEILING



```
   18   PLANNER INPUT DATA SET - MAJOR DONOVAN, 16 SEPTEMBER, 1970
000000          -1.        5.      72. -1. 91. -1.20000.ATMOSPHERIC ENVIRONM.  1
000500               6     5.      72.     91.    20000.ATMOSPHERIC ENVIRONM.  2
000635               6     5.      72.     91.    20000.ATMOSPHERIC ENVIRONM.  3
000800               6     5.      74.     91.    20000.ATMOSPHERIC ENVIRONM.  4
000900                     5.      74.     91.    20000.ATMOSPHERIC ENVIRONM.  5
001400                     5.      87.     69.    20000.ATMOSPHERIC ENVIRONM.  6
001800                     5.  .5  85.     69.     3000.ATMOSPHERIC ENVIRONM.  7
001905                     5.  1.  81.     69.     3000.ATMOSPHERIC ENVIRONM.  8
010100               2  .455.  1.  75.     91.     3000.ATMOSPHERIC ENVIRONM.  9
010400                     5.  .5  72.     91.     3000.ATMOSPHERIC ENVIRONM. 10
010500                     5.      72.     91.    20000.ATMOSPHERIC ENVIRONM. 11
010635                     5.      72.     91.    20000.ATMOSPHERIC ENVIRONM. 12
011300                     5.      85.     69.    20000.ATMOSPHERIC ENVIRONM. 13
011905                     5.      80.     69.    20000.ATMOSPHERIC ENVIRONM. 14
012300                     5.      72.     69.    20000.ATMOSPHERIC ENVIRONM. 15
020635                     5.      72.     69.    20000.ATMOSPHERIC ENVIRONM. 16
020900                     5.      74.     69.    20000.ATMOSPHERIC ENVIRONM. 17
021905                     5.      81.     69.    20000.ATMOSPHERIC ENVIRONM. 18
```

Figure 5.2-6 CHECKOUT PLANNER INPUT DATA SET

Checkout of ATMOS execution when no planner input data is supplied was also performed, however, the atmospheric environment generated was not used in the subsequent check of the complete System Assessment Model. In this case the Planner Input Data Set consisted of a single blank card.

5.2.2.5 Sample Output

No output is produced directly by ATMOS, however, a supporting subroutine, END, does generate a printed report of the atmospheric environment if this option was chosen by the planner (see the description of the ATMOMN main program). The reports generated during the checkout of the System Assessment Model are included in the description of Subroutine END. (Section 5.2.16).

5.2.3 SUBROUTINE PRECIP

5.2.3.1 Purpose

This subroutine supports ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to generate a time history of precipitation and non-precipitation events for the duration of the game.

5.2.3.2 Use and Description of Inputs

No input data must be manually supplied by the planner. A number of basic parameters including the duration of the game are passed to the subroutine through the BASICT common area. The subroutine generates the time history of sequential precipitation, non-precipitation events for a period of time corresponding to the duration of the game. In addition to identifying the beginning of the events, the level of precipitation and type of precipitation event (i.e. thunderstorm, rain, freezing rain, snow or hail) are determined.

5.2.3.3 Description of Logic and Processing

A macroflow diagram showing the major processing steps in Subroutine PRECIP is presented in Fig. 5.2-7.The first major step is the computation of the precipitation, non-precipitation event time history for a six-week period. This computation is carried out irrespective of the length of the game which must be six weeks or less. Using the instantaneous probability of precipitation supplied by Subroutine PROB1 (Section 5.2.4) a uniform random number is employed to determine whether the initial event will be a precipitation or non-precipitation period. The duration is then assigned to the event using the duration distribution parameters also supplied by Subroutine PROB1. The duration time in hours is determined by transforming a gaussian random number

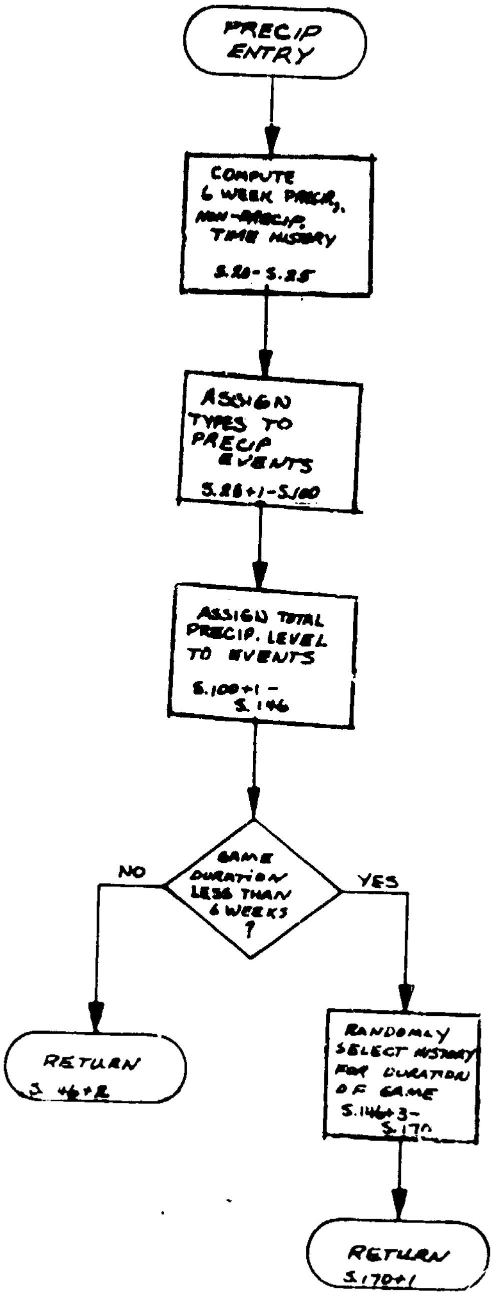


Figure 5.2-7 MACROFLOW DIAGRAM OF SUBROUTINE PRECIP

using the transformation describing a Johnson S_B distribution. (See Reference 3). The duration time for the event (in hours) is determined by

$$t_d = \frac{p_3 \, e^{\frac{z - p_1}{p_2}}}{1 + e^{\frac{z - p_1}{p_2}}}$$

where p_i, $i = 1, 2, 3$ are the three parameters provided by Subroutine PROB1. The correspondence between these parameters and the notation in the cited reference is $p_1 = \gamma$, $p_2 = \eta$ and $p_3 = \lambda$. A precipitation event duration time less than PDMIN is deleted and another duration time randomly selected. The current value for this location factor is 0.25 hour and is established using a data statement in the subroutine. By adjusting PDMIN the mean percentage of game time occupied by precipitation events can be made to agree with the instantaneous probability of precipitation. The expected number of hourly observations to be effected by the event, ENOBS, is also computed. It is easily shown that this quantity is equal to $t_d + 1$. Next, the internal clocks representing the time of day and elapsed time from the beginning of the game, both of which are expressed in seconds, are advanced and the computation is recycled to compute the duration of the next event; the events alternating between non-precipitation and precipitation events. This process is repeated until the history spans a period of six weeks or more.

The next major processing step is the assignment of types to the precipitation events. The type is identified through the use of an integer variable, IPCODE. This code describes the event as follows: 0 = no precipitation, 1 = thunderstorm, 2 = rain or drizzle, 3 = freezing rain or drizzle, 4 = snow or sleet, 5 = hail and 6 = fog. For the precipitation events IPCODE is assigned a value from 1 to 5 using the precipitation type probabilities supplied by Subroutine PROB2 (See Section 5.2.5). If hail has a non-zero probability, it is assigned first to the events which have the shortest duration. Similarly, if thunderstorms have a finite probability, they are assigned to the event of the shortest duration from the remaining non-identified events. These assignments are made until the expected value of the duration time of a particular type of event is exhausted. The remaining types of precipitation i.e., rain, freezing rain and snow are assigned to the remaining non-identified precipitation events until all these events have been specified.

The third step in Subroutine PRECIP is the assignment of the total amount of precipitation to each of the precipitation events. This is accomplished by transforming a gaussian random number using the parameters supplied by Subroutine PROB2 and describing the clock-hour precipitation rate. Again these parameters specify a Johnson S_B distribution (Reference 3) which is a transformation of the normal distribution. The clock-hour rate in inches per hour is given by

$$r = \frac{f_3 \, e^{\frac{z - f_1}{f_2}}}{1 + e^{\frac{z - f_1}{f_2}}}$$

where f_i, $i = 1, 2, 3$ are the parameters supplied by PROB2. Since the clock-hour rate represents the equivalent amount of rain in an one hour period, more than one value may be required to determine the total precipitation level for any one event. As noted above the expected number of observations that will be effected by any one event given that the observations are made on equally hour intervals is equal to one plus the duration of the event in hours. Therefore this number of clock-hour rates must be used to determine the total precipitation level for any one event. A random array is generated having a sufficient number of clock-hour rates to determine the total precipitation for all the precipitation events. The maximum clock-hour rates are assigned to the thunderstorm or hail events if any exist. The remaining rates are then randomly assigned to the other types of precipitation events. In the case of snow or hail events the total precipitation level represents the rain equivalent.

The last step in the subroutine is a random selection of a portion of the six-week history for the period identified for the game played. Should the duration of the game be six weeks this step is bypassed and execution returned to the calling program.

5.2.3.4 Sample Data Set

No input data is required by this subroutine.

5.2.3.5 Sample Output

No direct output is produced by this subroutine. The data required to specify the time history, namely the event starting times (ITCNG), the event identification code (IPCODE), and the total precipitation level for each event (TOTP), are returned to the calling program through the argument list.

5.2.4 SUBROUTINE PROB1

5.2.4.1 Purpose

This subroutine supports PRECIP in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to supply parameters describing the distribution for the duration of both precipitation or non-precipitation events.

5.2.4.2 Use and Description of Inputs

A PROB1 data set for the appropriate month and scenario area must be placed in the input data stream to be read by this routine. The order of the data sets in the input data stream is presented in the description of the main program ATMOMN (Section 5.2.1). The PROB1 data set contains the parameters of the distributions for the duration of both precipitation and non-precipitation events. The distributions are obtained from recorded weather data and provided by Mr. Allen R. Davis of the USAF Environmental Technical Application Center (ETAC), Building 159 Navy Yard Annex, Washington, D.C., 20333. A typical example is shown in Table 5.2-V. The empirical data can be satisfactorily fit by Johnson S_B distributions. (See Reference 3). The Johnson distributions are four-parameter transformations of the normal distribution. If z represents a standard normal random variable (i.e. zero mean and unit standard deviation) the random variable, x, described by the Johnson S_B distribution is given by

$$x = \frac{\epsilon + (\epsilon + \lambda) e^{\frac{z - \gamma}{\eta}}}{1 + e^{\frac{z - \gamma}{\eta}}}$$

AVERAGE NUMBER OF OCCURRENCES OF INDICATED NUMBER OF CONSECUTIVE OBSERVATIONS WITHOUT PRECIPITATION
FOR FIRST 'NO PRECIP' OBS. BEGINNING AT00-05 LST

SYNOPTIC CODES FOR PRECIP= 50-59,60-69,70-79,80-89,90-99,
EGLIN AFB,FLORIDA POR DEC 1958-OCT 1968

NR CONSEC OBS	1	2	3	4	5	6	7	8	9	10	11	12	13-18	19-24
JAN	1.30	0.10	0.40	0.50	0.20	0.30	0.00	0.10	0.10	0.00	0.10	0.20	0.00	0.00
FEB	1.00	0.50	0.30	0.20	0.30	0.10	0.00	0.10	0.00	0.00	0.20	0.20	0.20	0.30
MAR	0.40	0.30	0.10	0.00	0.00	0.40	0.10	0.00	0.10	0.00	0.00	0.00	0.40	0.00
APR	0.50	0.10	0.10	0.10	0.10	0.20	0.00	0.00	0.00	0.00	0.10	0.10	0.00	0.00
MAY	0.30	0.20	0.10	0.00	0.00	0.30	0.10	0.00	0.10	0.10	0.00	0.00	0.00	0.00
JUN	0.60	0.20	0.20	0.10	0.20	0.00	0.10	0.00	0.10	0.20	0.10	0.00	0.00	0.10
JUL	0.40	0.30	0.20	0.00	0.10	0.00	0.40	0.00	0.10	0.20	0.10	0.00	0.10	0.20
AUG	0.40	0.50	0.50	0.20	0.00	0.20	0.20	0.00	0.30	0.00	0.10	0.00	0.10	0.00
SEP	0.80	0.00	0.20	0.10	0.00	0.00	0.10	0.20	0.00	0.10	0.10	0.00	0.00	0.00
OCT	0.30	0.30	0.30	0.00	0.10	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.20	0.00
NOV	0.33	0.22	0.22	0.22	0.22	0.11	0.22	0.22	0.11	0.11	0.00	0.00	0.00	0.11
DEC	1.50	0.70	0.30	0.40	0.20	0.00	0.30	0.00	0.10	0.00	0.10	0.00	0.20	0.10
ANN	8.67	3.43	2.92	1.82	1.41	1.71	1.51	0.71	1.01	0.71	0.91	0.50	1.41	0.81

CONTINUED	25-36	37-48	49-72	73-96	97-120	121-144	145-168	EQ/GT169	UNDEC	NR OF MO	NR OF OBS	NR OBS WITHOUT PRECIP
JAN	0.10	0.00	0.40	0.40	0.50	0.10	0.00	0.40	0.0	10	1054	1701
FEB	0.20	0.30	0.50	0.60	0.20	0.10	0.10	0.10	0.0	10	1698	1563
MAR	0.30	0.20	0.20	0.30	0.10	0.00	0.20	0.30	0.0	10	1860	1702
APR	0.10	0.20	0.10	0.20	0.10	0.10	0.00	0.30	0.0	10	1800	1733
MAY	0.00	0.00	0.10	0.00	0.00	0.00	0.10	0.20	0.0	10	1860	1814
JUN	0.10	0.10	0.20	0.00	0.10	0.00	0.10	0.10	0.0	10	1800	1726
JUL	0.20	0.20	0.10	0.10	0.00	0.10	0.00	0.00	0.0	10	1860	1808
AUG	0.10	0.00	0.10	0.10	0.10	0.00	0.00	0.10	0.0	10	1860	1791
SEP	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.10	0.0	10	1800	1701
OCT	0.10	0.10	0.00	0.10	0.30	0.00	0.00	0.40	0.0	10	1860	1746
NOV	0.11	0.11	0.22	0.22	0.00	0.11	0.22	0.22	0.0	9	1620	1551
DEC	0.30	0.10	0.20	0.00	0.10	0.30	0.10	0.60	0.0	10	1860	1687
ANN	1.71	1.41	2.22	2.12	1.51	0.81	0.81	2.82	0.0	119	21732	20423

NMBRS.IN LAST TWO COLS. ARE COUNTS AT 00-05LST

Table 5.2-V DURATION DISTRIBUTIONS FOR NON-PRECIPITATION EVENTS (EGLIN AFB, FLORDIA, 00-06 L.S.T.)

where γ , η , ϵ and λ are the four parameters of the transformation. The value of x will be bounded between ϵ and $\epsilon+\lambda$. In the case of the duration distributions it is assumed that the lower bound, i.e. ϵ , is zero. The values of the remaining three parameters (γ , η and λ) are estimated using methods recommended in the cited reference. Cumulative distributions are formed by summing the empirical probability densities supplied by ETAC. In addition to the 0th and 100th percentile, the S_B distribution is forced to agree with the cumulative at two other percentiles. Several sets of percentiles are employed and the residual sum of squares between the fitted S_B distributions and the cumulative computed. The values for the parameters of the set of percentiles with the smallest residual (and hence the best fit) are used in constructing the PROB1 data set. The composition of the PROB1 data set (3 cards) is shown in Table 5.2-VI. We see that the duration distributions for both precipitation and non-precipitation events are determined as a function of the time of day classified into four intervals 00 to 06 hours, 06 to 12 hours, 12 to 18 hours, and 18 to 24 hours, Local Standard Time. Of the 28 parameters contained in the PROB1 data set the fifth through the twenty-eighth parameters, inclusive, are required to specify the eight duration distributions. The first 4 parameters are instantaneous precipitation probabilities conditioned on the time of day. These probabilities are obtained from standard weather summaries also supplied by ETAC. These summaries contain the percentage frequency of occurrence of weather conditions from hourly observations including the percentage of observations with precipitation. Due to the lack of sufficient data at the station located at Hue, data from the station at Da Nang (48855) was used as a suitable alternate for duration distribution data.

Two input variables are supplied to the subroutine through its argument list. The integer variable J (or JTIME in subroutine PRECIP) is the interval corresponding to the time of day. A second integer variable IP identifies the precipitation condition (IP = 1 designates a non-precipitation period; IP = 2 a precipitation period).

Table 5.2-VI Composition of PROB1 Data Set
(3 Cards)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	72X, 4I2	"Identifying Alpha/ Numeric Information," IDAREA, IMONTH, 1, 1	The first 72 spaces are provided for alpha/numeric information to allow identification of the data set. The four integers that follow serve as an identification code [IDAREA = scenario area, IMONTH = month to which the data set applies].
2	14F5, 4I2	[PARAM(I), I = 1, 14], IDAREA, IMONTH, 1, 2	PARAM(1)-PARAM(4) = probability of precipitation conditioned to time of day (1 = 00 to 06 hrs., 2 = 06 to 12 hrs., 3 = 12 to 18 hrs., 4 = 18 - 24 hrs. L.S.T.) PARAM(5)-PARAM(7) = non-precipitation duration dist'd, 00 to 06 hrs. PARAM(8)-PARAM(10) = non-precipitation duration dist'd, 06 to 12 hrs. PARAM(11)-PARAM(13) = non-precipitation duration dist'd, 12 to 18 hrs. PARAM(14) = part of non-precipitation duration dist'd, 18 to 24 hrs.
3	14F5, 4I2	[PARAM(I), I = 15, 28], IDAREA, IMONTH, 1,3	PARAM(15)-PARAM(16) = remainder of non-precipitation duration dist'd, 18 to 24 hrs. PARAM(17)-PARAM(19) - precipitation duration dist'd, 00 to 06 hrs. PARAM(20)-PARAM(22) = precipitation duration dist'd, 06 to 12 hrs. PARAM(23)-PARAM(25) = precipitation duration dist'd, 12 to 18 hrs. PARAM(26)-PARAM(28) = precipitation duration dist'd, 18 to 24 hrs.

5.2.4.3 Description of Logic and Processing

Fig. 5.2-8 shows a macroflow diagram of Subroutine PROB1 identifying the major processing steps. The first call of the subroutine (NCYCLE = 0) causes the PROB1 data set to be read from the input data stream. In the next step a value is assigned to the precipitation probability depending upon the time of day. If the subroutine has been previously called (NCYCLE = 1), the first two steps are bypassed and execution is transferred immediately to the third step. In this step the parameters for the duration distribution required by Subroutine PRECIP are set. After this step execution is returned to the calling program.

5.2.4.4 Sample Data Set

Fig. 5.2-9 shows the PROB1 data set prepared for an exercise in the Hue scenario area during the month of May.

5.2.4.5 Sample Output

No direct output is produced by this subroutine. The distribution parameters and precipitation probabilities are returned to the calling subroutine through the argument list.

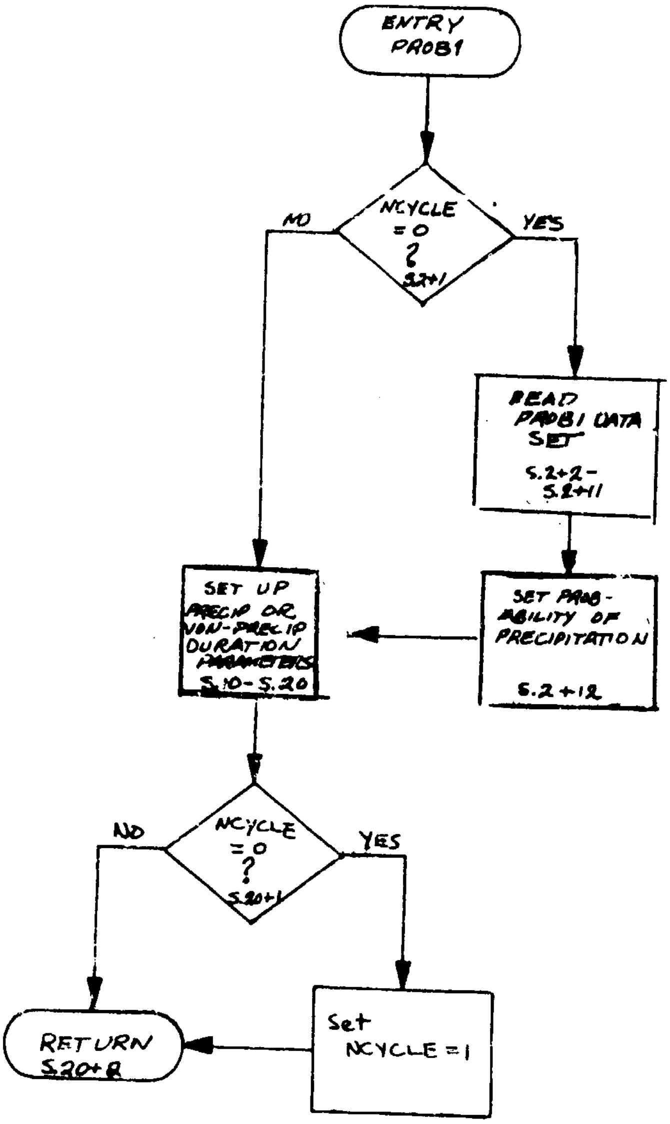
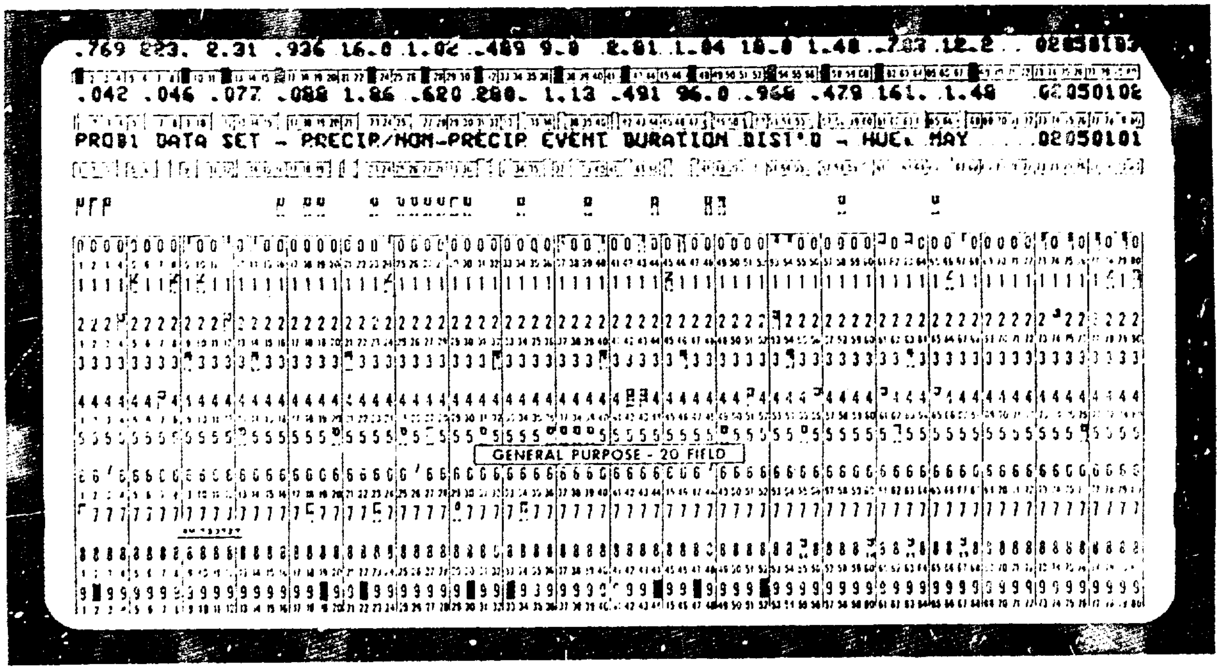


Figure 5.2-8 **Macroflow Diagram for Subroutine PROB1**



```
.769 223. 2.31 .936 16.0 1.02 .489 9.0  2.01 1.04 18.0 1.40 .783 12.2   02050103
.042 .046 .077 .088 1.86 .620 280. 1.13 .491 96.0 .968 .479 161. 1.48   02050102
PROB1 DATA SET - PRECIP/NON-PRECIP EVENT DURATION DIST'N - HUE, MAY     02050101
```

Figure 5.2-9 AN EXAMPLE OF A PROB1 DATA SET (3 CARDS)

5.2.5 SUBROUTINE PROB2

5.2.5.1 Purpose

This subroutine supports PRECIP (5.2.3) in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to supply parameters describing the distribution of the clock-hour precipitation rate and the discrete precipitation type probabilities.

5.2.5.2 Use and Description of Inputs

A PROB2 data set for the appropriate month and scenario area must be placed in the input data stream to be read by this subroutine. The order of the data sets in the input data stream is presented in the description of the main program ATMOMN (5.2.1). The PROB2 data set contains the parameters for the distribution of the clock-hour precipitation rate and the discrete probabilities for five classes of precipitation types as a function of the time of day classified into four intervals, 00 to 06 hours, 06 to 12 hours, 12 to 18 hours and 18 to 24 hours, Local Standard Time. The distributions of clock-hour precipitation rates are obtained from recorded weather data and provided by Mr. Allen R. Davis of the USAF Environmental Technical Application Center (ETAC), Building 159 Navy Yard Annex, Washington, D. C., 20333. The empirical data can be satisfactorily fit by Johnson S_B distributions. (See Reference 3). The Johnson distributions are four-parameter transformations of the normal distribution. If z represents a standard normal random variable (i.e. zero mean and unit standard deviation) the random variable, x, described by the Johnson S_B distribution is given by

$$x = \frac{\epsilon + (\epsilon + \lambda) e^{\frac{z - \gamma}{\eta}}}{1 + e^{\frac{z - \gamma}{\eta}}}$$

where γ, η, ϵ and λ are the four parameters of the transformation. The value of x will be bounded between ϵ and $\epsilon+\lambda$. In the case of the clock-hour rate distributions it is reasonable to assume that the lower bound, i.e. ϵ, is zero. The values of the remaining three parameters (γ, η and λ) are estimated using methods recommended in the cited reference. Cumulative distributions are formed by summing the empirical probability densities supplied by ETAC. In addition to the 0th and 100th percentile, the S_B distribution is forced to agree with the cumulative at two other percentiles. Several sets of percentiles are employed and the residual sum of squares between the fitted S_B distributions and the cumulative computed. The values for the parameters of the set of percentiles with the smallest residual (and hence the best fit) are used in constructing the PROB2 data set.

This data set also contains discrete precipitation type probabilities. Five types are defined; thunderstorms, rain, freezing rain, snow and hail. These probabilities are obtained from standard weather summaries also supplied by ETAC. These summaries contain the percentage frequency of occurrence of weather conditions from hourly observation. Unfortunately, when a weather observer reports thunder at his station this does not mean that a thunderstorm is directly overhead but only that thunder is heard at the station. The actual thunderstorm may be as far as ten miles from the station. The count of the number of observations that include both thunder and precipitation occurring is taken as more representative of the thunderstorm frequency at a point. Therefore in order to properly construct the discrete probabilities the percentage frequency of occurrence of both precipitation and thunder is also obtained from ETAC. The percentage frequency of occurrence of thunderstorms reported in the standard weather summaries are decreased by multiplying by this conditional frequency of occurrence of precipitation given thunder. The precipitation type probabilities are determined as a function of time of day classified into four intervals. The sum of the five probabilities in any one time interval totals to one.

The composition of the PROB2 data set (three cards) is shown in Table 5.2-VII. We see that the first three parameters specify the precipitation rate

Table 5.2.VII Composition of PROB2 Data Set
(3 Cards)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	72A, 4I2	"Identifying Alpha/ Numeric Information", IDAREA, IMONTH, 2, 1	The first 72 spaces are provided for alpha/numeric information to allow identification of the data set. The four integers that follow serve as an identification code [IDAREA = scenario area, IMONTH = month to which the data set applies].
2	14F5, 4I2	[PARAM(I), I = 1, 14], IDAREA, IMONTH, 2, 2	PARAM(1)-PARAM(3) = precipitation rate dist'd parameters, all hours PARAM(4)-PARAM(8) = precipitation type probabilities (thunderstorm, rain, freezing rain, snow and hail), 00-06 hrs. PARAM(9)-PARAM(13) = precipitation type probabilities, 06-12 hrs. PARAM(14) = part of precipitation type probabilities, 12-18 hrs.
3	14F5, 4I2	[PARAM(I), I = 15, 28], IDAREA, IMONTH, 2, 3	PARAM(15)-PARAM(18) = remainder of precipitation type probabilities, 12-18 hrs. PARAM(19)-PARAM(23) = precipitation type probabilities, 18-24 hrs. PARAM(24)-PARAM(28) = blank

distribution for all hours while the fourth through the twenty-third parameters are the discrete precipitation type probabilities for the four time-of-day intervals.

One input variable is supplied to the subroutine from its argument list. The integer variable J (or JTIME in subroutine PRECIP) is the interval corresponding to the time-of-day.

5.2.5.3 Description of Logic and Processing

Fig. 5.2-10 shows a macroflow diagram of subroutine PROB2 identifying the major processing steps. The first call of the subroutine causes the PROB2 data set to be read from the input data stream. In the second step the parameters of the clock-hour precipitation rate distribution are set since these parameters are not functions of the time-of-day. If the subroutine has been previously called, these first two steps are bypassed and execution is transferred immediately to the third step. In this step the discrete precipitation type probabilities are set appropriate to the time-of-day. After this step, execution is returned to the calling program.

5.2.5.4 Sample Data Set

Fig. 5.2-11. shows the PROB2 data set prepared for an exercise in the Hue scenario area during the month of May.

5.2.5.5 Sample Output

No direct output is produced by this subroutine. The distribution parameters for the clock-hour precipitation rate and the probability of the precipitation types are returned to the calling subroutine through the argument list.

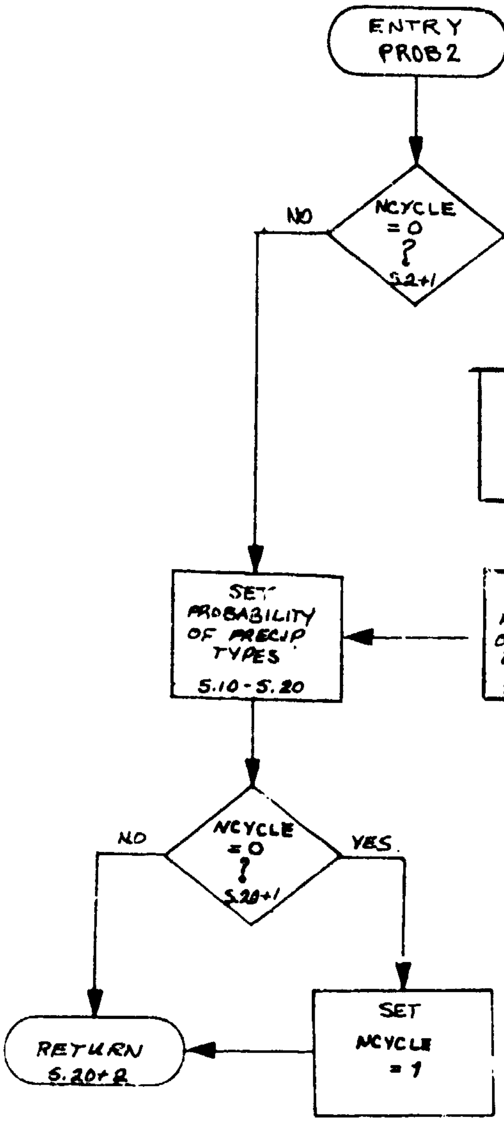


Figure 5.2-10 MACROFLOW DIAGRAM FOR SUBROUTINE PROB2

Figure 5.2-11 AN EXAMPLE OF A PROB2 DATA SET (3 CARDS)

5.2.6 SUBROUTINE WEATHR

5.2.6.1 Purpose

This subroutine supports ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to compute time histories for a number of meteorological variables including wind speed, visibility, atmospheric pressure, cloud cover, ceiling, dry bulb temperature and dew point depression.

5.2.6.2 Use and Description of Inputs

No input data must be manually supplied by the planner. The values for the arrays describing the precipitation, non-precipitation time history generated by Subroutine PRECIP are supplied to this subroutine through its argument list. In addition a logical array, PLANIN, describing the variables which the planner has elected to supply as input is also supplied to the subroutine through its argument list.

5.2.6.3 Description of Logic and Processing

A macroflow diagram showing the major processing steps of this subroutine is presented in Fig. 5.2-12.The purpose of the subroutine is to compute time histories of a number of meteorological factors. Table 5.2-VIII lists these factors along with the units in which the computation is made. Most of these factors as indicated in the Table are stored in ATMENV common area. This subroutine assigns a single value to each of the variables depending upon the elapsed time from the start of the game and the precipitation, non-precipitation time history generated previously by Subroutine PRECIP. The time history of these meteorological variables is generated by recycling to the call of Subroutine WEATHR

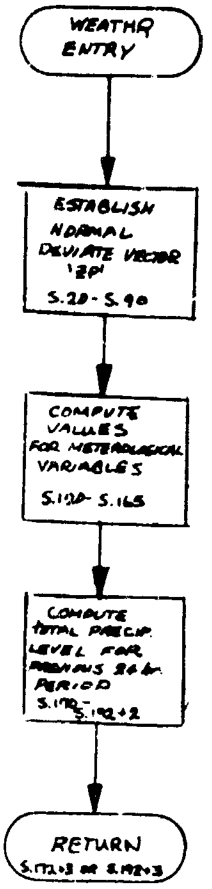


Figure 5.2-12 MACROFLOW DIAGRAM OF SUBROUTINE WEATHR

Table 5.2-VIII METEOROLOGICAL VARIABLES COMPUTED BY SUBROUTINE WEATHR

FORTRAN NAME	DESCRIPTION	UNITS	CORRESPONDING ELEMENT OF PLANIN ARRAY	OUTPUT MODE
PRATE	Instantaneous precipitation rate	Inches/sec.	None	ATMENV
WSPEED	Wind speed	Knots	3	ATMENV
VISIB	Meteorological visibility	Miles	8	ATMENV
PRESUR	Atmospheric pressure	Inches of Hg.	6	ATMENV
CCOVER	Cloud cover	Fraction	4	ATMENV
CEIL	Ceiling	Feet	9	ATMENV
ATEMP	Dry bulb temperature	Fahrenheit degrees	5	ATMENV
DEWDEP	Dew point depression	Fahrenheit degrees	7	Argument list
PTOT24	Total precipitation level during previous 24 hr. period	Inches	None	ATMENV

in Subroutine ATMOS and incrementing the elapsed time from the start of the game.

The first major step in WEATHR is the establishment of the normal deviate vector "ZP". This vector consists of seven elements which are standard normal deviates (zero mean and unit standard deviation). Different branches are also employed in the processing if the calculation is being made at the beginning of the game or depending upon the precipitation conditions (VLOG = .TRUE. indicates a precipitation event.)

In order to insure a time correlation between the normal deviate vector at successive times an element of the vector is generated by taking a portion of its previous value and adding a fraction of an uncorrelated random deviate supplied by the gaussian random number generator. If we let j be an index on time and Z_j represent the standard normal deviate with zero mean and unit standard deviation then an element of the "ZP" vector which we will call Z'_j is given by

$$Z'_j = C_1 Z'_{j-1} + C_2 Z_j$$

In order to insure that Z'_j is distributed normally with zero mean and unit standard deviation, we require that

$$C_1^2 + C_2^2 = 1$$

If we let ρ be the correlation coefficient for values of the meteorological variables over a one hour interval, we can show that

$$C_1 = \rho^{3600/i}$$

were t is the time difference $t_j - t_{j-1}$ in seconds. The current value of ρ, denoted by the Fortran name TCORR, is 0.97 and is established by a data statement in the subroutine. This was selected as a reasonable value based upon studies of persistence described in Reference 4.

In order to insure a smooth transition for the values of cloud cover and dew point depression from precipitation to non-precipitation events the values in the normal deviate vector "ZP" used in computing values for these meteorological variables are derived using an ordered array of independent normal deviates. These arrays are ordered so that they are monotonically decreasing over the first half of their length and monotonically increasing over the last half. This insures that the appropriate elements of the "ZP" vector will have a smooth transition from maximum to minimum back to maximum during a non-precipitation event. This permits a smooth transition of cloud cover from maximum to minimum to maximum and dew point depression from zero to a maximum value back to zero over the event.

The next step in Subroutine WEATHR is to compute values for the meteorological factors shown previously in Table 5.2-VIII. If the planner has elected to provide input data, the particular calculational step involved is bypassed. The areas in which the planner has selected to provide input are identified through the use of logical array, PLANIN. The elements of the array which are used as indicators for each of the meteorological factors is indicated in the table. The first variable to be calculated is the instantaneous precipitation rate. During a precipitation period the instantaneous rate is calculated using an algorithm based upon a half-cycle sinusoidal distribution in time over the duration of the event, namely

$$R(t) = \frac{\pi}{2}\left(\frac{P}{D}\right) \sin\left(\frac{\pi t}{D}\right)$$

where $R(t)$ is the instantaneous rate in inches per second, p is the total precipitation for the event in inches, d is the duration of the event in seconds and t is the elapsed time from the beginning of the event in seconds. In the case of a snow event the instantaneous rate is multiplied by 10 to account for the equivalence between rain and snow.

The values assigned to meteorological variables of wind speed, visibility, atmospheric pressure, cloud cover, ceiling, dry bulb temperature and dew point depression are made using the standard normal deviates contained in the "ZP" vector. The elements are transformed using several sets of parameters supplied by Subroutines PROB3 (5.2.7), PROB4 (5.2.8) or PROB5 (5.2.9). The parameters described a Johnson S_B distribution. (See Reference 3). The values for each of the meteorological factors are determined from the respective elements in the vector using the transformation

$$x = \frac{p_3 + p_4 e^{\frac{z-p_1}{p_2}}}{1 + e^{\frac{z-p_1}{p_2}}}$$

where p_i, $i=1,2,3,4$ are the parameters supplied by the supporting subroutines. The correspondence between these parameters and the notation in the cited reference is $p_1 = \gamma$, $p_2 = \eta$, $p_3 = \epsilon$ and $p_4 = \epsilon + \lambda$. If the current event is a precipitation period (VLOG = .TRUE.) the value of cloud cover is set equal to one and dew point depression equal to zero and the Monte-Carlo procedures for the calculation of these variables bypassed.

The final step in Subroutine WEATHR is the computation of the total precipitation during the previous 24-hour time period. If the elapsed time from the beginning of the game exceeds 24 hours, the calculation is made by summing the values in the TOTP array for the previous 24-hour period. At the beginning of the game, it is determined by computing the average 24-hour precipitation level over the duration of the game. For elapsed time between the beginning of the game and 24 hours, the value is determined using a monotonically decreasing value proportional to the total precipitation at the beginning of the game plus any precipitation occurring between the beginning of the game and the current time. After this calculation, execution is returned to the calling program.

5.2.6.4 Sample Data Set

No input data is required for this subroutine.

5.2.6.5 Sample Output

No output is produced directly by this subroutine. The values for the various meteorological variables are returned to the calling program through the ATMENV common area or the argument list. One of the supporting subroutines, (Section 5.2.16) END, will generate a printed report of the time history of the atmospheric environment if this option is chosen by the planner. This report will contain the values for many of the variables generated by WEATHR. Examples of the reports generated during a checkout of the model are included in the description of Subroutine END.

5.2.7 SUBROUTINE PROB3

5.2.7.1 Purpose

This subroutine supports WEATHR (5.2.6) in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to supply parameters describing the distribution of cloud cover, atmospheric pressure, visibility and wind speed.

5.2.7.2 Use and Description of Inputs

A PROB3 data set for the appropriate month and scenario area must be placed in the input data stream to be read by this routine. The order of the data sets in the input data stream is presented in the description of the main program ATMOMN (5.2.1). The PROB3 data set contains the parameters of the distributions for cloud cover, atmospheric pressure, visibility and wind speed. All of the distributions are determined as a function of the time of day classified into four intervals; 00 to 06 hours, 06 to 12 hours, 12 to 18 hours, and 18 to 24 hours, Local Standard Time. The distribution of atmospheric pressure is further divided into non-precipitation and precipitation periods. The visibility and wind speed distributions are divided into non-precipitation, light, medium or heavy precipitation periods. The distributions are obtained from recorded weather data and provided by Mr. Allen R. Davis of the USAF Environmental Technical Applications Center (ETAC), Building 159 Navy Yard Annex, Washington, D. C., 20333. The data required is in the form of bivariate frequency tables for each of the four time-of-day intervals. The specific tables required to assemble the PROB3 data set are visibility versus precipitation rate and wind speed versus precipitation rate. In addition marginal distributions for cloud cover and atmospheric pressure under conditions of precipitation and non-precipitation are also required. The empirical data can be satisfactorily fit by Johnson S_B distributions. (See Reference 3). The Johnson distributions are four-parameter transformations of the normal distribution. If Z represents a standard normal random variable (i.e. zero mean and unit standard deviation) the random variable, x, described by the Johnson S_B distribution is given by

$$x = \frac{\epsilon + (\epsilon + \lambda)\, e^{\frac{Z-\gamma}{\eta}}}{1 + e^{\frac{Z-\gamma}{\eta}}}$$

where γ, η, ϵ and λ are the four parameters of the transformation. The value of x will be bounded between ϵ and $\epsilon+\lambda$. The values of the parameters are estimated using methods recommended in the cited reference. Cumulative distributions are formed by summing the empirical probability densities supplied by ETAC. In addition to the 0th and 100th percentile, the S_B distribution is forced to agree with the cumulative at two other percentiles. Several sets of percentiles are employed and the residual sum of squares between the fitted S_B distributions and the cumulative computed. The values for the parameters of the set of percentiles with the smallest residual (and hence the best fit) are used in constructing the PROB3 data set. The composition of the PROB3 data set (23 cards) is shown in Tab. 5.2-IX. Due to the lack of sufficient data at the station located at Hue, data from the station at Da Nang (48855) was used as a suitable alternate for supplying the required empirical distributions.

Two input variables are supplied to the subroutine through its argument list. The integer variable JTIME is the interval corresponding to the time of day. A second integer variable IP identifies the precipitation condition (IP = 0 designates the non-precipitation period, IP = 1 a light precipitation period, IP = 2 a medium precipitation period and IP = 3 a heavy precipitation period).

5.2.7.3 Description of Logic and Processing

Fig. 5.2-13 presents a macroflow diagram of Subroutine PROB3 identifying the major processing steps. The first call of the subroutine (NCYCLE = 0) causes the PROB3 data set to be read from the input data stream. If the subroutine has

Table 5.2-IX **Composition of PROB3 Data Set**
(23 cards)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	72X, 4I2	"Identifying Alpha/ Numeric Information", IDAREA, IMONTH, 3, 1	The first 72 spaces are provided for alpha/numeric information to allow identification of the data set. The four integers that follow serve as an identification code [IDAREA = scenario area, IMONTH = month to which the data set applies].
2	8E9, 4I2	[PARAM(I), I = 1, 8], IDAREA, IMONTH, 3, 2	PARAM(1)-PARAM(4) = cloud cover dist'd, 00-06 hrs. PARAM(5)-PARAM(8) = atmospheric pressure dist'd, non-precipitation period, 00-06 hrs.
3	8E9, 4I2	[PARAM(I), I = 9, 16], IDAREA, IMONTH, 3, 3	PARAM(9)-PARAM(12) = atmospheric pressure dist'd. precipitation period, 00-06 hrs. PARAM(13)-PARAM(16) = visibility dist'd, non-precipitation period, 00-06 hrs.
4	8E9, 4I2	[PARAM(I), I = 17, 24], IDAREA, IMONTH, 3, 4	PARAM(17)-PARAM(20) = visibility dist'd, light precipitation period, 00-06 hrs. PARAM(21)-PARAM(24) = visibility dist'd, medium precipitation period, 00-06 hrs.
5	8E9, 4I2	[PARAM(I), I = 25, 32], IDAREA, IMONTH, 3, 5	PARAM(25)-PARAM(28) = visibility dist'd, heavy precipitation period, 00-06 hrs. PARAM(29)-PARAM(32) = wind speed dist'd, non-precipitation period, 00-06 hrs.
6	8E9, 4I2	[PARAM(I), I = 33, 40], IDAREA, IMONTH, 3, 6	PARAM(33)-PARAM(36) = wind speed dist'd, light precipitation period, 00-06 hrs. PARAM(37)-PARAM(40) = wind speed dist'd, medium precipitation period, 00-06 hrs.
7	8E9, 4I2	[PARAM(I), I = 41, 48], IDAREA, IMONTH, 3, 7	PARAM(41)-PARAM(44) = wind speed dist'd, heavy precipitation period, 00-06 hrs.
PARAM(45)-PARAM(48) on Card 7 and Card 8 through 12 are the parameters for distributions, 06-12 hr. time period.			
Cards 13-17 and PARAM(137)-PARAM(140) on Card 18 are the parameters for distributions, 12-18 hr. time period.			
PARAM(141)-PARAM(144) on Card 18 and Cards 19 through 23 are the parameters for distributions, 18-24 hr. time period.			

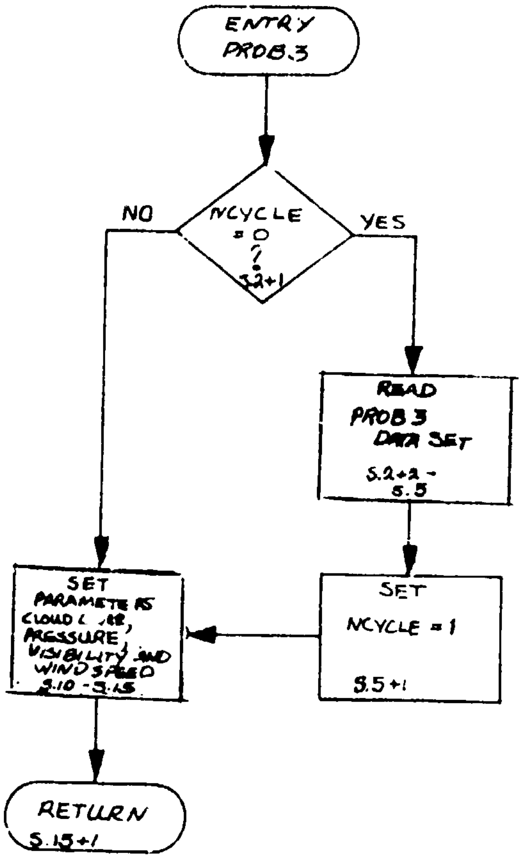


Figure 5.2-13 MACROFLOW DIAGRAM OF SUBROUTINE PROB3

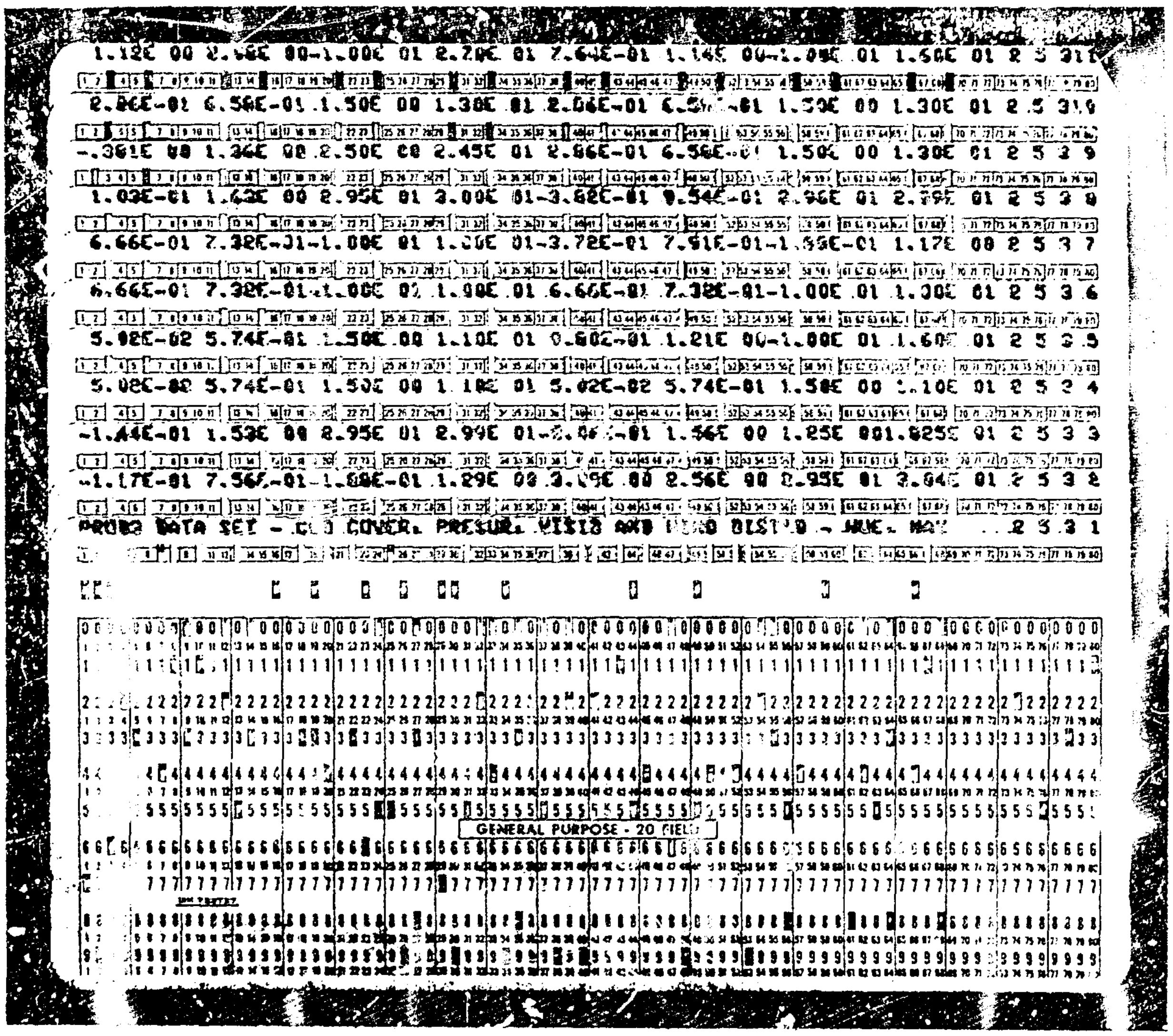
been previously called (NCYCLE = 1) this step is deleted and execution is immediately transferred to the second step. In this step the values for the parameters of the distribution of cloud cover, pressure, visibility and wind speed are set and execution is returned to the calling subroutine.

5.2.7.4 Sample Data Set

Fig.5.2-14 shows the PROB3 data set prepared for an exercise in the Hue scenario area during the month of May.

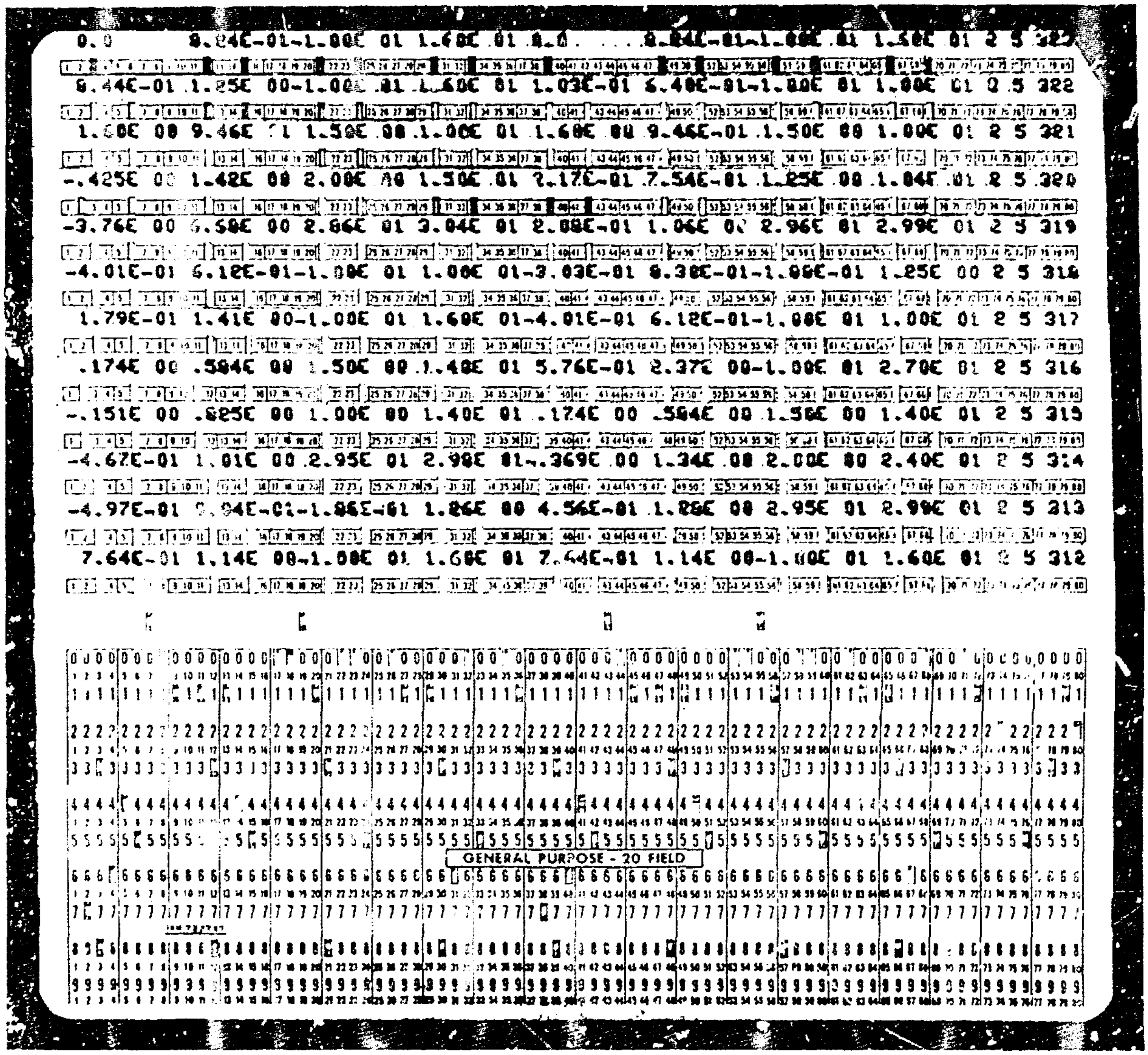
5.2.7.5 Sample Output

No direct output is produced by this subroutine. The distribution parameters are returned to the calling subroutine through the argument list.



```
1.12E 00 2.66E 00-1.00E 01 2.70E 01 7.64E-01 1.14E 00-1.00E 01 1.60E 01 2 5 311
2.86E-01 6.56E-01 1.50E 00 1.30E 01 2.06E-01 6.56E-01 1.50E 00 1.30E 01 2 5 310
-.361E 00 1.36E 00 2.50E 00 2.45E 01 2.86E-01 6.56E-01 1.50E 00 1.30E 01 2 5 3 9
1.03E-01 1.62E 00 2.95E 01 3.00E 01-3.62E-01 9.54E-01 2.96E 01 2.79E 01 2 5 3 8
6.66E-01 7.32E-01-1.00E 01 1.20E 01-3.72E-01 7.91E-01-1.55E-01 1.17E 00 2 5 3 7
6.66E-01 7.32E-01-1.00E 01 1.90E 01 6.66E-01 7.32E-01-1.00E 01 1.30E 01 2 5 3 6
5.92E-02 5.74E-01 1.50E 00 1.10E 01 9.60E-01 1.21E 00-1.00E 01 1.60E 01 2 5 3 5
5.08E-02 5.74E-01 1.50E 00 1.10E 01 5.02E-02 5.74E-01 1.50E 00 1.10E 01 2 5 3 4
-1.44E-01 1.53E 00 2.95E 01 2.99E 01-2.06E-01 1.56E 00 1.25E 001.625E 01 2 5 3 3
-1.17E-01 7.56E-01-1.88E-01 1.29E 00 3.09E 00 2.56E 00 2.95E 01 3.04E 01 2 5 3 2
PROB2 DATA SET - CLD COVER, PRESUR, VISIB AND WIND DISTRB - AUG, MAY      2 5 3 1
```

Figure 5.2-14 AN EXAMPLE OF A PROB2 DATA SET (23 CARDS)



```
0.0        8.24E-01-1.00E 01 1.60E 01 0.0        8.24E-01-1.00E 01 1.50E 01 2 5 323
8.44E-01 1.25E 00-1.00E 01 1.60E 01 1.03E-01 6.40E-01-1.00E 01 1.00E 01 2 5 322
1.00E 00 9.46E 01 1.50E 00 1.00E 01 1.60E 00 9.46E-01 1.50E 00 1.00E 01 2 5 321
-.425E 00 1.42E 00 2.00E 00 1.50E 01 2.17E-01 7.54E-01 1.25E 00 1.04E 01 2 5 320
-3.76E 00 6.58E 00 2.86E 01 3.04E 01 2.08E-01 1.06E 02 2.96E 01 2.99E 01 2 5 319
-4.01E-01 6.12E-01-1.00E 01 1.00E 01-3.03E-01 8.30E-01-1.06E-01 1.25E 00 2 5 318
1.79E-01 1.41E 00-1.00E 01 1.60E 01-4.01E-01 6.12E-01-1.00E 01 1.00E 01 2 5 317
.174E 00 .584E 00 1.50E 00 1.40E 01 5.76E-01 2.37E 00-1.00E 01 2.70E 01 2 5 316
-.151E 00 .825E 00 1.00E 00 1.40E 01 .174E 00 .584E 00 1.56E 00 1.40E 01 2 5 315
-4.67E-01 1.01E 00 2.95E 01 2.98E 01-.369E 00 1.34E 00 2.00E 00 2.40E 01 2 5 314
-4.97E-01 9.04E-01-1.06E-01 1.26E 00 4.56E-01 1.26E 00 2.95E 01 2.99E 01 2 5 313
7.64E-01 1.14E 00-1.00E 01 1.60E 01 7.44E-01 1.14E 00-1.00E 01 1.60E 01 2 5 312
```

Figure 5.2-14 EXAMPLE OF A PROB3 DATA SET (23 CARDS) (cont'd)

5.2.8 SUBROUTINE PROB4

5.2.8.1 Purpose

This subroutine supports WEATHR (5.2.6) in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to supply parameters describing the distribution of ceiling and air temperatures.

5.2.8.2 Use and Description of Inputs

A PROB4 data set for the appropriate month and scenario area must be placed in the input data stream to be read by this routine. The order of the data sets in the input data stream is presented in the description of the main program ATMOMN (5.2.1). The PROB4 data set contains the parameters of the distribution of ceiling and air temperature as a function of the time of day classified into four intervals; 00 to 06 hours, 06 to 12 hours, 12 to 18 hours and 18 to 24 hours, Local Standard Time. Separate distributions are presented for non-precipitation periods for both the air temperature and ceiling. In addition the distributions on ceiling are further conditioned on the value of visibility. For these purposes the visibility is classified into three intervals; 0 to 5 miles, 5 to 10 miles and over 10 miles. The distributions are obtained from recorded weather data and provided by Mr. Allen R. Davis of the USAF Environmental Technical Applications Center (ETAC), Building 159 Navy Yard Annex, Washington, D. C. 20333. These data include bivariate frequency tables of ceiling versus visibility for both precipitation and non-precipitation periods and the time-of-day interval. In addition marginal distributions of air temperature for non-precipitation periods and precipitation periods are also required. The empirical data can be satisfactorily fit by Johnson S_B distributions. (See Reference 3). The Johnson distributions are four-parameter transformations of the normal distribution. If z represents a standard normal random variable (i.e. zero mean and unit standard deviation) the random variable, x , described by the Johnson S_B distribution is given by

$$x = \frac{\epsilon + (\epsilon + \lambda)\, e^{\frac{z-\gamma}{\eta}}}{1 + e^{\frac{z-\gamma}{\eta}}} \; .$$

where γ, η, ϵ and λ are the four parameters of the transformation. The value of x will be bounded between ϵ and $\epsilon+\lambda$. The values of the parameters are estimated using methods recommended in the cited reference. Cumulative distributions are formed by summing the empirical probability densities supplied by ETAC. In addition to the 0th and 100th percentile, the S_B distribution is forced to agree with the cumulative at two other percentiles. Several sets of percentiles are employed and the residual sum of squares between the fitted S_B distributions and the cumulative computed. The values for the parameters of the set of percentiles with the smallest residual (and hence the best fit) are used in constructing the PROB4 data set. The composition of the PROB4 data set (17 cards) is shown in Tab. 5.2-X. Due to the lack of sufficient data at the station located at Hue, data from the station at Da Nang (48855) was used as a suitable alternative for the empirical distributions.

Two input variables are supplied to this subroutine through its argument list. The integer variable JTIME is the integer corresponding to the time-of-day. A second integer variable IP identifies the precipitation condition (IP = 0 designates a non-precipitation period, IP = 1 a precipitation period).

5.2.8.3 Description of Logic and Processing

Fig. 5.2-15 presents a macroflow diagram of Subroutine PROB4 identifying the major processing steps. The first call of the subroutine (NCYCLE = 0) causes the PROB4 data set to be read from the input data stream. If the subroutine has been previously called (NCYCLE = 1) this step is bypassed and execution is

Table 5.2-X Composition of PROBS Data Set
(17 Cards)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	72X, 4I2	"Identifying Alpha/ Numeric Information", IDAREA, IMONTH, 4, 1	The first 72 spaces are provided for alpha/numeric information to allow identification of the data set. The four integers that follow serve as an identification code [IDAREA = scenario area, IMONTH = month to which the data set applies].
2	8E9, 4I2	[PARAM(I), I = 1, 3], IDAREA, IMONTH, 4, 2	PARAM(1)-PARAM(4) = temperature dist'd, non-precipitation period, 00-06 hrs. PARAM(5)-PARAM(8) = ceiling dist'd, non-precipitation period, visibility from 0 to 5 miles, 00-06 hrs.
3	8E9, 4I2	[PARAM(I), I = 9, 16], IDAREA, IMONTH, 4, 3	PARAM(9)-PARAM(12) = ceiling dist'd, non-precipitation period, visibility from 5 to 10 miles, 00-06 hrs. PARAM(13)-PARAM(16) = ceiling dist'd, non-precipitation period, visibility over 10 miles, 00-06 hrs.
4	8E9, 4I2	[PARAM(I), I = 17, 24], IDAREA, IMONTH, 4, 4	PARAM(17)-PARAM(20) = temperature dist'd, precipitation period, 00-06 hrs. PARAM(21)-PARAM(24) = ceiling dist'd, precipitation period, visibility from 0 to 5 miles, 00-06 hrs.
5	8E9, 4I2	[PARAM(I), I = 25, 32], IDAREA, IMONTH, 4, 5	PARAM(25)-PARAM(28) = ceiling dist'd, precipitation period, visibility from 5 to 10, 00-06 hrs. PARAM(29)-PARAM(32) = ceiling dist'd, precipitation period, visibility over 10 miles, 00-06 hrs.
Cards 6 through 9 are the parameters for distributions in the 06-12 hr. time period			
Cards 10 through 13 are the parameters for distributions in the 12-18 hr. time period			
Cards 14 through 17 are the parameters for distributions in the 18-24 hr. time period			

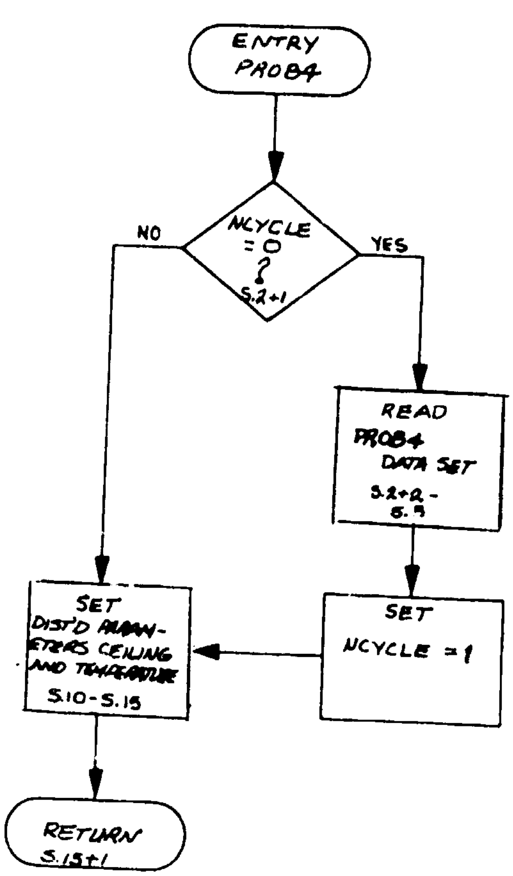


Figure 5.2-15 MACROFLOW DIAGRAM OF SUBROUTINE PROB4

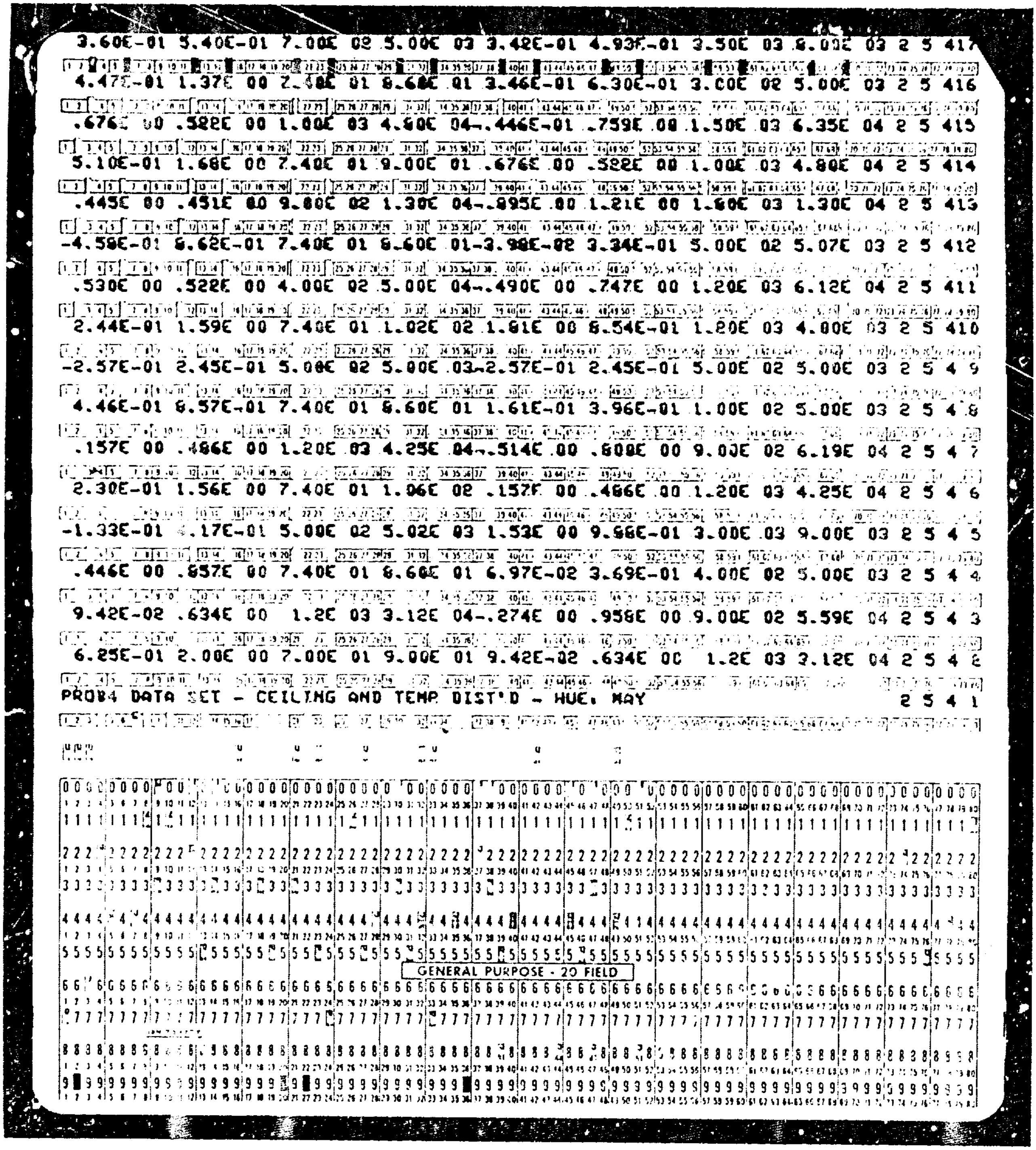
transferred immediately to the second step. In this step the parameters of the distribution of ceiling and temperature conditioned upon time-of-day precipitation and visibility are set. After this step execution is returned to the calling program.

5.2.8.4 Sample Data Set

Figure 5.2-16 shows the PROB4 data set prepared for an exercise in the Hue scenario area during the month of May.

5.2.8.5 Sample Output

No direct output is produced by this subroutine. The distribution parameters are returned to the calling subroutine through the argument list.



```
 3.60E-01 5.40E-01 7.00E 02 5.00E 03 3.42E-01 4.93E-01 3.50E 03 8.00E 03 2 5 417
 4.47E-01 1.37E 00 7.40E 01 6.60E 01 3.46E-01 6.30E-01 3.00E 02 5.00E 03 2 5 416
 .676E 00 .522E 00 1.00E 03 4.60E 04-.446E-01 .759E 00 1.50E 03 6.35E 04 2 5 415
 5.10E-01 1.68E 00 7.40E 01 9.00E 01 .676E 00 .522E 00 1.00E 03 4.80E 04 2 5 414
 .445E 00 .451E 00 9.80E 02 1.30E 04-.895E 00 1.21E 00 1.60E 03 1.30E 04 2 5 413
-4.58E-01 6.62E-01 7.40E 01 6.60E 01-3.98E-02 3.34E-01 5.00E 02 5.07E 03 2 5 412
 .530E 00 .522E 00 4.00E 02 5.00E 04-.490E 00 .747E 00 1.20E 03 6.12E 04 2 5 411
 2.44E-01 1.59E 00 7.40E 01 1.02E 02 1.61E 00 6.54E-01 1.20E 03 4.00E 03 2 5 410
-2.57E-01 2.45E-01 5.00E 02 5.00E 03-2.57E-01 2.45E-01 5.00E 02 5.00E 03 2 5 4 9
 4.46E-01 6.57E-01 7.40E 01 6.60E 01 1.61E-01 3.96E-01 1.00E 02 5.00E 03 2 5 4 8
 .157E 00 .486E 00 1.20E 03 4.25E 04-.514E 00 .608E 00 9.00E 02 6.19E 04 2 5 4 7
 2.30E-01 1.56E 00 7.40E 01 1.06E 02 .157E 00 .486E 00 1.20E 03 4.25E 04 2 5 4 6
-1.33E-01 4.17E-01 5.00E 02 5.02E 03 1.53E 00 9.66E-01 3.00E 03 9.00E 03 2 5 4 5
 .446E 00 .657E 00 7.40E 01 6.60E 01 6.97E-02 3.69E-01 4.00E 02 5.00E 03 2 5 4 4
 9.42E-02 .634E 00  1.2E 03 3.12E 04-.274E 00 .958E 00 9.00E 02 5.59E 04 2 5 4 3
 6.25E-01 2.00E 00 7.00E 01 9.00E 01 9.42E-02 .634E 00  1.2E 03 3.12E 04 2 5 4 2
PROB4 DATA SET - CEILING AND TEMP DIST'D - HUE, MAY                    2 5 4 1
```

Figure 5.2-16 AN EXAMPLE OF A PROB4 DATA SET (17 CARDS)

5.2.9 SUBROUTINE PROB5

5.2.9.1 Purpose

This subroutine supports WEATHR (5.2.6) in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to supply parameters for the distribution of dew point depression.

5.2.9.2 Use and Description of Inputs

A PROB5 data set for the appropriate month and scenario area must be placed in the input data stream to be read by this routine. The order of the data sets in the input data stream is presented in the description of the main program ATMOMN (5.2.1). The PROB5 data set contains the parameters for the distribution of the dew point depression as a function of the time of day classified into four intervals; 00 to 06 hours, 06 to 12 hours, 12 to 18 hours, and 18 to 24 hours, Local Standard Time. The bivariate frequency table of dew point or wet bulb temperature depression versus air temperature is frequently referred to as the psychrometric summary. The distributions are obtained from recorded weather data and provided by Mr. Allen R. Davis of the USAF Environmental Technical Applications Center (ETAC), Building 159 Navy Yard Annex, Washington, D. C., 20333. The empirical data can be satisfactorily fit by Johnson S_B distributions. (See Reference 3). The Johnson distributions are four-parameter transformations of the normal distribution. If z represents a standard normal random variable (i.e. zero mean and unit standard deviation) the random variable, x, described by the Johnson S_B distribution is given by

$$x = \frac{\epsilon + (\epsilon + \lambda)\, e^{\frac{z-\gamma}{\eta}}}{1 + e^{\frac{z-\gamma}{\eta}}}$$

where γ, η, ϵ and λ are the four parameters of the transformation. The value of χ will be bounded between ϵ and $\epsilon+\lambda$. The values of the parameters are estimated using methods recommended in cited references Cumulative distributions are formed by summing the empirical probability densities supplied by ETAC. In addition to the 0th and 100th percentile, the S_B distribution is forced to agree with the cumulative at two other percentiles. Several sets of percentiles are employed and the residual sum of squares between the fitted S_B distributions and the cumulative computed. The values for the parameters of the set of percentiles for the smallest residual (and hence the best fit) are used in constructing the PROB5 data set. The composition of the data set (18 cards) is shown in Tab. 5.2-XI.The dew point depression is conditioned as a function of the ambient air temperature. For this purpose the maximum to minimum range of air temperatures that can occur for the particular scenario area and month to which the data set applies is divided into eight degree intervals. A maximum of eight such intervals is permitted allowing a total maximum to minimum temperature range of 64°F. If a greater temperature range should occur in the empirical data, the 64° interval containing the majority of the air temperatures is employed. In most cases the temperature range will be less than the maximum 64° allowed and consequently all of the eight distributions (1 for each of the eight degree intervals) will not be required. In the example data shown later it is noted in this case that the maximum to minimum temperature differences specified on the second card all are less than 64° maximum difference allowed and consequently several sets of the parameters are not used and therefore set equal to zero in the data set. Due to the lack of sufficient data at the station located at Hue, data from the station at Da Nang (48855) was used as a suitable alternative for the temperature versus dew point bivariate data.

One input variable is supplied to the subroutine through its argument list. The integer variable JTIME is the integer corresponding to the time of day.

TABLE 5.2-XI Composition of PROBS Data Set
(18 cards)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	72X, 4I2	"Identifying Alpha/ Numeric Information", IDAREA, IMONTH, 5, 1	The first 72 spaces are provided for alpha/numeric information to allow identification of the data set. The four integers that follow serve as an identification code [IDAREA = scenario area, IMONTH = month to which the data set applies].
2	8E9, 4I2	[TMIN(I), TMAX(I), I = 1, 4], IDAREA, IMONTH, 5, 2	TMIN(1) = minimum temperature, 00-06 hrs. TMAX(1) = maximum temperature, 00-06 hrs. TMIN(2) = minimum temperature, 06-12 hrs. TMAX(2) = maximum temperature, 06-12 hrs. TMIN(3) = minimum temperature, 12-18 hrs. TMAX(3) = maximum temperature, 12-18 hrs. TMIN(4) = minimum temperature, 18-24 hrs. TMAX(4) = maximum temperature, 18-24 hrs.
3	8E9, 4I2	[PARAM(I), I = 1, 8], IDAREA, IMONTH, 5, 3	Distribution of Dew Point Depression, 00-06 hrs., conditioned on temperature from TMIN(1) to TMAX(1) in eight degree intervals (TMAX - TMIN $\leq$ 64°).
4	8E9, 4I2	[PARAM(I), I = 9, 16], IDAREA, IMONTH, 5, 4	
5	8E9, 4I2	[PARAM(I), I = 17, 24], IDAREA, IMONTH, 5, 5	
6	8E9, 4I2	[PARAM(I), I = 25, 32], IDAREA, IMONTH, 5, 6	
Cards 7 through 10 are parameters for distributions in the 06 to 12 hr. time period			
Cards 11 through 14 are parameters for distributions in the 12 to 18 hr. time period			
Cards 15 through 18 are parameters for distributions in the 18 to 24 hr. time period			

5.2.9.3 Description of Logic and Processing

Fig. 5.2-17 shows a macroflow diagram of Subroutine PROB5 identifying the major processing steps. The first call of this subroutine (NCYCLE = 0) causes the PROB5 data set to be read from the input data stream. If the subroutine has been previously called (NCYCLE = 1) this step is bypassed and execution is transferred to the second step. In this step the parameters for the distribution of dew point depression are set depending upon the time of day and the ambient air temperature. After this step execution is returned to the calling program.

5.2.9.4 Sample Data Set

Fig. 5.2-18 shows the PROB5 data set prepared for an exercise in the Hue scenario area during the month of May.

5.2.9.5 Sample Output

No direct output is produced by this subroutine. The dew point depression distribution parameters are returned to the calling program through the argument list.

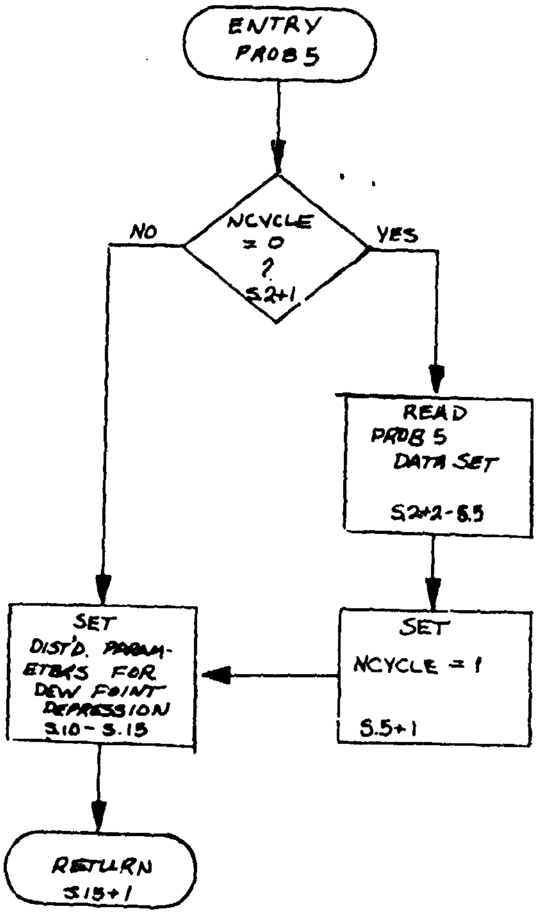
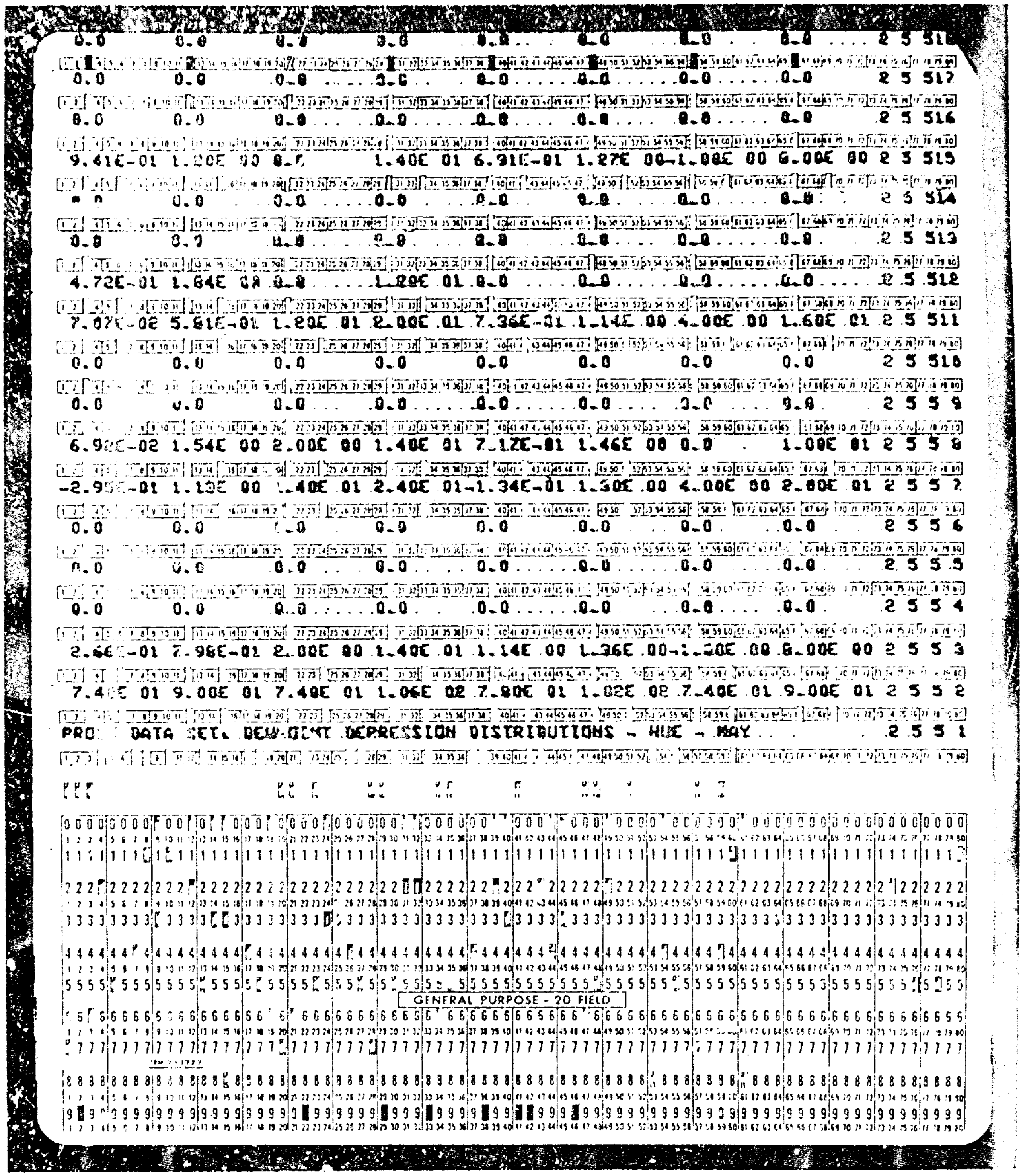


Figure 5.2-17 MACROFLOW DIAGRAM OF SUBROUTINE PROB5



```
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 518
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 517
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 516
 9.41E-01 1.20E 00 0.0      1.40E 01 6.91E-01 1.27E 00-1.08E 00 6.00E 00 2 5 515
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 514
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 513
 4.72E-01 1.64E 00 0.0      1.20E 01 0.0      0.0      0.0      0.0      2 5 512
 7.07E-02 5.61E-01 1.20E 01 2.00E 01 7.36E-01 1.14E 00 4.00E 00 1.60E 01 2 5 511
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 510
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 5 9
 6.92E-02 1.54E 00 2.00E 00 1.40E 01 7.12E-01 1.46E 00 0.0      1.00E 01 2 5 5 8
-2.95E-01 1.13E 00 1.40E 01 2.40E 01-1.34E-01 1.30E 00 4.00E 00 2.80E 01 2 5 5 7
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 5 6
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 5 5
 0.0      0.0      0.0      0.0      0.0      0.0      0.0      0.0      2 5 5 4
 2.66E-01 7.96E-01 2.00E 00 1.40E 01 1.14E 00 1.36E 00-1.20E 00 6.00E 00 2 5 5 3
 7.40E 01 9.00E 01 7.40E 01 1.06E 02 7.80E 01 1.02E 02 7.40E 01 9.00E 01 2 5 5 2
PRO    DATA SET. DEW-POINT DEPRESSION DISTRIBUTIONS - HUE - MAY         2 5 5 1
```

Figure 5.2-18AN EXAMPLE OF A PROB5 DATA SET (18 CARDS)

5.2.10 SUBROUTINE ORDER

5.2.10.1 Purpose

This subroutine supports Subroutine ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. This subroutine orders an input array such that the minimum value of the array is placed in the center of the output array and successive maximum values are placed at each end of the array. The array returned by the subroutine is therefore monotonically decreasing over the first half of its length and monotonically increasing over the second half.

5.2.10.2 Use and Description of Inputs

No manual input data is required by this subroutine. The input array to be ordered and the number of elements in the array are passed to the subroutine through its argument list.

Subroutine order is only called by Subroutine WEATHR (Section 5.2.6). It is used to order two vectors of gaussian random numbers such that each vector is monotonically decreasing over the first half of its length and monotonically increasing over the second half. The resulting ordered vectors of gaussian random numbers are then used to generate values for cloud cover and dew point depression (or relative humidity) during the non-precipitation periods of the game. This ordering insures that the values of cloud cover and relative humidity show a smooth transition between successive periods of precipitation and non-precipitation. During a period of precipitation both the cloud cover and the relative humidity are assumed to be 100%. At the end of the precipitation event or the beginning of a non-precipitation period, the ordering of the arrays allows values of both of these parameters to decrease smoothly achieving a minimum near the middle of the non-precipitation period.

5.2.10.3 Description of Logic and Processing

Figure 5.2-19 shows a macroflow diagram presenting the major steps in Subroutine ORDER. In the first step the maximum value of the input array is obtained. The next step is the ordering of the full array so that the maximum value is the first element in the array and the minimum value is the last element. This is accomplished by interchanging the maximum value located in the first step and the first element in the array and recycling through the initial loop which selects the maximum value in an array restricting the search to exclude the first element of the array since this contains the maximum value just found. This process is repeated and each time the size of the array searched for maximum value decreased by one element until the ordering is complete. The third and final step in Subroutine ORDER is the reordering of the array putting the minimum value at the center of the array and successive maxima at each end so that the array returned is monotonically decreasing over the first half of its length and monotonically increasing over the second half.

5.2.10.4 Sample Data Set

No input data set is required.

5.2.10.5 Sample Output

No direct output is produced by this subroutine.

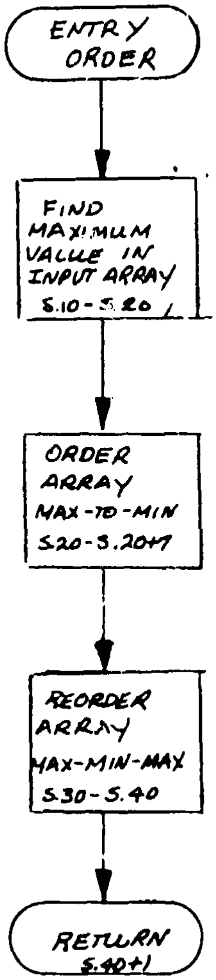


Figure 5.2-19 MACROFLOW DIAGRAM FOR SUBROUTINE ORDER

5.2.11 SUBROUTINE IRRAD

5.2.11.1 Purpose

This subroutine supports ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its function is to compute the spectral irradiance on a horizontal surface in the wavelength range of 0.4 to 0.9 microns for a clear sky (no vegetation or cloud cover).

5.2.11.2 Use and Description of Inputs

No input data must be manually supplied by the planner. The value of the spectral irradiance is computed given the time of year in seconds (TYR) and the latitude (ZLAT) and longitude (ZLONG) of the game area which are supplied to the subroutine through its argument list.

5.2.11.3 Description of Logic and Processing

No macroflow diagram is provided for this subroutine. It computes three amplitude coefficients [ASID ARRAY] given the solar and lunar altitude. These coefficients are subsequently used to compute the spectral irradiance at the ground. For clarity the model of spectral irradiance is discussed here although it is not directly employed in the subroutine.

It is convenient to break the ground irradiance into three parts:

(1) Direct solar and lunar components,
(2) Diffuse solar and lunar components (atmospheric scattering),
(3) Airglow (due to particle ionization).

Each of the above components is approximated with a constant (time independent) spectral function and an amplitude coefficient computed by this subroutine, namely

$$I(\lambda) = \sum_{i=1}^{3} \alpha \cdot s_i(\lambda)$$

where:* $I(\lambda)$ = spectral irradiance (watts/meter^3)

α_i = three amplitude coefficients, irradiance amplitude (watts/meter^2) and

$s_i(\lambda)$ = spatial irradiance density or SID Functions (meter^{-1})

The three SID functions integrate over wavelength to unity. Before discussing how the amplitudes, α_i, are generated by this subroutine, it is necessary to describe the SID functions.

There are many sources of data on the spectral composition of irradiance due to sun and sky. The approximation of these spectral characteristics to black-body radiators has long been recognized, and although there is some variance in the published values of equivalent temperature, nominal values of 6000°K for the direct solar component and 13,000°K for the diffuse solar sky component are employed to define two of the SID functions. Within the accuracy required, the albedo of the moon is assumed independent of wavelength (Reference 5) and therefore the above two black-body density functions apply to both sun and moon.

$$s_1(\lambda) = \frac{C_1 \lambda^{-5}}{e^{k/\lambda T_1} - 1} \qquad \text{(direct)}$$

$$s_2(\lambda) = \frac{C_2 \lambda^{-5}}{e^{k/\lambda T_2} - 1} \qquad \text{(diffuse)}$$

where C_1 = 9.43 X 10^{-24} meters^4, C_2 = 8.16 X 10^{-25} meters^4, k = 0.01439 meters·°K T_1 = 6000°K, T_2 = 13,000°K and λ = wavelength in meters. It should be restated that the constants k and C_1 or C_2 have been chosen so that $s(\lambda)$ ar

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* This approximation is considered valid due to the relative constancy of the spectral character of each of the components for solar angles several degrees above or below the horizon (e.g., Kondratyev, Ref. 2). During sunset there is a rapid transition from "day to night," during which some spectral errors can be expected. See also Reference 7, page 5-109.

$s_2(\lambda)$ integrate to unity over the wavelength range of 0.4 to 0.9 microns.

The third SID function (airglow) is obtained from a Honeywell report on the brightness of the night sky (Reference 6). It is found that the wavelength dependence of zenith radiance for airglow is approximately exponential with wavelength. It is assumed here that the corresponding ground irradiance will have essentially the same distribution, and a fit to the Honeywell data yields:

$$s_3(\lambda) = (2.44 \times 10^5)e^{(3.087\times 10^6)\cdot\lambda} \quad \text{meter}^{-1} \text{ (airglow)}$$

Having defined the three SID functions we can now identify the processing steps in Subroutine IRRAD. The amplitude coefficients α_i[ASID(I)] depend upon the altitude of the sun or moon. Expressions for the coefficients were determined using a single scatter model for the atmosphere. An additional section of this subroutine discussion (5.2.11.6) derives the solar portion of the α_1 and α_2 coefficients.

The algorithm for the direct solar irradiance is

$$\alpha_{s\odot}(h_\odot) = \begin{cases} a_{s00}\sin(h_\odot)e^{-\tau^*[\csc(h_\odot)-1]} & h_\odot > 0 \\ 0 & h_\odot \leq 0 \end{cases}$$

where $\alpha'_{s\odot}$ = direct ground irradiance due to sun (watts/meter^2),
$a_{s00} = \alpha_{s\odot}(\pi/2)$ (=375.5488 watts/meter^2),
$h_\odot$ = altitude of sun and
τ^* = optical thickness of the atmosphere (=0.379).

The value for a_{s00} follows from a solar zenith irradiance given by Rozenberg (Reference 7) of 65,000 lux and an efficiency of 173.080 lumens/watt in the wavelength range of 0.4 - 0.9μ for a 6000°K black-body. The value of optical thickness τ^* is given by Elterman (Reference 8) for the nominal wavelength value of 0.55μ.

The algorithm for the diffuse term is considerably more complex. The diffuse "daylight" irradiance expression developed in (Section 5.2.11.6) i.e.

$$\alpha_{D\odot} = 48.14128 \left[\frac{1 - e^{-\xi}}{\xi} \right]$$

where $\xi = (\csc h_{\odot} - 1)\tau^{*}$, is not valid at twilight or night.

It is seen from Rozenberg's Figure 11 (Reference 7) that the decay of ground illuminance during twilight is approximately exponential with solar altitude down to -15° at which time airglow becomes the dominant source of irradiance. If one fits Rozenberg's data with an exponential in the twilight zone and allows an efficiency of 357.747 lumens/watt in the 0.4 - 0.9μ range (13,000°K blackbody), it is found

$$\alpha_{D\odot} = \frac{10^{\frac{970 - 572.9587(\pi/2 - h_{\odot})}{22}}}{357.747}$$

Although the true behavior of the irradiance due to solar light scattered by the atmosphere is not indicated for solar altitude less than -15°, this region is unimportant since airglow becomes the dominant source.

The final step in developing the algorithm for the solar part of the diffuse coefficient, α_{z}, is the connection of this expression and the result of the diffuse "daylight" irradiance expression (Section 5.2.11.6). A simple straight line transition is adopted whose end points are selected to connect the two expressions with no slope discontinuity. Thus the algorithm becomes

$$\alpha_{D\odot}(h_\odot) = \begin{cases} 48.14128\left[\dfrac{1-e^{\xi}}{\xi}\right] & h_\odot \geq h_{\odot 1} \\ 20.50408 + 108.9356\,(h_\odot - h_{\odot 1}) & h_{\odot 2} \leq h_\odot \leq h_{\odot 1} \\ \dfrac{10^{\frac{970-572.958(\pi/2 - h_\odot)}{22}}}{357.747} & h_\odot \leq h_{\odot 2} \end{cases}$$

where $\xi = (\csc h_\odot - 1)\,\tau^*$, $h_{\odot 1} = 9^\circ$ = 0.15707 radians and $h_{\odot 2} = -1^\circ =$ -0.01745 radians.

In order to account for the contribution due to the moon, the same equations described above are employed for the direct and diffuse solar amplitudes but with reduction factors due to the much lower radiance level of the moons namely

$$\alpha_{S\rightmoon}(h_\rightmoon) = 2.3\times 10^{-6}\left[\frac{\sin\phi + \phi\cos\phi}{\pi}\right]\alpha_{S\odot}(h_\rightmoon)$$

$$\alpha_{D\rightmoon}(h_\rightmoon) = 2.3\times 10^{-6}\left[\frac{\sin\phi + \phi\cos\phi}{\pi}\right]\alpha_{D\odot}(h_\rightmoon)$$

where ϕ = lunar phase (zero phase at new moon) (radians). The factor of 2.3 X 10^{-6} represents the ratio of full moon to solar intensity (Reference 5) and the remainder corrects for the phase of the moon assuming the moon to be a diffuse reflecting sphere.

The desired amplitude coefficients α_1 (direct) and α_2 (diffuse) become

$$\alpha_1 = \alpha_{S\odot}(h_\odot) + \alpha_{S\rightmoon}(h_\rightmoon)$$

$$\alpha_2 = \alpha_{D\odot}(h_\odot) + \alpha_{D\rightmoon}(h_\rightmoon)$$

The final coefficient α_3 describing airglow does not depend upon solar or lunar altitude and is assigned a constant value. Rozenberg (Reference 7) has indicated a value of 0.0008 lux for ground irradiance due to airglow. In the 0.4 - 0.9μ range, the airglow spectral function $s_3(\lambda)$ has a luminous efficiency of 63.9839 lumens/watt. Thus it is found that

$$\alpha_3 = 1.25 \times 10^{-5} \text{ watts/meter}^2.$$

The major processing steps in Subroutine IRRAD include a call to EPHEM (Section 5.2.12) to determine the solar and lunar altitudes. This step is omitted if the planner has supplied these data. The second step involves calculation of $\alpha_{S\odot}(h)$ and $\alpha_{D\odot}(h)$ for both $h = h_{\odot}$ and $h = h_{\leftmoon}$. The final step is the computation of α_1, and α_2 using the algorithms described in detail above. Execution is then returned to the calling program.

5.2.11.4 Sample Data Set

No input data is required for the subroutine.

5.2.11.5 Sample Output

No output is produced directly by this subroutine. The values of the three amplitude coefficients [ASID(I), I = 1, 3] are returned to the calling program through the ATMENV common area. One of the supporting subroutines, END Section (5.2.16), will generate a printed report of the time history of the atmospheric environment if this option is chosen by the planner. This report will contain the values of the amplitude coefficients. Examples of the reports generated during a checkout of the model are included in the description of Subroutine END.

5.2.11.6 Supporting Derivation of the Solar Portion of the Direct and Diffuse "Daylight" Amplitude Coefficients

A first order linear differential equation for brightness propagation through the atmosphere which includes both the absorption and scattering by a differential volume can be solved for a source of brightness B_o at a slant distance χ with the result that the apparent brightness at the ground is given by

$$B = B_o e^{-\tau(x)} + \int_0^{\chi} S(y) e^{-\tau(y)} dy$$

where $\tau(y) = \int_0^y \beta(z) dz$ is the optical thickness of the atmosphere between 0 and y; $\beta(z)$ is the attenuation coefficient along the propagation path and $S(y)$ is an effective source term describing the light scattered into the propagation path (air light). *

The direct solar irradiance $\alpha_{S\odot}$ on a horizontal surface depends on both the solar elevation $h_\odot$ and the apparent brightness of the solar disc $(B_\odot)$

$$\alpha_{S\odot} \propto B_\odot \sin h_\odot$$

The apparent brightness $B_\odot$ clearly decreases with decreasing elevation due to the longer slant path through the atmosphere. We can account for this decrease by employing the brightness propagation equation above. Applying this equation to the solar disc yields

$$B_\odot = B_{\odot o} e^{-\tau(\infty)} + \int_0^{\infty} S(y) e^{-\tau(y)} dy$$

where $B_{\odot o}$ = inherent brightness of solar disc. We assume now that the integrated source term (unscattered light from the sky) will not significantly increase $B_\odot$. Thus we set $S(y) = 0$ and $B_\odot$ is written

$$B_\odot = B_{\odot o} e^{-\tau(\infty)}$$

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*This equation for brightness propagation of unpolarized light is a simplified version of the radiation transport equation. Detailed discussions of the transport equation can be found in Ref. 11 and 12.

e term $\tau(\infty)$ is simply the optical thickness of the entire atmosphere over he slant path to the sun, and in terms of solar elevation, it can be expressed as

$$\tau(\infty) = \tau^* \csc h_\odot$$

where τ^* = vertical optical thickness of entire atmosphere.

Combining these results yields

$$\alpha_{s\odot} \propto B_{\odot\odot} \sin h_\odot \, e^{-\tau^* \csc h_\odot}$$

The proportionality constant and $B_{\odot\odot}$ can be eliminated in terms of the value of $\alpha_{s\odot}$ when the sun is at zenith $(a_{s\odot\circ})$. Thus we have an expression for the direct solar irradiance namely

$$\boxed{\alpha_{s\odot}(h_\odot) = a_{s\odot\circ} \sin h_\odot \, e^{-\tau^*(\csc h_\odot - 1)}}$$

A precise computation of ground irradiance due to skylight would require for each point in the atmosphere (hemisphere above the horizontal surface in question) a determination of the light scattered toward the surface due to the sun, sky and ground surrounding the point, and its subsequent attenuation over the path to the surface. We shall make several approximations in the name of simplicity, and although they will not be made in the following discussion until required, they are listed now for the convenience of the reader.

(1) The primary source for unscattered light is due to direct sunlight. The sky and ground will be ignored.

(2) Phase function is assumed spherical. Since ground irradiance results from integration over a substantial range of sun angle, the importance of the shape of the phase function is reduced.

(3) To eliminate the difficulty of actually integrating over the angular coordinates of the sky, the ground irradiance is assumed to be proportional to the zenith sky brightness at the ground with the proportionality constant determined empirically.

We shall again use the general equation for brightness propagation

$$B = B_0 e^{-\tau(x)} + \int_0^x S(y)\, e^{-\tau(y)}\, dy$$

where

$$S(y) = \int_{4\pi} k\, B_s\, d\Omega$$

In order to perform the integration over atmospheric path it is first necessary to establish the source term $S(y)$ which in turn depends on the surround brightness B_s. Recalling our first assumption, the only contributor will be direct sunlight that is

$$B_s = \begin{cases} B_{SD} & \text{(within solar disc)} \\ 0 & \text{(otherwise)} \end{cases}$$

where B_{SD} = apparent brightness of solar disc. Thus we need the apparent brightness of the solar disc, and this can be determined from an independent preliminary use of propagation equation. Again assuming unscattered skylight can be ignored

$$B_{SD} = B_{SDO}\, e^{-\tau(x)}$$

where B_{SDO} = inherent brightness of solar disc and

$\tau(x)$ = optical thickness of atmosphere from point on slant path to sun.

Combining these results yields

$$S(y) = \int_{SD} k\, B_{SDO}\, e^{-\tau(x)}\, d\Omega$$

The small angular subtense of the solar disc allows this to be written

$$S(y) = k e^{-\tau(x)} \int_{SD} B_{SDO}\, d\Omega = k e^{-\tau(x)} I_{SDO}$$

where I_{SDO} = unattenuated solar flux density.

Thus the source term required for the apparent brightness of the zenith sky is established. Since the apparent brightness of the zenith sky is equivalent to the propagation of "zero brightness" $[B_0 = 0]$ from outside the atmosphere, we have

$$B = \int_0^\infty S(h)\, e^{-\tau(h)}\, dh$$

where $h(=y)$ is the distance vertically from the ground and $\tau(h)$ is the optical thickness between 0 and h. Inclusion of the source term yields

$$B = I_{SDO} \int_0^\infty k(h)\, e^{-[\tau(x) + \tau(h)]}\, dh$$

Recalling that $\tau(x)$ is the optical thickness of the slant path to the sun from any point in the atmosphere we have

$$\tau^* = \tau(h) + \tau(x) \sin h_\odot$$

where τ^* = vertical optical thickness of total atmosphere and
$h_\odot$ = solar altitude.

Elimination of $\tau(x)$ yields

$$B = I_{SDO}\, e^{-\tau^* \csc h_\odot} \int_0^\infty k(h)\, e^{\tau(h)[\csc h_\odot - 1]}\, dh$$

Within the assumption of a spherical phase function, the integral above can be carried out in closed form after a transformation of variables. We replace the independent variable h with optional thickness (τ) by employing the definition of τ

$$\tau(h) \equiv \int_0^h \beta(z)\,dz$$

$$d\tau = \beta(h)\,dh$$

and write

$$B = I_{SDO}\, e^{-\tau^* \csc h_\odot} \int_0^{\tau^*} \left[\frac{K(\tau)}{\beta(\tau)}\right] e^{(\csc h_\odot - 1)\tau}\, d\tau$$

The ratio K/β is simply the phase function ($\hat{k}$). Since we allow the phase function to be spherical, $\hat{k} = 1/4\pi$ which can be extracted from the integral

$$B = \frac{I_{SDO}}{4\pi}\, e^{-\tau^* \csc h_\odot} \int_0^{\tau^*} e^{(\csc h_\odot - 1)\tau}\, d\tau$$

Integrating

$$B = \frac{I_{SDO}\, e^{-\tau^*}\left(1 - e^{-\tau^*(\csc h_\odot - 1)}\right)}{4\pi(\csc h_\odot - 1)}$$

We now invoke the assumption that the sky ground irradiance $\alpha_{D\odot}$ is proportional to zenith sky brightness. Thus we have

$$\alpha_{D\odot} = C\, e^{-\tau^*}\left(\frac{1 - e^{-\tau^*(\csc h_\odot - 1)}}{\csc h_\odot - 1}\right)$$

The proportionality constant can be expressed in terms of the value of $\alpha_{D\odot}$ when the sun is at zenith $a_{D\odot o}$. Since the equation for $\alpha_{D\odot}$ is indeterminate at that point we allow the solar altitude to approach 90°

$$h_{\odot} \rightarrow \pi/2$$

$$\csc h_{\odot} \rightarrow 1$$

$$e^{-\tau^*(\csc h_{\odot}-1)} \rightarrow 1-\tau^*(\csc h_{\odot}-1)$$

and find that

$$\alpha_{D\odot} \rightarrow c\tau^* e^{-\tau^*} = a_{D\odot o}$$

Elimination of the proportionality constant yields the final expression for the ground irradiance due to sunlight scattered by the atmosphere namely

$$\boxed{\begin{aligned} \alpha_{D\odot}(h_{\odot}) &= a_{D\odot o}\left[\frac{1-e^{-\xi}}{\xi}\right] \\ \xi &= \tau^*(\csc h_{\odot}-1). \end{aligned}}$$

5.2.12 SUBROUTINE EPHEM

5.2.12.1 Purpose

This subroutine supports ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. In its supporting role this routine computes the altitude and azimuth of the sun and the moon and the apparent phase of the moon for any specified latitude, longitude and time of year.

5.2.12.2 Use and Descriptions of Inputs

No input data must be manually supplied by the planner. The values of time of year (T), latitude (ZLAT) and longitude (ZLONG) are supplied to this subroutine through its argument list.

5.2.12.3 Description of Logic and Processing

A macroflow diagram showing the processing steps is presented in Fig. 5.2-20. The first two steps involve the calculation of the solar declinations and local hour angle. Algorithms were developed to perform these calculations. The approach used is empirical and consists of a closed form model as a first approximation and a subsequent correction. The first approximation is simply that the orbits of the earth and moon are circular, and the Greenwich hour angle (GHA) can be expressed independent of declination. Correction terms are added to the first approximation to yield the following algorithms

$$D_\chi = D_{o\chi} \sin\left[\frac{2\pi}{\tau_{D\chi}} (t - t_{o\chi})\right] + C_{D\chi}(t)$$

$$GHA_\chi = GHA_{o\chi} + \left(\frac{2\pi}{\tau_{G\chi}}\right)t + C_{G\chi}(t)$$

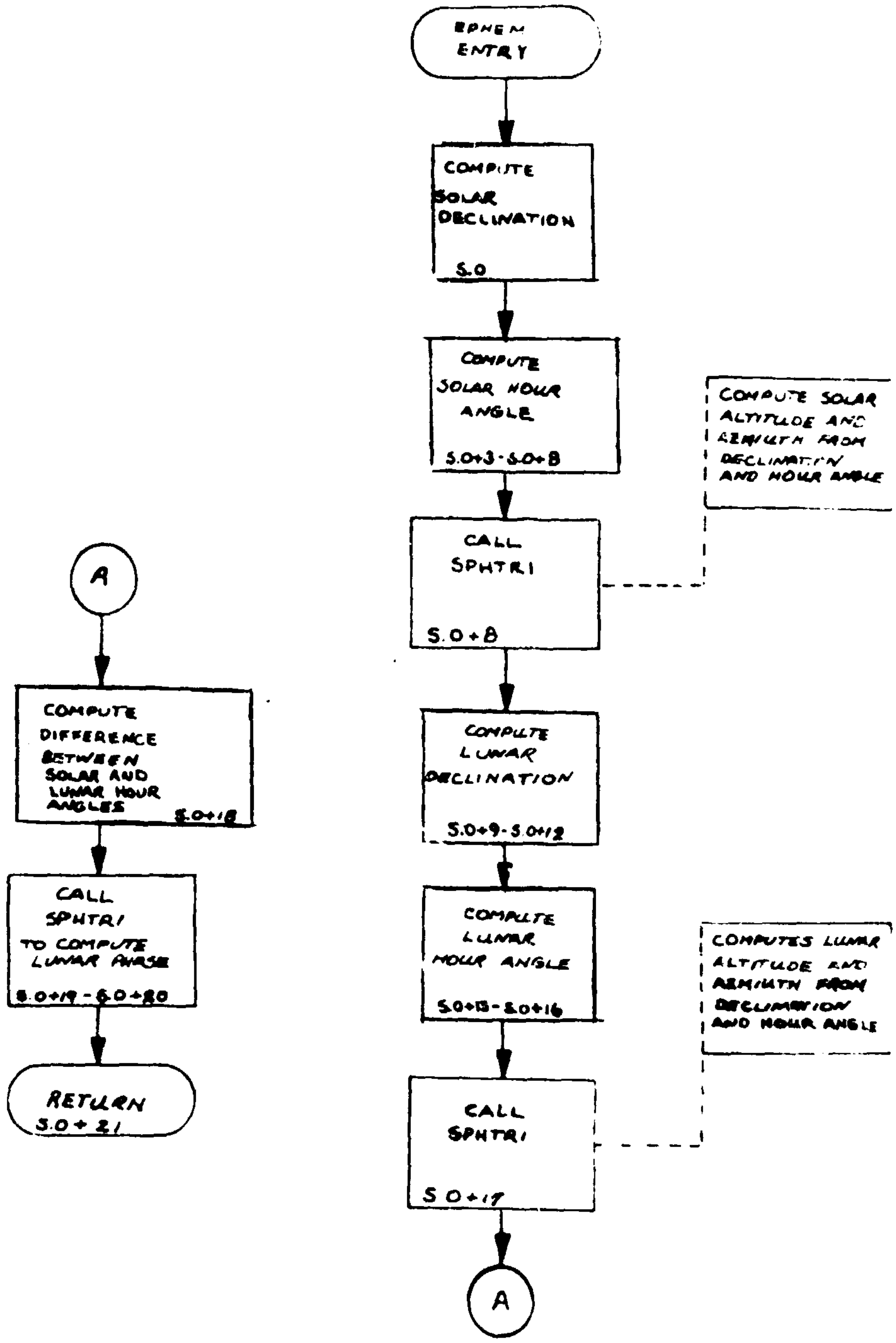

Figure 5.2-20 MACROFLOW DIAGRAM FOR SUBROUTINE EPHEM

The subscript X is a symbol representing either the sun (☉) or moon (☾), D = declination, GHA = Greenwich hour angle, D_0 = maximum declination, GHA_0 = maximum Greenwich hour angle, τ_D = period of declination, τ_G = period of hour angle and t_0 = time of year when the sun (or moon) crosses the equator heading north. The five parameters of the first approximation (i.e., D_0, τ_D, t_0, GHA_0, τ_G) were determined from published values and by inspection of the Nautical Almanac, 1969 (Reference 9). Although the year 1969 is used here, any desired year could have been employed.

By direct inspection of the almanac, a maximum solar declination is found to occur on 21 June 1969 thus $D_{0☉} = 23° 26.7' = 0.409192$ rad. The solar period for declination (tropical year) is given by Smart (Reference 10) as $\tau_{D☉}$ = 365.2422d = 3.15569×10^7 sec. Again using the almanac, it is noted that the solar declination is zero and tending north (vernal equinox) at 1906 hours on 20 Mar. 1969. Thus

$$t_{0☉} = 78 \text{ days} + 19 \text{ hours} + 6 \text{ minutes} = 6.80796 \times 10^6 \text{ sec.}$$

The use of these parameters yields a first approximation for the solar declination whose error does not exceed one degree and no correction is required.

The first approximation parameters required to calculate the Greenwich hour angle of the sun are given by

$$GHA_{0☉} = 180° = \pi \text{ rad.}$$

$$\tau_{G☉} = 24 \text{ hours} = 8.64 \times 10^4 \text{ sec.}$$

However, due to both the eccentricity of the earth's orbit and the orientation of the earth's axis to the ecliptic, the sun lags or leads its mean hour angle by as much as 16 minutes of time. This lag or lead is known as the "equation of time" and its value can be obtained from a harmonic expansion given by

Smart (Reference 10)

$$E = -97.8 \sin \ell - 431.3 \cos \ell + 596.6 \sin 2\ell - 1.9 \cos 2\ell + 4.0 \sin 3\ell + 19.3 \cos 3\ell - 12.7 \sin 4\ell$$

where E = equation of time (sec) with lag negative and
ℓ = mean celestial longitude of sun (rad)

Since the expansion is for the year 1931, slight differences were noted when compared to data from the 1969 almanac. In particular, a comparison of zeros and peaks of the equation of time imply the primary differences is simply a shift in hour angle of between one and two days. Accordingly, a shift Δ was included in the expression for the mean celestial longitude of the sun

$$\ell = \frac{2\pi}{\tau_{D\odot}} \left(t - t_{O\odot} - \Delta \right)$$

where $\Delta = 1.3984 \times 10^5$ sec.

Then, the correction $C_{G\odot}(t)$ required to compute the Greenwich hour angle of the sun is

$$C_{G\odot}(t) = \frac{2\pi}{\tau_{G\odot}} E$$

The local hour angle is obtained by subtracting the local longitude from the Greenwich hour angle

$$LHA_X = GHA_X - ZLONG$$

The third step shown in Fig.5.2-20 is a call to Subroutine SPHTRI (5.2.13) which computes the solar altitude and azimuth* using the solar declination, local solar hour angle, and local latitude. The fourth through the sixth steps repeat this process for the moon. The algorithms developed to perform the calculations of lunar declination and local hour angle are similar to those discussed for the solar calculations. The values of the five parameters of the first approximation model (i.e., $D_o, t_o, GHA_o, \tau_G, \gamma_o$) were obtained using the same procedure described for the solar model and were found to be

$$D_{o☾} = 28°30' = 0.497419 \text{ rad.},$$
$$\tau_{D☾} = 2.35114 \times 10^6 \text{ sec } (= \text{nodical month}),$$
$$t_{o☾} = 21 \text{ days} + 14 \text{ hours} + 21 \text{ minutes} = 1.8661 \times 10^6 \text{ sec},$$
$$GHA_{o☾} = 32°32.8' = 0.568052 \text{ rad. and}$$
$$\tau_{G☾} = 29.530588 \text{ days} = 255144 \times 10^6 \text{ sec } (= \text{synodical month}).$$

In this case, however, the correction terms $C_{D☾}(t)$ and $C_{G☾}(t)$ are much larger. These terms were determined by computing the difference between the values of lunar declination and lunar Greenwich hour angle obtained from the first approximation model and the true values presented in the almanac. These differences were evaluated on a three-day interval and stored in the Subroutine as FORTRAN data statements. The correction term for both lunar declination and Greenwich hour angle is evaluated by linear interpolation between adjacent differences.

The next step in the execution of EPHEM is the calculation of the difference between the solar and lunar local hour angles followed by a call to subroutine SPHTRI (5.2.13) to compute the altitude of the moon relative to the position of the sun. The lunar phase, defined to be zero at new moon, is computed by subtracting this altitude from $\pi/2$. After this last step, execution is returned to the calling program.

EPHEM was verified for three time series

(1) Beginning of each day in Greenwich time for the year 1969

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* Not used in present model.

(2) Beginning of each hour in local standard time for 6 May 1969

(3) Beginning of each hour in local standard time for 29 May 1969.

In series (2) and (3), the latitude and longitude of the Hue scenario area (16.5°N and 107.5°E) were employed. Comparison of values calculated to the values in the almanac indicates agreement to approximately one degree.

5.2.12.4 Sample Data Set

No input data is required by this subroutine.

5.2.12.5 Sample Output

The values of solar altitude (SOLALT), lunar altitude (ALTLUN) and lunar phase (PHSLUN) computed by EPHEM are returned to the calling program through the ATMENV labeled common area. Another supporting subroutine END (5.2.16) supplies a printed time history which includes the values of these variables if this option is chosen by the planner. For examples of this output refer to the description of subroutine END.

5.2.13 SUBROUTINE SPHTRI

5.2.13.1 Purpose

This subroutine supports ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. This routine computes altitude and azimuth of a celestial body (relative to an observer) from the geographical positions of the celestial body and the observer.

5.2.13.2 Use and Descriptions of Inputs

No input data must be manually supplied by the planner. The declination and local hour angle of the sun (or moon) and the local latitude are supplied to this subroutine through its argument list. It is used to establish the apparent positions of the sun and moon in order that the ground illumination level can be computed. SPHTRI is called only by subroutine EPHEM (5.2.12).

5.2.13.3 Description of Logic and Processing

Due to the direct nature of the processing and the small size of this subroutine (14 FORTRAN Statements), a macroflow diagram has not been provided. A spherical earth is assumed, and the relations between altitude and azimuth, and the geographical positions are given by the standard equations for a spherical triangle:

$$\sin(H) = \cos(D)\cos(L)\cos(LHA) + \sin(D)\sin(L)$$

$$\cos(A_z) = \frac{\sin(D) - \sin(H)\sin(L)}{\cos(H)\cos(L)}$$

where: H = altitude of celestial body,
D = declination of celestial body (north positive),
LHA = local hour angle of celestial body,
L = latitude of observer (north positive),
A_z = azimuth of celestial body.

The range of H is -90° (nadir) to +90° (zenith), and the range of A_z is 0 to 360° (clockwise from north). The computer algorithm for arcsin assures a proper value for H. However, the azimuth value returned by the arccos algorithm will always lie in the range of 0 to 180°. The test required to establish whether A_z lies within 0 to 180° (easterly) or 180° to 360° (westerly) is simply the sign of $\sin(LHA)\cos(D)$ namely,

$$\sin(LHA)\cos(D) \begin{cases} \le 0 & 0^\circ \le A_z \le 180^\circ \\ > 0 & 180^\circ < A_z < 360^\circ \end{cases}$$

5.2.13.4 Sample Data Set

No input data is required for this subroutine.

5.2.13.5 Sample Output

The output generated by the subroutine is used by subroutine EPHEM to calculate solar altitude, lunar altitude and lunar phase. None of the parameters describing the atmospheric environment are directly generated by SPHTRI.

5.2.14 SUBROUTINE EDIT

5.2.14.1 Purpose

This subroutine supports ATMOS in generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. This routine compares the values of the present ATMENV Common Area to the previous values saved and decides to keep the present values only if a change significant to the performance of the sensor has occurred.

5.2.14.2 Use and Description of Inputs

No input data is required for the execution of this subroutine. The values of the parameters to be compared are passed from ATMOS (5.2.2) to this routine through the ATMENV common area.

5.2.14.3 Description of Logic and Processing

Figure 5.2-21 shows a macroflow diagram describing the major steps in subroutine EDIT. Tests are made for significant changes in 11 of the parameters in the ATMENV Common Area. For eight of these parameters the tests are made using class numbers (integers assigned to sequential ranges of the parameter). Thus, the first step in EDIT is the computation of these class numbers for the current values in the ATMENV Common Area. The intervals used to generate the class numbers are presented in Table 5.2-XII. These class intervals were selected so that a change of interval and hence class number would produce a change in performance of one or more of the sensors modeled. As an illustration, consider the parameter of wind speed,

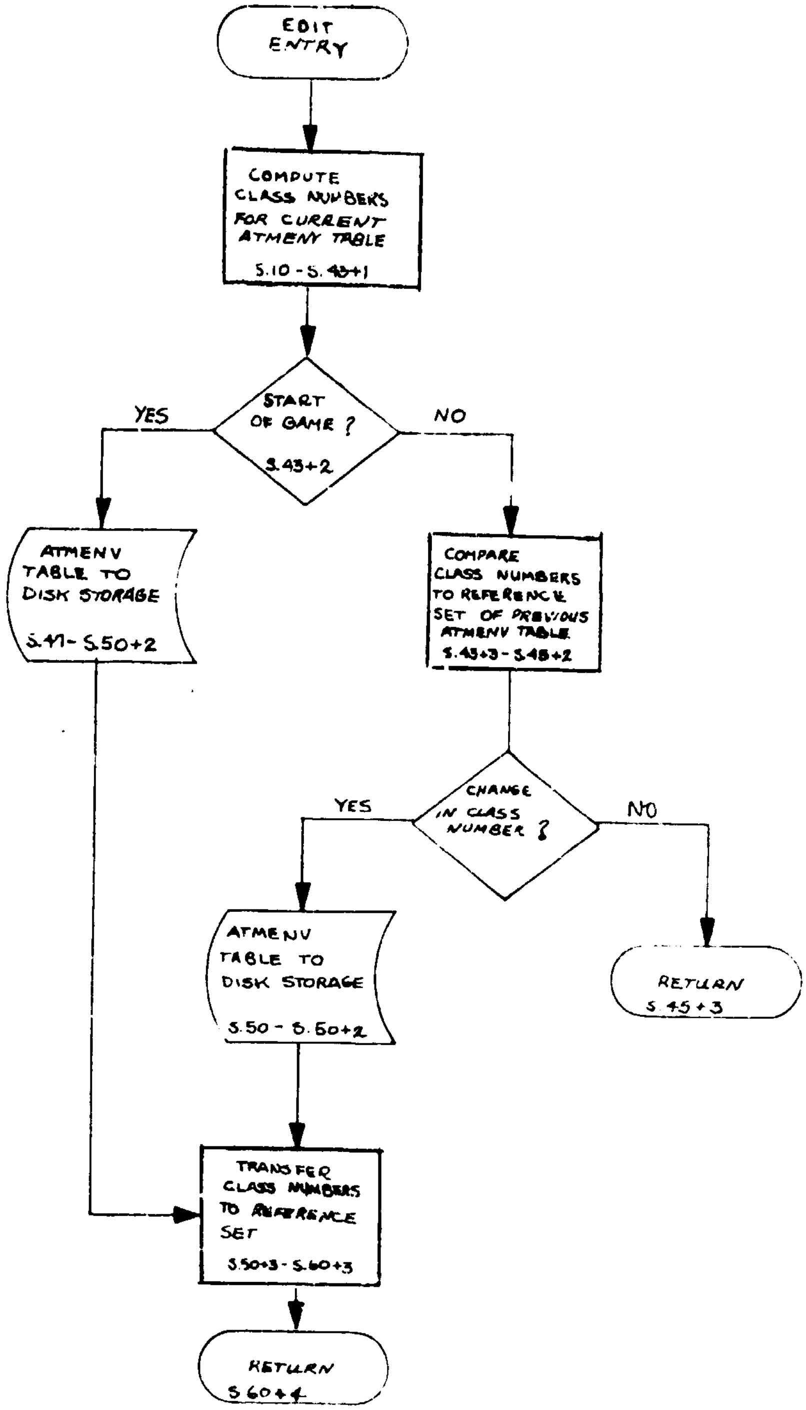

Figure 5.2-21 MACROFLOW DIAGRAM OF SUBROUTINE EDIT

Table 5.2-XII CLASS INTERVALS USED
FOR EDITING ATMENV TABLES

VARIABLE	FORTRAN NAME	CLASS NO.	RANGE
Solar or Lunar Altitude	SOLALT or ALTLUN	1	-10 ≤ , < -9 degrees
		2	- 9 ≤ , < -8
		3	- 8 ≤ , < -7
		4	- 7 ≤ , < -6
		5	- 6 ≤ , < -5
		6	- 5 ≤ , < -4
		7	- 4 ≤ , < -3
		8	- 3 ≤ , < -2
		9	- 2 ≤ , < -1
		10	- 1 ≤ , < 0
		11	0 ≤ , < 1
		12	1 ≤ , < 2
		13	2 ≤ , < 3
		14	3 ≤ , < 4
		15	4 ≤ , < 5
		16	5 ≤ , < 6
		17	6 ≤ , < 7
		18	7 ≤ , < 8
		19	8 ≤ , < 9
		20	9 ≤ , < 10
		21	10 ≤ , < 30 or -30 ≤ , < -10
		22	30 ≤ , < 50 or -50 ≤ , < -30
		23	50 ≤ , < 70 or -70 ≤ , < -50
		24	70 ≤ , ≤ 90 or -90 ≤ , < -70
Instantaneous Precipitation Rate	PRATE	0	0 mm/hr
		1	0 < , < .9 "
		2	.9 ≤ , < 9.9 "
		3	9.9 ≤ , < 99.9 "
		etc.	etc.
Absolute Humidity (Density of Water in Air)	PTOT24	1	0 ≤ , < 5 inch
		2	.5 ≤ , < 1.0
		3	1.0 ≤

Table 5.2-XII CLASS INTERVALS USED FOR
EDITING ATMENV TABLES - Cont.

VARIABLE	FORTRAN NAME	CLASS NO.	RANGE
Wind Speed	WSPEED	1	$0 \leq , < 5$ km/hr
		2	$5 \leq , < 10$
		3	$10 \leq , < 15$
		4	$15 \leq , < 20$
		etc.	etc. (note: 1 knot= 1.854 km/hr)
Cloud Cover	CCOVER	0	$0 \leq , < .2$ (fraction)
		1	$.2 \leq , < .4$
		2	$.4 \leq , < .6$
		3	$.6 \leq , < .8$
		4	$.8 \leq , < 1$
		5	$= 1$
Visibility	VISIB	1	$0 \leq , < .5$ miles
		2	$.5 \leq , < 1$
		3	$1 \leq , < 3$
		4	$3 \leq , < 5$
		5	$5 \leq , < 10$
		6	$10 \leq$
Ceiling	CEIL	1	$0 \leq , < 200$ feet
		2	$200 \leq , < 600$
		3	$600 \leq , < 1000$
		4	$1000 \leq , < 3000$
		5	$3000 \leq , < 5000$
		6	$5000 \leq , < 10000$
		7	$10000 \leq , < 20000$
		8	$20000 \leq$

WSPEED. The algorithm used to generate the class number is based upon intervals of 5 kilometers per hour. The PIRID sensor performance model uses a similar classification in the description of the effect of wind upon the performance. A change from a wind speed of 4 kilometers per hour to 6 kilometers per hour will produce a different performance and consequently different class numbers are assigned to these wind speeds.

In the case of air temperature (ATEMP) and absolute humidity (H2ODEN) the test is made on the basis of a percentage change; 10 percent for temperature and 20 percent for absolute humidity. Any change in IPCODE, the precipitation code in the ATMENV Common Area, will also cause the current values to be retained.

The next step in EDIT depends upon the current value of game time. At the start of the game, these would be the first values generated in the ATMENV Common Area and they are automatically saved in temporary disk (or tape) storage. On the other hand if the clock indicates a time beyond the start of the game, a comparison between the class numbers or parameter values to the previous class numbers or values stored in a reference set is made. If there is no change, control returns to ATMOS and execution proceeds. If there is a difference in one or more of the class numbers, or a significant change in parameter values, the current values of the parameters in the ATMENV Common Area are transferred to temporary disk (or tape) storage. The corresponding values of class numbers or parameter values are stored in the reference set so that they will be available for comparison to the values in the next ATMENV table and execution is returned to ATMOS.

5.2.14.4 Sample Data Set

No input data is required.

5.2.14.5 Sample Output

No output is produced by this subroutine.

5.2.15 SUBROUTINE EMSG

5.2.15.1 Purpose

This routine supports subroutine ATMOS in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. It's purpose is to provide the planner diagnostic information in the event that execution is terminated before reaching the normal stop in subroutine END, (5.2.16).

5.2.15.2 Use and Description of Inputs

No input data is required by this subroutine. The integer variable, KODE, is transferred to the subroutine through its argument list.

5.2.15.3 Description of Logic and Processing

Because of the direct nature of the logic employed in this subroutine a macroflow diagram has not been provided. Immediately after entry into the subroutine an output heading is printed and note is made that the execution of ATMOS has been terminated. The next step in the subroutine is a multiple branching procedure depending upon the value of the input parameter KODE which transfers execution to the appropriate write statement. The statement numbers assigned to the FORTRAN format statements coincide with the values of the parameter, KODE. After the appropriate diagnostic message has been printed execution is terminated.

5.2.15.4 Sample Data Set

No input data is required for this subroutine.

5.2.15.5 Sample Output

Table 5.2-XIII presents the diagnostic messages which can result from this subroutine. These messages identify the location where the call to subroutine EMSG occurred, the reason the call occurred, and the action required on the part of the planner to correct the present problem. Upon receiving the diagnostic message, the planner should take the appropriate action and resubmit the program for execution.

TABLE 5.2-XIII EMSG OUTPUT

KODE	PRINTED MESSAGE
100	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE ATMOS REASON: FIRST DATA CARD IN PLANNER INPUT DOES NOT COINCIDE WITH GAME START ACTION: REVISE PLANNER INPUT DATA SET OR START TIME
101	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE ATMOS REASON: PLANNER INPUT DATA SET CONTAINS TOO MANY PRECIP, NON-PRECIP AND FOG EVENTS ACTION: REVISE PLANNER INPUT TO CONTAIN 150 OR LESS EVENTS
200	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PRECIP REASON: GAME DURATION IS LONGER THAN SIX WEEKS ACTION: CHECK DURATION TIME SPECIFIED
201	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PRECIP REASON: NUMBER OF EVENTS IN THE PRECIP/NON-PRECIP TIME HISTORY EXCEEDS ALLOCATED STORAGE ACTION: RERUN SUBROUTINE ATMOS REVISING THE ORIGIN OF THE GAUSSIAN AND UNIFORM RANDOM NUMBER GENERATORS
202	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PRECIP REASON: NUMBER OF CLOCK-HOUR RATES REQUIRED TO COMPUTE PRECIP AMOUNT EXCEEDS ALLOCATED STORAGE ACTION: RERUN SUBROUTINE ATMOS REVISING THE ORIGIN OF THE GAUSSIAN AND UNIFORM RANDOM NUMBER GENERATORS
210	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB1 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH SCENARIO AREA SPECIFIED ACTION: CHECK DATA SET LABELED 'PRECIP/NON-PRECIP DURATION DISTRIBUTION ...'

Table 5.2-XIII EMSG OUTPUT
Cont.

KODE	PRINTED MESSAGE
211	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB1 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH MONTH AT GAME START ACTION: CHECK DATA SET LABELED 'PRECIP/NON-PRECIP DURATION DISTRIBUTION ...'
212	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB1 REASON: SEQUENCE OF DESIGNER INPUT DATA INCORRECT ACTION: VERIFY SEQUENCE OF DATA SETS IN INPUT STREAM
213	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB1 REASON: INPUT DESIGNER DATA CARDS IN SET LABELED 'PRECIP/NON-PRECIP DURATION DISTRIBUTION ...' ARE OUT OF ORDER ACTION: CORRECT
220	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB2 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH SCENARIO AREA SPECIFIED ACTION: CHECK DATA SET LABELED 'PRECIPITATION RATE AND TYPE DISTRIBUTIONS ...'
221	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB2 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH MONTH AT GAME START ACTION: CHECK DATA SET LABELED 'PRECIPITATION RATE AND TYPE DISTRIBUTIONS ...'
222	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB2 REASON: SEQUENCE OF DESIGNER INPUT DATA INCORRECT ACTION: VERIFY SEQUENCE OF DATA SETS IN INPUT STREAM

Table 5.2-XIII EMSG OUTPUT
Cont.

KODE	PRINTED MESSAGE
223	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB2 REASON: INPUT DESIGNER DATA CARDS IN SET LABELED 'PRECIPITATION RATE AND TYPE DISTRIBUTIONS ...' ARE OUT OF ORDER ACTION: CORRECT
300	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE WEATHR REASON: LENGTH OF ARRAYS OF NORMAL DEVIATES USED TO COMPUTE CLOUD COVER AND DEW POINT DEPRESSION EXCEED ALLOCATED STORAGE ACTION: RERUN SUBROUTINE ATMOS REVISING THE ORIGIN OF THE GAUSSIAN AND UNIFORM RANDOM NUMBER GENERATORS
310	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB3 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH SCENARIO AREA SPECIFIED ACTION: CHECK DATA SET LABELED 'CLOUD COVER, PRESSURE, VISIBILITY AND WIND SPEED DIST'D ...'
311	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB3 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH MONTH AT GAME START ACTION: CHECK DATA SET LABELED 'CLOUD COVER, PRESSURE, VISIBILITY AND WIND SPEED DIST'D ...'
312	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB3 REASON: SEQUENCE OF DESIGNER INPUT DATA INCORRECT ACTION: VERIFY SEQUENCE OF DATA SETS IN INPUT STREAM
313	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB3 REASON: INPUT DESIGNER DATA CARDS IN SET LABELED 'CLOUD COVER, PRESSURE, VISIBILITY AND WIND SPEED DIST'D ...' ARE OUT OF ORDER ACTION: CORRECT

Table 5.2-XIII EMSG OUTPUT
Cont.

KODE	PRINTED MESSAGE
320	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB4 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH SCENARIO AREA SPECIFIED ACTION: CHECK DATA SET LABELED 'CEILING AND TEMPERATURE DISTRIBUTIONS ...'
321	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB4 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH MONTH AT GAME START ACTION: CHECK DATA SET LABELED 'CEILING AND TEMPERATURE DISTRIBUTIONS ...'
322	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB4 REASON: SEQUENCE OF DESIGNER INPUT DATA INCORRECT ACTION: VERIFY SEQUENCE OF DATA SETS IN INPUT STREAM
323	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB4 REASON: INPUT DESIGNER DATA CARDS IN SET LABELED 'CEILING AND TEMPERATURE DISTRIBUTIONS ...' ARE OUT OF ORDER ACTION: CORRECT
330	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB5 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH SCENARIO AREA SPECIFIED ACTION: CHECK DATA SET LABELED 'DEWPOINT DEPRESSION DISTRIBUTIONS ...'
331	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROB5 REASON: INPUT DESIGNER DATA NOT IN AGREEMENT WITH MONTH AT GAME START ACTION: CHECK DATA SET LABELED 'DEWPOINT DEPRESSION DISTRIBUTIONS ...'

Table 5.2-XIII EMSG OUTPUT
Cont.

KODE	PRINTED MESSAGE
332	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROBS REASON: SEQUENCE OF DESIGNER INPUT DATA INCORRECT ACTION: VERIFY SEQUENCE OF DATA SETS IN INPUT STREAM
333	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE PROBS REASON: INPUT DESIGNER DATA CARDS IN SET LABELED 'DEWPOINT DEPRESSION DISTRIBUTIONS ...' ARE OUT OF ORDER ACTION: CORRECT
400	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE ATMOS HAS BEEN TERMINATED LOCATION: SUBROUTINE EDIT REASON: MORE THAN 1200 ATMENV TABLES WERE GENERATED ACTION: RERUN SUBROUTINE ATMOS REVISING THE ORIGIN OF THE GAUSSIAN AND UNIFORM RANDOM NUMBER GENERATORS

TABLE 5.2-XIV

ATMOS COMMON AREAS

USE	VARIABLES	USED BY
Common/BASICT/	P. 2-135, # 4 Prerun	Atmomn Atmos End Precip Prob 1, 2, 3, 4, 5
Common/ATMENV/	P. 2-135, # 2 Prerun	Atmos Edit End Ephem IRRAD Prob 3, 4, 5 Weathr
Common/ATTIME/	P. 2-135, # 1 Prerun	Edit End

5.2.16 SUBROUTINE END

5.2.16.1 Purpose

This subroutine supports ATMOS (5.2.2) in the generation of the atmospheric environment and is intended to be executed as part of a stand-alone program prior to the PRERUN. Its purpose is to transfer the ATMENV tables stored temporarily on disk to a final output tape and generate a printed report of the contents of the tables if this option was selected by the planner.

5.2.16.2 Use and Description of Inputs

No input data must be manually supplied by the planner. The number of ATMENV tables generated and the times when each table becomes effective are transferred to the subroutine through the ATTIME common area while the values in each of the ATMENV tables is available to the subroutine through temporary disk storage. The logical variable PROPT indicating whether or not the planner has elected to receive a printed report is supplied to the subroutine through its argument list.

5.2.16.3 Description of Logic and Processing

A macroflow diagram showing the processing steps included in subroutine END is presented in Fig.5.2-22. The first major step after entry into the subroutine is the printing of the contents of the BASICT table. This contains basic time information including the time of day, the start of the game, the duration of the game, the date the game is being played and the area in which the game is being played. If the printed report option has not been elected by the planner this step is bypassed and the second step is executed in which the contents of the BASICT common area and the ATTIME common area are written onto the final output tape. The next major step involves the reading of the first ATMENV table from the temporary disk storage. If the report option has been specified by the planner the contents of the ATMENV table are printed.

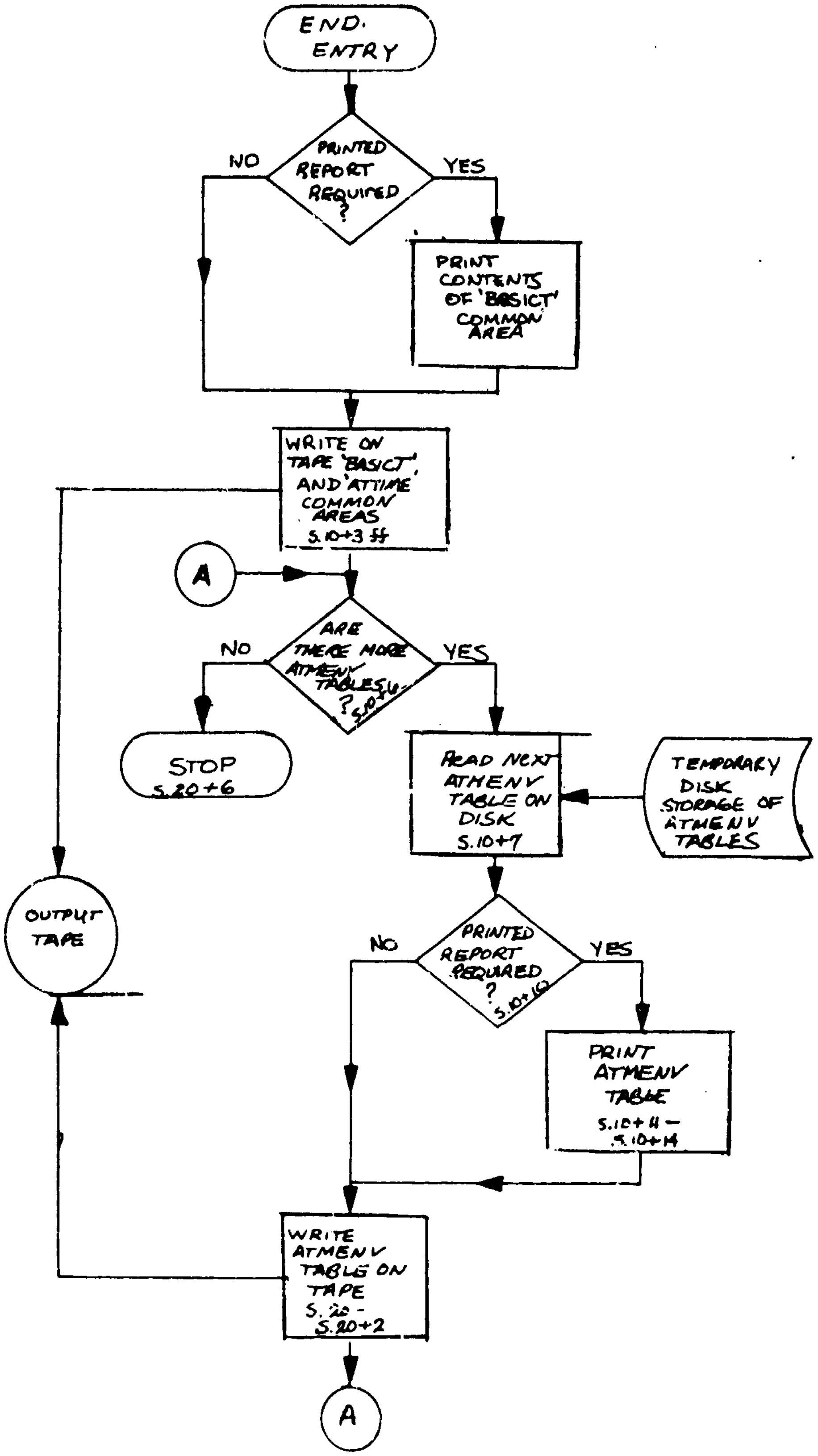

Figure 5.2-22 MACROFLOW DIAGRAM OF SUBROUTINE END

otherwise, this step is bypassed and the next step in which the complete ATMENV table is written onto the final output tape is executed. The processing is then recycled to read the next ATMENV table in the temporary disk storage. The recycling is continued until all of the ATMENV tables in temporary disk storage have been transferred to the final output tape at which time execution is terminated.

5.2.16.4 Sample Data Set

No input data is required for this subroutine.

5.2.16.5 Sample Output

The planner has the option of receiving a printed report of the time history of the atmospheric environment. (See the description of the main program ATMOMN (5.2.1) Figures 5.2-23 and 5.2-24 contain the printed reports generated during the checkout of the entire program package for generating the atmospheric environment. Figure 5.2-23 shows the time history generated using the planner input data set presented in Figure 5.2-6 of the description of subroutine ATMOS. Most of the column headings coincide directly with the FORTRAN names used for the parameters contained in the ATMENV common area or are direct abbreviations. For example, CC represents cloud cover, TC represents the cloud transmission factor, SALT represents the solar altitude, LALT represents the lunar altitude and so forth. The second report (shown in Figure 5.2-24) was generated without the use of any planner input and is a time history generated by the Monte-Carlo procedures built into the program.

```
        CONTENTS OF 'BASICT' TABLE
        **************************

ITIME=      0     ITOD=     0     ITODST=     0     ITOURN= 259200     IDATE=290569     IDAREA= 2

        CONTENTS OF 'ATMENV' TABLE
        **************************

ITIME      PRATE  PTOT24   WIND   CC   TEMP   PRES    VISIR    CEIL   H2ODEN    HUM   TC SALT LALT  PHI    ASID1      ADIS2      ASID3
     IPCODE
     0  0  0.0     3.81    9.3  0.0   22.2   752.   17715.   6096.  .000018  0.91  0.5  ***  38.  .39  3.5E-04    8.1E-05    1.2E-05
  3600  0  0.0     3.65    9.3  0.0   22.2   752.   15970.   6096.  .000019  0.91  0.5  ***  26.  .40  1.9E-04    7.2E-05    1.2E-05
 10800  0  0.0     3.33    9.3  0.0   22.2   752.   16157.   6096.  .000018  0.91  0.5  ***  -0.  .40  0.0        6.2E-06    1.2E-05
 14400  0  0.0     3.17    9.3  0.0   22.2   753.   14979.   6096.  .000019  0.91  0.8  ***  ***  .40  0.0        6.2E-08    1.2E-05
 18000  6  0.0     3.02    9.3  0.0   22.2   753.   14309.   6096.  .000019  0.91  0.5  -4.  ***  .40  0.0        4.1E-02    1.2E-05
 21600  6  0.0     2.86    9.3  0.0   22.2   753.   22869.   6096.  .000018  0.91  0.6   9.  ***  .40  7.3E-00    2.0E 01    1.2E-05
 25200  6  0.0     2.70    9.3  0.0   22.2   753.   27123.   6096.  .000019  0.91  0.5  23.  ***  .41  7.8E 00    3.6E 01    1.2E-05
 28800  6  0.0     2.54    9.3  0.0   23.3   753.   21646.   6096.  .000019  0.91  0.5  36.  ***  .41  1.7E 01    4.2E 01    1.2E-05
 32400  0  0.0     2.38    9.3  0.0   23.3   753.   15062.   6096.  .000019  0.91  0.5  50.  ***  .41  2.6E 01    4.6E 01    1.2E-05
 36000  0  0.0     2.22    9.3  0.0   23.3   753.   23082.   6096.  .000019  0.91  0.5  64.  ***  .41  3.2E 01    4.7E 01    1.2E-05
 39600  0  0.0     2.06    9.3  0.0   23.3   752.   22221.   6096.  .000019  0.91  0.5  78.  ***  .41  3.6E 01    4.8E 01    1.2E-05
 50400  0  0.0     1.59    9.3  0.0   30.6   751.   20670.   6095.  .000021  0.69  0.5  58.  ***  .42  3.0E 01    4.7E 01    1.2E-05
 54000  0  0.0     1.43    9.3  0.0   30.6   751.   21737.   6096.  .000021  0.69  0.5  44.  ***  .42  2.2E 01    4.4E 01    1.2E-05
 61200  0  0.0     1.11    9.3  0.0   30.6   752.   22320.   6096.  .000021  0.69  0.5  17.  11.  .42  4.2E 00    3.1E 01    1.2E-05
 64800  0  0.0     0.95    9.3  0.50  29.4   754.   14453.    914.  .000020  0.69  0.1   3.  24.  .42  3.8E-01    9.6E 00    1.2E-05
 68400  0  0.0     0.79    9.3  0.50  29.4   754.   16140.    914.  .000020  0.69  0.2  ***  35.  .42  3.4E-04    2.2E-04    1.2E-05
 72000  0  0.0     0.63    9.3  1.00  27.2   755.   17728.    914.  .000018  0.69  0.2  ***  45.  .43  4.7E-04    9.3E-05    1.2E-05
 75600  0  0.0     0.49    9.3  1.00  27.2   755.   17492.    914.  .000019  0.69  0.2  ***  52.  .43  5.6E-04    9.6E-05    1.2E-05
 86400  0  0.0     0.0     9.3  1.00  27.2   755.   19923.    914.  .000018  0.69  0.2  ***  44.  .43  4.6E-04    9.4E-05    1.2E-05
 90000  2  0.0     0.0     9.3  1.00  23.9   756.    6733.    914.  .000020  0.91  0.2  ***  34.  .43  3.3E-04    8.8E-05    1.2E-05
 90600  2  1.04    0.09    9.3  1.00  23.9   755.   14911.    914.  .000020  0.91  0.2  ***  32.  .43  3.0E-04    8.7E-05    1.2E-05
 97200  2  5.18    8.57    9.3  1.00  23.9   755.   11478.    914.  .000020  0.91  0.2  ***  10.  .44  2.1E-05    4.7E-05    1.2E-05
100800  0  0.0    11.43    9.3  0.50  22.2   756.   15022.    914.  .000018  0.91  0.2  ***  -3.  .44  0.0        4.3E-07    1.2E-05
104400  0  0.0    11.43    9.3  0.0   22.2   755.   16842.   6096.  .000018  0.91  0.5  -4.  ***  .44  0.0        4.2E-02    1.2E-05
108000  0  0.0    11.43    9.3  0.0   22.2   756.   25244.   6095.  .000018  0.91  0.6   9.  ***  .44  7.3E-00    2.0E 01    1.2E-05
111600  0  0.0    11.43    9.3  0.0   22.2   757.   24008.   6096.  .000019  0.91  0.5  23.  ***  .44  7.8E 00    3.6E 01    1.2E-05
115200  0  0.0    11.43    9.3  0.0   22.2   757.   24704.   6096.  .000018  0.91  0.5  36.  ***  .44  1.7E 01    4.2E 01    1.2E-05
118800  0  0.0    11.43    9.3  0.0   22.2   756.   24591.   6096.  .000018  0.91  0.5  50.  ***  .45  2.6E 01    4.5E 01    1.2E-05
126000  0  0.0    11.43    9.3  0.0   22.2   755.   27847.   6095.  .000018  0.91  0.8  78.  ***  .45  3.6E 01    4.8E 01    1.2E-05
133200  0  0.0    11.43    9.3  0.0   29.4   755.   26572.   6096.  .000020  0.69  0.5  72.  ***  .45  3.5E 01    4.8E 01    1.2E-05
136800  0  0.0    11.43    9.3  0.0   29.4   755.   27047.   6096.  .000020  0.69  0.5  58.  ***  .45  3.0E 01    4.7E 01    1.2E-05
140400  0  0.0    11.43    9.3  0.0   29.4   755.   25357.   6096.  .000020  0.69  0.5  44.  ***  .45  2.2E 01    4.4E 01    1.2E-05
147600  0  0.0    11.43    9.3  0.0   29.4   753.   26908.   6095.  .000020  0.69  0.6  17.  -2.  .46  4.3E 00    3.1E 01    1.2E-05
151200  0  0.0    11.43    9.3  0.0   29.4   755.   16483.   6095.  .000020  0.69  0.5   3.  11.  .46  4.6E-01    9.7E 00    1.2E-05
154800  0  0.0    11.43    9.3  0.0   29.4   755.   16686.   6096.  .000020  0.69  0.6  ***  22.  .46  1.7E-04    2.3E-04    1.2E-05
158400  0  0.0    11.43    9.3  0.0   26.7   755.   15712.   6096.  .000017  0.69  0.5  ***  33.  .46  3.3E-04    9.2E-05    1.2E-05
162000  0  0.0    11.43    9.3  0.0   26.7   755.   15939.   6096.  .000017  0.69  0.5  ***  42.  .46  4.7E-04    9.9E-05    1.2E-05
169200  0  0.0    11.43    9.3  0.0   22.2   754.   15272.   6096.  .000014  0.69  0.5  ***  50.  .46  5.7E-04    1.0E-04    1.2E-05
172800  0  0.0    11.43    9.3  0.0   22.2   753.   16185.   6096.  .000014  0.69  0.5  ***  46.  .47  5.3E-04    1.0E-04    1.2E-05
176400  0  0.0    11.43    9.3  0.0   22.2   753.   15481.   6096.  .000014  0.69  0.5  ***  39.  .47  4.3E-04    9.8E-05    1.2E-05
183600  0  0.0     2.86    9.3  0.0   22.2   754.   16897.   6096.  .000014  0.69  0.6  ***  19.  .47  1.2E-04    7.5E-05    1.2E-05
190800  0  0.0     0.0     9.3  0.0   22.2   754.   17927.   6096.  .000014  0.69  0.8  -4.  -6.  .47  0.0        4.3E-02    1.2E-05
194400  0  0.0     0.0     9.3  0.0   22.2   754.   26836.   6095.  .000014  0.69  0.5   9.  ***  .47  7.3E-00    2.0E 01    1.2E-05
198000  0  0.0     0.0     9.3  0.0   22.2   754.   26027.   6096.  .000014  0.69  0.5  23.  ***  .47  7.8E 00    3.6E 01    1.2E-05
201600  0  0.0     0.0     9.3  0.0   22.2   754.   27313.   6096.  .000014  0.69  0.5  36.  ***  .48  1.7E 01    4.2E 01    1.2E-05
205200  0  0.0     0.0     9.3  0.0   23.3   755.   27496.   6095.  .000014  0.69  0.5  50.  ***  .48  2.6E 01    4.5E 01    1.2E-05
212400  0  0.0     0.0     9.3  0.0   23.3   755.   29356.   6095.  .000014  0.69  0.5  77.  ***  .48  3.6E 01    4.8E 01    1.2E-05
223200  0  0.0     0.0     9.3  0.0   23.3   754.   29923.   6096.  .000014  0.69  0.8  59.  ***  .48  3.0E 01    4.7E 01    1.2E-05
226800  0  0.0     0.0     9.3  0.0   23.3   754.   30140.   6095.  .000014  0.69  0.7  44.  ***  .49  2.2E 01    4.4E 01    1.2E-05
234000  0  0.0     0.0     9.3  0.0   23.3   754.   31652.   6096.  .000014  0.69  0.6  17.  ***  .49  4.3E 00    3.1E 01    1.2E-05
237600  0  0.0     0.0     9.3  0.0   23.3   756.   20207.   6096.  .000014  0.69  0.5   3.  -3.  .49  5.3E-01    9.9E 00    1.2E-05
241200  0  0.0     0.0     9.3  0.0   23.3   757.   20304.   6095.  .000014  0.69  0.5  ***   9.  .49  1.9E-05    2.1E-04    1.2E-05
244800  0  0.0     0.0     9.3  0.0   27.2   757.   20532.   6095.  .000019  0.69  0.5  ***  21.  .49  1.5E-04    7.9E-05    1.2E-05
249400  0  0.0     0.0     9.3  0.0   27.2   757.   19661.   6095.  .000018  0.69  0.5  ***  31.  .51  3.1E-04    9.3E-05    1.2E-05
```

Figure 5.2-23 **EXAMPLE OF A REPORT GENERATED WITH PLANNER INPUT**
(refer to Figure 5.2-3 SUBROUTINE ATMOS**)**

```
          CONTENTS OF 'BASICT' TABLE
          **************************

ITIME=      0      ITOD=     0      ITODST=     0       ITOURN= 259200       IDATE=290569        IOAREA= 2

          CONTENTS OF 'ATMENV' TABLE
          **************************

  ITIME      PRATE   PTOT24     WIND    CC    TEMP     PRES      VISIB      CEIL      H2ODEN     HUM    TC  SALT  LALT   PHI     AS(1)     AS(2)      A
        IPCODE
      0  0   0.0      11.25      0.0  0.23  27.6     754.      19572.    12906.    .000018   0.67   0.9  ***   39.    .39   3.5E-04  8.1E-05   1.2E-05
   3600  0   0.0      10.78      0.0  0.26  27.3     753.      18245.    12428.    .000018   0.67   0.9  ***   25.    .40   1.9E-04  7.2E-05   1.2E-05
  10800  0   0.0       9.85      0.0  0.34  26.9     753.      17668.    13674.    .000017   0.68   1.0  ***   -0.    .40   0.0      6.2E-06   1.2E-05
  18000  0   0.0       8.91      0.0  0.46  26.5     753.      16488.    12383.    .000017   0.69   1.0  -4.   ***    .40   0.0      4.1E-02   1.2E-05
  21600  0   0.0       8.44      0.0  0.60  33.4     754.      25717.    15613.    .000027   0.74   0.6   9.   ***    .40   7.3E-00  2.0E 01   1.2E-05
  25200  0   0.0       7.97      0.0  0.69  33.0     754.      26124.    15433.    .000026   0.75   0.7  23.   ***    .41   7.9E 01  3.6E 01   1.2E-05
  28800  0   0.0       7.50      0.0  0.79  32.5     754.      25439.    16262.    .000026   0.76   0.9  36.   ***    .41   1.7E 02  4.2E 01   1.2E-05
  30627  2   0.0       7.26      0.0  1.00  26.6     754.      10488.     1428.    .000025   1.00   0.2  43.   ***    .41   2.2E 02  4.4E 01   1.2E-05
  31227  2   0.07      7.19      0.0  1.00  26.7     755.      11636.     1513.    .000025   1.00   0.2  46.   ***    .41   2.3E 02  4.5E 01   1.2E-05
  32427  2   0.20      7.08      0.0  1.00  26.9     755.      11114.     1516.    .000026   1.00   0.2  50.   ***    .41   2.6E 02  4.6E 01   1.2E-05
  37827  2   0.70      7.08      0.0  1.00  27.6     755.      12872.     1516.    .000027   1.00   0.2  71.   ***    .41   3.5E 02  4.8E 01   1.2E-05
  43227  2   0.85      7.59      0.0  1.00  29.1     752.      17286.     3342.    .000029   1.00   0.3  84.   ***    .41   3.7E 02  4.9E 01   1.2E-05
  47427  2   0.67      7.95      0.0  1.00  28.6     753.      16042.     2807.    .000028   1.00   0.3  70.   ***    .42   3.4E 02  4.8E 01   1.2E-05
  50427  2   0.42      8.02      0.0  1.00  28.2     753.      16408.     3221.    .000027   1.00   0.3  58.   ***    .42   3.0E 02  4.7E 01   1.2E-05
  51027  2   0.36      8.01      0.0  1.00  28.0     753.      15794.     2170.    .000027   1.00   0.2  56.   ***    .42   2.9E 02  4.6E 01   1.2E-05
  52827  2   0.16      7.91      0.0  1.00  28.1     753.      12918.     1928.    .000027   1.00   0.2  49.   ***    .42   2.5E 02  4.5E 01   1.2E-05
  54290  0   0.0       7.75      0.0  0.86  33.5     754.      23895.    13508.    .000029   0.77   0.9  43.   ***    .42   2.2E 02  4.4E 01   1.2E-05
  57890  0   0.0       7.28      4.0  0.97  32.0     753.      23919.    13483.    .000026   0.78   0.8  29.   -1.    .42   1.7E 02  4.0E 01   1.2E-05
  61490  0   0.0       6.81      3.8  1.00  31.6     753.      23077.    12910.    .000026   0.80   0.7  16.   12.    .42   3.6E 00  3.0E 01   1.2E-05
  65090  0   0.0       6.34      0.0  1.00  27.5     754.      16555.    13452.    .000023   0.99   0.5   2.   25.    .42   1.1E-03  7.5E 00   1.2E-05
  68590  0   0.0       5.87      0.0  1.00  27.8     754.      16406.    15439.    .000024   0.89   0.9  ***   36.    .42   3.5E-04  1.3E-04   1.2E-05
  75890  0   0.0       4.94      0.0  1.00  27.4     754.      17149.    15139.    .000023   0.89   1.0  ***   52.    .43   5.6E-04  9.5E-05   1.2E-05
  79490  0   0.0       4.47      0.0  1.00  27.5     755.      15964.    11096.    .000023   0.88   1.0  ***   54.    .43   5.9E-04  9.7E-05   1.2E-05
  83090  0   0.0       4.00      0.0  1.00  27.5     755.      16287.    16320.    .000023   0.87   1.0  ***   51.    .43   5.5E-04  9.6E-05   1.2E-05
  90290  0   0.0       3.57      0.0  0.94  27.0     754.      20260.    13552.    .000019   0.75   0.8  ***   33.    .43   3.1E-04  8.7E-05   1.2E-05
  97490  0   0.0       3.57      0.0  0.67  27.0     754.      20745.    14667.    .000018   0.68   0.6  ***    9.    .44   1.5E-05  4.3E-05   1.2E-05
 101090  0   0.0       3.57      0.0  0.59  27.2     754.      19899.    13916.    .000018   0.68   1.0  ***   -4.    .44   0.0      3.0E-07   1.2E-05
 104690  0   0.0       3.57      0.0  0.52  27.3     754.      19777.    13780.    .000018   0.67   1.0  -3.   ***    .44   0.0      1.3E-01   1.2E-05
 109290  0   0.0       3.57      5.3  0.55  34.0     755.      26993.    16574.    .000027   0.72   0.6  13.   ***    .44   1.1E 00  2.2E 01   1.2E-05
 111890  0   0.0       3.57      3.7  0.54  33.3     754.      29850.    15245.    .000025   0.71   0.7  24.   ***    .44   8.5E 00  3.7E 01   1.2E-05
 115490  0   0.0       3.57      4.6  0.55  34.0     753.      28177.    15057.    .000027   0.72   0.9  37.   ***    .44   1.8E 02  4.3E 01   1.2E-05
 119090  0   0.0       3.50      4.5  0.58  33.3     753.      27729.    14051.    .000026   0.72   1.0  51.   ***    .45   2.6E 02  4.6E 01   1.2E-05
 122690  0   0.0       3.09      1.1  0.65  33.9     753.      27517.    14175.    .000027   0.72   1.0  65.   ***    .45   3.3E 02  4.7E 01   1.2E-05
 126290  0   0.0       2.39      6.3  0.76  33.7     753.      24698.    12687.    .000027   0.73   1.0  79.   ***    .45   3.7E 02  4.8E 01   1.2E-05
 126732  2   0.0       2.28      0.0  1.00  27.3     753.      10561.      966.    .000026   1.00   0.2  80.   ***    .45   3.7E 02  4.8E 01   1.2E-05
 127332  2   1.84      2.32      0.0  1.00  27.3     754.       9866.     1163.    .000026   1.00   0.2  92.   ***    .45   3.7E 02  4.9E 01   1.2E-05
 127932  2   0.79      2.44      0.0  1.00  27.6     754.      10772.     1283.    .000027   1.00   0.2  93.   ***    .45   3.7E 02  4.9E 01   1.2E-05
 128124  0   0.0       2.42      0.0  0.79  27.1     753.      17575.    10698.    .000018   0.69   1.0  84.   ***    .45   3.7E 02  4.9E 01   1.2E-05
 131724  0   0.0       1.58      8.5  0.93  32.7     751.      26200.    13772.    .000025   0.73   1.0  77.   ***    .45   3.6E 02  4.9E 01   1.2E-05
 135324  0   0.0       0.90     10.6  0.93  33.3     751.      25721.    14647.    .000025   0.71   1.0  64.   ***    .45   3.2E 02  4.7E 01   1.2E-05
 137435  1   0.0       0.63      0.0  1.00  27.5     752.       9921.     1318.    .000026   1.00   0.2  56.   ***    .45   2.9E 02  4.6E 01   1.2E-05
 138035  1   5.69      1.05     10.5  1.00  29.0     752.      11305.     2510.    .000029   1.00   0.3  54.   ***    .45   2.8E 02  4.6E 01   1.2E-05
 138635  1  10.66      2.40      9.7  1.00  29.0     752.      11688.     2411.    .000029   1.00   0.2  51.   ***    .45   2.6E 02  4.6E 01   1.2E-05
 139235  1  15.06      4.54      9.0  1.00  28.9     752.      11548.     2545.    .000029   1.00   0.3  49.   ***    .45   2.5E 02  4.5E 01   1.2E-05
 141035  1  18.66     13.56      7.0  1.00  28.5     752.      12021.     2641.    .000028   1.00   0.3  42.   ***    .45   2.1E 02  4.4E 01   1.2E-05
 142835  1   8.06     20.74      6.4  1.00  28.6     751.       9826.     2708.    .000028   1.00   0.3  35.   ***    .45   1.6E 02  4.2E 01   1.2E-05
 143699  0   0.0      21.72      7.7  0.92  33.5     753.      23402.    15521.    .000027   0.74   0.8  32.   ***    .45   1.4E 02  4.1E 01   1.2E-05
 147299  0   0.0      21.72     13.1  1.00  32.6     752.      22433.    14543.    .000025   0.73   0.7  18.   -3.    .46   4.9E 00  3.2E 01   1.2E-05
 150899  0   0.0      21.72     10.9  1.00  32.5     752.      23089.    14251.    .000026   0.75   0.5   4.   10.    .46   3.2E-00  1.2E 01   1.2E-05
 154499  0   0.0      21.72      0.0  1.00  27.9     755.      14718.     5150.    .000025   0.91   0.6  -9.   21.    .46   1.6E-04  5.4E-04   1.2E-05
 158099  0   0.0      21.72      0.2  1.00  28.7     755.      15846.     5377.    .000025   0.92   0.7  ***   32.    .46   3.2E-04  9.2E-05   1.2E-05
 161699  0   0.0      21.72      1.6  1.00  28.6     755.      13796.     7301.    .000026   0.93   0.5  ***   41.    .46   4.6E-04  9.4E-05   1.2E-05
 172499  0   0.0      21.72      0.0  1.00  27.8     755.      15382.     6438.    .000025   0.93   0.5  ***   47.    .47   5.4E-04  1.0E-04   1.2E-05
 176099  0   0.0      21.72      0.0  1.00  26.4     755.      15147.     6810.    .000020   0.80   0.5  ***   40.    .47   4.4E-04  9.8E-05   1.2E-05
 183299  0   0.0      21.72      0.0  0.91  25.8     755.      14044.     3538.    .000019   0.79   0.3  ***   20.    .47   1.4E-04  7.7E-05   1.2E-05
 186899  0   0.0      21.72      0.0  0.77  25.6     755.      15237.     3143.    .000018   0.76   0.3  ***    8.    .47   1.1E-05  4.2E-05   1.2E-05
 190499  0   0.0      21.72      0.0  0.45  25.3     755.      14339.     3948.    .000017   0.72   0.3  -5.   -5.    .47   0.0      1.4E-02   1.2E-05
 194099  0   0.0      21.72      0.0  0.25  25.1     755.      15000.     4026.    .000015   0.70   0.5   8.   ***    .47   4.5E-00  1.8E 01   1.2E-05
 197699  0   0.0      21.72      5.4  0.24  30.4     756.      21516.    10191.    .000019   0.61   0.7  21.   ***    .47   7.1E 00  3.5E 01   1.2E-05
 201299  0   0.0      21.72     11.3  0.20  31.2     756.      24997.     9143.    .000020   0.61   0.5  35.   ***    .48   1.6E 02  4.2E 01   1.2E-05
 208499  0   0.0      21.72     13.9  0.16  30.3     754.      27246.     8771.    .000019   0.61   0.5  63.   ***    .48   3.2E 02  4.7E 01   1.2E-05
 212099  0   0.0      21.72     11.5  0.15  30.1     754.      26905.    13042.    .000019   0.61   1.0  76.   ***    .48   3.6E 02  4.8E 01   1.2E-05
 215699  0   0.0      21.26      7.3  0.15  30.8     755.      27013.    12371.    .000019   0.62   1.0  84.   ***    .48   3.7E 02  4.8E 01   1.2E-05
 219299  0   0.0      21.26     15.3  0.30  29.6     752.      25165.    11975.    .000016   0.56   1.0  73.   ***    .48   3.5E 02  4.9E 01   1.2E-05
 222899  0   0.0      21.26     14.2  0.36  29.8     753.      23843.    11312.    .000017   0.57   1.0  59.   ***    .48   3.0E 02  4.7E 01   1.2E-05
 226499  0   0.0      13.10     11.9  0.42  29.9     753.      24049.    10566.    .000017   0.58   1.0  46.   ***    .49   2.3E 02  4.5E 01   1.2E-05
 230099  0   0.0       0.0      12.4  0.50  30.1     753.      26092.     8334.    .000023   0.77   0.5  32.   ***    .49   1.4E 02  4.1E 01   1.2E-05
 232747  1   0.0       0.0       0.0  1.00  25.4     757.      12104.      252.    .000024   1.00   0.2  22.   ***    .49   7.2E 00  3.5E 01   1.2E-05
 233347  1  14.51      1.27      4.9  1.00  27.1     754.      13048.      397.    .000026   1.00   0.2  19.   ***    .49   5.8E 00  3.4E 01   1.2E-05
 233947  1  21.66      4.42      7.0  1.00  27.2     754.      13651.      406.    .000026   1.00   0.2  17.   ***    .49   4.4E 00  3.2E 01   1.2E-05
 235147  1   4.91      9.84      8.5  1.00  27.7     754.      12257.      436.    .000027   1.00   0.2  13.   ***    .49   2.1E 00  2.6E 01   1.2E-05
 235334  0   0.0       9.97      8.9  0.48  31.8     756.      24531.     7236.    .000023   0.69   0.5  12.   ***    .49   1.8E 00  2.5E 01   1.2E-05
 238934  0   0.0       9.97      0.0  0.62  27.5     756.      14285.      998.    .000023   0.89   0.1  -2.    2.    .49   1.7E-10  8.6E-01   1.2E-05
 242534  0   0.0       9.97      0.0  0.73  27.5     756.      14986.      788.    .000023   0.89   0.2  ***   14.    .49   5.9E-05  6.5E-05   1.2E-05
 246134  0   0.0       9.97      0.0  0.73  27.5     756.      14945.     1246.    .000024   0.89   0.2  ***   25.    .49   2.1E-04  8.6E-05   1.2E-05
 249734  0   0.0       9.97      0.0  0.70  27.6     755.      15512.     2225.    .000023   0.88   0.2  ***   34.    .51   3.6E-04  9.6E-05   1.2E-05
 256934  0   0.0       9.97      0.0  0.50  27.4     755.      17141.     6893.    .000022   0.94   0.5  ***   46.    .51   5.4E-04  1.0E-04   1.2E-05
```

Figure 5.2-24 EXAMPLE OF A REPORT GENERATED WITHOUT PLANNER INPUT

5.2 REFERENCE LIST

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5.3 TERRAIN

5.3.1 Terrain Tape

In the mainstream of system simulation, specifically PRERUN Job Step 9, line-of-sight (LOS) calculations are made for LOS-dependent types of sensors. The so-called "detailed" mode of evaluation by definition requires moderately high resolution digital terrain data.

An auxiliary, pre-PRERUN program package is available for the preparation of radar masking contour plots. This package requires digital terrain data.

An auxiliary RF data link package, for analysis of RF propagation losses, also requires digital terrain data.

In all three applications, the detailed digital terrain data come from from an operational or "sparse"* terrain tape. The general characteristics of data on this tape are described below (5.3.1.1).

It is perhaps important to emphasize that the three program packages mentioned above simply use a tape with proper data content and format, regardless of how that tape may have been generated. At the present time (i.e., the date of this report), definite procedures have been established for the formation of an operational tape, based on a higher-resolution TOPOCOM tape supplied by CDC/ISA. The program that makes the conversion is called MAKTAP, and is briefly discussed in Section 5.3.1.2.

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* The designation "sparse" reflects current procedures, in which the generated tape contains about 1/64 as many data as the source tape supplied by CDC/ISA (modified from TOPOCOM source tape).

However, the present procedures are not self-limiting. That is, alternative and perhaps more efficient procedures developed in the future may be used, provided only that they produce a tape with proper data content and format. Possibilities, for example, are: (a) revision of the mechanics of reading source data, to produce directly a suitable, FORTRAN-readable tape; and (b) production of a tape in which height values are determined randomly, according to statistics that reflect the more important characteristics of terrain in the selected scenario area.

It may also be noted that tape generation, by whatever means, needs be done but once for a given scenario (geographic) area... regardless of the number of different simulation runs that may be exercised within the area. The first runs made with the CAL-supplied System Assessment Model were based on a tape (also supplied) covering a rectangular area in the Hue area, South Vietnam.

5.3.1.1 Content of Operational Digital Terrain Tape

Programmers will realize that physical and system aspects of the operational tape are necessarily fixed for any one application; but in the typical software context of modern computer installations, the corresponding details are largely controlled by Job Control Language (JCL) or, at worst, by simple changes in FORTRAN coding of the programs that have read or write instructions associated with that tape. For example, the "tape" might in fact be defined as a disk unit by suitable JCL.

Hence, in this discussion the emphasis is on the information content and general logical structure of this content on the data file.

First, the <u>general</u> content of information on the tape is a set of terrain height values, defined at discrete (x,y) coordinates over a rectangular area. The maximum size of this area that can be handled by the SAM is 30 km by 30 km; more explicitly, the maximum dimension in either the x (east-west) or y (north-south) coordinate is 30 km. The (x,y) points form a uniform point grid over the area, with a nominal spacing between adjacent points -- in either direction -- of 100 meters*.

In the present programs, the stored terrain height data have an integer-type numeric representation, and the tape is read or written in binary mode. Terrain heights are expressed in meters above mean sea level.**

A logical record basically covers the sequence of terrain heights for a single vertical (i.e., y-direction, or north-south direction) scan line. Thus, a particular point would be determined by:

x-position: determines which scan line is to be used

y-position: determines the count within one scan line.

In practice, the programs that use the tape are supported by subroutines that provide the appropriate access operations, storage control, and bookkeeping for applications.

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* Exact value corresponds to 0.08 inches on a 1:50000 scale map, hence 4000 inches = 101.60 meters of actual ground distance.

** Terrain heights are expressed in the same units as the USATOPOCOM map from which they were obtained, i.e., meters in SEA and Europe and feet in CONUS. The present programs are written in meters with no provision for automatic conversion of feet to meters.

5.3.1.2 The MAKTAP Program

The MAKTAP program is one mechanism for producing a digital terrain tape, by appropriate mapping of a high-resolution CDC/ISA-supplied, FORTRAN-readable tape into one with 1/8 the linear resolution (i.e., 8 times the distance between grid points).

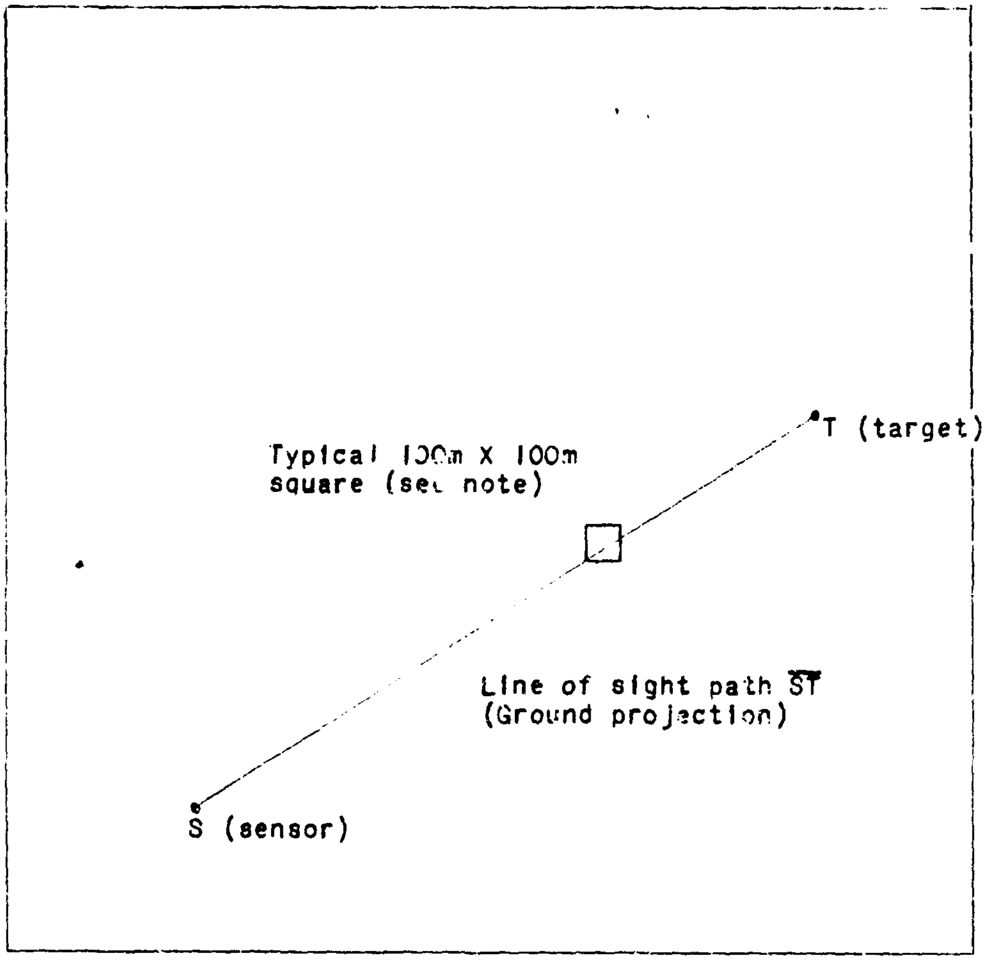
Although the concept of changing from one resolution (nominally 12.5 meters between points) to a factor of eight lower resolution (nominally 100 meters between points) appears at first glance to be a matter of using every 8'th point in both x and y directions, such a simple procedure ignores information contained in 63 out of every 64 original datum values.

The actual algorithm used for reduction of resolution is based on a nonlinear averaging process, that appears particularly sound for the primary use of the data, in determining line of sight.

Consider Figure 5.3-1 representing a general ground projection of a nominal line-of-sight ray between two points (S, sensor and T, target). In actual LOS calculation, the total distance is generally treated in three distinct regions:

(a) near the sensor (typically, a cleared area is assumed to exist, at least for stationary sensors)

(b) near the target (here, individual clumps of vegetation and local variations, over a few meters, of terrain are more of a determination of LOS than general terrain characteristics. These local effects are not within the resolution of the digital terrain data, and are treated on a probabilistic basis).



NOTE: On 1:50000 scale map, a 100m X 100m square of actual distance would be 0.08 inches square. Scale exaggerated above for clarity.

Figure 5.3-1 ILLUSTRATIVE LINE OF SIGHT GROUND TRACK

(c) the interior segment.

The digital terrain data are primarily significant in the interior region.

Again with reference to Fig. 5.3-1, consider the particular 100 meter square shown, through which the ray passes. It is clear that the cross-section of the terrain along this cut influences line of sight, according as the maximum value is or is not above the connecting line from sensor to target.

However, Figure 5.3-1 shows only one possible line-of-sight cut through the given square. It would not be valid to consider only the one maximum value, for a "typical" arbitrary cut, because it might correspond to an unusually low (valley) cut, or it might cross an area at or near the maximum height within the entire square. The correct "average maximum," based on an average over all possible rays (random angles and translations) through the square, appears to be a reasonable value for an assigned terrain height value if (a) one value must be chosen to represent the entire square, and (b) the primary use is line of sight calculations for "interior" regions of sensor-to-target line segments.*

A practical algorithm, approaching this theoretical concept, is used in program MAKTAP. Original data for the 100 meter square actually consists of a 9 point by 9 point grid (8 intervals by 8 intervals), as indicated in Figure 5.3-2. Computation does not attempt to treat "all"

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* This argument is not necessarily valid for other applications of the terrain height data... for example, determining effective altitude of a radar position.

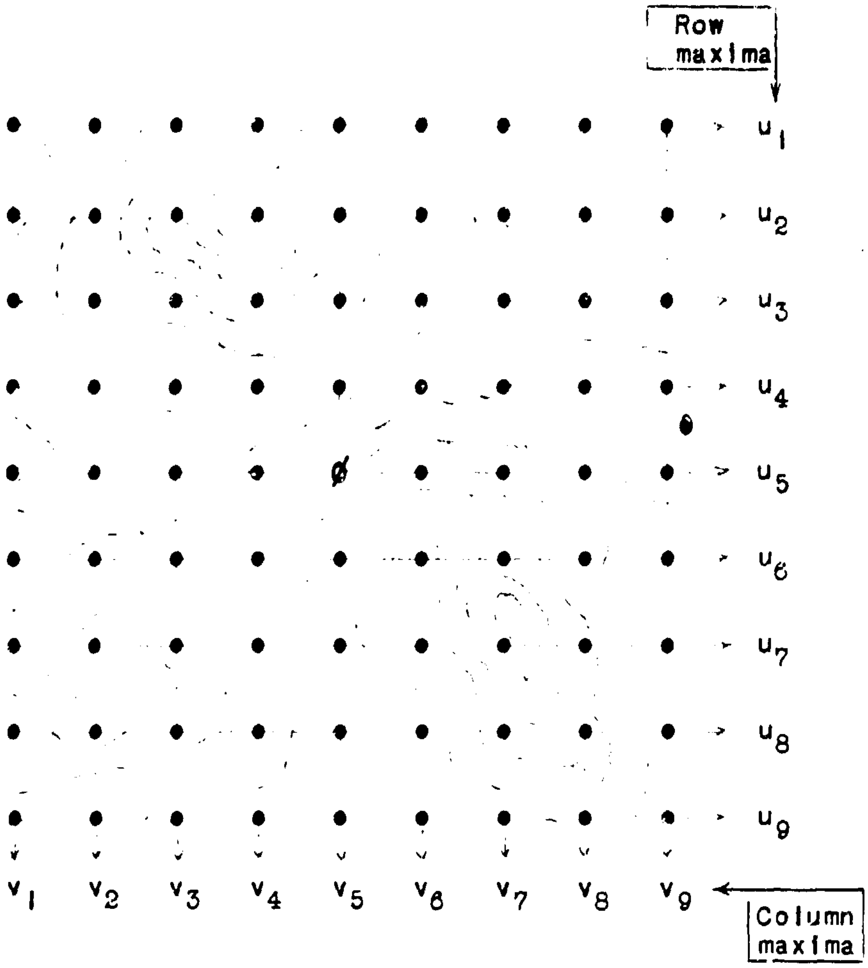
possible angles and translations of paths through this grid-defined square; but it does treat the two primary angles (0 and 90 degrees), and the nine simple and meaningful translations for each angle. That is, the terrain height assigned to the center of the square is the average of the easily computed ray maxima -- i.e., the average of the 9 row maxima and the 9 column maxima.

Additional details on the MAKTAP program may be found in the program listings. The mechanism of operating the program, and information on the source tape, are given in the Users' Manual, Volume II.

TABLE 5.3-I

MAKE TERRAIN TAPE COMMON AREAS

USE	VARIABLES	USED BY
Common/TAPE/, Ktimes		
	Ktimes - Scan line Index of Sparse tape.	Maktap Read
Common/TAPE/, NX, NY		
	NX - Length of X axis of topocom map in inches X 100 (integerized) NY - Length of Y axis of topocom map in inches X 100 (integerized)	Maktap Read



NOTES: $\emptyset$ is center point of 100 m. x 100 m. square

● other points (original resolution) within the square

Terrain height value assigned to $\emptyset$ given by following formula:

$$(u_1+u_2+\ldots+u_9+v_1+v_2+\ldots+v_9)/18$$

Figure 5.3-2 NONLINEAR MAPPING FROM HIGH TO LOW RESOLUTION GRID

5.3.2 Subroutine TERAN

5.3.2.1 Purpose

This routine supplies the data describing the terrain environment description required by both the PRERUN and the Main Simulation portions of the model.

5.3.2.2 Use and Description of Inputs

Two input data sets must be placed in the input data stream to be read by this routine. Figure 5.3-3 shows the order of these data sets. The description of the terrain environment is based upon the definition of homogeneous areas called unit terrains. Values assigned to a set of twenty parameters describe the environment within a unit. By assigning different unit terrains to various portions of the scenario area, a non-homogeneous playing area can be constructed. The UTVSXY data set describes the areal extent of the unit terrain types over the scenario area. The unit terrains are assigned to the game area using a 500 meter square grid whose origin is

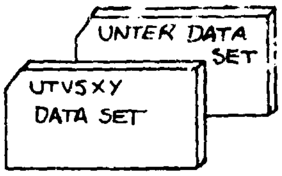


Figure 5.3-3 REQUIRED INPUT DATA STREAM

placed at the southwest corner of the game area. The cards composing UTVSXY data set are described in Table 5.3-II. The number of cards can range from two to sixty-one (2 to 61) depending upon the size of the scenario area. In addition to the first card which supplies identifying information, one card is required for each 500 meter block or fraction thereof within the north-to-south extent of the scenario area. For example, if the north-to-south size of the scenario area is 30 kilometers, 61 data cards are required for the UTVSXY data set; if the north-to-south extent of the scenario area is 12 kilometers, 25 cards will be required in this data set. This data set is prepared by overlaying a 500 meter square grid on top of a terrain map of the scenario area. In the case of areas within South Vietnam, the cross-country movement maps of tactical scale studies are ideal for this purpose. The maximum size of the 500 meter square grid is 60 by 60 blocks which would cover a game area of 30 kilometers by 30 kilometers. The single east-to-west row of 500 meter square blocks is referred to as a track. The variable NTRACK is the number of these tracks required to cover the north-to-south extent of the playing area. Thus, as described above, the number of data cards in the UTVSXY data set is equal to NTRACK + 1. In preparing the data set, the planner should first assign a unit terrain type to each of the 500 meter blocks covering the playing area. Currently there are eight unit terrains available for describing a scenario area in South Vietnam. The description of these unit terrains is presented in Table 5.3-III. Each unit terrain type is identified by an integer number, IUT. They were defined principally on the basis of the vegetation type classification used in the cross-country movement maps of tactical scale studies from two potential scenario areas in the northern part of South Vietnam. The correspondence between the vegetation classification and the unit terrain types is presented in Table 5.3-IV. Those vegetation types not included in the present unit terrain descriptions did not occur with sufficient regularity within the potential scenario areas. Expansion to scenario areas in other parts of South Vietnam, of course, may require that additional unit terrains be defined. Unit terrain classifications were also developed for a potential Fort Hood scenario area. The description of the seven unit terrains for the Fort Hood area is presented in Table 5.3-V. In order to exercise the Model at other locations appropriate unit terrain descriptions must be generated by the planner.

Table 5.3-II Composition of UTVSXY Data Set
(2 to 61 Cards as Required)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	I2, 78X	NTRACK, "Identifying Alpha/Numeric Information"	NTRACK is the integer number of 500 meter high east-west tracks (or strips) which are required to cover the north-south extent of the scenario area. (1 ≤ NTRACK ≤ 60). The last 78 spaces are provided for alpha/numeric information to allow identification of the data set.
n	15(I4, 1X), 5X	[IUTXY(K, n-1), K = 1, 15]	IUTXY is an integer formed from the number of 500 meter square sequential blocks of a constant unit terrain type.
n = 2, 3,..., NTRACK + 1 ≤ 61			

Table 5.3-III SOUTH VIETNAM UNIT TERRAINS

IUT	Description
1	Single crop rice on river flood plains and coastal plains.
2	Single canopy light undergrowth forest on rolling hills.
3	Brushwood, including grasses and scrub deciduous trees on rolling hills.
4	Brushwood, including grasses and scrub deciduous trees on flat river valleys.
5	Multi-canopied forest with dense undergrowth on upper mountain slopes.
6	Multi-canopied forest with dense undergrowth on lower mountain slopes.
7	Bamboo thickets within single canopied or multi-canopied forests on moderate to steep slopes.
8	Dune grass and scrub pine on moderately sloping sand dunes.

Table 5.3-IV CORRESPONDENCE BETWEEN TACTICAL SCALE STUDY VEGETATION CLASSIFICATION AND UNIT TERRAINS

Vegetation Type		Unit Terrain Number, IUT =
No.	Description	
1	Multi-Canopied Dense Undergrowth Forest	5 or 6 depending upon terrain gradient
2	Multi-Canopied Dense Undergrowth Forest W/Bamboo	7
5	Single Canopy Light Undergrowth Forest W/Bamboo	7
6	Single Canopy Light Undergrowth, Rubber and Palm Plantations	2
7	Brushwoods, Coffee and Tea Plantations	3 or 4 depending upon terrain gradient
9	Dune Grass and Casuarina on Sand	8
13	Rice, Single Crop	1
14	Rice, Double Crop	1

Once the planner has identified the appropriate unit terrain for each 500 meter block within the scenario area, these data are transferred to cards to form the desired data set. Each card describes the unit terrain assignments along a single east-to-west track within the playing area. The first card describes the unit terrain assignments in the most southern track while the last data card describes the unit terrain assignments in the most northern track. In transferring the data from the grid to the data cards the planner is allowed 15 specifications of unit terrain along the track. The format for specifying the unit terrains along the jth track from <u>west to east</u> is

$$N_{1j}, I_{1j}\ N_{2j}, I_{2j}\ \ldots\ N_{kj}, I_{kj}$$

where N_{kj} is a two-digit integer equal to the number of consecutive 500 meter blocks with unit terrain type I_{kj} and $k \leq 15$. Thus

2006 3001 1002

would indicate that the first 20 blocks in the track were unit terrain type 6, the next 30 blocks unit terrain type 1 and the last 10 blocks unit terrain type 2. As indicated in Tab. 5.3-IIthe first card in the data set which proceeds the cards containing the unit terrain assignments contains the number of tracks required to cover the playing area (NTRACK) and identifying alpha/numeric information which the planner desires to use to allow identification of the particular data set. An example of an UTVSXY data set prepared for a 13 x 17.5 kilometer scenario area near Hue, South Vietnam is shown in Fig. 5.3-5.

The second data set which must be placed in the input data stream presents the data which specifies the parameters defining each unit terrain.

Table 5.3-V FORT HOOD UNIT TERRAINS

IUT	Description
1	Scrub mesquite on gently rolling plateau tops
2	Oak woodland on gently rolling plateau tops
3	Oak woodland with dense undergrowth on moderately sloping plateau sides
4	Grassland on high stream terraces
5	Scattered oak trees on undulating plateau sideslopes
6	Widely spaced oak trees on gently rolling plateau tops
7	Narrow bands of trees along larger drainways

The composition of the UNTER data set is presented in Table 5.3-VI. This data set can consist of two to eleven (2 to 11) cards depending upon the number of terrain units defined for a particular scenario area, MAXIUT, which is currently limited to a maximum of 10 units. In addition to the first card, one additional card is required for each unit terrain type and therefore the number of cards in this data set is equal to MAXIUT + 1. For the South Vietnam unit terrain types identified previously in Table 5.3-III, this data set would require 9 data cards; for the Fort Hood unit terrains presented in Table 5.3-V, this data set consists of 8 data cards. Twenty-two variables are used in describing the terrain environment (see Table 5.3-VII). Except XFIELD, YFIELD and ZFIELD, the components of the earth's magnetic field, these variables can have a different value for each unit terrain. When new unit terrains are defined, the assignment of the values for each variable should be made by the persons with expertise in geography. The data required to make the assignment for the South Vietnam unit terrains was obtained from the text associated with the cross-country movement maps of tactical scale studies. In the case of the Fort Hood unit terrains this convenient source of data did not exist. In this case several sources of data were used. The upper and lower limits of slope gradient for each of the unit terrain types were determined from topographic maps. Measurements of tree canopy heights and spacing were made from stereo photography at a scale of 1:23,000 which is considered to be a reasonably reliable procedure. Other parameters such as tree density and canopy enclosure were estimated using the single photographic image. The ground-to-ground visibility, of course, could not be measured but was estimated from the density and height of the vegetation. The reliability of these estimates is not known and in most cases these data should be substantiated by field measurements. Information on soil types and soil moisture conditions was facilitated by referral to soil maps of the Fort Hood area prepared by the Soil Conservation Service of the United States Department of Agriculture.

Should additional scenario areas be defined for exercising the Model new unit terrains and hence new UNTER data sets will have to be prepared.

Table 5.3-VI Composition of UNTER Data Set
(2 to 11 Cards as Required)

CARD NO.	FORMAT	LIST	DESCRIPTION
1	42X, I2, 3E10, 3I2	"**Identifying Alpha/ Numeric Information**", MAXIUT, XFIELD, YFIELD, ZFIELD, IDAREA, IMONTH, 1	The first 42 spaces are provided for alpha/numeric information to allow identification of the data set. MAXIUT is the number of unit terrain types for the scenario area to which the data set applies. XFIELD, YFIELD and ZFIELD are the X, Y and Z components of the earth's magnetic field at the scenario area The next three integers serve as an identification code [IDAREA = scenario area, IMONTH = month to which the data set applies].
n	8F4, I2, 2F4, 2I2, F4, 3I2, 2F6, 6X, 3I2	SGLL(J), SGUL(J), CHLL(J), CHUL(J), TDLL(J), TDUL(J), SPLL(J), SPUL(J), ITRDEN(J), CCLL(J), CCUL(J), IVCOV(J), IBACK(J), TVEG(J), [ISM(K, J), K = 1, 3], VISBLL(J), VISBUL(J), IDAREA, IMONTH, n	Value for parameters in UNTER Table (see Table 5.3-VII)
n = 2, 3,..., MAXIUT + 1 ≤11			

Table 5.3-VII VARIABLES USED IN DESCRIBING A UNIT TERRAIN

Variable Name	Type*	Description	Units
XFIELD YFIELD ZFIELD	Real " " " "	x-, y- and z- components of Earth's magnetic field	Oersted " " " "
SGLL	Real Array	Lower limit of slope gradient	Percent
SGUL	" "	Upper limit of slope gradient	" "
CHLL	" "	Lower limit, canopy or vegetation height	Meters
CHUL	" "	Upper limit, canopy or vegetation height	" "
TDLL	" "	Lower limit of tree diameters (DBH)	" "
TDUL	" "	Upper limit of tree diameters (DBH)	" "
SPLL	" "	Lower limit, stem or clump spacing	" "
SPUL	" "	Upper limit, stem or clump spacing	" "
ITRDEN	Integer Array	Tree Density 1 = Sparce; 150 trees/100m^2 2 = Lightly forested, 200 trees/100 m^2 3 = Dense forest, 500 trees/100 m^2	-
CCLL	Real Array	Lower limit, % canopy closure	Fraction
CCUL	" "	Upper limit, % canopy closure	" "
IVCOV	Integer Array	Index describing vegetation cover 1 = Heavy 2 = Medium 3 = Light 4 = Open 5 = Rice/Water	-
IBACK	" "	Index identifying the most likely background reflectance function between 0.4 to 0.9 microns 1 = Tree/grass - summer 2 = Coniferous trees 3 = Trees/grass - autumn 4 = Leaves 5 = Elephant grass	-
TVEG	Real Array	Transmittance of Vegetation cover of canopy for light between 0.4 and 0.9 microns	Fraction
ISM	2-Dimensional Integer Array	Index describing soil moisture conditions ISM(1, IUT) = ambient soil moisture ISM(2, IUT) = soil moisture after 1/2 inch of rain ISM(3, IUT) = soil moisture after 1 inch of rain 1 = Dry; 25% saturated 2 = Moist; 25-50% saturated 3 = Wet; 50-100% saturated 4 = Inundated, 100% saturated	
VISBLL	Real Array	Lower limit, ground-to-ground visibility	Meters
VISBUL	" "	Upper limit, ground-to-ground visibility	" "

*All of the variables in the Unter Table are one-dimensional arrays (except for XFIELD, YFIELD, ZFIELD and ISM) with the subscript being IUT which identifies the unit terrain type. In the case of ISM, which is two-dimensional, IUT is the second subscript. XFIELD, YFIELD and ZFIELD are constants independent of the unit terrain type.

In this case the use of data sources such as those used above for the Fort Hood area is recommended as well as the acquisition of field measurements in order to insure reasonable accuracy of these data. A number of variables such as IVCOV, an index describing the vegetation cover within the unit terrain and IBACK, an index identifying the most predominant background reflectance in the unit terrain may require extension beyond the five classes presently provided for in Table 5.3-VII. To compute the net transmittance through a multi-leave canopy, we form the product of the individual leaf transmittances. If there are n leaves per canopy layer and c is the effective number of canopy layers then, TVEG, the transmittance of the vegetation cover in the visible region is given by

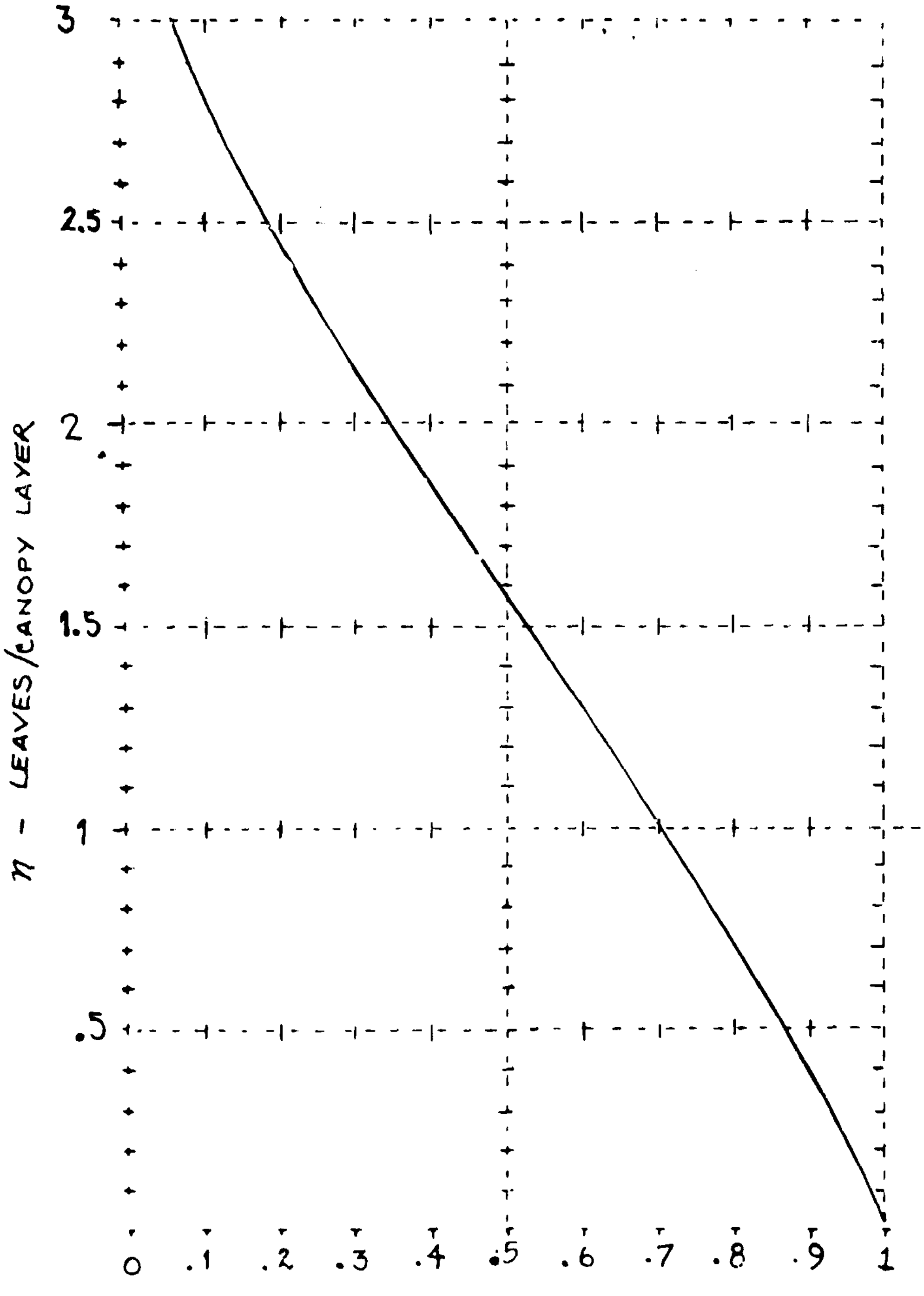
$$t = (1-a)^{n.c}$$

where a is the absorption of a single leaf (approximately 0.70 for a normal leaf) and the product n.c represents the average number of leaves in the vertical direction for the canopy. The number of leaves per canopy layer is estimated from the ground area coverage by employing the graph presented in Figure 5.3-4. For purposes of illustration, the calculation of TVEG for each of the South Vietnam unit terrains identified previously in Table 5.3-III is outlined in Table 5.3-VIII.

5.3.2.3 Description of Logic and Processing

Figure 5.3-5 is a macroflow diagram presenting the major steps in Subroutine TERAN. The first step is to read the UTVSXY Data set describing the areal extent of the terrain units over the game area. During the process of reading this data set, several checks are made on its continuity. If an error is detected the reading process is interrupted, a diagnostic message is printed and execution is terminated. Once the data set has been read, the areal extent of the unit terrain types is stored in the IUTXY common area. The algorithm used to store the data is

$$\text{IUTXY}(K_{ij}) = 100^{*}N_{kj} + I_{kj},\ k \leq 15,\ j \leq 60$$



GROUND AREA COVERAGE

Figure 5.3-4 ESTIMATED FOLIAGE STRUCTURE OF HARDWOOD CANOPY

Table 5.3-VIII CALCULATION OF CANOPY TRANSMITTANCE-TVEG (SOUTH VIETNAM UNIT TERRAINS)

UNIT TERRAIN NUMBER (IUT)	MEAN GROUND AREA COVERAGE P_c (1)	NORMAL NUMBER OF CANOPY LAYERS C	GROUND AREA COVERAGE P (2)	NO. OF LEAVES PER LAYER n (3)	NORMAL TRANSMITTANCE t	EFFECTIVE NO. OF CANOPY LAYERS C* (4)	EFFECTIVE TRANSMITTANCE t* (5)
1	0	0	0	6	1.0	0	1.0
2	.65	2	.41	1.8	.01	1	.10
3	.30	1	.30	2.1	.08	.3	.50
4	.30	1	.30	2.1	.08	.3	.50
5	.95	3	.54	1.45	.005	2	.03
6	.95	3	.54	1.45	.005	2	.03
7	$\sim$.95	2	.68	1.1	.07	1.7	.10
8	.03	1	.03	$\sim$ 3.0	.02	$\sim$.01	$\sim$.95

(1) An average of the upper and lower limits of closure.

(2) Determined using the expression $P = 1 - (1-P_c)^{1/C}$.

(3) Determined using Figure 5.3-4.

(4) An estimate of the present condition of the canopy due to the use of defoliants.

(5) Values used for TVEG in Unter data set.

Reference:

Magorian, T. R. and Naylor, J., FIBRE II, Vol. 2, Ballistic Behavior of Projectiles in Vegetation. AD818975. Also CAL Report GM-2146-6-1.

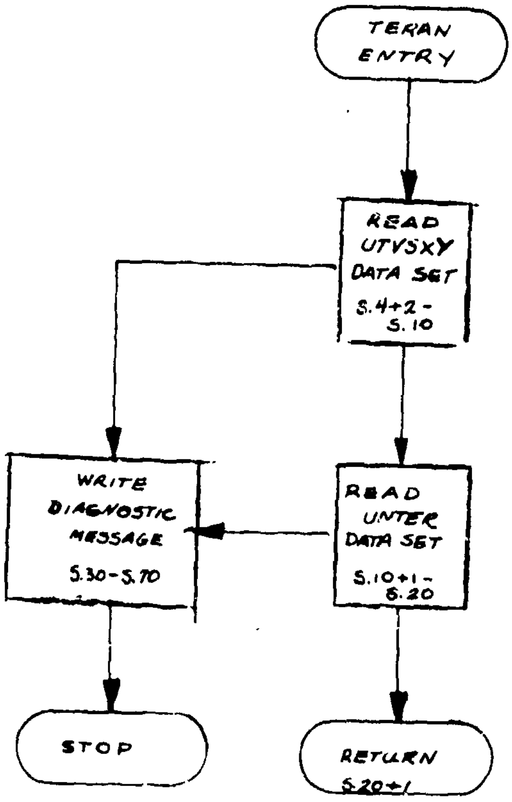


Figure 5.3-5 MACROFLOW DIAGRAM FOR SUBROUTINE TERAN

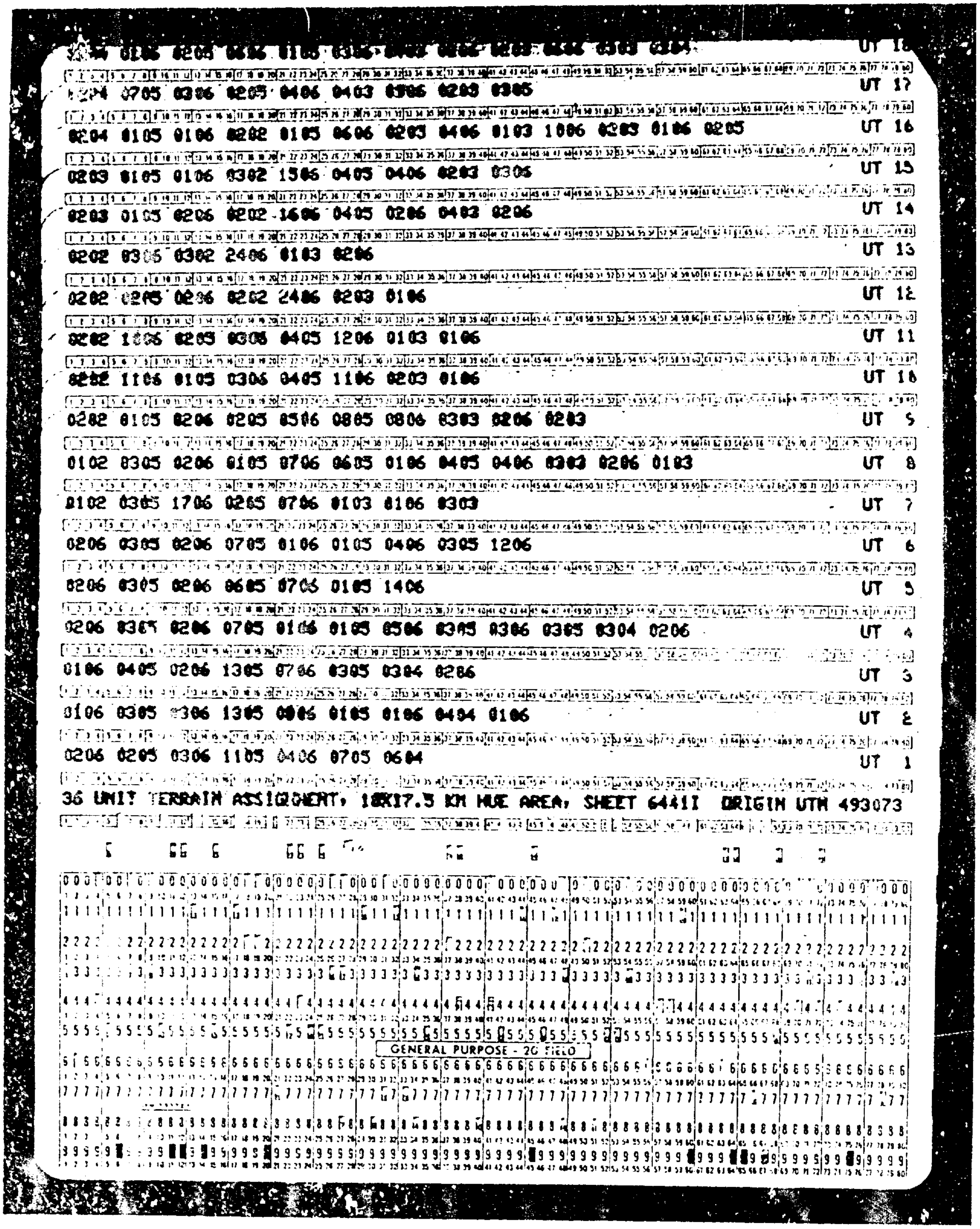
The second major step is the reading of the UNTER data set. If an error in the continuity of the data set is detected, a diagnostic message is printed and the execution terminated. Once the completed data set has been read, the contents of the UNTER data set will be stored in the UNTER Common Area and execution returned to the calling program.

5.3.2.4 Sample Data Set

Fig. 5.3-6 showed a sample UTVSXY data set prepared for an 18 by 17.5 kilometer scenario area near Hue, South Vietnam. Fig.5.3-7 shows the UNTER data set for the 8 unit terrains for South Vietnam identified previously in Table 5.3-III.

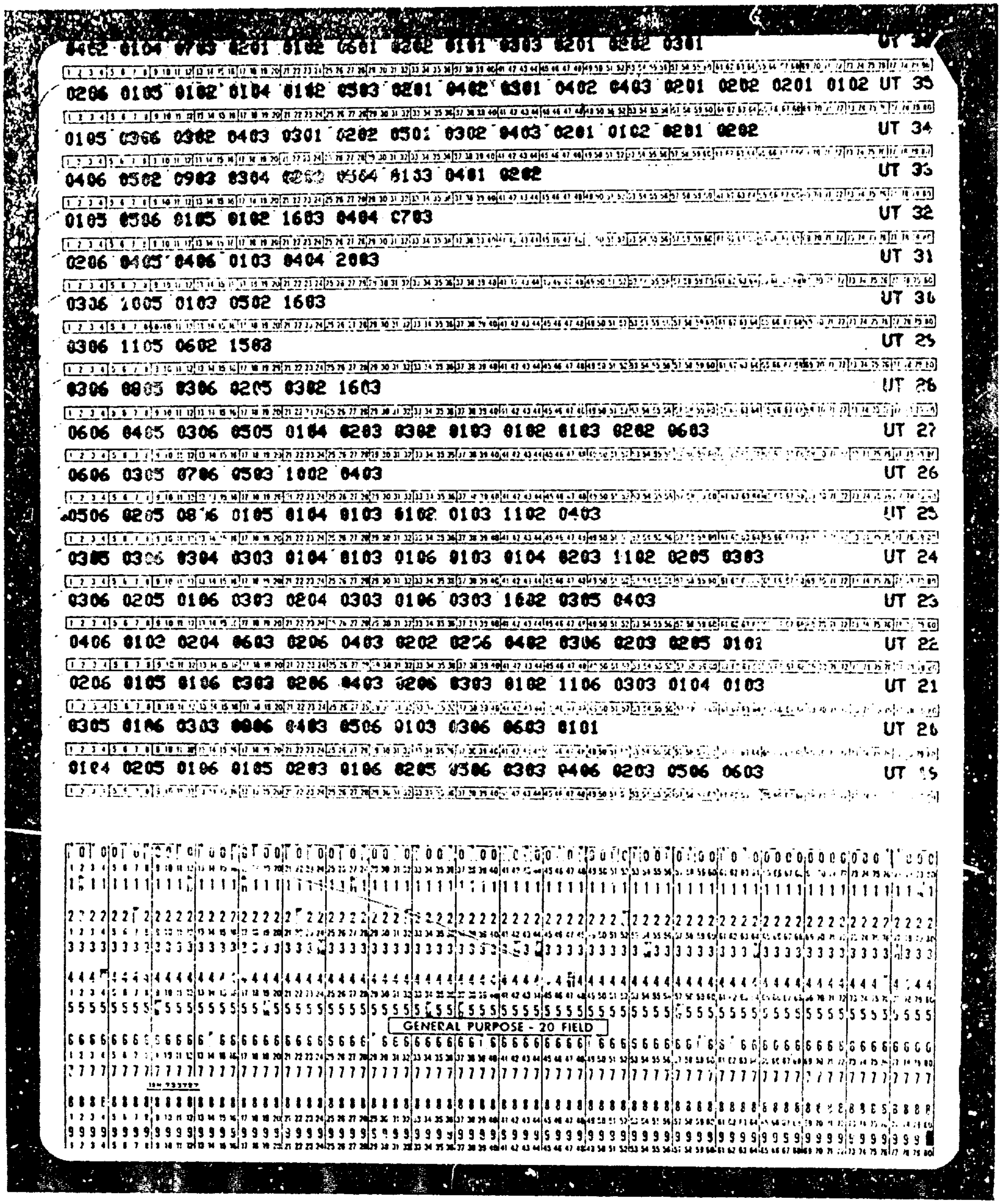
5.3.2.5 Sample Output

No direct output is produced by this subroutine unless an error is detected in the UTVSXY or UNTER Data Sets. If an error is detected one of the diagnostic messages shown in Table 5.3-IX is printed.



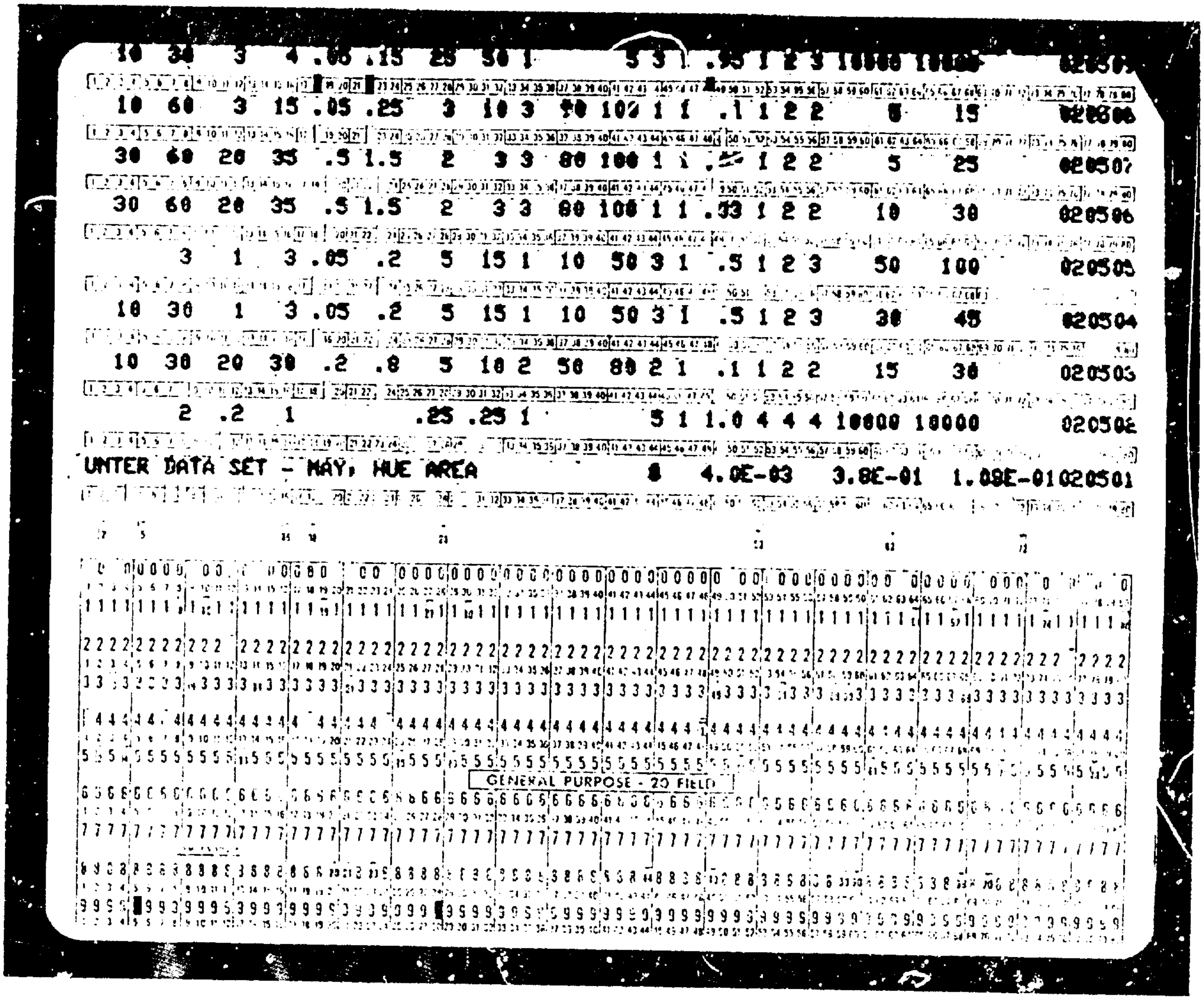
```
[illegible] 0105 0206 0505 0105 0305 [illegible] [illegible] 0203 [illegible] 0303 0304   UT 18
0204 0705 0306 0205 0406 0403 0506 0203 0305                UT 17
0204 0105 0106 0202 0105 0606 0203 0406 0103 1006 0203 0106 0205   UT 16
0203 0105 0106 0302 1506 0405 0406 0203 0306                UT 15
0203 0105 0206 0202 1606 0405 0206 0403 0206                UT 14
0202 0305 0302 2406 0103 0206                               UT 13
0202 0205 0206 0202 2406 0203 0106                          UT 12
0202 1006 0205 0305 0405 1206 0103 0106                     UT 11
0202 1106 0105 0306 0405 1106 0203 0106                     UT 10
0202 0105 0206 0205 0506 0805 0806 0303 0206 0203           UT  9
0102 0305 0206 0105 0706 0605 0106 0405 0406 0303 0206 0103 UT  8
0102 0305 1706 0205 0706 0103 0106 0303                     UT  7
0206 0305 0206 0705 0106 0105 0406 0305 1206                UT  6
0206 0305 0206 0605 0706 0105 1406                          UT  5
0206 0305 0206 0705 0106 0105 0506 0305 0306 0305 0304 0206 UT  4
0106 0405 0206 1305 0706 0305 0304 0206                     UT  3
0106 0305 0306 1305 0606 0105 0106 0404 0106                UT  2
0206 0205 0306 1105 0406 0705 0604                          UT  1
36 UNIT TERRAIN ASSIGNMENT, 10X17.5 KM HUE AREA, SHEET 6441I  ORIGIN UTM 493073
```

Figure 5.3-6 EXAMPLE OF A UTVSXY DATA SET



```
0402 0104 0703 0201 0102 0601 0202 0101 0303 0201 0202 0301                UT 36
0206 0105 0102 0104 0102 0503 0201 0402 0301 0402 0403 0201 0202 0201 0102 UT 35
0105 0306 0302 0403 0301 0202 0501 0302 0403 0201 0102 0201 0202           UT 34
0406 0502 0903 0304 0202 0504 0133 0401 0202                               UT 33
0103 0506 0105 0102 1603 0404 0703                                         UT 32
0206 0405 0406 0103 0404 2003                                              UT 31
0306 1005 0103 0502 1603                                                   UT 30
0306 1105 0602 1503                                                        UT 29
0306 0805 0306 0205 0302 1603                                              UT 28
0606 0405 0306 0505 0104 0203 0302 0103 0102 0103 0202 0603                UT 27
0606 0305 0706 0503 1002 0403                                              UT 26
0506 0205 0806 0105 0104 0103 0102 0103 1102 0403                          UT 25
0305 0306 0304 0303 0104 0103 0106 0103 0104 0203 1102 0205 0303           UT 24
0306 0205 0106 0303 0204 0303 0106 0303 1602 0305 0403                     UT 23
0406 0102 0204 0603 0206 0403 0202 0206 0402 0306 0203 0205 0101           UT 22
0206 0105 0106 0303 0206 0403 0206 0303 0102 1106 0303 0104 0103           UT 21
0305 0106 0303 0006 0403 0506 0103 0306 0603 0101                          UT 20
0104 0205 0106 0105 0203 0106 0205 0306 0303 0406 0203 0506 0603           UT 19
```

Figure 5.3-6 EXAMPLE OF A UTVSXY DATA SET (cont'd)



```
 10  30   3   4 .05 .15  25  50 1          5 3 1 .95 1 2 3 10000 10000         02050
 10  60   3  15 .05 .25   3  10 3  90 100 1 1  .1 1 2 2      5     15          020508
 30  60  20  35  .5 1.5   2   3 3  80 100 1 1  [illegible] 1 2 2      5     25          020507
 30  60  20  35  .5 1.5   2   3 3  80 100 1 1 .33 1 2 2     10     30          020506
      3   1   3 .05  .2   5  15 1  10  50 3 1  .5 1 2 3     50    100          020505
 10  30   1   3 .05  .2   5  15 1  10  50 3 1  .5 1 2 3     30     45          020504
 10  30  20  30  .2  .8   5  10 2  50  80 2 1  .1 1 2 2     15     30          020503
      2  .2   1          .25 .25 1             5 1 1.0 4 4 4 10000 10000       020502
UNTER DATA SET - MAY, HUE AREA                 8  4.0E-03   3.8E-01   1.08E-01020501
```

Figure 5.3-7 EXAMPLE OF AN UNTER DATA SET

Table 5.3-IX TERAN OUTPUT

STATEMENT NUMBER	PRINTED MESSAGE
31	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE TERAN HAS BEEN TERMINATED INPUT VALUE FOR NTRACK OUTSIDE RANGE OF 1 TO 60 NTRACK=__________
41	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE TERAN HAS BEEN TERMINATED UNTER TABLE INPUT DATA SET IS NOT IN AGREEMENT WITH SCENARIO AREA IDAREA=___CHECK INTEGER IN COLS. 75-76
51	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE TERAN HAS BEEN TERMINATED UNTER TABLE INPUT DATA SET IS NOT IN AGREEMENT WITH MONTH OF GAME IMONTH=___CHECK INTEGER IN COLS. 77-78
61	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE TERAN HAS BEEN TERMINATED CARDS IN UNTER TABLE DATA SET ARE OUT OF ORDER
71	DIAGNOSTIC MESSAGE EXECUTION OF SUBROUTINE TERAN HAS BEEN TERMINATED INPUT VALUE FOR MAXIUT OUTSIDE RANGE OF 1 TO 10 MAXIUT=__________

5.4 BATTLE AND CULTURE ENVIRONMENT SUBROUTINES

5.4.1 General

The Battle and Culture Subroutines are designed to simulate the military and culture environmental effects normally occurring in the area of operations that have the potential of influencing the performance of STANO equipments. The seismic, acoustic and imaging type sensors are thought to be particularly susceptible to stimuli originating in the operations area from both military and other activities. For the Phase I SAM, therefore, the battle and culture subroutines are designed to simulate the occurrences of disturbances pertinent to the operation of these sensors. The subroutines can be readily expanded to handle other types of events that affect performance of these or different sensor types.

These disturbances created by the battlefield and cultural events are expected to affect the sensor performance in three ways.

(1) as events with sufficient residual energy at the sensors to cause a "detection" to be generated by the sensor routines, i.e., a false target.

(2) as an addition to the overall environmental background "noise" level that affects the sensor threshold.

(3) modify illumination levels that influence visual and electronic aided detection.

Thus, the battle and culture subroutines must account for the above three effects as separate and identifiable events for processing by the sensor's routines.

Because of the infinite variety of both battle and cultural environments that may be encountered even in a SEA area of operations, it was necessary to develop a set of guidelines to assist in the technical development of the subroutine logic. These guidelines were:

a. Maintain realism (from sensor viewpoint)

b. Allow many levels of activity

c. Keep input data requirements reasonable

d. Provide for combination of events

e. Allow detailed planner inputs but provide capability for insertion of aggregated inputs

f. Applicable to areas other than SEA

In line with the above guidelines, the battle and cultural subroutines were designed to handle up to 100 type events for battle and 50 type events for culture. The levels of activity can be varied at will by the planner simply by changing the frequency of occurrence. Provisions have been incorporated so that the planner may elect to detail the type, location, and frequency of the events or to provide only general information by specifying a type level and quantity (by quarters of a day) of events desired and let the subroutines select the location, and exact time on a random basis. Combinations of events are provided for simply by processing all events occurring in each time interval. Multiple elements of a single event, (e.g., the six round volley) are processed by keeping track of the event (i.e., a particular event type and class) and the number of elements per event type. Expansion to areas other than SEA can be implemented simply by utilizing planner inputs to account for changes in the battle and cultural environments as a result of changes in the geographic location of the area of operations. Realism with respect to the effect of the battle and cultural events on the sensor system performance is in the current version of the sensor system subroutines limited by the available knowledge regarding:

a. Generation of seismic and acoustic signals by each event

b. Propagation of these signals in differing environments

The battle and cultural subroutines, however, have been so designed that as more data becomes available, only relatively minor modifications to the battle and culture subroutines and to the sensor performance subroutines will be required.

5.4.2 Battlefield Environment Subprogram

5.4.2.1 Purpose

The purpose of the battlefield environment subroutine is to introduce into the simulation the battlefield activity (both friendly and enemy) that might have some influence on the sensor systems. The model accounts for the more significant (in terms of the effect on sensors) disturbances created by military action such as explosions, ground and air vehicle movement and illumination. Both friendly and enemy troop movements are excluded since they are specifically treated as "blue" and "red" forces in the basic simulation. The type of events permitted in the battle subroutine are tabulated in Table 5.4-I. Provisions have been made for up to 20 different event types with five classification levels for each type. The subroutine simulates the occurence of these activities in terms of type, class, location, time and frequency of occurence according to a schedule specified by the planner inputs. The battle subroutine exercised in PRERUN, generates false target data that is passed to the ELPDT subroutine for further processing. After processing in ELPDT the false targets are added to the Event 1 data stream and subsequently passed to MSM for further processing against the sensor routines. The illumination data are determined, stored on tape and eventually merged in the data stream passed to MSM. In addition to creating false target information the battle subroutine determines the nominal effect of the battlefield activities on the overall background noise levels for seismic and acoustic sensors and this information is passed to MSM as part of the sensor parameter change data stream (Event 3).

5.4.2.2 Rationale for Battlefield Environment Model

For purposes of clarity it is apropos to establish the rationale and assumptions underlying the Battle Subroutine by separating the discussion into two parts as follows:

a. the physical phenomena which affect the sensors, and

b. the operational activities which generate the physical phenomena.

5.4.2.2.1 Physical Phenomena. It is noted in Section 3 that seismic and acoustic waves are generated by many sources and propagate in many modes. For many types of battlefield events, the transient nature of energy distribution takes the form shown in Figure 5.4-1 where the area under the curve is the energy distribution. The sharp energy peak is assumed to give rise to seismic and acoustic waves which will exceed the sensor threshold, thus causing a detection.

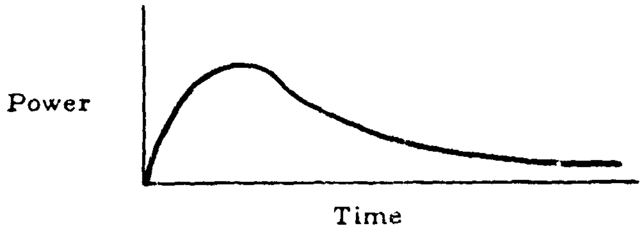


Figure 5.4-1

Table 5.4-I
EVID DESCRIPTIONS FOR SUBROUTINE BATTLE

Event No.	Type Event	Event Class 1	 2	 3	 4	 5
01	Small arms firing	⑮ 7.62mm 30 cal	12.7mm 14.5mm 50 cal	20mm 23mm	30mm	(Spare)
02	Mortar firing	⑯ 45-50mm 60mm 81-82mm	4.2-inch 107mm 120mm	155mm 160mm	⑰ 240mm	420mm
03	Mortar impacting	45-50mm 60mm 81-82mm	4.2-inch 107mm 120mm	155mm 160mm	240mm	420mm
04	Artillery firing	76-94mm 100-105mm-Chg 2 122mm-Low Chg	100-105mm-Chg 5 122mm-Med Chg 152-155mm-Chg 2	100-105mm-Chg 7 122mm-High Chg 152-155mm-Chg 5	152-155mm-Chg 7 175mm-Med Chg 8-inch-Med Chg	175mm-High Chg 8-inch-High Chg 310mm
05	Artillery impacting	76mm 94mm	100mm 105mm 122mm	152mm 155mm	175mm 8-inch	310mm
06	Direct Fire (Firing)	37-40mm 57mm	85-88mm 90mm	100mm	115mm 122mm	152mm
07	Direct Fire (Impacting)	37-40mm 57mm	85-88mm 90mm	100mm	115mm 122mm	152mm
08	Rockets & Missiles (Firing)	3.5-inch REDEYE RPG 2 & 7	82mm RL 115mm RL 130mm RL 140mm	TOW SS-11 Shillelagh	250mm 318mm (LJ) 400mm	600mm 762mm (HJ) 850mm

Table 5.4-I (Cont.)

EVID DESCRIPTIONS FOR SUBROUTINE BATTLE

Event No.	Type Event	Event Class 1	2	3	4	5
09	Rockets & Missiles (Impacting)	⑯ 3.5-inch REDEYE 40mm (RPG)	82mm 115mm 130mm 140mm	TOW SS-11 Shillelagh	⑰ 250mm 318mm 400mm	600mm 762mm 850mm
10	Recoilless Rifle (Firing)	57mm	75mm 82mm	105mm 107mm	(Spare)	(Spare)
11	RR (Impacting)	57mm	75mm 82mm	105mm 107mm	(Spare)	(Spare)
12	Mines	Hand Grenades, AP mines	10-15 lb AT	105mm (wired)	155mm (wired)	155mm (Cache TNT)
13	Bombs	⑰ 250 lb	500 lb	750 lb	1000 lb	2000 lb
14	* Nuclear	Less 2 KT	2-20 KT	20-100 KT	0.1-1 MT	Greater 1 MT
15	Illumination	Trip Flare 45,000 CP 30 sec burn	60mm 250,000 CP 30 sec burn	81 & 105mm 500,000 CP 60 sec burn	155mm 1,000,000 CP 60 sec burn	Photo Flash 120,000,000 CP 0.04 sec burn
16	* Dust Cloud	Light cal artillery	Med & Hvy cal artillery	250-500 lb bombs	750-2000 lb bombs	Nuclear
17	Aircraft	④ Light & Med Hel-LOH; UH-1; AH-1G; AH-56	Large Hel-CH-47; CH-54	⑩ Fixed-wing LP-OV-1; L-19	Fixed-wing-HP- OV-10; AD-5	⑪ Jet Fighters F4; F-100 thru F-106
18	Military Vehicles	⑤ Light Wheeled Less 1 Ton	Med Wheeled 1-5 Ton	⑥ Hvy Wheeled Greater 5 Ton	Light Tracked Less 20 Ton	⑦ Hvy Tracked Greater 20 Ton
19	Spare					
20	Spare					

* Not currently included in SAM I.

Table 5.4-I (Cont.)
EVID DESCRIPTIONS FOR SUBROUTINE BATTLE TARGET CATEGORIES FROM TABLE 4.4-I

⑤	SMVEH
⑥	HVYTRK
⑦	TANK
⑨	HELO
⑩	LT A/C
⑪	JET A/C
⑮	LT AMMO
⑯	MD AMMO
⑰	HVY AMMO

The average energy, however, when combined with that from many sources will cause an increase in the background noise. If this increase in background is sufficiently great, i.e., such that the RMS noise level is greater than sensor threshold value for fixed gain sensors then a high false alarm rate will result. For automatic gain control sensors, the increase in RMS noise will cause the sensor to operate at a reduced value of gain and in addition will produce an increase in threshold crossings due to increased variance in background noise. Because these two effects cause distinctly different sensor responses, the Battle subroutine creates battle targets (BATLTG) based on the occurrence of the peak energy and battle background effects (BATLBK) based on the average energy dissipated for each event.

For battle targets, Table 5.4-I groups the allowed events into five classes. For each type of event, e.g., artillery firing, the specific events are grouped according to peak energy level. That is, for event number 042, it is assumed that the 105-mm, charge-5 firing is equivalent in terms of seismic and acoustic wave generation to a 155-mm firing charge-2. The variability in propagation of the generated waves to the vicinity of the sensors is such an unknown that in actual practice, the assignment of groupings is at best only an indication of relative source strengths. For the purpose of the SAM I, however, the event classes were necessarily further aggregated by mapping the events of Table 5.4-I into a lesser number of categories (See Table 4.4-I Section 4.4) for establishing valid sensor target combinations. This reduction in resolution for the battle events is necessitated by the design of the sensor routines which can only accept the target designation shown in the table (sensor routines can be readily expanded when sufficient data is available). Because of the lack of data regarding complex propagation phenomena associated with the transmission of both seismic and acoustic waves and the assumptions regarding such effects as refraction, acoustic to seismic coupling, height-of-burst effects, etc., it became necessary to limit the detailed modeling of these signals in the sensor routines and concomitantly introduced the necessity for mapping the large number of battle events into a lesser number. The mapping incorporated in SAM I is shown by the numbered blocks inclosed by the accentuated line drawn on Table 5.4-I. The divisions correspond to the target categories of Table 4.4-I. Type 1 events are treated as a single target type and are mapped into the light ammunition category. Events 2 through 12 are all mapped into medium and heavy ammunition categories. Event type 13 is mapped into the heavy ammunition category for all classes. Event types 14 and 16 are not currently included in SAM I, hence no mapping is required. Event type 17 is mapped into target categories of helicopters, light aircraft, and jet aircraft. Event type 18 is mapped into the small vehicle, heavy truck, and tank target categories.

For assessing the effects of battle events on the background "noise" level, the average energies are summed (in BATLBK subroutine) over a period of time according to the following formula:

$$y_n = \alpha \quad y_{n-1} + \beta x_n$$

where

y_n = the present background energy level

y_{n-1} = the previous background energy level

x_n = the average energy level of the new battle event

α = a noise ratio fade constant less than 1 to insure that the energy level decays with time

β = the square root of the number of battle events occurring simultaneously

n = index of events distributed over a given time interval.

For purposes of the Phase I SAM, the time interval chosen is equal to one hour, α = 0.99 and x_n = the appropriate value tabulated in Designer Input Table ZNOMAS (See Volume II, Appendix I, Table I-22). These values were selected arbitrarily; however, when the battle background subroutine was exercised with scenario data background noise level increases up to 4 dB were supplied to the sensor routines. Additional validation with appropriate test data, however, is required to arrive at more realistic values.

5.4.2.2.2 Operational Activities. In addition to requiring information concerning the physical phenomena of wave generation and propagation, simulation of the battlefield environment required knowledge of the time, location, frequency and type of event. To reduce the planner input preparation load, the set of designer input tables described in Section 5.4.2.4 have been provided. These designer input tables incorporated in Block Data Set (JFBLK6) are designed to account for the more significant parameters affecting the simulation of each event. For example, data concerning levels of safety, projectile flight times, range limitations, firing characteristics of weapons, aircraft altitude and speed, and ground vehicle speed and convoy size are provided. The values included in these tables are taken from such references as artillery firing tables, from reports on artillery practices and procedures, and operational reports on SEA experience. Because of the heavy reliance on SEA operational experiences and pre-day practices and procedures with current equipment, it may be necessary to revise these tables to include more representative values for other areas of operations. As long as the dimensions of the tables are not exceeded, this will require only a simple recompilation with the new values.

5.4.2.2.3 Battlefield Illumination. The data required by subroutine Image for description of the illumination on the battlefield due to flares and searchlights (with the exception of direct searchlight which is assumed to be associated with a sensor) are the following:

XLITE
YLITE
FLARHT
AINTNS
MODE

The first two inputs give the x and y coordinates of the flare or indirect searchlight. FLARHT is the height of the flare. AINTNS is the candlepower of the flare or searchlight. If multiple flares are used, the candlepowers are added to from AINTNS. For indirect searchlight, the candlepower can be one of the several values depending on the type of searchlight employed. MODE is a description generated to identify either flare or searchlight. If MODE is used to indicate searchlight, then one of six possible alternatives follow--namely, unfiltered searchlight with a beam width of .017, .051, or .085 radians for MODE 2, 3, 4 or a pink filter searchlight for the same beam width values for MODE 5, 6 and 7.

5.4.2.3 Description of Planner Inputs

Provisions are made for the planner to input very detailed and/or general information for events that may occur. In preparing the inputs the planner should first carefully define the "planner input events set" (PIEVT)[*] in accord with the scenario. Events that are called for in the scenario can be specified in detail by use of these input data cards. This planner input should include all battle activities desired as specific events.

After preparing the PIEVT cards for both enemy and friendly scenarios, exclusion areas should be designated by drawing rectangles (side parallel to coordinate axes) and designating their coordinates in the XCLUA[**] data set. These exclusion areas can be sanctuaries, fire bases, villages, strong points, etc., or any area in which friendly or enemy weapon impacting events would not be desired. Any weapon impacting event placed in the PIEVT set will ignore the exclusion boundary; however, if designated in the XCLUA data set, such events will be excluded except for fire support weapon firing, aircraft events, and military vehicle events.

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[*] See Volume II, Appendix F, Data Set XXIII

[**] See Volume II, Appendix F, Data Set XXV

The next data set is the random events (RSEVT)* that will occur at random times within certain time limits and at random locations (outside of exclusion areas) and with random parameters, selected from the other data sets.

The final planner data set required for battle subroutine is the Fire Support Base Set (FSPTB)**. This set identifies the x, y, coordinates of each Fire Support Base and the weapons that are located at this base.

Data on sensors (location, type and performance) and on paths other than for event type 17 (trails, roads, streams, rivers, railroads, and air corridors) are not included. These data (sensors and paths) are used in several other subroutines; hence their input preparation is described elsewhere in the report.

The input for most of the data sets do not use a common format. Data cards, with format, are included in Volume II, Appendix F.

Each event in the Battle Subroutine is fully described by a four digit number referred to as EVID. The first two digits indicate the general type of event, such as a vehicle, an aircraft, or an artillery round impacting. The third digit describes the class of the event, such as a light vehicle, a heavy tracked vehicle, etc. The fourth digit indicates whether the event is generated by enemy (0) or friendly (1) activities. Table 5.4-I lists the event types and class considered in Battle. As an example, consider that a friendly 4.2-inch mortar is fired. The EVID to describe this event would be 0221. The first two digits, 02, designate the event as a mortar firing. The third digit, 2, designates the class of mortar as a 4.2-inch. The suffix, 1, designates that it is a friendly mortar. As a further example, an enemy 60-mm mortar impact would be designated by the EVID 0310.

The event classes listed in Table 5.4-I are suggested categories to be used by the planners. Other categories may be substituted as desired by the planner provided the substituted class behaves in a similar manner. That is other vehicles may be substituted for those shown, but whatever is substituted must behave like a vehicle.

The planner input data sets required for BATTLE are described in greater detail in Volume II, Appendix F, Data Sets XXIII to XXVI. The data sets must be modified for each new scenario.

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*Volume II, Appendix F, Data Set XXIV.

**Volume II, Appendix F, Data Set XXVI.

5.4.2.4 Designer Input Tables

Twelve designer input tables have been included in the current model to assist in processing the various Battle effects. These tables are shown in Volume II, Appendix I, as Tables I-11 through I-22 and are contained in block data set, JFBLK6. The tables are designed with dimensions to permit additional events and values to be added for scenario needs. Events and values currently included were designed to satisfy the model checkout requirements. These tables are used whenever the planner elects not to input certain battle event data, but rather elects to have the data chosen randomly from these tables. The contents of each of these tables is discussed as follows:

a. Safety Margin Table (Volume II, Appendix I, Table I-11.This table has the dimensions 15 EVIDS by three safety levels. For each EVID, three levels of safety are given. The first or lowest level uses the criteria of being approximately equal to weapon CEP. The medium level has criteria of 90% assurance damage range plus 1.83 CEP's. The greatest margin criteria is 99% assurance damage radius plus 2.5 CEP's. The values of safety margin are added to the maximum x and y boundaries and subtracted from the minimum x and y boundaries at planner designated exclusion areas.

b. Firing Characteristics at Weapons (FCWPN) (Volume II, Appendix I, Table I-12). This three-dimensional table provides for five EVID groups and three percentages of time that specific characteristics will occur. The five characteristics covered are: (1) number of volleys, (2) time between volleys if less than or equal to three volleys, (3) time between volleys if greater than three volleys, (4) rounds per volley, and (5) type fuzing. The three percents of time occuring used are 60%, 30% and 10%.

c. Fire Base Weapons (FBWPN) (Volume II, Appendix I, Table I-13) This table with dimensions 4 x 12, provides for selecting the fire base weapon type that could have caused each impact type EVID at or less than the range of range bin indicator shown, but greater than the range of the previous range bin indicator. The range bin indicators are specified in Table I-14(d. below) of the designer inputs. Two firing EVID's (052 and 053) are currently included, but space is available for two additional impact EVID's.

d. Range Bin Limits (RNG-BN) (Volume II, Appendix I, Table I-14).
This table assigns range bin indicator numbers from 1 to 12 to the upper limit of range boundary. This table provides indicators for use in Tables I-13 and I-15. When entered with the calculated range between a firing point and impact point, the indicator is selected which is less than or equal to entering range, but greater than range of next lowest range given.

e. Weapon Projectile Flight Times (WPFLT) (Volume II, Appendix I, Table I-15).
This table, with dimensions 8 x 12, provides times of flight for artillery projectiles and indirect fire rockets and missiles at each of 12 range indicators (see d. above).

f. Weapon Range Limitations (WRLIM) (Volume II, Appendix I, Table I-16).
This table, with dimensions 3 x 2, was designed to apply to small weapon EVID's such as mortars, direct fire weapons, small rockets and missiles, and recoiless rifles. For given impact EVID, it provides minimum and maximum ranges from firing point.

g. Aircraft Speed Set (ACSPD) (Volume II, Appendix I, Table I-17).
This table, with dimensions 5 x 3, for five aircraft EVID's, provides the aircraft's speeds for the two separate legs of flight paths. Three speeds for each EVID are included: (1) the speed expected 60% of the time, (2) that expected 30% of the time, and (3) that expected 10% of the time.

h. Aircraft Altitude Set (ACALT) (Volume II, Appendix I, Table I-18).
This table, with dimensions 5 x 3, is similar to previous one, I-17, but for altitude.

i. Vehicle Speed Set (VSPED) Volume II, Appendix I, Table I-19).
This table, with dimensions 5 x 3, provides three vehicle speeds which are equally likely within each of five vehicle EVID's.

j. Convoy Size Set (CNVOY) (Volume II, Appendix I, Table I-20).
This table, with dimensions 5 x 8, provides eight values of number of vehicles in a convoy which are equally likely within each of five vehicle EVID's.

k. Spacing Between Vehicle Set (SPACE) (Volume II, Appendix I, Table I-21)
This table, with dimensions 5 x 4, provides four values of the interval between similar points, i.e., centers of gravity, of adjacent vehicles in a convoy which are equally likely within each of five vehicle EVID's.

l. Nominal Effect on Sensor of Particular EVID in Period of Consideration (ZNOMAS) (Volume II, Appendix I, Table I-22).
This table, with dimensions 3 x 20,* provides for three sensor types, the average effect on background due to a given EVID. Values for acoustic and seismic sensors are currently included. The numbers shown are only indicators of relative amplitudes for the average energies (after the peak amplitudes have been processed as targets) that are used to account for increases in background noise levels. See Section 5.4.2.2 for additional details.

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* Must be changed as additional event classes are added.

5.4.3 Cultural Environment Subprogram

5.4.3.1 Purpose

The purpose of the Cultural Environment subprogram is to account for the activities of the noncombatants in the area of operations that have the potential for influencing the performance of the sensor systems to produce either false targets or raise the threshold of sensitivity of these sensors. Table 5.4-II tabulates the culture events provided for in the simulation. Provisions have been made for ten event types with five classification levels for each type. The subprogram simulates these events in accordance with a schedule specified by the planner. The culture subprogram generates false targets which are added to the Event 1 data stream in PRERUN that is passed to the MSM for further processing with the sensor subroutines. Changes in the background level created by the cultural activities are determined and passed to the MSM as part of the sensor parameter data stream (Event 3).

5.4.3.2 Rationale for Cultural Environment Model

The treatment of the cultural events is similar to that employed for the battlefield events; however, there are some significant differences in the type of events occurring as a result of cultural activity that must be accounted for. Many of the normally occurring cultural activities do not generate the peak energy levels often associated with battlefield events. These events are also generally distributed throughout a larger area, e.g., a village. Because of these attributes, the events 01 through 05 shown in Table 5.4-II are treated as events which contribute to the change in "background noise level".

For all acoustic and seismic sensors, a background noise level is computed as a function of the distance of the source from the sensor field. Values of CEVID event source strength in volts from Designer Input Table I-26 (see Volume II, Appendix I) are used to set the maximum background noise levels. These peak signal strengths in volts are degraded by multipliers, from the Designer Input Table I-23, to account for low, medium, and high levels of relative strength and fluctuations in time of day with and without curfew in effect. It is assumed that the source signal strength is constant in the vicinity of distributed sources (e.g., a village) and that the energy level falls off with range from the boundary as r^{-2}

Events 06 through 10, except for event 101, are played as events that create false targets provided they are close enough to the sensors for the generated signal to exceed the sensor threshold. These events are not treated as contributing to the background noise level.

Since the valid cultural sensor target combinations accepted by the sensor subroutines are limited in the same fashion as the battle targets, events 06 through 10 are mapped into a lesser number of categories (see Section 4.4, Table 4.4-I) as shown by the vertical lines shown in Table 5.4-II. Event 06 is mapped into the categories of small vehicles

TABLE 5.4-II
CEVID DESCRIPTIONS FOR SUBROUTINE CULTURE

Event No.	Type Event	Event Class				
		1	2	3	4	5
01	Built-up populated area	Rural Village No Machinery Less than 50 people	Small Village Limited machinery, 50 to 500 people	Large Village Some machinery, limited industry, 500 to 2000 people	Town, with factory, modern facilities and some traffic 2000-10,000	Dense population Dense traffic Industrial Over 10,000
02	Single source noise generators	Small pumps and engines	Water wheels	Small generator, 30 KW	Large generator, 100 KW	Single point power source-pile driver, etc.
03	Air terminals	Dirt runway Light acft	Hard surface Sparse-light and medium acft	Surfaced Moderate, medium acft	Surfaced Heavy traffic, propellor	Surfaced, heavy traffic, mixed
04	Surf	Light lapping waves	Moderate, small waves	Large waves on beach	Large waves against rocks	Turbulent, stormy
05	Vehicle traffic (background)	Bicycles, carts scooters, etc. Less than 500 lbs	Powered light vehicles w/ class 1, less than 2000 lbs	Small cars, light trucks w/ class 2, less than 4000 lbs	Class 3 plus medium trucks up to 2 1/2 ton	Class 4 plus heavy trucks, buses, over 2 1/2 ton
06	Vehicles	⑤ "	"	"	"	⑥ "
07	Boats	⑫ Canoes, gondolas, row boats (no engines)	⑬ Sampans, small power boats and rafts	Medium size power boats and speed boats	⑭ Large, paddle-wheel type boats and screw prop	Large, powered, SES and hydrofoil
08	Railroad trains	⑧ Hand pump car	Small powered engine	Passenger train-several cars	Engine w/ moderate-size freight train	Diesel powered locomotive and large freight train

TABLE 5.4-II (Cont.)
CEVID DESCRIPTIONS FOR SUBROUTINE CULTURE

Event No.	Type Event	Event Class 1	2	3	4	5
09	Aircraft	⑩ Light-cub Single engine	Light-twin engine	Medium size (DC 3) twin engine	Heavy propeller transport DC 6	⑪ Heavy jet transport, 707
10	Animals	⑱ Small rodents, crickets, birds and animal noises	⑲ Small dogs, cats, rabbits	Wild boar, deer, large dogs, monkeys	Large animals, lion, tigers, bears, apes	Horses, water buffalo, cattle

TARGET CATEGORIES (FROM TABLE 4.4-I)

⑤ SMVEH
⑥ HVYTRK
⑧ TRAIN
⑩ LTA/C
⑪ JETA/C

⑫ RAFT
⑬ OUTBOARD
⑭ PTBOAT
⑱ SMANM
⑲ LGANM

and heavy trucks. . Event 07 is mapped as shown to correspond to the categories of raft, outboard, and PT boat. Event 08 is mapped into the train category. Event 09 is mapped to correspond to light and jet aircraft. Event 101 is mapped into the small animal category, which is considered to contribute only to background noise. Events 102 through 105 are mapped to correspond to the large animal category of Table 4.4-I.

5.4.3.3 Description of Planner Inputs

In a manner similar to that for Battle Events, provisions have been made for the planner to input either detailed or general information concerning the frequency of occurrence and type of cultural events. If the game designer desires to treat all or part of the cultural events in a random fashion (thought to be a realistic treatment since the events are not likely to be well controlled), then planner input events set "random cultural events" (RCEVT)* is required. This set specifies the type and number of events which the planner desires as random events for each quarter of a day, and for each day of game play. Event types playable are limited to events causing a false target response from sensors (Events 06 through 10) except for Event 101.

If the planner desires to simulate the cultural events in greater detail, then the "planner input cultural event" (PCEVT)** must be completed. This planner set includes provisions for specifying not only the type of event, time of occurrence, location, paths, air corridors, etc., for each event, but whether or not a curfew is in effect.

The third planner input event set is the culture sensor field x-y bound set (SNFDX-Y). This set is used when moving animal events are included in the random culture event (RCEVT) set. This set establishes the boundaries of the sensor fields in the vicinity of the sources of background noise signals. These data are used to establish the nominal range of the signal source location with respect to the sensor field. Only CEVID types and classes 102, 103, 104, and 105 utilize these data. This table is used to insure that if animal type events are played the events will occur near the sensors.

These three planner input data sets used in subroutine CULTURE are described in greater detail in Volume II, Appendix F, Data Sets XXVII, XXVIII and XXIX.

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*See Volume II, Appendix F, Data Set XXVIII.
**See Volume II, Appendix F, Data Set XXVII.

5.4.3.4 Cultural Designer Input Tables

Five designer input tables are included in the current model to assist in processing the various Cultural effects. These tables are shown in Volume II, Appendix I, as Tables I-23 through I-27, and are contained in block data set JFBLK6. The tables have been designed with dimensions to permit additional type cultural events to be added for scenario needs. The events and values currently included were designed to satisfy SEA environment and model checkout needs. Tables I-24, I-25, and I-27 are used whenever the planner elects not to input certain data applicable to cultural target type events, but rather elects to have the data chosen randomly from these tables of representative values. Tables I-23 and I-26 are used by all cultural background events in the determination of background noise contributions by these events. The contents of each table are as follows:

a. Signal Characteristics of Background Noise Sources (SCHAR) (Volume II, Appendix I, Table I-23)

This table provides multipliers that degrade the signal or disturbance from its maximum sustained value due to the relative strength of the event and the activity level of that event. Space for twenty CEVID groups is provided. The strength levels include low, medium, and high, plus time of day activity levels with and without curfew in effect.

b. PATH SPEED (PSPED) (Volume II, Appendix I, Table I-24)

This table, with dimension 15 x 3, provides for each of 15 CEVID groups, three values of path speed, which are expected to occur 60%, 30%, and 10% of the time respectively.

c. Cultural Aircraft Altitude (CACAL) (Volume II, Appendix I, Table I-25)

This table, with dimensions 5 x 3, provides for each of 5 CEVID's, three values of altitude, which are expected to occur 60%, 30%, and 10% of the time respectively.

d. CEVID Signal Strength (CEVDBA) (Volume II, Appendix I, Table I-26)

This table, with dimensions 20 x 4, provides the maximum sustained voltage effect of 20 background CEVID groups upon given sensor type at minimum range from sensor.

e. Animal Speed (ANSPD) (Volume II, Appendix I, Table I-27)

This table, with dimensions 4 x 3, provides, for each of four animal CEVID's, three values of speed on path, which are expected to occur 60%, 30%, and 10% of the time respectively.

5.4.4 General Description of Processing

A macroflow diagram for processing of battle and culture events is shown in Figure 5.4-2. This processing is accomplished in PRERUN Step 6. The sequence of processing is described below:

PRERUN EXECUTIVE STEP 6 (PREMN6) reads the common game information and planner input tables. It locates path and excluded area planner data and places in appropriate arrays and determines the number of days and quarter days. Calls sub-executive routines CULTEX and BATEX to locate planner input data in Input Data Stream.

Subroutine CULTEX calls subroutine CSCHDL to complete culture schedule for each type of event as specified in planner table. Random events are determined and added to schedule.

Next subroutine BATLTG is called to generate false targets according to the schedule previously determined. BATLTG defines the target position, time, altitude, velocity, length of target and visual security descriptive parameter.

CULTEX also calls cultural background subroutine CULTBK which for acoustic and seismic sensors, computes a background noise level as a function of the distance of the source from the sensor. Subroutine SENXY locates sensors and designer input table CEVDBA is used to set noise levels. The target data and noise background information are then stored on disks for additional processing.

Battle Subroutine (BATEX) locates planner input in input data stream and calls subroutine BSCHDL to complete schedule for each event specified by planner and determines all random events. Subroutine BATLTG is then called to generate false targets according to BSCHDL. BATLTG again defines the target position, time, altitude, velocity, length of target, and visual security descriptive parameter.

Next battle background subroutine BATLBK is called to determine seismic and acoustic noise levels. The background noise levels are computed as a function of a), number of volleys for explosive devices, and, b), number of vehicles, and time of duration for military ground vehicles and aircraft. Designer input table (ZNOMAS) values are used to compute the noise levels.

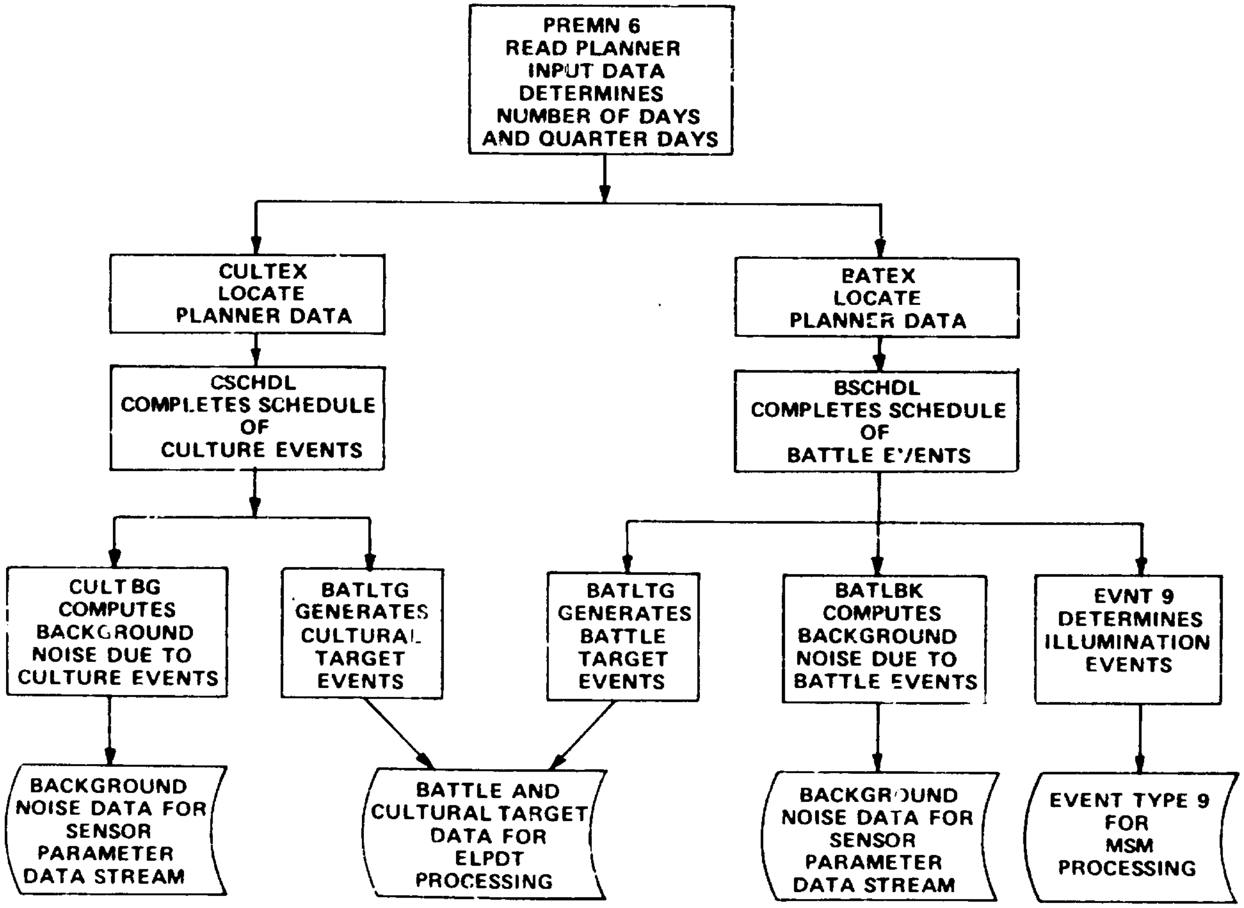

Figure 5.4-2 BATTLE AND CULTURAL FLOW DIAGRAM

Battle illumination subroutine EVNT9 is then called to add to the illumination events occurring in the area of operations.

Finally the target data, acoustic and seismic background data and the illumination events are stored on disks for further processing.

Section 6

AUXILIARY MODEL ELEMENTS

6.1 INTRODUCTION

As development of the Phase I Systems Assessment Model progressed, it became necessary to design several auxiliary submodels and not link them directly into the main model structure. (See Figure 1.4-1, Section 1). These auxiliary models fall in two categories. First, there are the auxiliary input models which take planner inputs and other input parameters and either compute particular data needs of the PRERUN or MSM or investigate particular aspects of STANO systems performance. Two of the input models have been discussed previously. The atmospherics input model was presented in Section 5.2 while the Terrain input processing was discussed in Section 5.3. Two additional auxiliary input programs are presented in this section. They are the Radar Contour Plot model and the RF Data Link Analysis model. Both of these models provide methods for investigating particular problems in certain STANO systems.

The Radar Contour Plot model provides a useful technique for the planner and user to examine the expected coverage of ground mounted radars given the terrain and foliage surrounding a radar site. It uses the digital terrain tape and unit terrain descriptions together with radar location and characteristics to print out a plot of radar coverage contours. Masked areas are quickly shown and revised siting may be shown necessary for further game play. The operation of this model is contained in Section 6.2.

The second auxiliary input model is the RF Data Link Analysis program. This model uses the previously prepared digital terrain tape, the foliage data from TERAN, and the unattended ground sensor and monitor locations and radio characteristics to compute propagation path losses between data links. These results are used to predict which data links can be expected to achieve successful data transmission performance. This model is expected to be particularly useful to scenario planners to investigate siting problems at sensors and monitors and to locate relays where required. This model has the future applicability of being linked directly to the MSM output if desired in order to simulate transmission of the UGS activations to monitors. The operation of this model is covered in detail in Section 6.3.

There are also three auxiliary submodels which are in the category of output processing elements. Their use is foreseen primarily as tools for deriving further information on STANO systems performance using the fundamental MSM outputs of sensor equipment detection events. The first of these submodels is the Unattended Sensor Analysis program which was developed to simulate in a limited degree the analysis process carried out by UGS monitor operators. It uses input from simulated activations at sensors in arrays together with sensor locations (game play) to derive information concerning the cause of the activations. By examining the time sequenced activation history it differentiates between targets and false alarms and depending on the data may also derive information on target classification, location, movement, and arrival time at selected locations. Target identification (friendly or enemy) is not possible, however, using only the UGS activation inputs. This auxiliary model, as presently designed, is a stand-alone program requiring the use of separately, manually prepared inputs. The primary item required is time sequenced sensor activations which can be derived from the MSM output. Linking it directly to the MSM at some future time is feasible, but at the same time may limit in some respects its flexibility. Further should it be linked to the MSM, consideration should be given to also linking in the RF Data Link Analysis model between sensor activation and monitor input as a simulation of data transmission capabilities. A possible disadvantage of a direct MSM linkage would be the loss of an economical and potentially very valuable auxiliary model for detailed evaluation of monitor analysis problems. These considerations, together with time and effort limitations, dictated its present design as a separate auxiliary model. The Unattended Sensor Analysis model is presented in detail in Section 6.4.

A similar auxiliary model to the Unattended Sensor case has been designed, although in less detail, for attended sensors. Sensors falling into this category include operator manned radars and the imaging devices. The sensor models themselves in the MSM yield only detection occurrence events with none of the data normally obtained by an operator as a result of viewing a radar presentation or seeing a target in an imaging device. It is the purpose of the Attended Sensor Analysis model to present in an exemplary way how such data can be developed using the variety of data available in the MSM. It is provided with direct linkages to the MSM output in order to demonstrate how this and other similar output processing programs can be so linked if desired. The time and effort available allowed only limited design effort on this program. It is discussed in Section 6.5.

The final output processing submodel developed is the Tactical Communications program (TACCOM). This model was designed to provide information on STANO-related message flow within a brigade as a result of STANO systems intelligence collection activities. The design concept centers on presenting the time delay from initiation to presentation of each STANO message introduced into the communications nets simulated. Four nets are included and four communications levels (i.e., platoon, company, battalion, brigade). Provisions are made for interacting STANO traffic with non-STANO traffic and also for message precedence considerations. This model presently uses manually prepared inputs, the primary one of which is a chronological listing of STANO messages. These messages may be derived from either MSM sensor detection data or Sensor Analysis model outputs if desired. TACCOM is a stand-alone submodel and is discussed further in Section 6.6.

6.2 CONTOUR PLOTS

As part of the overall System Assessment Model (SAM), an auxiliary program package was provided that (optionally) may be used to obtain computer-generated plots of coverage contours for radars and other line-of-sight dependent sensors.

Contractor-coded programs within this package include the main program (assigned the name CONTUR) and five subprograms. Basic plotter-control subroutines are also called. Most computer installations having plotters have control subprograms with the calling sequences used*.

Input to this package comprises (a) an operational SAM digital terrain tape (see Section 5.3.1) and (b) planner specifications of sensor positions, heights, sector-defining angles and ranges. With simple program changes, a planner/programmer may also control parameters that would otherwise be set by default (e.g., plotting scale, normally at 1:50000 in anticipation of use as overlay on a standard scale map).

Output consists of graphic plots, in which visible regions are marked (black) and masked regions, or regions beyond maximum range, are left unmarked (white). Fig. 6.2-1 shows an illustrative plot for one radar. It is also possible to prepare plots that include multiple sensor positions on the same output page.

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* Although CAL plotter software is extensive, the program was intentionally restricted to calls to minimum number of elementary plot routines. For other installations, however, the user/programmer may have to compare calling sequences and, if necessary, make minor changes for compatibility.

Operational procedures for running the contour plot package are covered in the Users' Manual (Volume II) of this report. Described there are subprogram requirements, including names of plot-control programs; data preparation, both content and formats; and options that can be exercised by simple program changes. The basic computational logic for this program package is discussed in the following sections, below.

6.2.1 Program Concept: Masking Contours

The program operation is based on numerical determination of masking contours, tabulated as a set of range values for a discrete set of angle values that cover the sector of coverage. Fig. 6.2-2 shows a simplified* diagram of a representative terrain cross section over the region from sensor to the maximum range point, that is used as the reference for definitions and concepts.

To the extent that this cross section reflects typical line of sight masking, segments of terrain surface become classified as visible or masked. The boundaries between visible and masked areas are determined by those lines from the sensor that are just tangent at the peaks. Each such line in the diagram shown defines two boundaries: those marked r_1, r_2,... are range values at the tangent points; visibility occurs to the left and masking to the right. The points marked R_1, R_2,... are the range values at which the tangent lines intersect terrain beyond the tangent points; visibility occurs to the right and masking to the left.

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* This diagram ignores foliage, and fact that target has non-zero height. Implicitly, it also ignores fine structure of the terrain that could, for example, create a masked region of a few feet dimension. See section 6.2.2.

6.2.2 Program Scope

As a qualitative statement, it may be said that the contour plotting programs determine the set of "r" and "R" values, as in Fig. 6.2-2, for a set of closely spaced angular values that collectively cover the sector assigned for the sensor... and therefrom prepares a plot in which the visible regions are marked (black) and the masked regions are left unmarked (white).

However, the preparation of such a program required a limit on scope -- that is, exactly how many masking contours would be computed and stored. And it involved some considerations of fine detail that do not appear in the simplified diagram of Fig. 6.2-2.

In the program supplied, the numerical search over terrain for any angle terminated at whichever of the following points occurred first:

(a) end of third masked region, i.e., the point marked R_3 in Fig. 6.2-2

(b) the maximum range value, R_{max}

or

(c) the edge of the defined scenario area.

Thus, no conceptual error would exist if (b) or (c) should occur. But if case (a) should occur, the program has not resolved visible vs. masked regions from the point R_3 to the ultimate limit (i.e., to R_{max} or edge of area). For this situation, the following assumption was made in order that the corresponding plot at least be defined and consistent:

Assumed: Terrain beyond point R_3 (see Fig. 6.2-2), if such a point exists in the searched region, is assumed to be visible.

This assumption is slightly superior to the converse (that is, masking assumed beyond R_3), for it is at least consistent over the area immediately beyond R_3 and hence has a chance of being consistent to the final limit.

The scope of the program, as specified in the preceding paragraph, is adequate or not, depending upon terrain roughness. Its full usefulness, and the possible need to extend the original program to more contours (at the expense of machine time and storage), has yet to be established against real terrain data in scenarios of interest. Applied to rough terrain in the Hue area, South Vietnam, results have appeared to be useful (see Fig. 6.2-1).

6.2.3 Fine Structure of Logic

Not explicitly shown in Fig.6.2-2 are two effects that are taken into account in the actual program. First, foliage cover, to the extent that its height may be inferred from information in the UNTER tables*, is added to the bare-earth heights from the terrain tape when masking angles are being determined. Second, the target is assumed to have an effective height, for purposes of observation by the sensor, that is set to 1.5 meters in the initial coding. A simple change of one FORTRAN statement can give an alternative value if desired. Fig. 6.2-2 does show graphically the displacement of sensor above ground. This height is supplied for each sensor by planner data card.

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* Unit terrain tables. See Section 5.3.2.

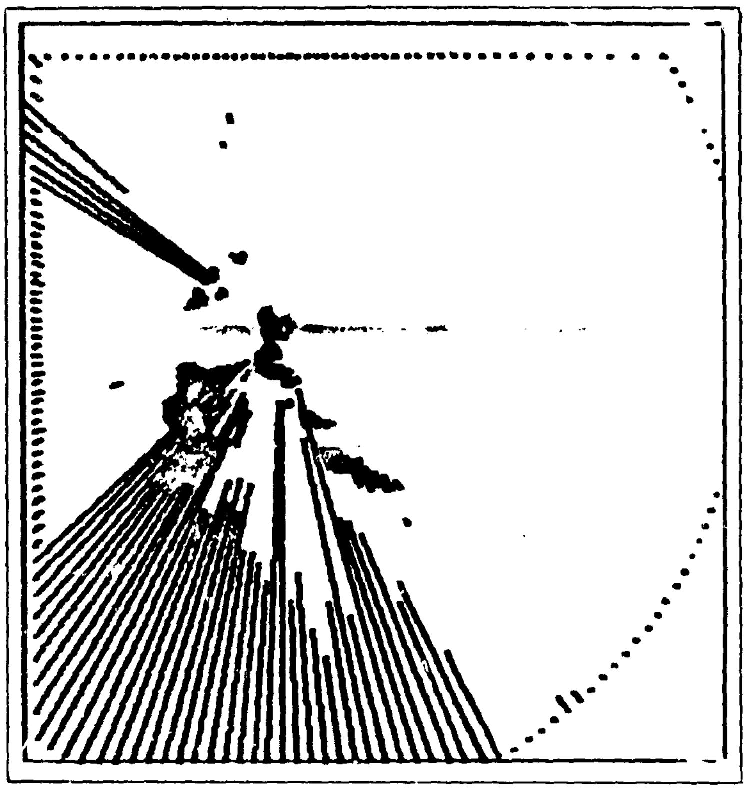
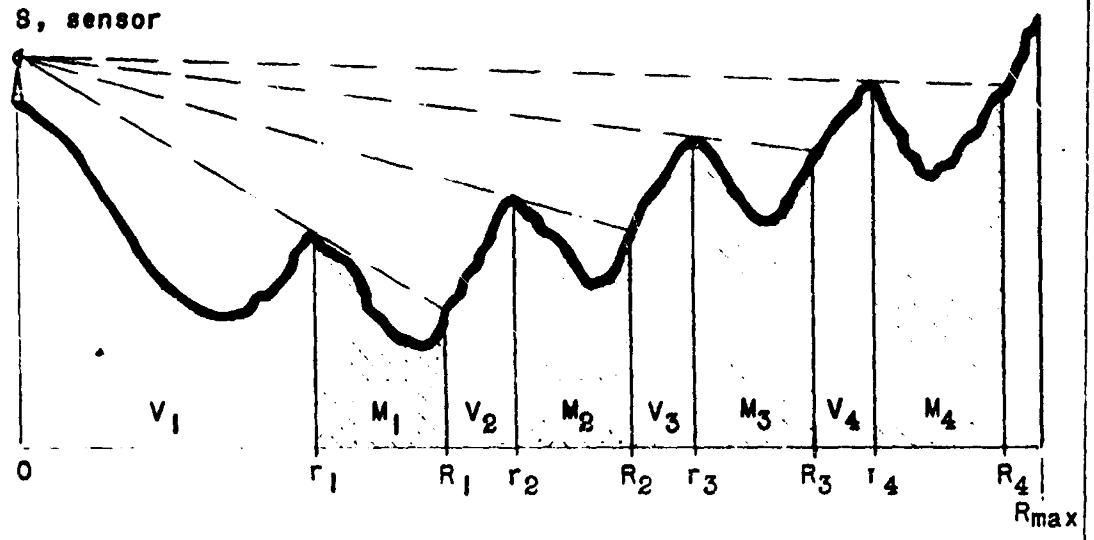


Figure 6.2-1

ILLUSTRATIVE CONTOUR PLOT

(RADAR SITING. HUE AREA, SOUTH VIETNAM)



NOTES:

1. V_1, V_2... first, second,... visible regions
2. M_1, M_2... first, second,... masked regions
3. For an actual cross section, the number of alternations (visible/masked) can vary depending upon terrain roughness and R_{max}. This figure illustrative only.
4. If (as in this figure) more than 3 masked regions occur, the CONTOUR PLOT program terminates search at the end of the third masked region (i.e., at point R3). Visibility is assumed for remainder of distance to R_{max}.
5. R_{max} is either range limit assigned to sensor, or edge of scenario area... whichever is smaller distance from sensor.

Figure 6.2-2

ILLUSTRATIVE TERRAIN CROSS SECTION

(FOR DEFINITION OF MASKING CONTOURS)

The planner, incidentally, may exercise some judgment in specifying the effective sensor height. For, say, a radar antenna the physical mounting dictates the height above ground at the immediate point of location. However, terrain data from the digital terrain tape do not have sufficient resolution to show minor variations over a distance less than 100 meters. In field operations, small variations in x,y positioning would in fact be made to take advantage of small local variations. Thus, a planner may wish to specify as effective sensor height a value somewhat greater than the nominal value, to reflect local effects.

TABLE

CONTOUR PLOT MODEL COMMON AREAS

USE	VARIABLES	USED BY
Common/BASICT/	P. 2-135, # 4	
		Contur Teran
Common/UNTER/	See Appendix C, Vol 2, User's Manual	
		Folage Teran
Common/UTVSXY/	See Section 5.3.2, Vol I, Part II, Model Description	
		IUTEVL (X, Y) Teran
Common/RADAR/	KMAXRG, RADELV, XR, YR, SCANG, SCWDTH, ANGINC, DGD, AVEHT, NOANG	
	KMAXRG - maximum range of radar in meters RADELV - elevation of radar above ground level (meters) XR - Radar X coordinate (meters) YR - Radar Y coordinate (meters) SCANG - Angle at which to begin radar scan SCWDTH - scan width of radar ANGINC - Azimuth angle increment - 2^{o} in radians DGD - Grid size for stepping along range (meters) AVEHT - Average target height added to elevation if > foliage height before radar mask is determined. NOANG - number of azimuth angles to scan	Contur OUTCTR RADCTR RADSEL TERCTR

USE	VARIABLES	USED BY
Common/OUT/	TITL (20), THE (181), MSKTAB (9, 181), PLTAB (14, 181), MAP (301, 101)	
	TITL (20) - alphanumeric title information for the run	Contur OUTCTR RADCTR RADSEL TERCTR
	THE (181) - Theta array containing azimuth angles computed	
	MSKTAB (9, 181) - array containing masking ranges and elevation angles	
	PLTAB (14, 181) - Plot table containing coordinate values for MSKTAB	
	MAP (301, 101) - array of terrain elevations (meters)	
Common/PA/	MXREF, MYREF, MXTENT, MYTENT, XMINPA, YMINPA, XMAXPA, YMAXPA, XMIN, YMIN, XMAX, YMAX, PALIM, SIZE	
	MXREF - X origin of playing area	Contur OUTCTR RADCTR RADPLT RADSEL TERCTR
	MYREF - Y origin of playing area	
	MXTENT - X coordinate of extent of playing area	
	MYTENT - Y coordinate of extent of playing area	
	XMINPA - X coordinate of minimum playing area boundary	
	YMINPA - Y coordinate of minimum playing area boundary	
	XMAXPA - X coordinate of maximum playing area boundary	
	YMAXPA - Y coordinate of maximum playing area boundary	
	XMIN - X coordinate of minimum terrain boundary in core	
	YMIN - Y coordinate of minimum terrain boundary in core	
	XMAX - X coordinate of maximum terrain boundary in core	
	YMAX - Y coordinate of maximum terrain boundary in core	
	PALIM - playing area limit (square meters)	
	SIZE - independent scale of standard plot	

6.3 DATA LINK ANALYSIS MODEL

6.3.1 Introduction

This section describes the Systems Assessment Model program capable of simulating the RF data and command link performances of STANO unattended intrusion sensors. It is designed to operate outside of the main simulation and can thus be used at any time to check such performances as part of the overall evaluation process. To this end the model has been equipped with subroutines to analyze the propagation path profiles between transmitters and receivers and to predict radio propagation losses over the profiles for the 20 MHz to 40,000 MHz frequency region, with either vertical or horizontal polarization. In order to increase the applicability of the model to propagation paths typified by antennas located beneath a foliage canopy, a foliage loss prediction capability has been incorporated for the 100 MHz - 400 MHz frequency region of particular interest (sensor data frequencies are centered about 170 MHz while the command channel frequencies are close to 300 MHz). Model utility is further enhanced by the fact that propagation paths exhibiting a broad range of antenna heights (ground mounted or up to 3000 m. high) can be effectively analyzed, thus making it possible to include evaluations of ground-to-air data or command links which may be present in typical scenarios. The Data Link Analysis model utilizes propagation loss predictions in conjunction with parametric descriptions of the link RF equipment, i.e., transmitter, receiver, antennas, etc., in the determination of link performance descriptors, such as receiver signal-to-noise ratio (S/N), detection error rates, and path S/N margin. These descriptors are available in the subroutine printout and can be used by the model user to evaluate the capability afforded by the sensor communication links delineated in the game scenario.

6.3.2 General

The Data Link Analysis model has been designed to derive propagation path profile data (at 0.1 km. intervals) using the propagation path profile generation subroutine PROFIL which employs digital terrain tape data. Subroutine PROFIL is an adaptation of the line of sight program which is described in detail in Section 4.6. The resulting profile description consists of terrain height plus median foliage height at each data point, except for the path terminations where terrain height and foliage canopy height are specified separately. Other externally supplied (user) model input data includes structural antenna heights, electrical constants of the propagation surface, parametric descriptions of the link RF equipment used, etc. Volume II contains all the input data required for model operation, including typical values representative of STANO equipment.

The printout data available to the model user is not restricted to the basic model outputs, such as propagation path loss, received S/N, margin in received S/N, etc., but includes a broad range of intermediate computed data associated with predicting path loss, and a compilation of the link descriptive parameters assumed in the scenario. Since the data are printed out for each path analyzed, the model user can determine if a particular RF link is operational, marginally so, or inoperative because of insufficient received signal.

A more thorough study of the output will enable the user to reach important conclusions concerning the general feasibility and possible alteration of the data and command link configuration stipulated in the scenario. For example, in situations where the model output indicates a number of marginal or inoperative links, the user is equipped with sufficient information to decide which of the possible link modifications would be most appropriate to raise the affected links to the operational state. Modification "fixes" could involve one of the following: increasing transmitter or receiver antenna height, operating on higher transmitter power, using higher gain antenna systems, etc. Successful use of these "fixes" is clearly dependent on relatively moderate requirements for increased received signal.

Data and command links requiring a greater increase in received signal than would likely result from the above link changes may either be eliminated from the scenario if they are few in number and considered noncritical in importance, or additional modifications to the link network may be considered for their successful usage. These high loss propagation paths could be due to the effect of local terrain obstructions present in the path profile (indicated by large horizon angles on the printout). Subsequent inspection of a topographic map of the scenario area may indicate to the user that a relatively small change in sensor emplacement location may yield essentially the same intrusion detection capability and yet result in a link propagation path with considerably lower losses (reduced horizon angles). Although this approach would appear to be practical for a small number of isolated cases, it would clearly become unwiedly if a sizeable number of sensor data or command links should be pronounced inoperative because of excessive propagation losses. Such a circumstance probably warrants the addition of an RF relay capability to the data and command link network defined in the scenario if the desired communications are to be established. Should an RF relay already be involved, it may indicate that the chosen location does not provide optimum coverage, or that a second relay is required to successfully communicate with the affected sensors. The selection of the additional relay site, or the relocation of an existing one, is facilitated since the specific location of the inoperative links is known; study of a topographic scenario map should result in a relay site decision. In the event that a suitable relay site does not appear to be available, an alternate location for the sensor monitoring station (annunciator) may be considered an acceptable means of communicating with the sensors adversely affected by the existing scenario. Either solution clearly requires a rerun of the simulation to determine the suitability of the appropriate link modifications, as do most of the changes discussed earlier.

Data and command link performance, per se, is not being simulated in the System Assessment Model MSM, nor has any possible RF interference or cross-talk effects between the various RF emitters in the intrusion detection system been given consideration. Interference and cross-talk problems are considered beyond the scope of the current effort, and as far as environmental effects, such as rain, snow, etc., are concerned, they have been neglected because of their very minor influence on typical STANO data and command links. The small influence is due, of course, to the relatively short path involved (typically < 50 km) and the low frequency range of interest (< 400 MHz).

In addition to delineating the basic theory and functional operation of the Data Link Analysis model, the following discussion presents the assumptions used in model derivation, including their supporting rationale.

6.3.3 Propagation Loss Prediction Capability of the Data Link Analysis Model

The Data Link Analysis model has been structured about a propagation loss prediction computer method developed by ESSA (Environmental Science Services Administration) while under contact to USAECOM (U.S. Army Electronics Command). (Ref. 1.) As originally derived, the ESSA computer method has the fundamental capability of predicting median reference values of propagation loss over irregular terrain and a broad range of operating parameters. Median propagation losses represent the RF transmission losses one would experience over propagation paths which exhibit the median terrain characteristics to be found within a specified area. The basic ESSA method consists of a propagation loss model which does not require detailed descriptions of specific path profiles. All the descriptive terrain parameters necessary for loss prediction are supplied as median quantities computed from empirically derived expressions. The empirical relationships are all functions of a single fundamental terrain irregularity parameter used to characterize the general area occupied by the propagation paths of interest. The basic ESSA method thus has the useful capability of predicting median propagation losses over irregular terrain defined only by a single descriptor supplied by the user.

Employed in the more involved point-to-point application however, the basic ESSA method is also capable of closely predicting the path loss of individually defined propagation paths, rather than the median loss, which can quite understandably be considerably in error if applied to particular paths. It is the point-to-point expansion of the basic ESSA method which has actually been implemented in the Data Link Analysis model. Computed profile characteristics of individual paths replace the median path characteristics utilized by the basic ESSA method. The propagation loss prediction capability is significantly improved in particular instances where the basic method has relatively poor or no inherent capability. A noteworthy basic ESSA method insufficiency is that it does not treat the propagation loss effects of terrain vegetation in a quantitative manner. Foilage losses can be highly significant to the performance of STANO data and command links in many practical situations. The Data Link Analysis model has been designed to include this important path loss effect during its prediction of overall link propagation loss. Other deficiencies inherent in the basic ESSA loss prediction method have also been accounted for and are delineated later.

6.3.3.1 Functional Description of System Assessment Model Data Link Analysis Sub Model

The following presentation delineates the Data Link Analysis model developed for the simulation of STANO sensor data and command link performance. As was indicated earlier, the model derives pertinent descriptions of link data transmission performance from computed predictions of propagation loss, and appropriate parametric definitions of the RF communications equipment involved.

Path loss predictions are based on an expansion of the basic ESSA computer method noted earlier. Improved model performance is obtained by compensating for two deficiencies inherent in the design of ESSA computer method. The first adjustment consists of the inclusion of the propagation loss effects produced when the link antennas are submerged in foliage, while the second corrects the ESSA method loss predictions when common horizon paths (same terrain peak forming both of the path horizons) are evident.

The RF Data Link Analysis model is controlled by a two-step process. The first (subroutine TPDISK) reads in the terrain data available on the prepared scenario area digital terrain tape. The second step, for which MAINSY is the main program, reads all the necessary inputs, then calls computational subroutines to derive the desired outputs. Two subroutines associated with providing the path terrain data and foliage characteristics are first used (PROFIL and TERAN). TERAN is discussed in detail in Section 5.3 so will not be repeated here. It provides the tabular data for unit terrain descriptors and for x, y locations of terrain types, including foliage descriptions necessary in the RF data link loss program. PROFIL is a routine which was adapted from the LOS Subroutine (See section 4.6) for the RF data link problem. Given the location of two RF terminals it extracts the terrain heights of significance at intervals between the terminals and makes them available for later use. It also adds in foliage heights where appropriate. Next RFLINK is called to make the data link performance calculations. The main program flow diagram of this portion of the model is shown in Figure 6.3-1. It will be noted that the model does not treat RF links whose length is less than 200 meters; such short links are summarily proclaimed to be "operational", i.e., path losses are sufficiently low for reliable operation. Path losses for distances less than 200 meters (including jungle paths) are generally within the sensitivity capabilities of typical STANO data and command links.

The propagation loss prediction capability of the Data Link Analysis model to be described below can be considered as consisting of the following three major subdivisions: (1) subroutine programs to classify and examine individual terrain profiles for their particular characteristics; (2) the basic ESSA computer method of loss prediction; and, (3) finally, supplementary loss prediction computations which are used to define path loss in those instances where the ESSA model is known to perform deficiently.

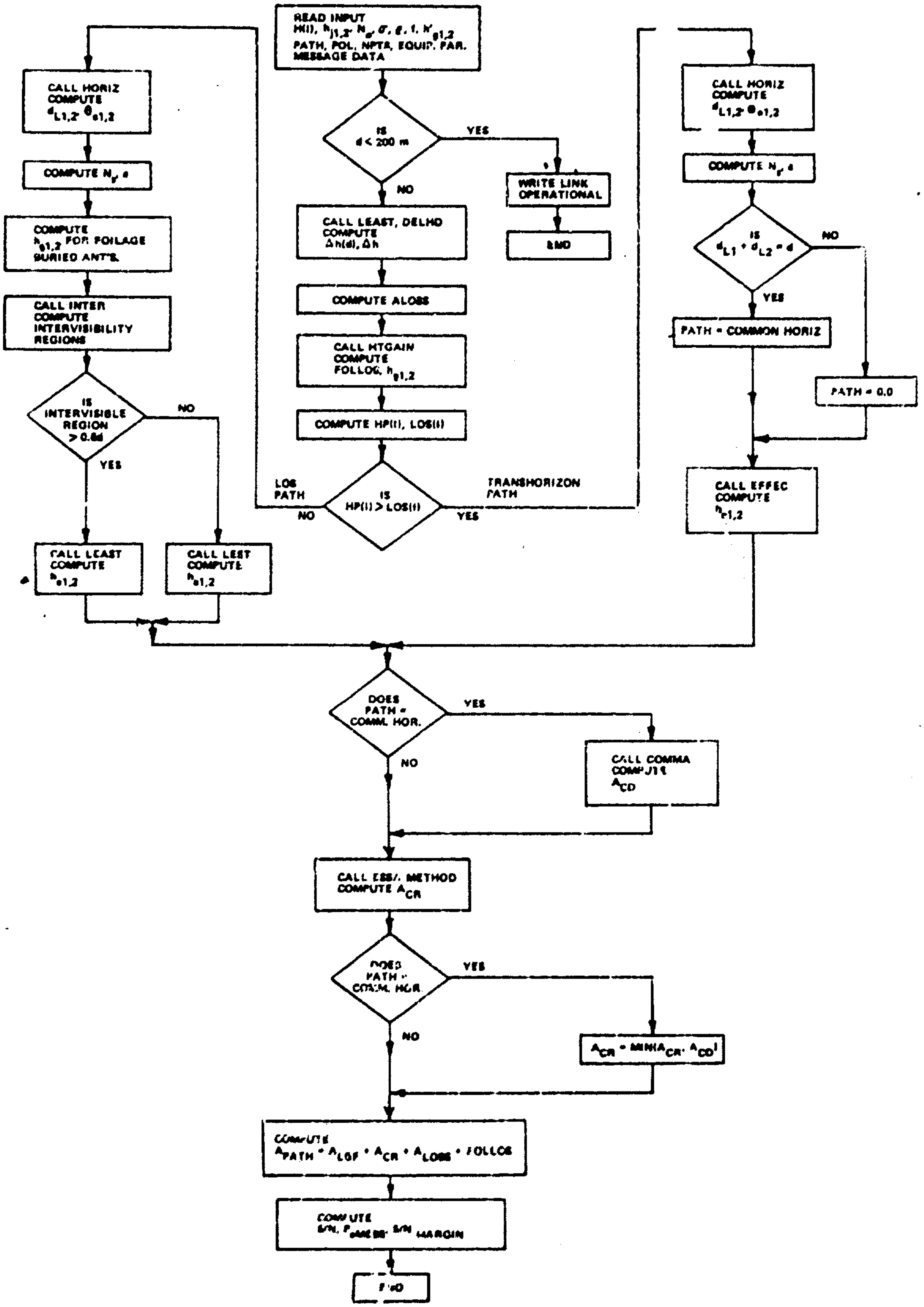


Figure 6.3-1 DATA LINK ANALYSIS MODEL, RFLINK SUBROUTINE FLOW DIAGRAM

The point-to-point application of the ESSA method requires that each path handled must be scrutinized for the terrain irregularity parameter (Δh), horizon distances ($d_{L1,2}$), angles $\theta_{e1,2}$, and also appropriate values for the effective antenna heights ($h_{e1,2}$) and surface refractivity (N_s). Well established techniques (Ref. 2) have been implemented for determining the required path parameters from details of the individually described path profiles.

The fundamental objective of the ESSA point-to-point loss prediction method is to predict a below free space reference value (A_{CR}) of propagation loss for each input path description. Once determined for the particular path, A_{CR} is summed with a corresponding free space loss term and other data loss contributors and the total is reported as the reference path loss.

In general, the Data Link Analysis model relies on the point-to-point ESSA subroutine (as it may now be termed, since it now is part of a more involved loss prediction model) for the determination of A_{CR}. This remains the case for both radio LOS and transhorizon paths with the ESSA subroutine reacting to this characteristic difference solely through the magnitudes of the path parameters it receives via the main program, e.g., the horizon angles. However, in transhorizon situations involving common horizon paths, for which the ESSA method tends to overpredict, a separate loss prediction subroutine called COMMA is also used for comparison. The smaller of the two loss values is then used to define A_{CR} for the common horizon path. This selection process is shown on the lower part of Fig. 6.3-1.

6.3.3.2 Propagation Path Classification

Although the ESSA method is employed in the same manner for both radio LOS and transhorizon propagation paths, basic differences do exist between the techniques used in the two cases to determine the path descriptive parameters required by the ESSA subroutine. It is therefore necessary for the Data Link Analysis model to analyze the details of each propagation path so that a decision can be reached as to whether the path should be classified as either LOS or transhorizon. Radio LOS cannot be determined by comparing heights of the path profile above sea level, as is available from subroutine PROFIL, to the height of the optical line of sight between the terminal locations for two reasons. First, and perhaps the most obvious, is the natural curvature (fall off) of the earth's surface which must be accounted for. Second, the refractive properties of the earth's atmosphere results in the bending of radio waves back towards the earth which, in effect, increases the radius of the earth, thereby actually aiding propagation. The increased earth's radius (commonly called the effective earth's radius) is roughly 4/3 times the actual earth's radius, but its actual value is a function of the local surface refractivity. (The functional relationship between the effective earth's radius and surface refractivity is given in Section 6.3.3.4.) In view of the above, the model first obtains the required curvature corrected terrain profile, HP(I), by modifying the path profile definition* H(I)

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*Median foliage height along the profile is added to the appropriate topographic terrain height data.

as follows:

$$HP(I) = H(I) - d_I^2/2a$$

where d_I is the distance to the I'th terrain point and a is the nominal effective earth's radius given in the same units as HP(I) and H(I). The term $d_I^2/2a$ represents the height correction necessary because of atmospheric refraction and the earth's natural curvature. A particular path is flagged as a LOS path if all the curvature corrected profile heights (HP(I)) are less than the height of a spatial line through the corrected heights of the antennas at the path terminals. If a greater profile height is detected the path is conversely flagged as a transhorizon path. In either case, local surface refractivity propagation effects are included at a later point in model (6.3.3.4). Fig. 6.3-1 indicates that the LOS-transhorizon decision is reached following determinations of the path terrain irregularity parameter (Δh) and A_{LOSS}, a propagation loss quantity associated with ground mounted antennas. The Δh parameter is obtained by least squares fitting to a straight line through the profile data points, determining the interdecile range* of profile heights $\Delta h(d)$ about the curve fit, and substituting $\Delta h(d)$ into the empirical expression:

$$\Delta h = \Delta h(d)\,(1-0.8\exp(-0.02d))^{-1} \qquad \text{(from Ref. 1)}$$

where d is the path length in km. A_{LOSS} represents a propagation loss quantity which is included whenever the data link antenna of a sensor device is mounted with its base on the ground, e.g., ground implanted STANO sensors. This is a necessary requisite because of the RF power absorption properties of the earth. Ground absorption reduces the transmitted power as well as reducing the received signal when the system is receiving external commands. Thus, whenever the structural antenna height is sensed to be less than 1.0 m, the model assumes a ground mounted antenna situation and compensates for this by setting A_{LOSS} equal to 10 dB. The ground proximity loss has been determined (Ref. 3) to be approximately 10 dB for average ground and the 100-400 MHz frequency range. A_{LOSS} is set to 0.0 dB if both structural antenna heights or greater than 1.0 m. Foliage loss is also calculated prior to the propagation path decision but a discussion of this subroutine will be deferred to a later section.

6.3.3.3 Horizon Parameter Computations

Immediately following the LOS-transhorizon path decision the model analyzes the details of the input propagation path for its characteristic horizon parameters (distances and angles). Subroutine HORIZ is called regardless of the path decision reached, to determine the most positive (elevated) angle formed between an imaginary line from the path antennas to each of the curvature corrected terrain profile data points, and the horizontal. The most elevated angle (angles below the horizontal are considered as negative) experienced over the complete profile is stored as the desired horizon angle, and the terrain profile point responsible is likewise stored to define the horizon distance. This procedure is carried out

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*The distribution width from the 10% to the 90% probability points.

twice using both of the antenna locations as reference points for angle and distance determinations; the result, of course, is a specification of the horizon distances and angles as viewed from the two path antennas. The algebraic sum of the horizon angles θ_{e1} and θ_{e2} is always greater than zero for transhorizon paths and either zero or less than zero for LOS paths.

6.3.3.4 Surface Refractivity and Effective Earth's Radius Computations

Of particular importance to the accurate prediction of path loss over long distances is the correct specification of surface refractivity (N_s) and the related effective earth's radius (a) parameter. Both quantities are utilized by the ESSA subroutine in the prediction of forward scatter propagation loss. Surface refractivity is dependent on the geographic area of concern, time of year and the local height above sea level. The model determines minimum values of these quantities from the input parameter N_o* which specifies the minimum monthly refractivity parameter (normalized to sea level) for the geographic area, and a descriptive terrain elevation above sea level (h_s). A single value of N_o is used because of the relatively short propagation distances involved. Individual methods are used to define h_s for a given path and these are dependent on its classification as either a LOS or transhorizon propagation case. For LOS path situations the model defines h_s as the ground elevation immediately below the lower (with respect to sea level) of the two antenna heights. In transhorizon situations, however, h_s is defined for both ends of the path, as the elevation of the respective horizon peaks. If an antenna is more than 150 meters below its corresponding horizon, the specification of h_s changes to that of the ground elevation below the antenna.

Surface refractivity is computed from the appropriate h_s elevation and the input N_o parameter by means of:

$$N_s = N_o \exp(-0.1057\ h_s)$$

where h_s is in km above sea level. The above equation is used twice for transhorizon paths using the two h_s quantities so that an average N_s parameter can be specified for the total path. The corresponding effective earth's radius parameter is computed from:

$$a = 6370\ (1-0.04665\exp\ (0.005577N_s))^{-1} \qquad \text{(from Ref. 1)}$$

where a is in km.

6.3.3.5 Effective Antenna Height Computations

In addition to an examination of each propagation path for its characteristic horizon parameters, the Data Link Analysis model evaluates the details of each terrain profile to determine whether, and how much, a particular path antenna should be effectively raised above its structural height because of advantageous propagation conditions, e.g., terrain depressions below large portions of the ray paths. This determination of "effective" antenna height is an important modification to the basic ESSA model.

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* See B.R. Bean, J.D. Horn

For radio LOS situations, the model defines a dominant reflecting plane between the path terminals for the purpose of establishing reference points from which to measure effective antenna height provided at least 60% of the total profile is visible from both antennas (intervisibility). The subroutine INTER, responsible for the LOS path intervisibility tests, is called in LOS cases immediately following determinations of surface refractivity and effective earth's radius (See Fig 6.3-1).

Subroutine INTER sequentially searches the terrain profile for an intervisible region which is at least 60% as long as the total path length. During the path search the criteria used allows a maximum of 15% of the required intervisible region to be non-intervisible (both antennas do not view the same terrain) as a practical compromise. If the 15% non-intervisibility figure is exceeded, the model proceeds to search the same profile in the opposite direction, using the same criteria. Failure to meet the criteria in both search directions is appropriately flagged to set a program switch (See Fig.6.3-1) In situations where the above criteria have been met, the INTER subroutine specifies the intervisibility region end points to be used by a subsequent (LEAST) subroutine in the definition of a dominant plane reflecting surface for effective antenna height determinations. Subroutine LEAST determines path effective heights by either defining the antenna height above the dominant reflecting plane fitted to the intervisibility region, or the terrain immediately below the antenna -- whichever has the highest elevation. The required reflecting plane is obtained by fitting a smooth curve to the intervisible terrain region and extrapolating the function to the points below the two path antennas. Construction of the smooth curve is accomplished by fitting a straight line (using least squares) to the profile height data of the intervisible region and modifying the resulting function for earth's curvature. Whenever the height of the extrapolated smooth curve has an elevation lower than the terrain below the associated antenna, the effective antenna height is defined as its height above the curve. In cases where the height of the extrapolated curve is higher than the terrain immediately below the antenna, the effective antenna height is defined to be equal to the structural antenna height.

A study of the flow diagram of Figure 6.3-1 indicates that for radio LOS paths which do not meet the intervisibility criteria of INTER, the main program selects subroutine LEST rather than LEAST. This subroutine sets effective antenna height equal to structural height unless the model user has specified that the path in question is a relay path (at least one of the antennas is located on a hilltop), and the structural height of the particular antenna is less than 10 m. The rationale used is that for most relay paths, propagation takes place across valleys, etc., which allow for effective antenna heights which are greater than the structural values. Subroutine LEST computes relay path effective antenna height ($h_{e1,2}$) as a function of structural height ($h_{g1,2}$), terrain irregularity (Δh) and a factor (k) which is proportional to the actual structural height, namely:

$$h_{e1,2} = h_{g1,2} + k \exp(-2 h_{g1,2} / \Delta h)$$

The procedure used for determining transhorizon path effective antenna height is based on examining the path profile only from the antenna locations to their respective horizons rather than potentially the entire path as is true in LOS situations. The method used in subroutine EFFEC provides for effective antenna height values which are increased over their structural heights whenever a large portion of the terrain between the antenna and its horizon is lower than the terrain below the antenna itself; a fundamental technique not unlike that used in LOS cases. Specifically, subroutine EFFEC compares the average height of the central 80% of the terrain profile between the antenna and its horizon to the terrain height immediately below the antenna as the critical test. If the average height is lower than the terrain at the antenna location, the effective antenna height is measured from the average terrain height, which obviously results in a larger value than the structural height. When the average height computed is higher than the terrain elevation below the antenna, the subroutine sets the effective height equal to the structural height. The procedure is, of course, repeated for each end of the transhorizon path.

Following determinations of effective antenna height in either LOS or transhorizon situations, the Data Link Analysis model has available all the path descriptive data required by the ESSA loss prediction subroutines. Except for the special case of transhorizon paths exhibiting the same profile data point for both horizons, the ESSA loss prediction subroutine is called directly after the definition of effective antenna height. In the case of common horizon paths the model exercises an auxiliary loss prediction subroutine (COMMA) prior to calling the ESSA subroutine (see Fig. 6.3-1). COMMA is specifically designed to predict propagation loss over isolated obstacle, common horizon paths with greater accuracy than is generally available from the ESSA method.

6.3.3.6 Common Horizon Path Loss Computations

The purpose of subroutine COMMA is to predict path loss over single, isolated terrain peaks, and it does so independently of the ESSA path loss computations. The techniques used have been shown (Ref. 4) to predict the common horizon situation with good results provided the characteristic path parameters (horizon, and effective antenna heights) are available. Unlike the ESSA loss prediction subroutine, the loss prediction method used in COMMA does not employ the terrain irregularity parameter, Δh, but it does account for multipath reflections from the terrain adjacent to the horizon peak.

Since obstacle isolation is a necessary prerequisite for the loss prediction technique used, subroutine COMMA analyzes the shape of the particular profile in order to determine the relative "isolation" that the common horizon peak has from the surrounding terrain. The performance characteristics of the ESSA model are such that it does not suffer from prediction errors unless the common horizon obstacle is prominently isolated on the path profile. In general, the criteria used to define whether a horizon peak can be classified as "isolated" depends upon the operating frequency and the estimated radius of curvature exhibited by the peak itself. At the higher operating frequencies, peaks are considered "isolated" even though their radius of curvature is relatively large whereas sharper peaks are necessary to pass the criteria at the lower frequencies. The model obtains the peak radius of curvature by fitting a circle to the terrain data points consisting of the horizon peak itself and the profile points immediately to either side. The test for peak "isolation" is carried out by COMMA immediately following the program call and entry to the subroutine.

Subroutine COMMA determines propagation loss over isolated peak, common horizon paths by computing the diffraction loss over a representative single, perfectly conducting, rounded knife edge, and then combining this result with appropriate loss terms which account for adjacent ground reflection effects. Diffraction loss over the rounded knife edge $A(V, \rho)$ is determined as a function of operating frequency, geometry of the particular ray path (horizon angles and distances), and an approximation to the actual radius of curvature of the horizon peak in question. $A(V, \rho)$ is an increasing function of the terrain peak radius of curvature, and can be 5-20 dB or greater, depending on the exact circumstances, than would result if perfect knife edge diffraction were assumed. In path situations, where the relative height between the antennas and the terrain peak is large, the $A(V, \rho)$ term actually represents the total A_{CR} loss since ground effects are minimal because of the comparatively large path-to-terrain separation. This is especially true if the horizon distances are short. However, when the antenna to terrain peak height differential is small as may be generally found when low antennas are situated in relatively smooth terrain, the effects of ground reflection are maximized. In such cases the actual A_{CR} losses can exceed $A(V, \rho)$ by 20 dB or greater with the difference being attributable to the signal cancellation effects of ground reflections on either side of the terrain peak.

The additional loss quantities produced by ground reflections are accounted for in COMMA by analyzing the details of the individual propagation paths and determining the appropriate loss terms which are to be summed with $A(V, \rho)$. Ground effect loss terms $G(h_{1,2})$ are defined for each side of the path, and they are determined as functions of operating frequency, effective antenna height, and horizon distance. The $G(h_{1,2})$ losses increase with horizon distance, but vary inversely with frequency and effective antenna height. Actual usage of the $G(h_{1,2})$ terms only take place, however, when an examination of the path profile indicates that the average terrain height between the antenna and the horizon (central 80%) is higher than the near mid-portion of the first Fresnel zone elipse, which has the antenna and horizon peak as its focii; otherwise the particular $G(h)$ terms remain unused. Total below free space path loss (termed A_{CD} rather than A_{CR}, in subroutine COMMA) for common horizon paths is finally computed from the rounded knife edge diffraction loss and the $G(h)$ terms, viz

$$A_{CD} = A(V, \rho) + K_1 G(h_1) + K_2 G(h_2)$$

where K_1 and K_2 are weighting functions dependent on the path characteristics.

6.3.3.7 ESSA Propagation Loss Computations

A fundamental characteristic of the ESSA loss prediction method is that the model compensates for observed differences between the loss predictions of pure theoretical models and measured data. Factors relating to terrain roughness are used to closely correlate classical propagation mode loss predictions with propagation losses which have actually been experienced. Terrain irregularity factors are employed by the ESSA method in a series of empirical weighting processes in a manner resulting in propagation loss predictions which compare favorably with measured data.

The input data required for the utilization of the ESSA computer model are as follows: terrain irregularity parameter (Δh); interdecile range ($\Delta h(d)$) of profile heights; operating frequency (f) in MH_z; path length (d) in km; structural antenna heights above the ground (h'_{g1}, h'_{g2}) in m; surface refractivity (N_S); propagation surface conductivity (σ) in mhos/m and relative permittivity (ϵ); horizon distances (d_{L1}, d_{L2}) in km; horizon angles (θ_{e1}, θ_{e2}) in radians; effective antenna heights (h_{e1}, h_{e2}) in m; and antenna polarization.

The primary task of the ESSA loss prediction model is to determine the below free space, reference value of propagation loss (A_{CR}). Once determined, this quantity must be summed with a basic free space loss quantity (L_{BF}) for the same path distance and operating frequency to give the total reference value of path loss (L_{CR}), namely

$$L_{CR} = L_{BF} + A_{CR}$$

where free space losses are described by

$$L_{BF} = 32.45 + 20 \text{ Log}_{10} f + 20 \text{ Log}_{10} d$$

and operating frequency (f) and path distance (d) are in MHz and km respectively. L_{CR} only represents total path loss if foliage losses and ground mounted antennas are not involved for a particular path in question, however.

Three distinct propagation distance intervals are isolated by the ESSA method and their particular lengths are determined by characteristics of the specific propagation situation. The three regions are known as the radio line of sight (LOS), diffraction, and forward scatter regions. For path lengths less than the smooth earth LOS distance (d_{Ls}), the ESSA method employs two-ray optics mode propagation in a weighted sum with diffraction mode propagation to predict A_{CR}. Beyond d_{Ls}, the diffraction mode is used exclusively in the loss prediction, while at still greater ranges (300-400 km) forward scattering is the dominant mode used to compute A_{CR}. Diffraction losses <u>per se</u> are also the result of a weighting process as was the case for radio <u>LOS</u> region losses. Diffraction propagation losses are computed as the weighted sum of appropriate double knife edge and round earth diffraction loss terms. The weighting factors used in the determination of radio LOS and diffraction region losses are determined from two separate empirically derived functions. They are, however, each dependent on the input terrain irregularity parameter Δh.

The three propagation region's defined by the ESSA method are readily identified from the computer model attenuation curve shown on Fig. 6.3-2, where it will be observed that all three loss functions are melded into a continuous loss versus distance relationship. The loss curve shown is representative for a particular set of model input parameters which were delineated above, i.e., terrain irregularity, antenna heights, surface refractivity, ground propagation constants, etc. The radio LOS-diffraction region separation point, distance d_{Ls}, is defined as the sum of both the path smooth earth horizon distances, $d_{Ls1,2}$, as viewed from each antenna, viz.

$$d_{Ls} = d_{Ls1} + d_{Ls2}$$

The distance from each antenna to its horizon, over a smooth earth, is given by

$$d_{Ls1,2} = (0.002\ a\ h_{e_{1,2}})^{1/2}$$

where a is the effective earth's radius in km as a function of the surface refractivity (N_s) viz

$$a = 6370\ (1-0.04665\ \exp\ (0.005577\ N_s))^{-1}$$

and $h_{e_{1,2}}$ are the effective antenna heights in meters.

As was indicated above, for path lengths less than the smooth earth radio LOS distance (d_{Ls}), A_{CR} is computed by combining weighted values of a two-ray optics loss and a diffraction loss quantity. For path lengths greater than d_{Ls}, but less than d_X, the distance where diffraction losses and forward scatter losses have the same value, the ESSA method utilizes the double knife edge, round earth diffraction loss alone to define A_{CR}. Paths exhibiting lengths greater than d_X are described with a forward scattering loss term since path loss due to diffraction propagation exceeds that due to forward scatter in this long distance region.

The ESSA subroutine is programmed to perform, regardless of the path distance involved, diffraction region computations as the first major operation in the prediction of propagation loss over rough terrain. The requirement for an early definition of diffraction region losses becomes apparent when one considers that diffraction type losses can be an important

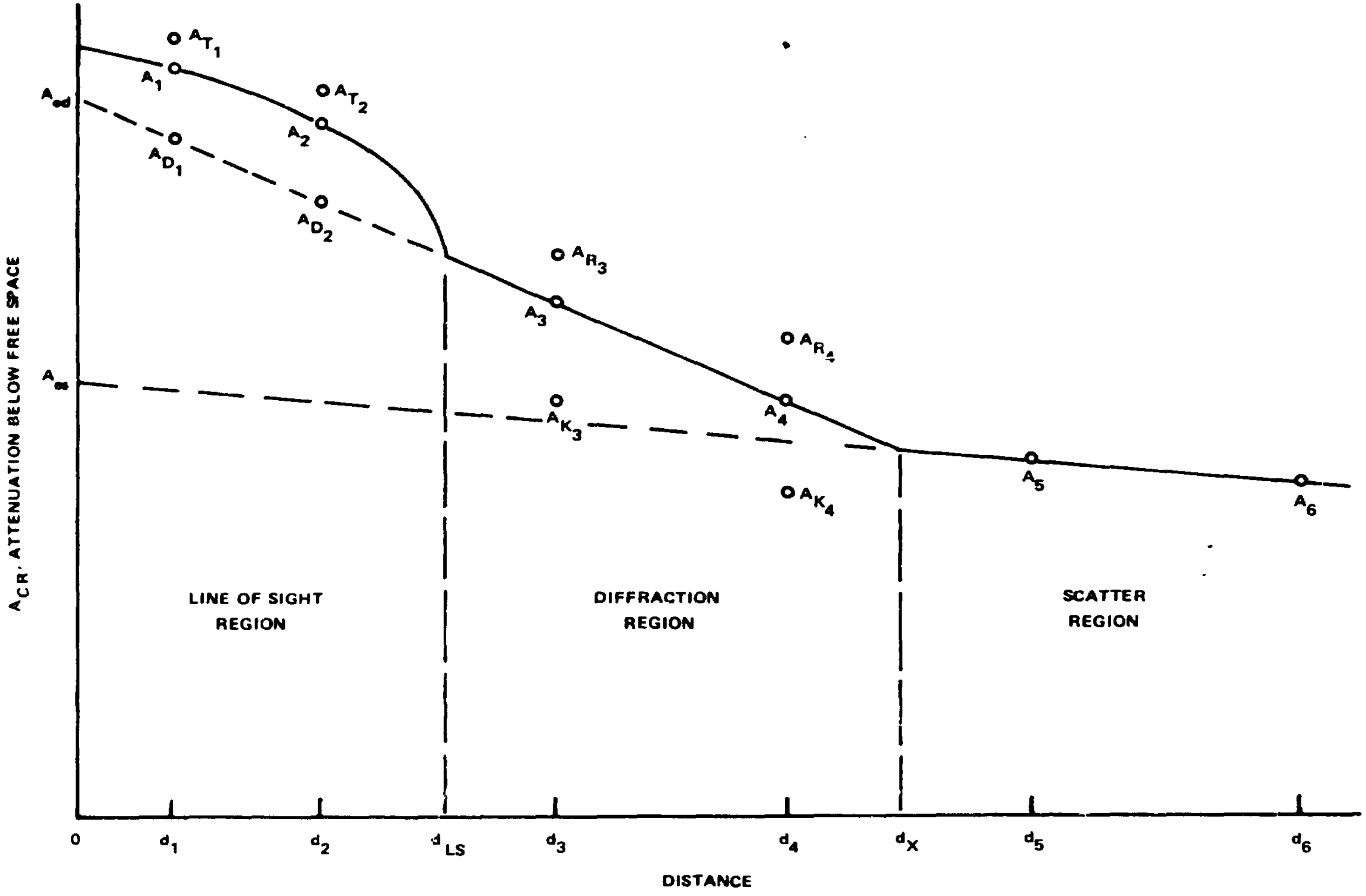

Figure 6.3-2 ATTENUATION BELOW FREE SPACE VERSUS DISTANCE

contributor to path loss when the path distance is less than, as well as greater than, the smooth earth radio LOS distance (d_{Ls}). Another reason is that long range paths require a definition of d_X, the separation distance between diffraction and forward scatter loss regions, before the correct propagation mode loss term can be selected. Distance, d_X, is, as was indicated above, a direct function of the losses predicted for the diffraction region. **Fig. 6.2-3**, the flow diagram of the ESSA section of the RFLINK subroutine illustrates the computational sequence used in determining the appropriate loss quantities. The flow diagram indicates that radio LOS ($d < d_{Ls}$) paths call the diffraction loss subroutine before the total path loss can be determined by the DLLOS subroutine, whereas the long range ($d > d_{Ls}$) cases compute diffraction losses and forward scatter loss in sequence before the appropriate loss term is selected by the diffraction subroutine.

Diffraction region calculations performed by the DIFF subroutine are based on the determination of diffraction losses at two discrete distance (d_3 and d_4 on Fig.6.3-2)chosen well within the diffraction ($d > d_{Ls}$) zone. Knife-edge diffraction losses (based on Fresnel-Kirchoff theory) are calculated at these distances resulting in attenuations A_{K3}, A_{K4} with their magnitudes proportional to the input horizon distance and angle parameters. Thus, the use of double knife edge terms treats the situation as though the propagation path traversed a pair of isolated sharp ridges. Smooth (round) earth diffraction losses A_{R3}, A_{R4}, are also calculated at distances d_3 and d_4 to include these effects for the longer paths. The smooth earth technique used is based on a method developed by Vogler ((Ref. 2) which estimates the attenuation experienced over the smooth bulge of the earth. Total diffraction losses at the two distances are given by

$$A_{3,4} = (1-W)\,A_{K3,4} + W\,A_{R3,4}$$

where W is an empirically determined weighting factor (Ref. 2) which is a function of the input Δh terrain irregularity parameter and other path descriptive data. The A_{CR} loss within the diffraction region is then represented as a linear dB loss versus distance relationship through the points (A_3, d_3) and (A_4, d_4) which defines the zero range intercept A_{ed} (see dashed line on Fig. 6.3-2) and the slope m_d, as computed by

$$m_d = (A_4 - A_3)/(d_4 - d_3)$$

and

$$A_{ed} = A_{fo} + A_4 - m_d d_4$$

when A_{fo} is an empirical clutter factor (Ref. 1) proportional to terrain irregularity, operating frequency, and antenna height. A_{CR} at any distance (d) greater than the smooth earth distance ($d > d_{Ls}$), and less than d_X (where diffraction losses equal forward scatter losses), is finally determined by the following:

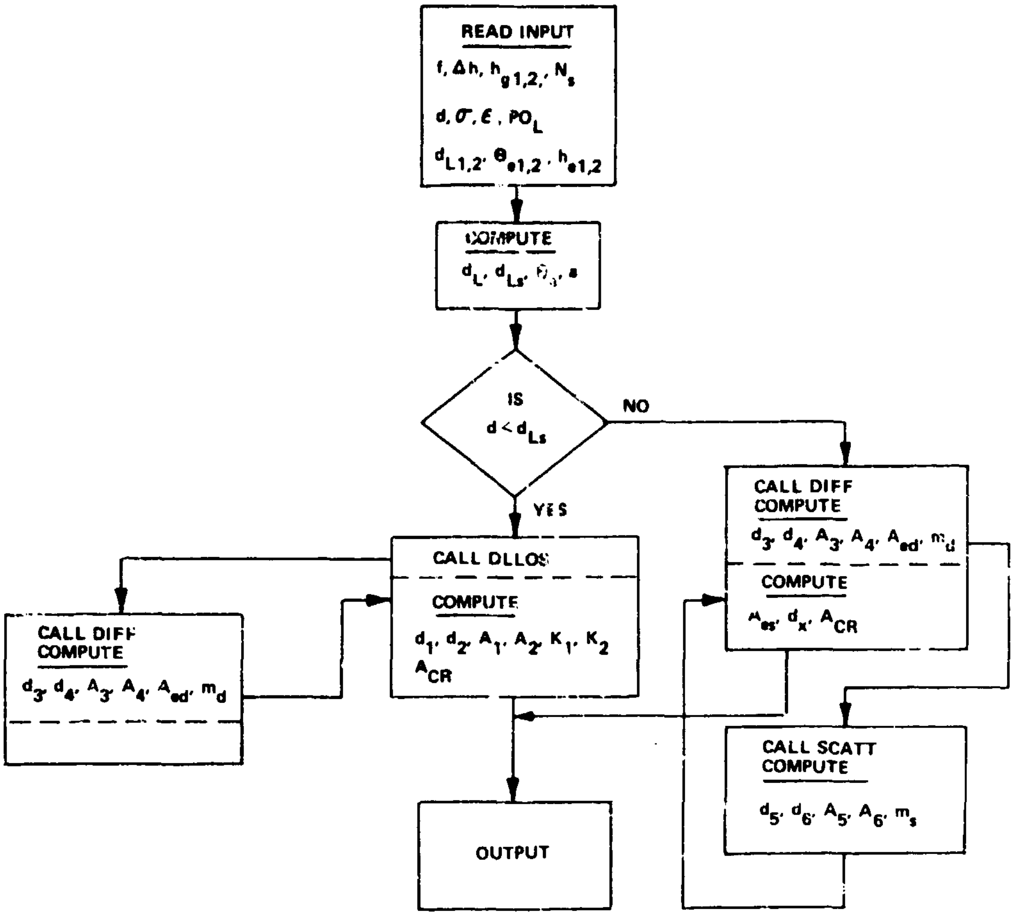

Figure 6.3-3 ESSA LOSS PREDICTION METHOD, FLOW DIAGRAM

$$A_{CR} = A_{ed} + m_d\, d \quad \text{for } d_{Ls} \leq d \leq d_X$$

For paths within the radio LOS distance, the ESSA method determines a weighted average of an extrapolated diffraction region propagation loss term and a two-ray optics loss from the same input data. The two-ray optics loss prediction technique used by the DLLOS subroutine is valid for frequencies greater than 20 mHz and accounts for the cancellation effects of earth-reflected signals at the path antennas. The DLLOS subroutine employs the following expression for the computation of two-ray optics losses as a function of path distance (d) and other path descriptors:

$$A_T = 10\, \mathrm{Log}_{10}\left(1 + R_e^2 - 2\, R_e \cos\left(\frac{2\pi \Delta R}{\lambda} - C\right)\right)$$

where $2\pi\Delta R/\lambda$ is the path length difference between the direct and ground reflected rays expressed in degrees and is equal to

$$\frac{2\pi\Delta R}{\lambda} = 2.4017\, (10^{-3})\, f\, h_{e1}\, h_{e2}/d$$

with f in MHz, $h_{e1,2}$ in meters, and d in km. R_e is the magnitude of the effective ground reflection coefficient and C is the phase of the coefficient relative to 180°. The magnitude of the reflection coefficient (R_e) is a function of operating frequency, path distance, effective antenna height, terrain irregularity, and the electrical constants of the propagating surface, while its phase is also dependent on the same quantities except for terrain irregularity.

Subroutine DLLOS computes the two-ray optics losses A_{T1} and A_{T2} at specified distances d_1 and d_2 selected well within the d_{Ls} distance (see Fig.6.3-2). Distances d_1 and d_2 are chosen so that the difference between the direct and ground-reflected rays does not exceed a distance comparable to one-quarter of a wavelength; distance d_1 also approximates the greatest distance at which the attenuation below free space is zero. The subroutine then employs the diffraction region loss function (intercept A_{ed} and slope m_d) to determine extrapolated diffraction region losses A_{D1} and A_{D2} at the distances d_1, d_2, and d_{Ls}, viz

$$A_{D1,2} = A_{ed} + m_d\, d_{1,2}$$

and

$$A_{Ls} = A_{ed} + m_d\, d_{Ls}$$

The total attenuation at d_1 and d_2 is then computed as

$$A_{1,2} = W_o A_{T1,2} + (1-W_o) A_{D1,2}$$

where Wo is an empirically determined weighting function* dependent on the operating frequency and the terrain irregularity parameter Δh. A_{CR} losses for the entire $d < d_{Ls}$ region are then defined as a logarithmic function fitted through the points (A_1, d_1), (A_2, d_2), and (A_{Ls}, d_{Ls}). This is accomplished by determining the slopes K_1 and K_2 of a smooth fitted curve of A_{CR} versus distances and employing these quantities in the following relationship:

$$A_{CR} = A_1 + K_1 (d - d_1) + K_2 \log_{10} (d/d_1)$$

This procedure results in a melding of the LOS and diffraction region loss versus distance functions without a discontinuous gap at d_{Ls}. If, in the event the loss computed from the preceeding equation is less than zero at any distance $(d < d_{Ls})$, the model sets A_{CR} equal to zero. The ESSA method does not attempt to describe the multiple lobes for LOS paths of irregular terrain.

In a treatment similar to that used by the DIFF subroutine for computing diffraction region losses, the SCATT subroutine employs a two-point linear curve fit technique to predict path loss in the forward scatter region, i.e., loss terms are computed at a pair of distances and a linear loss versus distance function is established through the resultant data points. The definitive loss functions used were developed (Ref. 2) from existing forward scatter propagation models which were appropriately modified to fit a wide range of measured data. The SCATT subroutine predicts the expected long term median path loss during periods of greatest attenuation from the minimum monthly value of surface refractivity (N_s) and important features of the propagation path (horizon angles and distances). The minimum monthly value of N_s usually occurs during the winter months and it should be noted that the ESSA method will over-predict median forward scatter losses somewhat in other seasons. Forward scatter attenuation is determined from a series of empirical loss relationships involving N_s and the product of path distance d and θ, the angle between the path horizon rays as computed from:

$$\theta = \theta_{e1} + \theta_{e2} + d/a$$

where $\theta_{e1,2}$ are the path horizon angles and a is the effective earth radius. The particular loss definitive relationship selected by the subroutine is dependent on the magnitude of the θd term.

Scatter attenuations A_5 and A_6 are computed from the selected empirical relationships at two distances, d_5 and d_6 (see Fig. 6.3-2)

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*High terrain irregularity or high operating frequencies result in a small W_o, or a large weighting towards diffraction type loss.

chosen large enough to be effectively beyond the influence of diffraction propagation fields. A linear loss versus distance function is then established through the points (A_5, d_5) and (A_6, d_6) as follows:

$$m_s = (A_6 - A_5)/(d_6 - d_5)$$

and

$$A_{es} = A_5 - m_s d_5$$

where A_{es} is the zero range intercept of the linear scatter loss function. Thus, for distances greater than d_x, A_{CR} is defined by

$$A_{CR} = A_{es} + m_s d \quad \text{for } d > d_x$$

which is a linear dB loss versus distance relationship similar to that used to describe below free space attenuation for the diffraction loss region ($d_{Ls} \leq d \leq d_x$). Distance d_x, where scatter loss equals diffraction loss, is given by:

$$d_x = (A_{es} - A_{ed})/(M_d - M_e)$$

6.3.3.8 Foliage Loss Computations

As was indicated earlier, the ESSA method did not specifically treat foliage effects on propagation loss in a quantitative sense. At 100 MHz and above, however, the surface vegetation is opaque enough to be considered as an integral part of the path profile characterized by its own descriptive electrical parameters (conductivity and permittivity). For the higher VHF frequencies and above, therefore, the foliage height may simply be added to the topographic terrain data to more closely define the actual propagation profile. The adoption of this technique in the Data Link Analysis model results in the inclusion of basic foliage propagation effects if the path antennas themselves are relatively clear of vegetation (no foliage canopy), i.e., foliage height will be reflected in the path descriptive parameters Δ h, $\theta_{e1,2}$, and $d_{L1,2}$. Stands of trees are treated as diffraction obstacles in a manner identical to that used for terrain peaks. A loss prediction model incorporating only this provision cannot, however, predict the sizeable additional losses which result if one or more of the actual path antennas are located appreciably beneath the canopy of a dense growth of vegetation. The implemented model accomplishes this task by combining the other loss predictions with appropriate foliage loss quantities derived in a subroutine called HTGAIN. As can be seen in Figure 6.3-1, HTGAIN is called prior to the path selection process.

Jungle environment propagation measurements (Ref 5), covering the frequency range of 100-400 MHz, have demonstrated that the effects of local (overhead canopy) vegetation on propagation loss are essentially independent of path length for paths longer than approximately 0.15 km, i.e., the additional propagation losses experienced as the antennas were lowered into the foliage were found to be independent of path length when the path became longer than approximately 0.15 km. This significant characteristic suggests the existance of a comparitively low loss propagation mode along, or near, the foliage top-air interface (lateral wave) which is independent of the antenna penetration depth into the vegetation. The field measurement program allowed the empirical derivation of so-called "height gain" functions (H_{TG}) which define the local foliage losses in terms of antenna penetration down into a 24.5 m high jungle*, and the operating frequency. Separate "height gain" functions are required to describe the foliage losses for the upper VHF and lower UHF frequency regions of interest. The appropriate foliage losses are defined by the following:

$$H_{TG} = 37.4-26.9 \log_{10} (24.5-F_{PN}) \qquad 130 < f < 200 \text{ MHz}$$

$$H_{TG} = 41.2-29.7 \log_{10} (24.5-F_{PN}) \qquad 250 < f < 350 \text{ MHz}$$

where F_{PN} is the distance in meters from the foliage-air interface to the actual physical position of the antenna within the foliage, and f is the operating frequency in MHz.

Thus, it follows that if the "distance" loss along or above the foliage-air interface can be accurately predicted, the total path loss for foliage immersed antenna situations is merely the sum of the foliage loss quantities defined by above equations and the predicted "distance" loss. Limited tests using ESSA loss computations with inputs as prepared in this model have indicated that it is possible to closely predict the "distance" loss quantity for a wide range of path profile shapes. Comparisons between model predictions and measured data at 100 and 250 MHz for approximately 20 paths resulted in a mean prediction error of +3.5 dB and a standard deviation of 3.0 dB. The "distance" loss for antenna-in-foliage situations was successfully predicted by redefining the propagation path to one characterized by ficticious antennas located directly over their actual positions--close to the canopy top-air interface mentioned above. With the antennas repositional in this manner the ESSA method can be employed in a manner identical to that discussed above which assumed that the antennas were relatively clear of foliage with no overhead canopy, i.e., regarding LOS-transhorizon path decisions, computations of path horizon parameters, etc.

The foliage loss prediction technique outlined above has been incorporated in the Data Link Analysis model with the major logical operations and loss computations being performed by subroutine HTGAIN mentioned above. Following its call, HTGAIN compares structural antenna

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*Only 10% of the tree growth at the site of the measurements exceeded this canopy height.

height to the height of the foliage canopy* in the immediate vicinity. If the structural antenna heights ($h'_{g1,2}$) are found to be greater than the local foliage height, antenna height ($h_{g1,2}$) is set equal to ($h'_{g1,2}$) and the foliage losses ($H_{TG1,2}$) are summarily set to zero (0.0) dB. Whenever the structural antenna heights ($h'_{g1,2}$) are less than the foliage height ($h_{j1,2}$) at their respective locations, subroutine HTGAIN redefines antenna height ($h_{g1,2}$) from the actual structural height to the height of the local foliage canopy. The purpose of this operation is to facilitate computation of the path "distance" losses. Path type (LOS-transhorizon) decisions, and horizon parameter determinations are then accomplished with the antenna in the elevated position.

In buried antenna situations, foliage loss quantities are computed from the equations for H_{TG} as functions of antenna penetration distance (F_{PN}) into the foliage medium. Since these equations were derived from propagation measurements characteristic of a particular foliage (24.5 m high jungle) environment, and are therefore only strictly valid for those foliage conditions, subroutine HTGAIN approximates foliage loss over a more general class of foliage conditions by judiciously modifying the actual antenna penetration distance (F_{PN}) an amount which is dependent on the existing foliage height at the antennas. The technique used is based on the assumption that as the tree canopy growth becomes taller, the less dense will be the vegetation closer the ground, due to the reduced sunlight filtering through. This assumption implies that the rate of foliage loss attenuation (dB/meter of foliage penetration) decreases (for comparatively large antenna penetration) as the foliage canopy height increases and vice versa as it decreases. Path loss data (Ref. 6) obtained in a tall (37 m) jungle tends to confirm this particular assumption. The measured losses indicated that the maximum $H_{TG1,2}$ foliage losses (antennas 3.0 m from the ground) were about the same for both the 37 m and 24.5 m high jungles, and also that the $H_{TG1,2}$ losses were about the same for the first 12 m of antenna penetration into each jungle. These findings therefore attribute the remaining loss to 12.5 m of foliage in the case of the 24.5 m high jungle and 25 m of foliage in the 37 m high jungle -- a definite indication of a higher rate of foliage attenuation (dB/m) for the lower canopy jungle. Although not thoroughly supported by measured data, subroutine HTGAIN employs the identical foliage loss vs. antenna penetration (F_{PN}) function for the first 12 m of F_{PN} regardless of foliage canopy height at the antenna sites. If the combination of canopy height and structural antenna height results in F_{PN} greater than 12 m, the subroutine applies a linear weighting factor to the penetration distance exceeding 12 m which is a function of the particular canopy height, viz

$$F_{PN1,2} = 12 + 10 \left[\frac{F'_{PN1,2} - 12}{h_{j1,2} - 15} \right] \text{ when } (F'_{PN1,2} \quad 12.0 \text{ m})$$

---

[*] Canopy height descriptions are only made available to the model for the path terminals, whereas median foliage height appears in summation with terrain height for the remainder of the input profile definition.

where $F_{PN1,2}$ is the penetration distance substituted into the loss expression (H_{TG}) and $F'_{PN1,2}$ is the actual antenna foliage penetration distance in meters from the canopy top. Fig. 6.3-4 illustrates the results of employing the above foliage loss prediction technique for three different jungle canopy heights at a frequency of 170 MHz. The three foliage loss curves are not only indicative of the loss magnitudes predicted for a foliage submerged antenna, but they also depict the adopted philosophy of relating foliage loss to the height of the vegetation canopy.

Subroutine HTGAIN does not continue increasing the rate of high penetration foliage attenuation with decreasing canopy height for canopy heights less than 18.3 m (60 ft) since the slope of loss function clearly becomes unrealistic (see Fig. 6.3-4). Foliage losses for canopy heights greater than 3 m, but less than 18.3 m, are described by the lower F_{PN} portion of the $H_{j1,2}$ = 24 m function shown in Fig. 6.3-4. This technique provides an approximate prediction of foliage loss for the lower vegetation heights by adopting a foliage loss function descriptive of relatively high antennas within a 24 m jungle. The approximation appears reasonable, but its validity can only be determined by field experimentation. The 18.3 m canopy height limitation discussed above also carries the implication that foliage canopies less than this height do not exhibit the thick, relatively low-lying vegetation growth characteristic of jungle type vegetation. The possibility exists, therefore, that for jungle environments less than 18.3 m high, the model may tend to underpredict foliage losses somewhat. From another viewpoint, however, it may be argued that vegetation growth less than 18.3 m or thereabouts is not in many cases a jungle situation, but a deciduous forest exhibiting very little low-lying vegetation growth -- making the above approximation somewhat more realistic. Prediction of foliage losses for canopy heights less than 3.0 m is not attempted at all in the model; HTGAIN sets H_{TG1} or H_{TG2} to zero (0.0) whenever the respective input canopy heights are less than 3.0 m since the resulting loss terms would be quite small.

The sum of H_{TG1} and H_{TG2} actually represents a predicted median value of foliage loss for the path in question. This is due to the fact that measured data (Ref. 5) from which the H_{TG} expressions were derived was obtained by averaging several measurements as the physical position of the antenna was perturbed; a necessary procedure since foliage loss is sensitive to the physical arrangements of the vegetation immediately surrounding the antenna proper. It is therefore quite possible that the median foliage loss quantities predicted by the H_{TG} expressions will considerably underestimate this component of path loss in many practical situations. Subroutine HTGAIN accounts for this non-deterministic possibility by performing a random selection from a normal density distribution characteristic of the loss randomness observed during field measurements. For each foliage submerged antenna situation, a random draw is made from a zero mean, 5 dB standard deviation normal distribution. If the resulting loss increment (AF_{VAR}) proves to be positive (loss greater than the median) it is added to the median H_{TG} value; negative loss increments

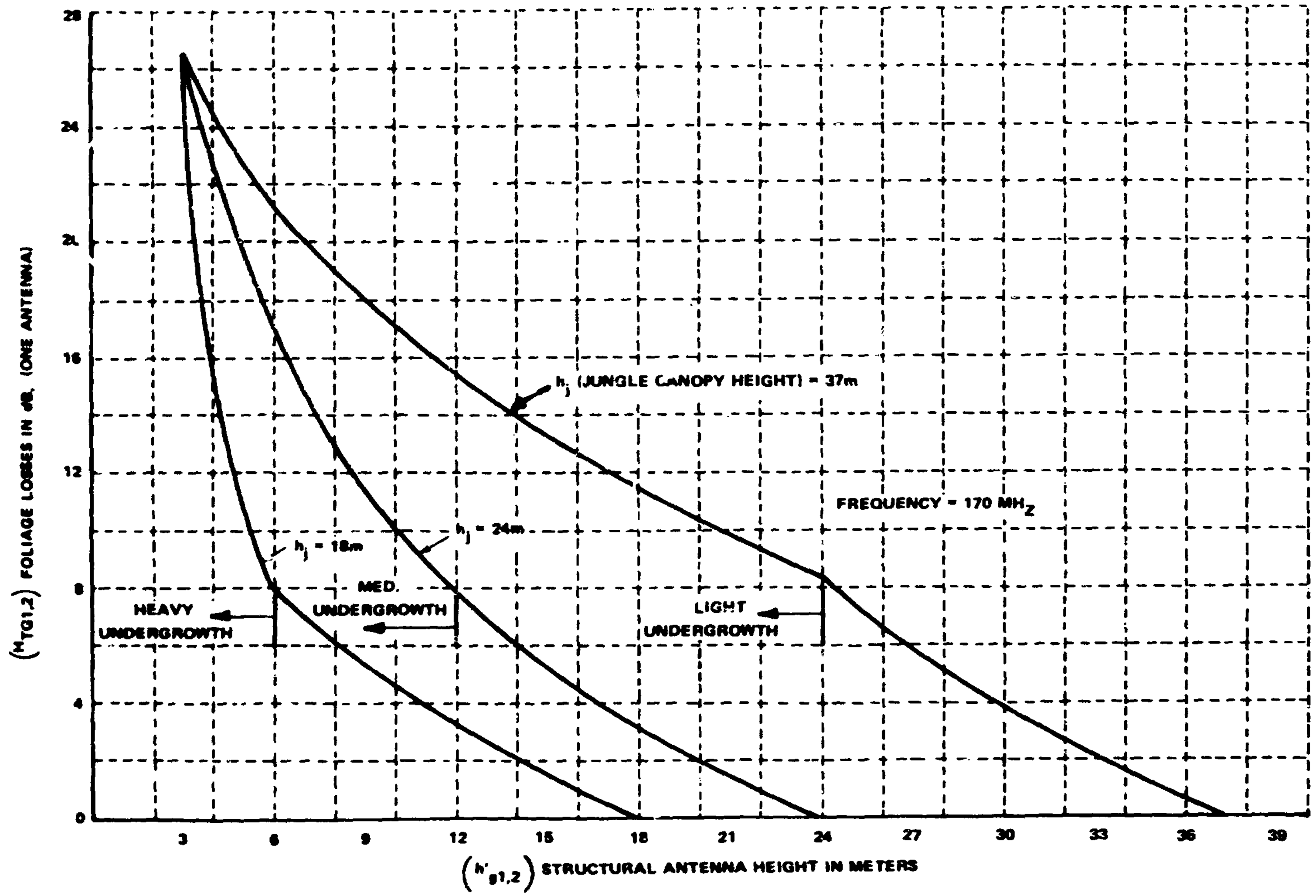

Figure 6.3-4 FOLIAGE PROPAGATION LOSS VS ANTENNA HEIGHT

are ignored and AF_{VAR} is set to zero (0.0). Thus, the actual foliage loss (FOLLOS) reported by subroutine HTGAIN is actually the sum of four (4) loss terms, two median quantities and two variable quantities, viz

$$\text{FOLLOS} = H_{TG1} + H_{TG2} + AF_{VAR1} + AF_{VAR2}$$

Any or all of the terms may, of course, be zero depending on the particular occurrences stipulated above.

6.3.3.9 Data Link Performance Definition Computations

The final operation performed by the Data Link Analysis model involves the determination of the actual data transmission performance of the particular RF link being considered. Performance is delineated in several ways including receiver S/N ratio, detection error probabilities, and an estimate of S/N margin referenced to an acceptable level of received S/N. Parametric descriptions of the system RF components, e.g., transmitter power, receiver noise figure, antenna gains, etc., are utilized, along with path loss predictions, to derive the link receiver signal-to-noise ratio (S/N). Thus, each data link analyzed must be fully described by a complete set of pertinent equipment characteristics, in addition to the definitions of path profile height, foliage canopy height at the antennas, etc., required for propagation loss determinations. These data are made available to the Data Link Analysis model, either directly via user inputs, or from associated programs which supply environmental descriptions of the game area.

Total path loss (A_{PATH}) is simply obtained through a direct summation of all the individual propagation loss terms derived at various points in the analysis model. APATH is computed late in the flow sequence of the RFLINK subroutine. (See Figure 6.3-1) just prior to the determination of receiver S/N, and it consists of the following summation:

$$A_{PATH} = A_{LBF} + A_{CR} + A_{LOSS} + \text{FOLLOS}$$

where A_{LBF} is the free space loss, A_{CR} is the reference below free space loss, A_{LOSS} is the ground mounted antenna loss, and FOLLOS is the total path foliage loss. A_{LOSS} and/or FOLLOS may, of course, be non-existent (0.0 dB) depending on the particular physical situation.

Receiver signal-to-noise ratio (S/N) is computed for each path analyzed from the following expressions:

$$S/N = 10 \operatorname{Log}_{10} (P_T) + G_T + G_R - 10 \operatorname{Log}_{10} (NF \cdot K \cdot T \cdot B) - A_{PATH}$$
$$-A_{LT} - A_{LR}$$

where

P_T = transmitter power (Watts)
G_T = transmit antenna gain (dB)
G_R = receive antenna gain (dB)
NF = receiver noise figure (power ratio)
T = temperature (degrees)
B = receiver bandwidth (overall) (H_Z)
A_{LT} = transmit system RF losses (dB)
A_{LR} = receive system RF losses (dB)
A_{PATH} = total basic propagation loss (dB)

S/N as defined above represents a fundamental performance indicator of overall data link performance, particularly so, if the error behavior characteristics of the signal and data interpretation processes (electronic and human) are known as functions of S/N. Since several aspects of the interpretation processes are largely unknown because of the lack of experimental data or because extensive analysis would be required for their definition, receiver S/N, therefore, is probably the least uncertain descriptor of link performance available from the analysis model is its present configuration.

Despite the lack of detailed information alluded to, the Data Link Analysis model provides a reasonable criteria for determining whether the data link under scrutiny is adequate in terms of its ability to transfer data messages. The criteria is based on the computation of a path S/N margin quantity which is referenced to a minimum acceptable level of receiver S/N. The implemented approach assumes that the communication systems are of the digital type employing noncoherent frequency-shift keying (FSK) modulation techniques. It is further assumed that the digital information to be transmitted is coded in binary forms, and that the receiver employs two identical detection channels to discriminate between the two binary data states (represented by a pair of discrete frequencies). Receiver front-end noise is the only competing signal considered by the model as influencing the decision process. The probability of making an error in estimating whether a zero or one was transmitted in noncoherent FSK systems is related to the energy content of the received signal waveform (E) and the competing receiver noise power density (N_d) by the following theoretical (Ref. 7) expression:

$$P_{eBIT} = 1/2 \exp(-E/2\,N_d)$$

where E, the energy content is in coulombs, and N_d, the noise power density, is in watts per unit bandwidth. The error probability described by this equation is the probability that the wrong detection decision will be made by the receiver given a transmitted bit of information. If it is assumed that receiver noise becomes decorrelated between bit transmissions, the probability that a message word N bits long will contain at least one bit detection error is given by:

$$P_{eMESS} = 1 - (1-P_{eBIT})^N$$

Thus, the above equations can be used to define the detected message error probability in terms of the received signal, and receiver internal noise. The error behavior described by the error probability equations is used in the analysis model to establish a baseline receiver S/N ratio which forms the reference for individual path S/N margin determinations. Adopting this method to indicate overall performance of the link message transfer process results, however, in a somewhat pessimestic requirement for receiver S/N since error reduction techniques such as parity checks, information redundancy, human interpretation, etc., have all been ignored. Nevertheless, in view of the uncertainties connected with the prediction of propagation loss, the adopted approach would appear to yield viable performance criteria.

The minimum acceptable (baseline) receiver S/N ratio is obtained by solving the error probability equations for an allowable minimum received signal energy to noise power density ratio ($E/N_{d\ min}$), and converting the ratio to receiver S/N. After some manipulation

$$E/N_{d\ min} = -4.605\ \mathrm{Log}_{10}\left[1-(1-P_{eMESSmax})^{1/N}\right] - 1.386$$

where $P_{eMESS\ max}$ is the maximum allowable message error probability set by the analysis model user (e.g., 5-10%). Received E/N_d can be converted to a signal to noise power ratio (S/N), in a general sense, without a knowledge of the transmitter modulation characteristics, if the receiver bandwidth relative to the received signal spectrum is known. This is seen as follows:

$$E/N_d = \frac{P_R \tau}{N/B} = \frac{P_R \tau}{\frac{N/BTP}{\tau}} = \frac{P_R BTP}{N} = BTP\ (S/N)$$

where τ is the duration of the received signal in one of the detection channels B is the overall bandwidth, P_R is the received signal power, N is the receiver noise power appearing in one of the detection channels, and BTP is the ratio of the detection channel bandwidth to the spectrum of the received signal. Thus, the minimum acceptable (baseline) receiver S/N ratio (in dB) becomes

$$S/N_{min} = 10\ \mathrm{Log}_{10} \frac{E/N_{d\ min}}{BTP} + 7.0$$

A corrective term must be applied to this equation before it actually represents the baseline S/N ratio for practical situations -- its derivation was predicted on the theoretical error behavior of noncoherent FSK systems. Operational receivers of this type exhibit a similar detection error probability vs. E/Nd relationship except for the fact that approximately 6-8 dB higher E/N_d ratios are required for given output error probabilities. (Ref. 8). The expression for the data link analysis model takes into consideration by employing the following determination of S/N baseline ratio:

$$S/N_{min} = 10 \, Log_{10} \frac{E/N_{d\,min}}{BTP} + 7.0$$

Path S/N margin is then computed from:

$$S/N_{marg} = S/N - S/N_{min}$$

Clearly, S/N_{marg} can either be positive or negative depending on the magnitude of the computed value of the link receiver S/N ratio. Supplementing S/N margin, the model also determines the bit error probability and message (word) error probability for each path analyzed.

An example of the Data Link Analysis Output Formats is given on pages 6-36.50, 6-36.51, and 6-36.52.

6.3 REFERENCES

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4. A.G. Longley and R.K. Reasoner, "Comparison of Propagation Measurements with Predicted Values in the 20-10000 MHz Range," ESSA Tech Rpt. ERL-148-ITS97, January 1970.

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7. P.F. Panter, "Modulation, Noise, and Spectral Analysis," McGraw-Hill Book Co., 1965.

8. R.R. Mosier, "A Data Transmission System Using Pulse Phase Modulation," PG-MIL Convention Record, June 17-19, 1957.

USE	VARIABLE	USED BY
Common/BASICT/	Page 2-135, #4	MAINSY TERAN
Common/	XMIN, YMIN	
	XMIN - Minimum X coordinate of terrain held in core YMIN - Minimum Y coordinate of terrain held in core	MAINSY PROFIL TERANE
Common/	ITRNHT(30401), Short, RMAX	
	ITRNHT(30401) - Integerized terrain in storage SHORT - The range of short range sensors RMAX - The maximum range of a radar	MAINSY PROFIL TERANE
Common/	DGD, MXREF,MYREF, MXTENT,MYTENT, DRAY	
	DGD - Grid size per stepping along range (100) MXREF - Integerized X reference of playing field MYREF - Integerized Y reference of playing field	MAINSY PROFIL TERANE

USE	VARIABLE	USED BY
	MXTENT - Integerized X extent of playing field MYTENT - Integerized Y extent of playing field DRAY - Incremental distance along line of sight in XY plane	
Common/	XS(10), YS(10), XT(10), YT(10), ZSO(10), ZTO(10), NXGD	
	XS - X coordinate of sensor YS - Y coordinate of sensor XT - X coordinate of target YT - Y coordinate of target ZS0 - Interpolated elevation of sensor ZT0 - Interpolated elevation of target NXGD - Grid size for stepping along range	MAINSY
Common/	RSEN(15)	
	RSEN - Array no longer in use (Program card could be deleted)	MAINSY
Common/HEIGHT	H(500), CH(500), XTR(500), [illegible]P(500,	

USE	VARIABLE	USED BY
	H( ) - Propagation path profile (terrain plus foliage) data array (meters)	COMMA DELHD EFFEC HORIZ LEAST READC RFLINK
	CH( ) - Height vs. Distance function of straight line fit for profile points.	
	XTR( ) Difference between fitted line and actual terrain.	
	HP( ) - Propagation profile (terrain plus foliage) height for earth curvature and atmospheric refraction (meters).	
Common/NR	JZ, W, SW3, SW4, SA3, SA4, SAFO	
	JZ - Index no longer in use (used in model check-out)	DIFF DLLOS
	W - Line of sight region loss weighting factor	
	SW3 - Stored value of diffraction loss weighting factor (defined at distance d_3)	
	SW4 - Stored value of diffraction loss weighting factor (defined at distance d_4)	
	SA3 - Stored value of effective earth's radius between the path horizon and distance d_3.	
	SA4 - Stored value of effective earth's radius between the path horizon and distance d_4.	
	SAFO - Stored value of terrain roughness clutter loss.	

USE	VARIABLE	USED BY
Common/MAR14/	D3, D4, T5	
	D3 - Distance chosen well within the diffraction loss region. D4 - Distance chosen well within the diffraction loss region. T5 - Angle between the path horizon rays for distance d_5.	DIFF SCATT
Common/M/	F, D, NS, A, DH, DHS, S, E, POL, KM, RITE, DHD, ILOS, PATH	
	F - Link operating frequency D - Ground distance between transmitter and receiver terminals. NS - Average surface refractivity for transmitter and receiver ends of propagation path. A - Effective earth's radius (corrected for regional surface refractivity)(km) DH - Path profile roughness descriptor. DHS - Stored value of Δh terrain irregularity parameter. S - Conductivity of propogation surface (MHo/m) E - Relative Permativity of propagation surface. POL - Link antenna polarization	DIFF DLLOS RFLINK SCATT

USE	VARIABLE	USED BY
	KM - Program switch; calls SCATT subroutines if path distance is greater than the radio LOS distance.	
	RITE - Program switch no longer in use (used in model check-out)	
	ILOS - Line of sight propagation path switch 0 = No 1 = Yes	
	PATH - Relay link propagation path switch (one antenna on prominent peak) 0 = No 1 = Yes	
	DHD - Interdecile range of terrain hgts above & below straight line curve fit	DLLOS
Common/MP/	H1E, H2E, H1G, H2G, DLS1, DLS2, DL1, DL2, DL, DLS, TE1, TE2, TE, KL	
	H1E - Effective transmitter antenna height above propagation profile (meters)	DIFF DLLOS RFLINK SCATT
	H2E - Effective receiver antenna height above propagation profile (meters)	
	H1G - Transmitter antenna height above propagation profile modified for local jungle foliage (meters)	
	H2G - Receiver antenna height above propagation profile modified for local jungle foliage (meters)	

USE	VARIABLE	USED BY
	DLS1 - Ground distance from transmitter antenna to smooth earth horizon (km)	
	DLS2 - Ground distance from receiver antenna to smooth earth horizon (km)	
	DL1 - Ground distance from transmitter to profile point forming THETA1 (km)	
	DL2 - Ground distance from receiver to profile point forming THETA2 (km)	
	DL - Sum of distances DL1, DL2	
	DLS - Sum of smooth earth distance DLS1, DLS2.	
	THETA1 - Most elevated angle horizon between transmitter antenna and propagation path profile (radians)	
	THETA2 - Most elevated angle horizon between receiver antenna and propagation path profile (radians)	
	TE - Sum of elevation angles THETA1 and THETA2, or DL/A, whichever is larger.	
	KL - Index no longer in use (used in model check-out.	

USE	VARIABLE	USED BY
Common/MLDS/	AG, AD, ACR, AED, MD, AH50, AH5, D5, MS, AES, DX, H5	
	AG - Two-way optics loss (below free space). AD - Diffraction region loss (below free space). ACR - Median reference propagation loss below free space. AED - The zero range intercept of the ACR. MD - The slope of the ACR loss within the diffraction region represented as a linear dB loss vs. distance relationship. AH50 - Forward scatter loss defined at distance $d = d_{xo}$ (d_{xo} = distance where diffraction loss and scatter loss over smooth earth are equal) AH5 - Estimate of scatter loss vs distance d_5. D5 - Distance chosen well within the scatter loss region. MS - Slope of the ACR loss within the scatter region represented as a linear dB loss vs. distance relationship. AES - Zero range intercept of the linear scatter loss function. DX - The separation distance between diffraction and forward scatter loss regions. H5 - Scatter loss frequency gain function determined at distance d_5.	DIFF DLLOS RFLINK SCATT

USE	VARIABLE	USED BY
Common/ML/	D0, D1, D01, D02, A0, A1, K1, K2, AL, ALS, AOG	
	D0 - Approximate distance for which below free space loss is zero. D1 - The greatest distance within the line of sight region at which ACR is zero. D01 - Estimate of distance d_1 when $A_{ed} \geq 0$. D02 - Estimate of distance d_1 when $A_{ed} < 0$. A0 - LOS region loss computed at distance d_1 (below free space) A1 - LOS region loss computed at distance d_2 (below free space). K1 - Polarization sensitive parameter used to predict round earth diffraction loss. AL - Diffraction reg. loss computed at dist d_{LS} (d_{LS} = sum of smooth earth path horizon distances). ALS - Diffraction region loss computed at distance d_L. AOG - LOS region loss computed at distance d_1 (below free space)	
Common/UNTER	See Appendix C, Volume 2, User's Manual	
		FOLAGE TERAN

USE	VARIABLE	USED BY
Common/ANGLE/	TE1(500), TE2(500)	
	TE1( ) - Array of angles for all profile points referenced to the transmitter antenna (radians) TE2( ) - Array of angles for all profile points referenced to the receiver antenna (radians)	HORIZ INTER RFLINK
Common/UTVSXY/	IUTXY(15, 60)	
	See Section 5.3.2, Volume I, Part. II, Model Description	Function IUTEVL(X,Y) TERAN
Common/ERRLIM/	NFIX(4)	
	NFIX - Array no longer in use (Program card could be deleted)	RFLINK

```
ARRAY [illegible]   4   MONITOR NUMBER   1

TERRAIN RETRIEVED FOR   1 TIME.
ITS ORIGIN IS LOCATED AT    10700.     4700. AND EXTENDS TO     13800. METERS IN THE X- DIRECTION AND
  11700. METERS IN THE Y-DIRECTION.
THE GRID RESOLUTION IS AT      100. METERS AND RANGES     3100. METERS IN THE X-DIRECTION, AND     6900. IN THE Y-DIRECTION.

127 109 100  95  74  61  47  62  58  52  44  41  44  45  64  55  72  76  68  68  77  91 111 113  97  75  54  41  35  33
106  97  99  96  71  43  39  42  43  55  61  53  42  43  45  50  61  75  83  95 172 138 141 173  89  66  49  39  35  34
 86  83  91  89  70  48  38  36  49  72  81  75  47  49  55  63  75  92 108 130 160 171 156 118  86  66  46  39  37  36
 72  71  89  71  58  49  38  35  44  63  80  87  62  67  76  86 106 129 156 173 179 172 145 108  87  69  47  39  39  38
 59  82  80  58  49  41  41  40  48  57  67  74  73  94 108 119 145 170 189 192 177 146 117 101  86  67  46  42  43  40
 55  72  67  57  40  44  61  64  61  71  74  73  86 116 135 148 167 177 179 168 143 112  94  87  74  57  49  55  56  49
 43  50  46  44  37  56  84  91  77  79  90  94 105 126 149 160 166 164 144 118  99  86  79  74  72  70  65  64  63  60
 57  55  55  44  40  60  89 102 104 100  97  94 103 116 143 166 173 168 149 118  94  84  90  98  91  82  73  70  70  70
 92 100  97  69  54  68  94 114 128 128 112  99 103 111 140 179 190 183 163 128 104  96 102 106  97  85  77  73  73  74
113 139 134  96  64  76 107 128 130 129 121 116 123 135 164 201 206 187 165 136 117 106 105 106  96  84  78  77  77  77
103 139 130 100  67  69  94 111 108 104 109 122 141 163 191 213 206 184 165 140 120 108 111 109  94  83  80  79  80  79
 92 118 111  97  69  72  84  86  94  98 100 122 153 183 208 215 195 171 153 129 112 107 114 108  95  88  84  81  80  79
 95 110 103  87  66  82 101 100 107 115 114 129 162 193 211 207 183 160 139 120 111 111 113 107  99  94  89  85  82  79
103 113  98  74  64  81 105 114 117 122 133 151 176 197 204 195 177 157 138 124 118 113 110 105 100  96  92  89  86  81
119 119 101  87  86  96 110 114 114 121 146 176 200 212 206 193 178 159 144 133 126 120 112 104 100  97  95  92  89  84
135 124 105 105 115 124 129 129 126 129 157 189 217 230 217 197 179 162 150 143 138 128 113 103 100 101  99  94  89  84
136 120 103 107 123 135 139 139 137 139 161 188 219 235 223 200 180 168 161 155 147 133 115 106 106 108 105  95  87  82
117 101  94 101 117 122 127 130 128 134 154 183 214 228 223 209 193 187 184 175 163 147 129 119 115 115 111  96  83  79
106  95  90  94 100 100 112 120 120 128 150 179 202 210 216 222 219 214 206 196 187 170 146 130 124 122 115 100  87  80
115 104  84  76  82  96 113 119 116 117 134 164 182 187 205 227 232 220 201 194 196 186 164 150 147 137 121 109 100  86
122 105  76  76  92 114 128 121 100 100 119 143 157 167 193 217 216 193 167 166 182 188 183 179 174 157 135 122 112  95
119  96  76  94 118 132 137 122  92  95 116 130 137 156 186 204 190 155 130 137 163 187 201 204 193 171 147 127 112  96
107  85  80 105 128 135 130 110  93 104 117 116 129 161 189 197 174 132 113 128 157 187 212 224 212 184 154 127 108  95
 88  70  82 108 122 123 110  92  92 108 105 106 134 171 193 193 164 121 106 124 155 186 213 230 221 188 155 126 106  97
 75  69  96 102 105 104  92  83  93  98  94 110 141 169 183 175 146 110  98 117 147 178 203 214 204 174 146 119  98  89
 65  63  11  88  81  83  79  85  95  83  87 114 135 148 153 144 121  95  91 109 137 166 187 189 173 146 125 103  83  76
 60  63  76  79  68  70  83  94  88  76  88 109 112 112 114 111  98  85  91 110 135 161 177 171 147 122 103  88  75  70
 60  70  76  77  66  69  84  84  71  76  93  96  86  80  79  80  83  87 100 121 144 151 168 156 128 107  90  80  75  68
 50  62  75  73  62  52  55  57  56  72  83  79  76  76  76  80  93 104 116 134 150 160 157 139 112  97  86  80  75  68
 43  52  69  68  52  47  46  41  43  57  71  76  78  79  85  96 108 114 116 125 136 150 148 131 107  94  87  80  75  70
   1      32.00       0.0   13700.00   4700.00      113.42
   2      68.32     100.00  13660.24   4791.75      113.42
   3      70.47     200.00  13620.48   4883.51      113.42
   4      72.70     300.00  13580.71   4975.26      113.42
   5      75.72     400.00  13540.95   5067.02      113.42
   6      85.58     500.00  13501.19   5158.77      113.42
   7      94.54     600.00  13461.43   5250.42      113.42
```

Figure 6.3-5 DATA LINK ANALYSIS OUTPUT FORMAT

```
  8    101.41     700.00   13421.67    5342.28     113.42
  9    106.63     800.00   13381.91    5434.03     113.42
 10    110.90     900.00   13342.14    5525.79     113.42
 11    113.33    1000.00   13302.38    5617.54     113.42
 12    116.53    1100.00   13262.62    5709.29     113.42
 13    122.15    1200.00   13222.86    5801.05     113.42
 14    129.44    1300.00   13183.10    5892.80     113.42
 15    133.05    1400.00   13143.34    5984.55     113.42
 16    134.88    1500.00   13103.57    6076.31     113.42
 17    136.20    1600.00   13063.81    6168.06     113.42
 18    139.50    1700.00   13024.05    6259.82     113.42
 19    149.20    1800.00   12984.29    6351.57     113.42
 20    165.75    1900.00   12944.53    6443.32     113.42
 21    186.58    2000.00   12904.77    6535.08     113.42
 22    210.20    2100.00   12865.00    6626.83     113.42
 23    222.44    2200.00   12825.24    6718.59     113.42
 24    218.43    2300.00   12785.48    6810.34     113.42
 25    205.68    2400.00   12745.72    6902.09     113.42
 26    191.97    2500.00   12705.96    6993.85     113.42
 27    172.96    2600.00   12666.20    7085.60     113.42
 28    153.33    2700.00   12626.43    7177.36     113.42
 29    142.20    2800.00   12586.67    7269.11     113.42
 30    140.96    2900.00   12546.91    7360.86     113.42
 31    144.81    3000.00   12507.15    7452.62     113.42
 32    148.53    3100.00   12467.39    7544.37     113.42
 33    141.14    3200.00   12427.63    7636.13     113.42
 34    123.99    3300.00   12387.86    7727.88     113.42
 35    118.52    3400.00   12348.10    7819.63     113.42
 36    131.10    3500.00   12308.34    7911.39     113.42
 37    141.80    3600.00   12268.58    8003.14     113.42
 38    133.27    3700.00   12228.82    8094.89     113.42
 39    120.32    3800.00   12189.05    8186.65     113.42
 40    101.26    3900.00   12149.29    8278.40     113.42
 41    100.02    4000.00   12109.53    8370.16     113.42
 42    107.40    4100.00   12069.77    8461.91     113.42
 43    116.34    4200.00   12030.01    8553.66     113.42
 44    123.78    4300.00   11990.25    8645.42     113.42
 45    118.63    4400.00   11950.48    8737.17     113.42
 46    103.53    4500.00   11910.72    8828.93     113.42
 47     83.96    4600.00   11870.96    8920.68     113.42
 48     41.62    4700.00   11831.20    9012.43     113.42
 49     31.72    4800.00   11791.44    9104.19     113.42
 50     24.78    4900.00   11751.68    9195.94     113.42
 51     36.06    5000.00   11711.91    9287.70     113.42
 52     50.27    5100.00   11672.15    9379.45     113.42
 53     65.07    5200.00   11632.39    9471.20     113.42
 54    108.39    5300.00   11592.63    9562.96     113.42
 55    130.12    5400.00   11552.87    9654.71     113.42
 56    145.98    5500.00   11513.11    9746.46     113.42
 57    141.96    5600.00   11473.34    9838.22     113.42
 58    132.53    5700.00   11433.58    9929.97     113.42
 59    122.72    5800.00   11393.82   10021.73     113.42
 60    126.88    5900.00   11354.06   10113.48     113.42
 61    144.86    6000.00   11314.30   10205.23     113.42
 62    145.14    6100.00   11274.54   10296.99     113.42
 63    161.18    6200.00   11234.77   10388.74     113.42
 64    182.19    6300.00   11195.01   10480.50     113.42
 65    191.42    6400.00   11155.25   10572.25     113.42
 66    182.95    6500.00   11115.49   10664.00     113.42
 67    172.33    6600.00   11075.73   10755.76     113.42
 68    178.13    6700.00   11035.96   10847.51     113.42
 69    189.26    6800.00   10996.20   10939.27     113.42
 70    194.43    6900.00   10956.44   11031.02     113.42
 71    205.06    7000.00   10916.68   11122.77     113.42
 72    212.83    7100.00   10876.92   11214.53     113.42
 73    228.57    7200.00   10837.16   11306.28     113.42
 74    211.17    7300.00   10797.39   11398.04     113.42
 75    243.71    7400.00   10757.63   11489.79     113.42
 76    247.40    7500.00   10717.87   11581.54     113.42
                0.35000E 02            0.30000E 02
```

Figure 6.3-5 (Cont) DATA LINK ANALYSIS OUTPUT FORMATS

```
 [illegible] [illegible] DATA
NO. OF [illegible]=     76  FOLIAGE HT AT TRANSMITTER=   35.00  FOLIAGE HT AT RCVR=   30.00

  [illegible] PARAMETERS
[illegible]=   170.00  TRANS ANT HT=      0.28  RCVR ANT HT=     10.00  PERMITTIVITY=  0.000050
CONDUCTIVITY=      1.01  REFRACTIVITY=  315.000  MIN SR=        0.0  PATH=       0.0
POLARIZATION=       1.0
TRAN POWER=      2.00  TRAN ANT GAIN=      0.0   RCVR ANT GAIN=      0.0   LT=      1.00  LR=      1.00
NOISE FIG=    10.00  TEMP=   400.00  B=  1000.00  SIP=       1.50  PEMMAX=     0.0500
[illegible]=    24

  FOLIAGE PROPAGATION LOSS
  HIGH(1)=    0.2670E 02
  HIGH(2)=    0.1455E 02

 TRANSMISSION PATH

   D IS LESS THAN DLS
DATA LINK NO. IS       5

  COMPUTED TERRAIN DATA
HO(D)=   100.728  DH=   323.433  THETA1=    0.3631  THETA2=   -0.0155
THETA=    0.3677  DL1=      0.10  DL2=       5.30  KL=        2
N=       56  NS=     310.41  EARTH RADIUS=   8648.24  HA=    304.09

  MODIFIED ANTENNA HEIGHTS
TRANS ANTENNA=      35.00  RCVR ANTENNA=      30.00  TRANS EFFECTIVE ANT HT=     35.00  RCVR EFFECTIVE ANT HT=    210.14
RANGE BETWEEN TRANSMITTER AND RECEIVER=      7.50  KILOMETERS

  ITEMIZED PROPAGATION LOSSES
LOSS DUE TO GROUND MOUNTED ANTENNA       10.00  DB
LOSS DUE TO ANTENNA IN FOLIAGE           41.09  DB
LOSS DUE TO DL LESS THAN DLS              0.0   DB
MEDIAN REFERENCE LOSS                    66.00  DB
FREE SPACE LOSS                          94.56  DB
VARIABLE FOLIAGE LOSS TRANS               0.0   DB

VARIABLE FOLIAGE LOSS RCVR                8.21  DB
TOTAL PATH LOSS                         221.66  DB

  SIGNAL TO NOISE VALUES
RCVR SIGNAL/NOISE=    -57.02  PROBILITY BIT ERROR=    0.5000E 00  PROBILITY WORD ERROR=    0.1000E 01
[illegible] SIGNAL TO NOISE [illegible]=   -0.7264E 02
```

NOT REPRODUCIBLE

Figure 6.3-5 (Cont) DATA LINK ANALYSIS
OUTPUT FORMATS

6.4 UNATTENDED SENSOR DATA PROCESSING MODEL

6.4.1 Introduction

In present field operations, the time dependent activation patterns obtained from various types, combinations and deployments of unattended ground sensors (UGS) are displayed on monitors to operators who attempt to classify and identify them. They also attempt to derive additional characteristic information from those patterns that are judged to be enemy targets. The operator is closely attuned to the events that occur around him. He may possibly have a priori information of friendly or enemy troop movements, suspect areas, civilian activity, etc. In addition he will likely be in contact with higher levels of command via hardwire lines or radio. The operator will also be exposed to other activity in his area, (munition bursts, passage of aircraft, etc.). Many of these noise sources or events cause responses by emplaced sensors. These responses are observable as activation events on the monitor annunciator and display for an array of UGS which have been deployed.

The UGS are generally designed to provide activation events only when certain signal levels and logic requirements have been achieved at a sensor. Depending on the particular sensor design characteristics and environmental conditions, however, the activation reports may be due to targets, false targets or false alarms. Based on the patterns of sensor activations that an operator observes, certain information can be gleaned regarding the presence of a target and some estimates of its type, rate of movement, number of elements, heading, length etc., can be developed.

Sensors are activated in two basic ways: (1) by signals of the proper class from objects different from the steady state environment and (2) from noise. The activations received from objects which are enemy forces are categorized as true targets. Activations received from any other objects are categorized as false targets. Random excursions of noise which cause sensor activations are categorized as false alarms. Sources that cause sensor activations under the categorizations of true targets, false targets and false alarms are defined as follows:

True Targets	False Targets	False Alarms
Enemy MAV • M = men	• Own or friendly MAV	• Cultural phenomena
• A = activities	• Friendly or neutral populace	• Natural phenomena
• V = vehicles	• Insects and animals	• Battlefield noise
	• Friendly or enemy aircraft	• Electronic equipment

A principal objective of monitor operator decision making is to attempt to classify and identify the source of UGS activation signals. Classification of the source of the activations is defined as determining what the source is; that is, a target, or a nontarget. Identification is defined as determining who the classified source is; that is, an enemy, a friend, or a neutral. Targets are divided into true and false targets. Nontargets consist of false alarms. False alarms may be caused by cultural phenomena such as noise emanating from towns or villages, by natural phenomena that includes wind, rain, hail, lightning, thunder, running water, earth tremors, etc., by battlefield noise or by electrical interference from electronic equipment that cause pseudo activations to be displayed on monitors.

The Phase I System Assessment Model is a large computer simulation. An overview of this model is shown in Figure 6.4-1 in which the relationship of the UGS sensor data processing model to the remainder of the SAMI simulation is indicated.

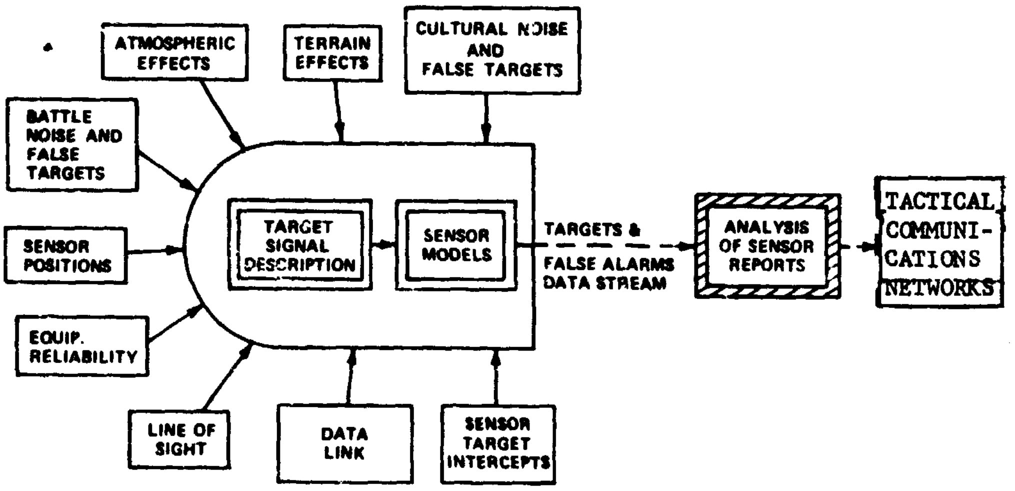


Figure 6.4-1 PHASE I SAM OVERVIEW

Enemy forces (Targets) are moved around a selected game play area in which their movement, paths and speeds are controlled by planner inputs. The target's signal at the source is selected to fit the target's description and attenuated over the sensor-to-target range in order to determine the target's signal at the sensor. Isolating this target signal-to-sensor problem from the rest of the complex situation for the moment, the problem is then to determine what information can be derived from the series of sensor activations that result from a target moving through the sensor's area of coverage.

One complication which occurs in analyzing the time histories of sensor activations is that not only real targets but other objects may cause the sensors to activate. In addition, random excursions of noise may also cause sensor activations. The SAM simulation identifies the other sources as battlefield, cultural, atmospheric, and terrain environment. The battle and culture subroutines create the battlefield and non-military activities that may cause the sensor to activate. These activations are entered into the game play as false targets and noise. The atmospheric and terrain subroutines create the natural environment, part of which includes wind, rain, vegetation, etc. which contribute to the noise and, therefore, to false alarm activations.

Other major functions that can affect the sensor activation time histories are:

1. Sensor position subroutines that emplace the sensor so that the commander's knowledge of the sensor's emplacement position is an estimate of its actual location.
2. Reliability subroutines that determine the time histories of the equipment that are functioning.
3. Line-of-sight subroutines that compute whether the line-of-sight between the sensor and target is masked by foliage or terrain features.
4. Data link subroutines that compute the sensor-to-monitor RF propagation losses and determine if the sensor activation reports can be received at the monitor.
5. Those subroutines that solve the geometry of game play and determine the locations of specified targets associated with specified sensor coverage areas.

The UGS Data Processing model performs an analysis of sensor reports utilizing target and false alarm data streams (sensor activation time histories) as prepared from MSM output (presently manually). The output of this model is then formated in terms of timeliness, accuracy and content of monitor reports. The content of a target report will vary depending on mission objectives and the types and combinations of UGS utilized. The target information derivable may vary from only detecting the presence of a target to the maximum amount of information as listed below.

1. Presence of enemy activity
2. Type
3. Direction of movement
4. Number of elements
5. Speed
6. Length

7. Estimated time of arrival (ETA) at some future position
8. Location
9. Time
10. False alarm filtering
11. False target filtering

The timeliness of the report is derivable from item 9 above. Accuracy of the report can also be summarized. For example, target estimated speed, number of elements, length, ETA at some future position location, etc., can be compared with ground truth information to determine errors and, therefore, accuracy of the report.

6.4.2 Model Description

An overview flow chart of the Unattended Sensor Data Processing model is shown in Figure 6.4-2. This program consists of 22 subroutines* which are listed as follows:

ANALMN (main program)
LILMSM
ANLYZE
RODRUM
CALLIT
INSPCT
ARRIVL
JSIETA
LOCATE
COUNTR
CRLATE
FSTARG
RESET
INOUT (block data)
MONLST (block data)
MCHART (block data)
NMOD
CNNECT
IDIST
ALPHA
RADIAN
SNAIDR

One data set is needed (SYSIN)

The UGS Data Processing model is presently a stand-alone program which utilizes a manually prepared sensor/monitor data stream output from the main simulation model (MSM). After first reading in the system configuration data cards and forming the necessary logical connections, the program initiates an analysis of sensor/monitor activation time histories. This program and its subroutines initially determine from the most recent activation time history of each sensor/monitor combination whether the frequency density of the activations indicates the presence of a target. If a target is indicated, the program initiates an analysis of the data to determine the duration of the sensor/monitor activation and the activation sequence start and stop times. For the tactical situation in which any pair of UGS are emplaced along a trail and connected to the same monitor(s), the durations of the activation sequences occurring on each sensor, the start and stop times of these activations and the commander's estimate of the separation distances between the sensors are utilized to estimate the speed and length of the target. Knowing the values of these target parameters, additional computations are then performed to determine the estimated times of arrival of the target at preselected firetrap kill points along the trail. Following this, other target information, as was listed previously, is then determined in a similar manner depending on the types of sensors being utilized and the nature of their tactical deployment.

---

*The main program ANALMN is an additional Executive routine that is utilized to call the Unattended Sensor Data Processing Model.

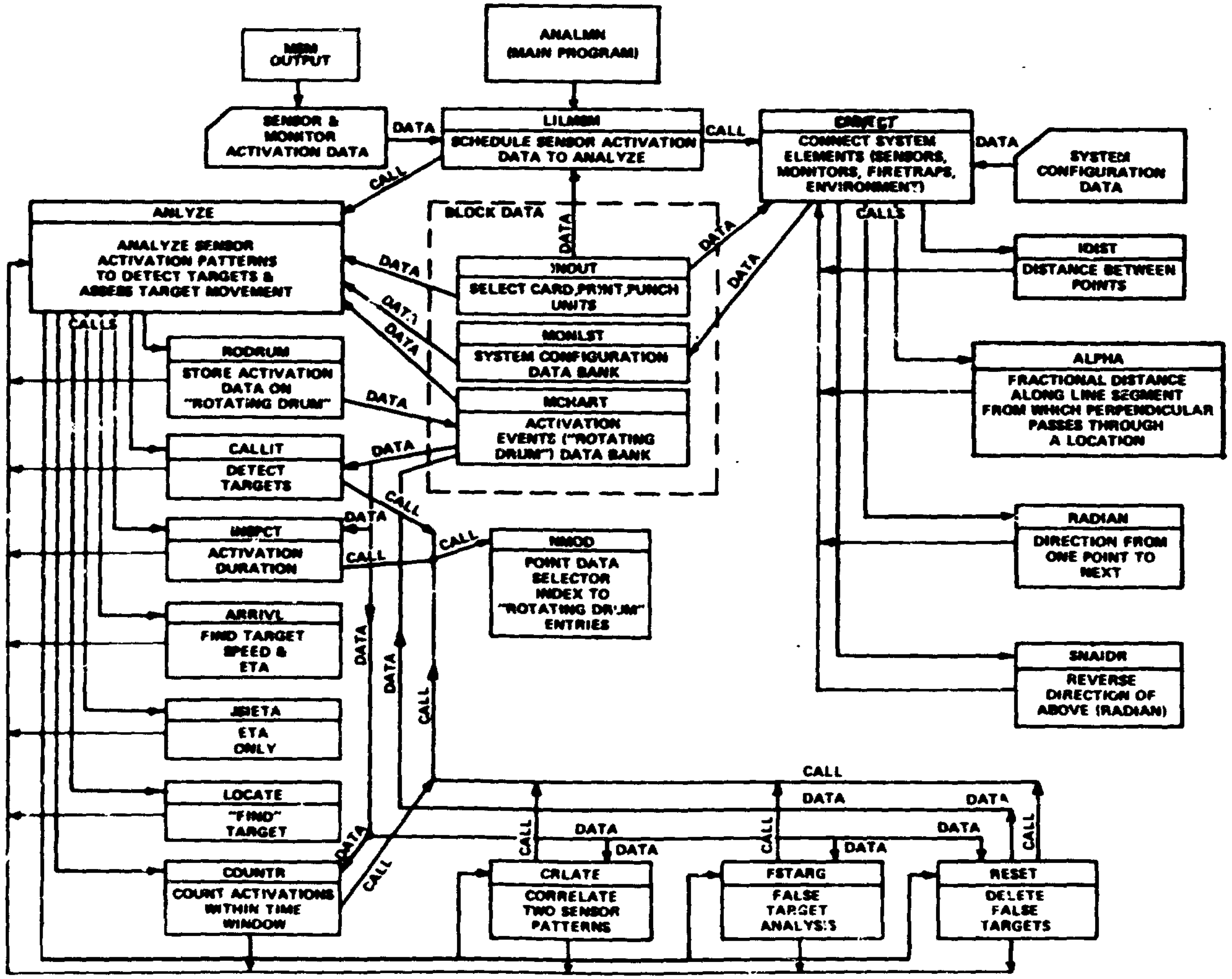


Figure 6.4-2 OVERVIEW FLOW CHART OF UGS DATA PROCESSING MODEL

It is important to note that the activation time history of each sensor/monitor combination must be inserted into the program in an ascending time sequence. If a sensor/monitor activation time history has one or more data cards that are placed out of order in the deck, the program will get out of step internally and erroneous outputs will result. Subroutine CNNECT is presently programmed to set up the entire system structure by computation from card input data. This subroutine may be changed to by-pass some of the computations if the data cards already contain the data that is computed. In addition, subroutine CNNECT and its related subroutines may be substituted by a corresponding set of subroutines if the data supplied by it is already in storage as a result of previous computations.

A description of each of the 21 (excluding the executive, ANALMN) subroutines that comprise the model as presently formulated is presented below together with a flow diagram of each subroutine. Together these describe their purpose, method and useage.

6.4.2.1 LILMSM Subroutine

Since the UGS Data Processing model is a stand-alone program, Subroutine LILMSM is required to accept time-phased sensor/monitor activation data streams summarized on data input cards and to schedule the sensor activation data for analysis by subroutine ANLYZE. It calls subroutine CNNECT in order to link up required system elements for each particular application and subroutine ANLYZE to perform the analysis of the event oriented activation data. Block data is supplied through subroutines INOUT, MONLST, and MCHART. Subroutine LILMSM plus the sensor/monitor activation data input cards takes the place of a direct connection to the MSM. However, LILMSM may be replaced by MSM in the future if on-line operation is desired. A flow diagram of subroutine LILMSM is shown in Figure 6.4-3. The block data subroutines which supply information to subroutines LILMSM, ANLYZE, CNNECT and CALLIT are next described.

6.4.2.2 Block Data Subprograms

6.4.2.2.1 INOUT

The purpose of subprogram INOUT is to define the input-output units. The card reader, printer and output card punch are designated Numbers 5, 6 and 7 respectively. The user may redefine these input-output units if desired by changing the numbers assigned to ICARD, IPRINT and IPUNCH in the data statement of the INOUT block data subprogram. The information supplied by this subroutine is utilized by LILMSM, ANLYZE and CNNECT subroutines. A diagram of computer subprogram INOUT is shown in Figure 6.4-4.

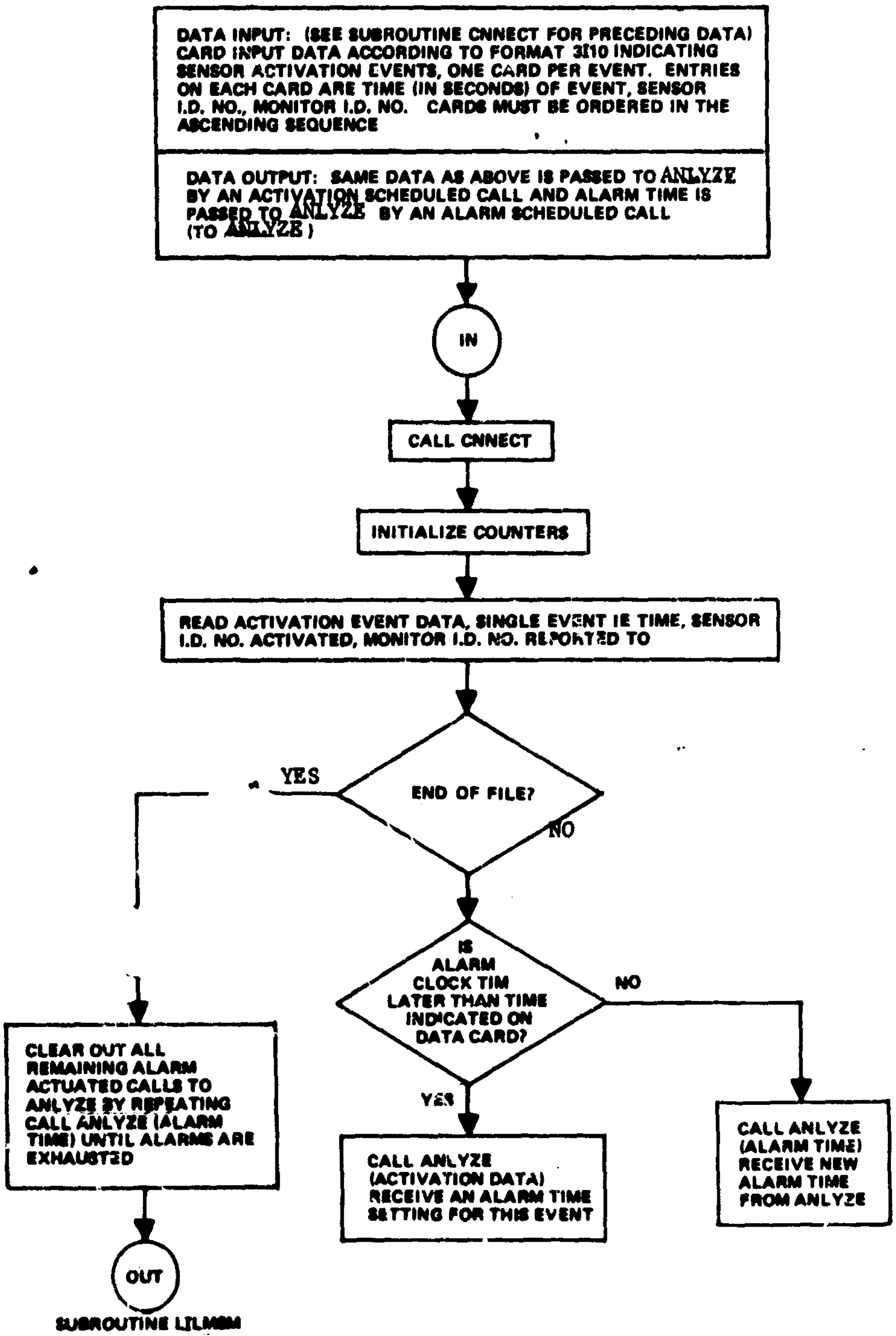
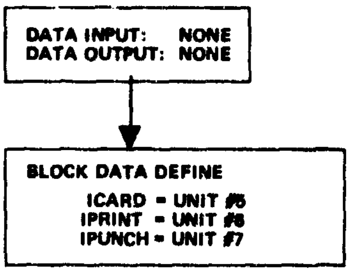


Figure 6.4-3 SUBROUTINE-LILMSM MACROFLOW



BLOCK DATA SUBPROGRAM INOUT

PURPOSE: TO DEFINE INPUT-OUTPUT UNITS NUMBER 5 AS THE CARD READER, NUMBER 6 AS THE PRINTER, AND NUMBER 7 AS THE OUTPUT CARD PUNCH

Figure 6.4-4 SUBPROGRAM INOUT MACROFLOW

6.4.2.2.2 MONLST

The Block Data subprogram MONLST contains output data generated by subroutine CNNECT for use by subroutine ANLYZE. Included in this storage are master lists of the activation sequence start and stop times (JMSTRT, JMSTOP) associated with the ID number of each sensor (J)-monitor (M) combination. Also stored are system configuration data and other computed outputs from subroutine CNNECT when it utilizes subroutine IDIST, ALPHA, RADIAN and SNAIDR. The structure of the block data is shown in Figure 6.4-5.

6.4.2.2.3 MCHART

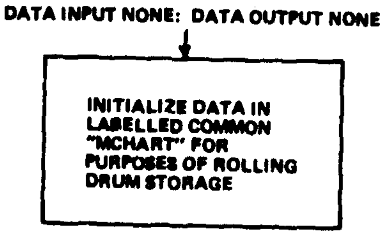
Computer block data subprogram MCHART initializes a common area labeled "MCHART" which sets the master event counter and time slot entry in the computer to zero and establishes the dimension of the simulated "rolling drum" (events recording storage area) at 2000 event entries. Subprogram MCHART is closely associated with Computer subroutine RODRUM from which it obtains activation data for common data area storage (data blank). This data is made available to all target data evaluation subroutines through subroutine ANLYZE. A diagram of computer subprogram MCHART is shown in Figure 6.4-6. Since MCHART is closely related to subroutine RODRUM, it is also shown on the flow diagram for RODRUM later on.

6.4.2.3 CNNECT Subroutine

The purpose of subroutine CNNECT is to make a sensor-to-monitor connection list. Each sensor array is identified with a sensor field. In turn, each sensor is identified within an assigned sensor array, the monitor or monitors to which it reports and the Commander's estimate of each sensors position coordinates. Those sensors that are co-located pairs (primary + auxiliary) are also identified together with the reporting sequence of each sensor. This subroutine also established the physical relationships between the sensor locations and the geometry of the geographic configuration (e.g., a trail) under the surveillance of the sensors belonging to a given monitor or monitors. This data is called by subroutine LILMSM for utilization in subroutine ANLYZE to predict target movement, arrival at firetrap kill points and other items that make up the target reports which have been previously discussed. Referring again to Figure 6.4-2, data cards are utilized to input required system configuration information to subroutine CNNECT. In performing its functions subroutine CNNECT also calls supporting subroutines IDIST, ALPHA, RADIAN and SNAIDR as required to supply additional computed data. These supporting subroutines are described below. A flow diagram of subroutine CNNECT is shown in Figure 6.4-7.

```
.....MONLST
     BLOCK DATA
...........................................................................................
   A BLOCK DATA SUBPROGRAM TO INITIALIZE THE VALUES OF COMMON
        PARAMETERS USED IN SUBROUTINES CNNECT AND ANLYZE
...........................................................................................
     DATA RETURNED FROM SUBROUTINE
        NONE
     DATA REQUIRED BY SUBROUTINE
        NONE
     DEFINITIONS
        IN VIEW OF THE NUMBER OF VARIABLES ONLY SOME BASIC DEFINITIONS
        ARE PROVIDED
        JX,JY,JS,JOFFST=X-,Y-,S-,OFFSET-COORDINATES OF THE SENSORS
        AN S-COORDINATE IS THE CUMULATIVE DISTANCE ALONG A GIVEN
        TRAIL OF THE SENSOR,ETC.,FROM SOME REFERENCE POINT ON THE
        TRAIL,USUALLY THE FIRST NODE ON THAT TRAIL. OFFSET OF A SENSOR
        IS WITH RESPECT TO THE NEAREST POINT ON THE TRAIL
        IBPX,IBPY,IBPS=X-,Y-,S-COORDINATES OF THE NODES OF A TRAIL
        KXTRAP,KYTRAP,KSTRAP=X-,Y-,S-COORDINATES OF FIRETRAPS ON THE
        TRAIL
...........................................................................................
     LOGICAL BGINNG
     COMMON/MONLST/BGINNG,ICNFIG(100),ISTIME(100),JMSTRT(100),
   .    JMSTOP(100),JLIST(1500),JX(500),JY(500),JTYPE(500),JARRAY(500),
   .    JMONTS(500),JMONTR(5,500),JS(500,5),JOFFST(500,5),
   .    IBPA(100),IBPB(100),IDNODE(1000),IBPX(1000),IBPY(1000),
   .    IBPS(1000),NTRAIL(1000),DFRWRD(1000),DBKWRD(1000),
   .    KTRAPA(100),KTRAPB(100),IDTRAP(500),KXTRAP(500),KYTRAP(500),
   .    KSTRAP(500),KTRAIL(500),KTYPE(500),
   .    DREFS(10,10),BUFFER
     DATA BGINNG/.TRUE./,ICNFIG/100*0/,ISTIME/100*-9999999/,
   .    JMSTRT/100*0/,JMSTOP/100*0/,JLIST/1500*0/,JX/500*0/,JY/500*0/,
   .    JTYPE/500*0/,JARRAY/500*0/,JMONTS/500*0/,JMONTR/2500*0/,
   .    JS/2500*0/,JOFFST/2500*0/,IBPA/100*0/,IBPB/100*0/,
   .    IDNODE/1000*0/,IBPX/1000*0/,IBPY/1000*0/,IBPS/1000*0/,
   .    NTRAIL/1000*0,KTRAPA/100*0/,KTRAPB/100*0/,IDTRAP/500*0/,
   .    KXTRAP/500*0/,KYTRAP/100*0/,KSTRAP/500*0/,KTRAIL/500*0/,
   .    KTYPE/500*0/,DREFS/100*0.01/,BUFFER/4HBUFR/
     END
```

Figure 6.4-5 Block data stored in subprogram MONLST



DATA SUBPROGRAM FOR COMMON/MCHART/

PURPOSE: TO INITIALIZE COMMON AREA LABELLED "MCHART". IT SETS MASTER EVENT COUNTER TO 0, SLOT ENTRY TO 0, AND ESTABLISHES DIMENSION OF "DRUM" AT 2000 EVENT ENTRIES.

Figure 6.4-6 SUBPROGRAM MCHART (DATA INITIALIZATION) MACROFLOW

DATA INPUT: (VIA DATA CARDS, 8I10 FORMAT OR 10F82 FORMAT, AS APPLICABLE)

(A) NUMBER OF MONITORS

FOR FIRST MONITOR:

(B) NUMBER OF SENSORS, NUMBER OF FIRETRAPS, NUMBER OF GEOGRAPHIC NODES, CONFIGURATION TYPE NUMBER

(C) SENSOR I.D. NO., TYPE NO., X-COORDINATE, Y-COORDINATE, S-COORDINATE, OFFSET ARRAY NO.
REPEAT, ONE CARD PER SENSOR

(D) FIRETRAP I.D. NO., FIRETRAP TYPE NO., X-COORDINATE, Y-COORDINATE, S-COORDINATE, TRAIL NO.
REPEAT, ONE CARD PER FIRETRAP

(E) GEOGRAPHIC NODE I.D. NO., X-COORDINATE, Y-COORDINATE, S-COORDINATE, TRAIL NO.
REPEAT, ONE CARD PER NODE
(NOTE: NODES REFER TO NODES IN TRAILS IN THIS PROGRAM)

REPEAT STEPS (B) TO (E) FOR SECOND MONITOR
REPEAT STEPS (B) TO (E) FOR THIRD MONITOR
REPEAT STEPS (B) TO (E) FOR FOURTH MONITOR
ETC.
NOTE: ALL ABOVE ENTRIES ARE INTEGER DATA

(F) 10 BLANK CARDS OR 10 CARDS, 10 ENTRIES EACH (FLOATING POINT) INDICATING DETECTION THRESHOLD VALUES (THESE ARE NOT USED AT PRESENT BUT MAY BE IMPLEMENTED IN FUTURE PROGRAMMING TO ENTER TARGET DETECTION THRESHOLDS IN IMPULSES PER SECOND OF SENSOR TYPE (I) IN OPERATING ENVIRONMENT (J) WHERE I REFERS TO CARD AND J IS THE ENTRY NUMBER IN EACH CARD)

DATA OUTPUT: STORAGE & ARRANGEMENT OF DATA IN COMMON AREA MONLST INDICATING MONITOR-SENSOR-FIRETRAP GEOGRAPHIC SURVEILLANCE AREA HOOKUP

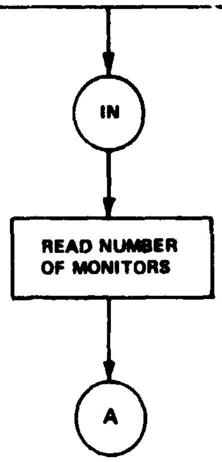


Figure 6.4-7 SUBROUTINE-CNNECT MACROFLOW
(Sheet 1 of 3)

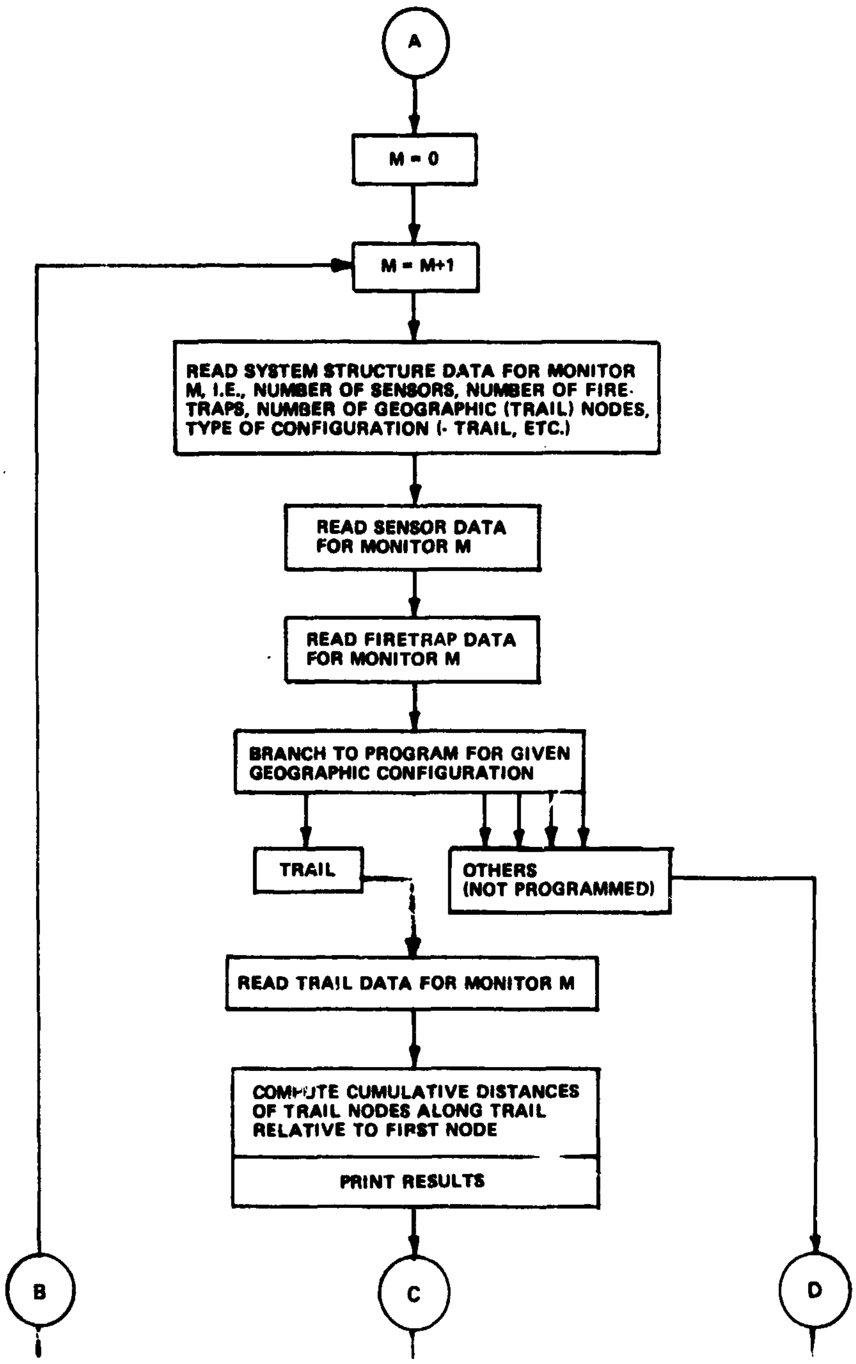
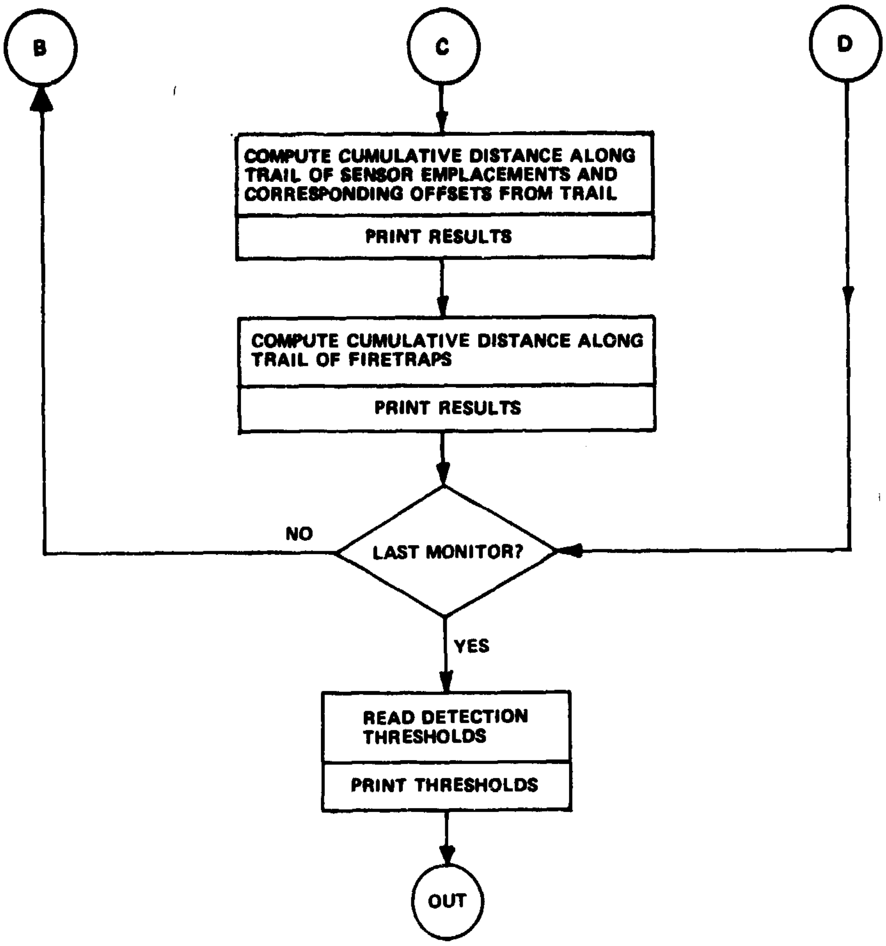


Figure 6.4-7 SUBROUTINE-CNNECT MACROFLOW
(Sheet 2 of 3)



PURPOSE: TO READ & COMPUTE DATA DESCRIBING THE STRUCTURE OF THE SURVEILLANCE SYSTEM

Figure 6.4-7 SUBROUTINE-CNNECT MACROFLOW
(Sheet 3 of 3)

6.4.2.3.1 IDIST Subroutine

When called by subroutine CNNECT subroutine IDIST provides an analytical routine for computing the straightline distance between two locations x_1, y_1, and x_2, y_2, along a trail. The output of this subroutine is the rounded distance between any two points whose x, y coordinates are given in integer value. A flow diagram of subroutine IDIST is shown in Figure 6.4-8.

6.4.2.3.2 ALPHA Subroutine

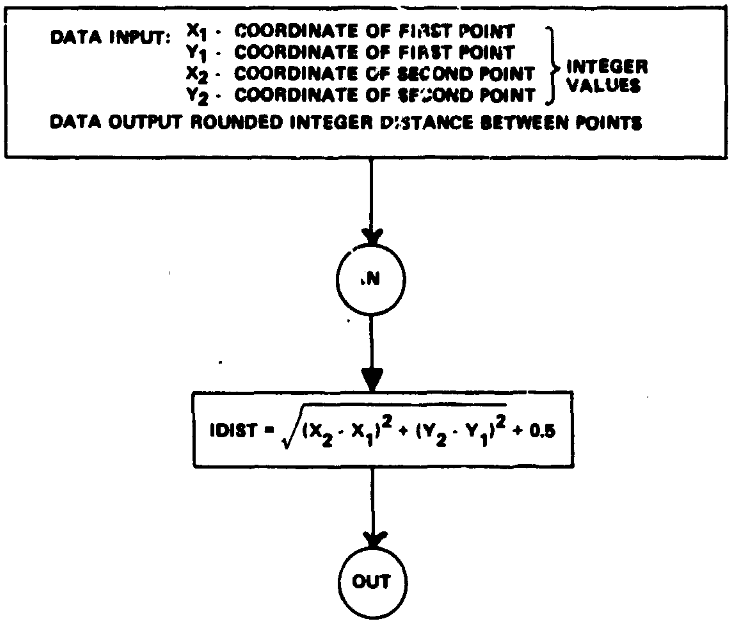
When called by subroutine CNNECT subroutine ALPHA determines the emplacement location of a sensor with respect to the breakpoints (BP1 and BP2) of a straight line segment of a trail. The subroutine determines whether the sensor location is either outside of BP1 or BP2 or between BP1 and BP2. If the sensor is located somewhere between BP1 and BP2, the distance from BP1 to the sensor is determined as measured along the straight line segment. The routine determines the fractional distance along a line segment at which a perpendicular drawn from an arbitrary point with respect to this straight-line segment intersects it. If $0 \leq \text{ALPHA} \leq 1$, the intersection is internal to the line segment. If $\text{ALPHA} < 0$, the intersection is external at the first end of the line segment. If $\text{ALPHA} > 1$, the intersection is external to the second end of the line segment. A flow diagram of subroutine ALPHA is shown in Figure 6.4-9.

6.4.2.3.3 RADIAN Subroutine

When called by subroutine CNNECT subroutine RADIAN provides an analytical routine for computing the heading of a target in radians measured in a clockwise direction with the zero starting point corresponding to 90° (compass reading). These headings are subsequently translated into mils as measured clockwise from true north by this computer subroutine. The subroutine computes the mathematical direction (y/x) in radians that the target is heading from one point to the next when their coordinates are given in integer values. A flow diagram of subroutine RADIAN is shown in Figure 6.4-10.

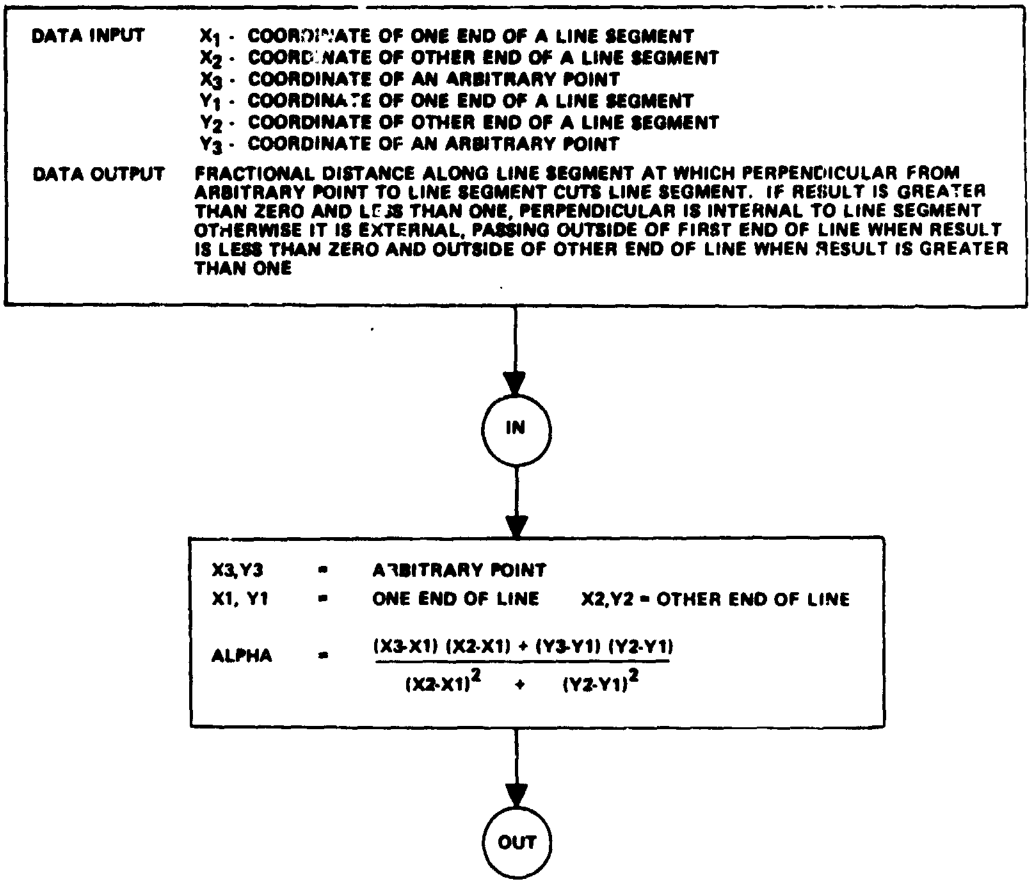
6.4.2.3.4 SNAIDR Subroutine

When called by subroutine CNNECT subroutine SNAIDR determines the reverse directional heading of a target going from position coordinates x_2, y_2 to x_1, y_1 as compared to the forward directional heading of a target going from x_1, y_1 to x_2, y_2 as computed by subroutine RADIAN. The data input to subroutine SNAIDR is the forward heading in radians provided by subroutine RADIAN through subroutine CNNECT. The data output of subroutine SNAIDR is the reverse direction of the forward heading in radians. The heading is measured in a clockwise direction with the starting point corresponding to 90° compass reading. These headings are subsequently translated into mils as measured clockwise from true north by this computer subroutine. A flow diagram of subroutine SNAIDR is shown in Figure 6.4-11.



PURPOSE: TO FIND ROUNDED DISTANCE BETWEEN POINTS WHOSE X-Y COORDINATES ARE GIVEN IN INTEGER VALUES

Figure 6.4-8 SUBROUTINE IDIST MACROFLOW



DATA INPUT

X_1 - COORDINATE OF ONE END OF A LINE SEGMENT
X_2 - COORDINATE OF OTHER END OF A LINE SEGMENT
X_3 - COORDINATE OF AN ARBITRARY POINT
Y_1 - COORDINATE OF ONE END OF A LINE SEGMENT
Y_2 - COORDINATE OF OTHER END OF A LINE SEGMENT
Y_3 - COORDINATE OF AN ARBITRARY POINT

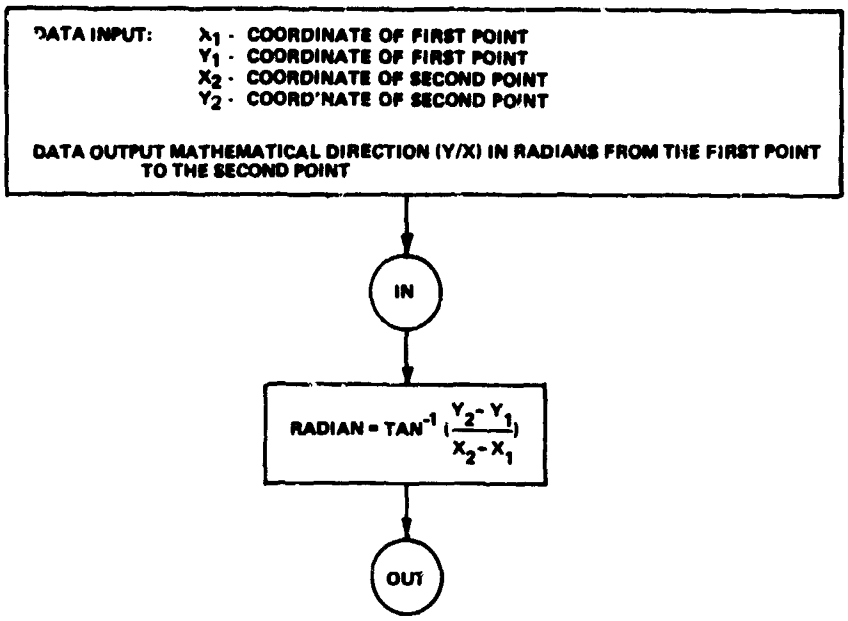
DATA OUTPUT FRACTIONAL DISTANCE ALONG LINE SEGMENT AT WHICH PERPENDICULAR FROM ARBITRARY POINT TO LINE SEGMENT CUTS LINE SEGMENT. IF RESULT IS GREATER THAN ZERO AND LESS THAN ONE, PERPENDICULAR IS INTERNAL TO LINE SEGMENT OTHERWISE IT IS EXTERNAL, PASSING OUTSIDE OF FIRST END OF LINE WHEN RESULT IS LESS THAN ZERO AND OUTSIDE OF OTHER END OF LINE WHEN RESULT IS GREATER THAN ONE

X3,Y3 = ARBITRARY POINT
X1, Y1 = ONE END OF LINE X2,Y2 = OTHER END OF LINE

$$\text{ALPHA} = \frac{(X3-X1)\,(X2-X1) + (Y3-Y1)\,(Y2-Y1)}{(X2-X1)^2 + (Y2-Y1)^2}$$

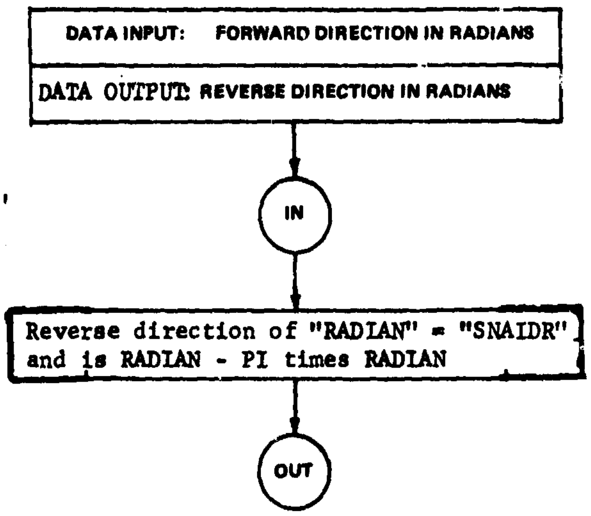
PURPOSE TO FIND FRACTIONAL DISTANCE ALONG A LINE SEGMENT AT WHICH A PERPENDICULAR FROM AN ARBITRARY POINT TO THIS LINE INTERSECTS THE LINE SEGMENT. IF $0 \leq$ ALPHA ≤ 1 INTERSECTION IS INTERNAL TO LINE. IF ALPHA < 0, INTERSECTION IS EXTERNAL OF FIRST END OF SEGMENT, IF ALPHA > 1, INTERSECTION IS EXTERNAL OF SECOND END OF LINE SEGMENT.

Figure 6.4-9 SUBROUTINE ALPHA MACROFLOW



PURPOSE TO FIND THE MATHEMATICAL DIRECTION (Y/X) IN RADIANS FROM ONE POINT TO THE NEXT WHEN THEIR COORDINATES ARE GIVEN IN INTEGER VALUES.

Figure 6.4-10 SUBROUTINE RADIAN MACROFLOW



PURPOSE: TO FIND REVERSE DIRECTION IN RADIANS OF A GIVEN FORWARD DIRECTION GIVEN IN RADIANS

Figure 6.4-11 SUBROUTINE SNAIDR MACROFLOW

6.4.2.4 ANLYZE Subroutine

Presently, the UGS activation data streams are outputed from the MSM on tapes. This activation data is subsequently transferred to input data cards on a time-ordered and event-oriented basis and inputed to subroutine LILMSM as indicated previously in Figure 6.4-2. When called by subroutine LILMSM, subroutine ANLYZE provides an executive program for determining the timeliness, accuracy and content of target reports. In order to accomplish this function, subroutine ANLYZE must receive various information on system configurations and characteristics from computer block data subprogram MONLST. When called by subroutine LILMSM, this data is supplied to MONLST through subroutine CNNECT and the subroutines IDIST, ALPHA, RADIAN and SNAIDR which it controls. Subroutine ANLYZE also receives data from computer block data subprograms INOUT and MCHART. Subprogram MCHART supplies UGS activationevents data to subroutine ANLYZE utilizing UGS activation data stored on a "rotating drum" which is controlled by subroutine RODRUM and its executive subroutine ANLYZE.

Executive subroutines ANLYZE also calls on subroutine RODRUM, CALLIT, INSPCT, ARRIVL, JSIETA, LOCATE, COUNTR, CRLATE, FSTARG and RESET as required to analyze the UGS activation data and other information that are made available to them. In turn these subroutines supply outputs to ANLYZE that are utilized in formulating target reports. Target reports can include the time that a target report is generated, target type, length, velocity, heading, ETA at "firetrap kill" points, number of elements, accuracies in target length, velocity and position etc., as discussed previously. A flow diagram of subroutine ANLYZE is shown in Figure 6.4-12. Those computer subroutines that are called and controlled by executive subroutine ANLYZE are described next.

6.4.2.4.1 RODRUM Subroutine

When called by executive subroutine ANLYZE, subroutine RODRUM stores activation events (detections and false alarm) data streams from each sensor that are generated by the various sensor performance models during game play. These events are associated with each respective sensor/monitor (identification number) and times of occurrence in game play. They are stored in a "simulated rolling drum" (events record storage area) in the computer for use in subsequent analyses by the various other data processing subroutines. These data are supplied to block data subprogram MCHART for this purpose. A flow diagram of computer subroutine RODRUM is shown in Figure 6.4-13. A conceptual diagram of the simulated "rolling drum" storage area (indicated in Figure 6.4-13 is shown in Figure 6.4-14. An illustrative example of the "rolling drum" in the storage of activation event times as associated with UGS/monitor identification (I.D.) numbers and useage for subroutine INSPCT is depicted.

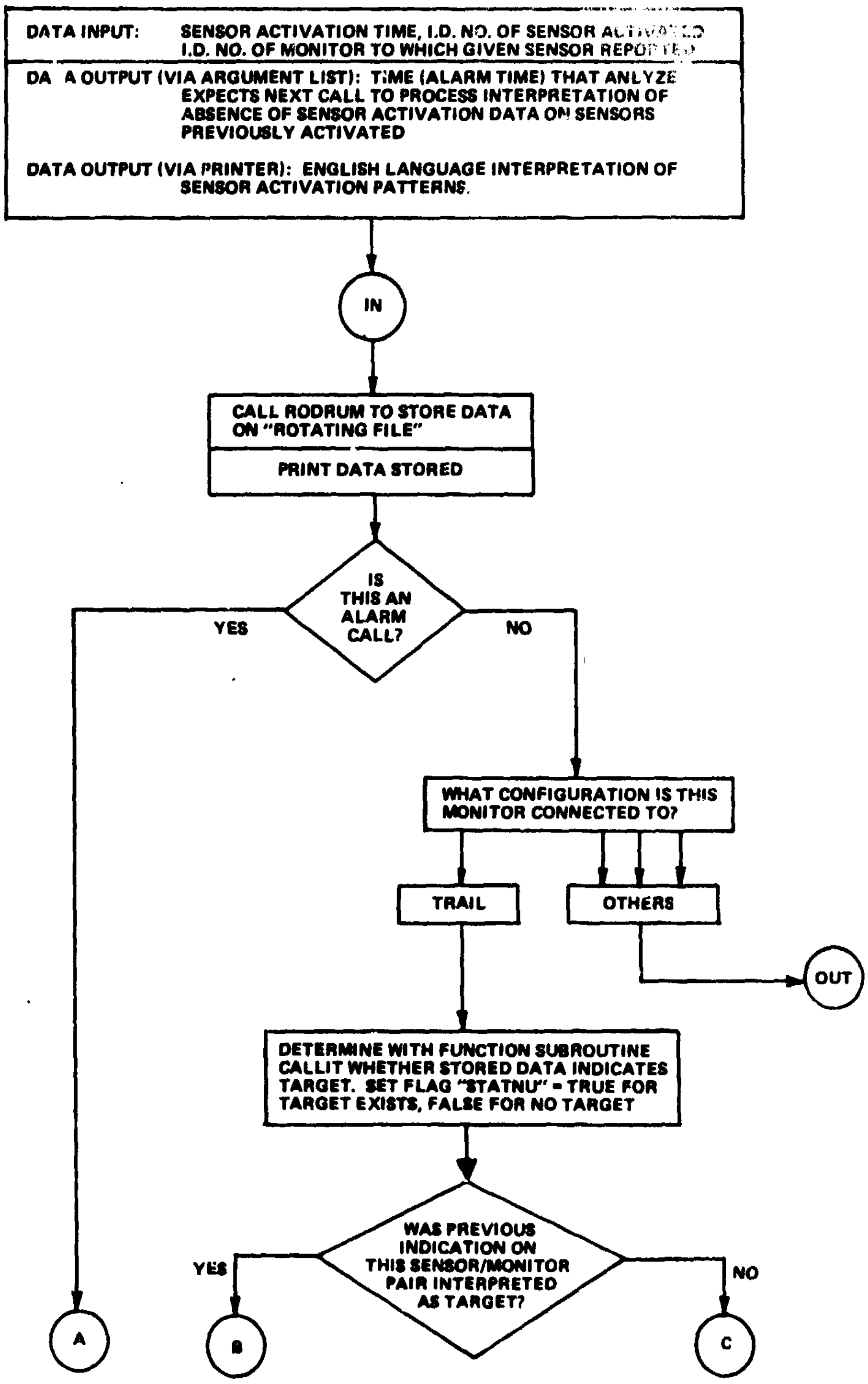


Figure 6.4-12 SUBROUTINE ANLYZE MACROFLOW
(Sheet 1 of 4)

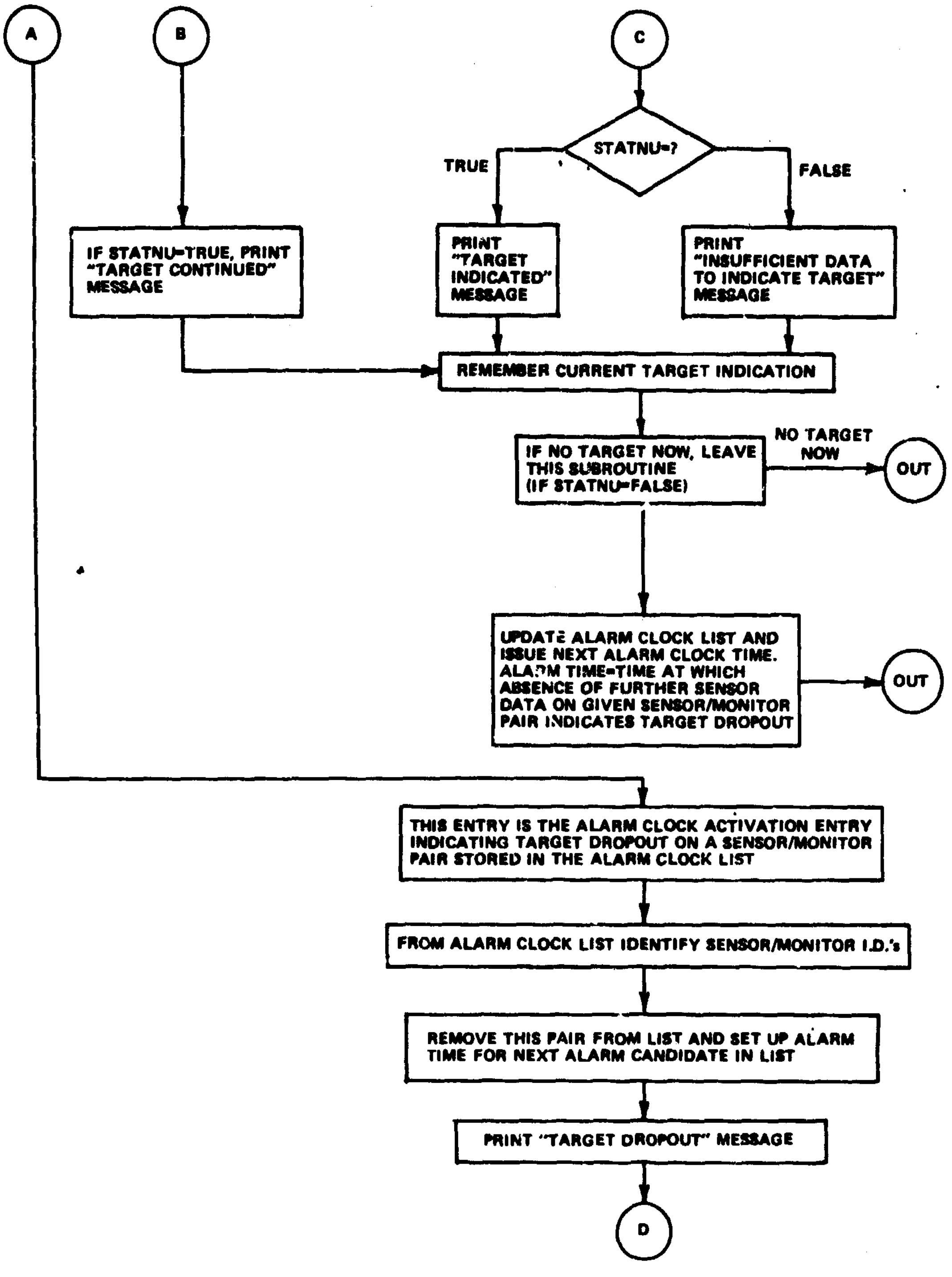


Figure 6.4-12 SUBROUTINE ANLYZE MACROFLOW
(Sheet 2 of 4)

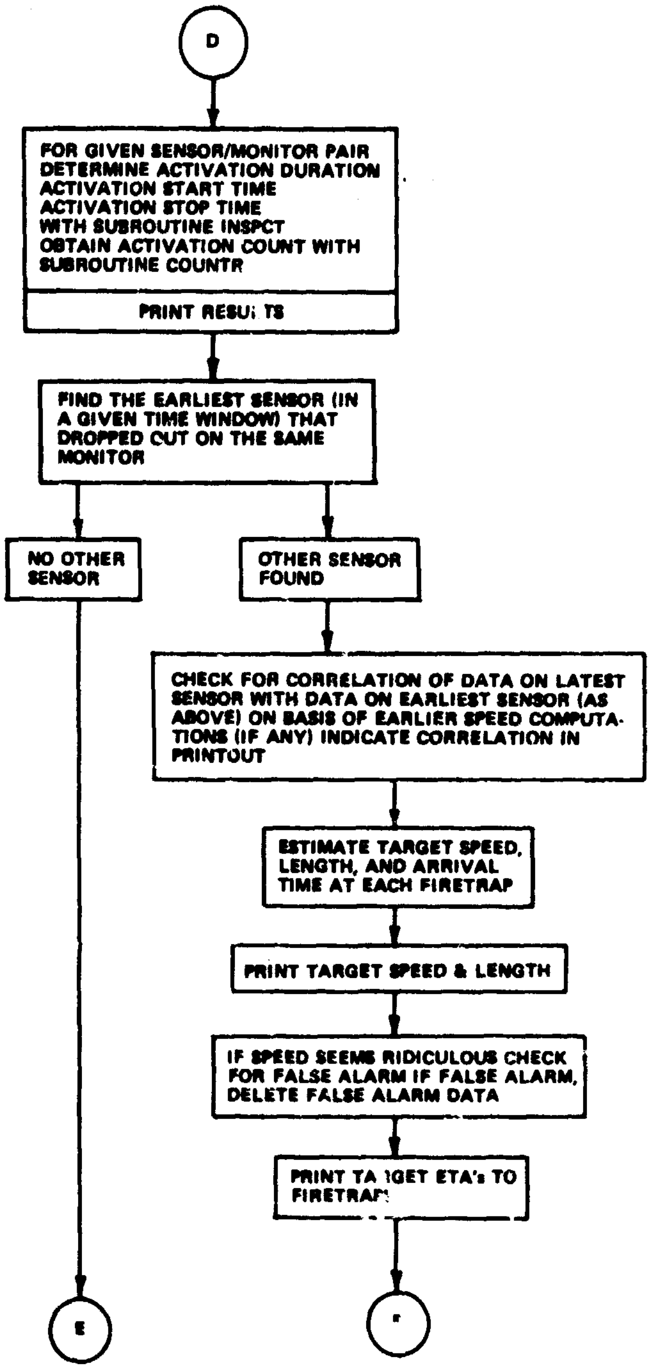
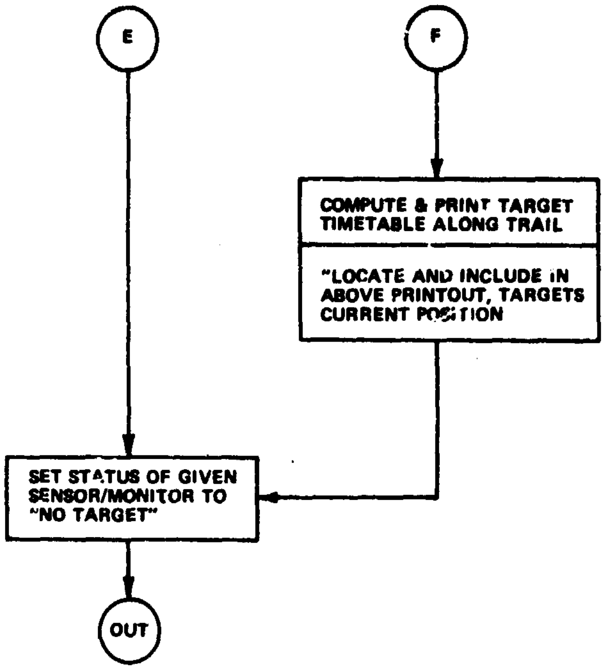


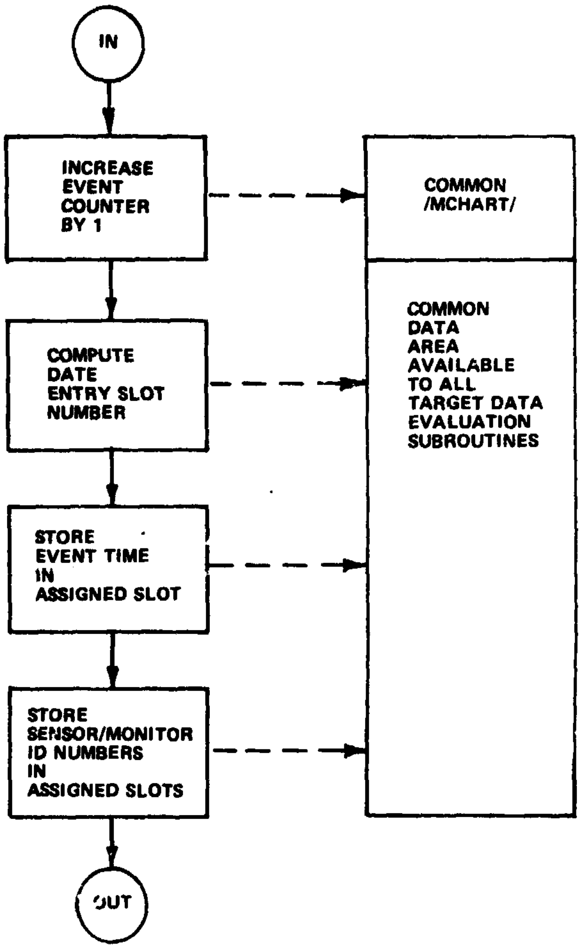
Figure 6.4-12 SUBROUTINE ANLYZE MACROFLOW
(Sheet 3 of 4)



PURPOSE: TO RENDER AN ENGLISH LANGUAGE INTERPRETATION OF SENSOR/MONITOR ACTIVATION TIME HISTORIES

Figure 6.4-12 SUBROUTINE ANLYZE MACROFLOW
(Sheet 4 of 4)

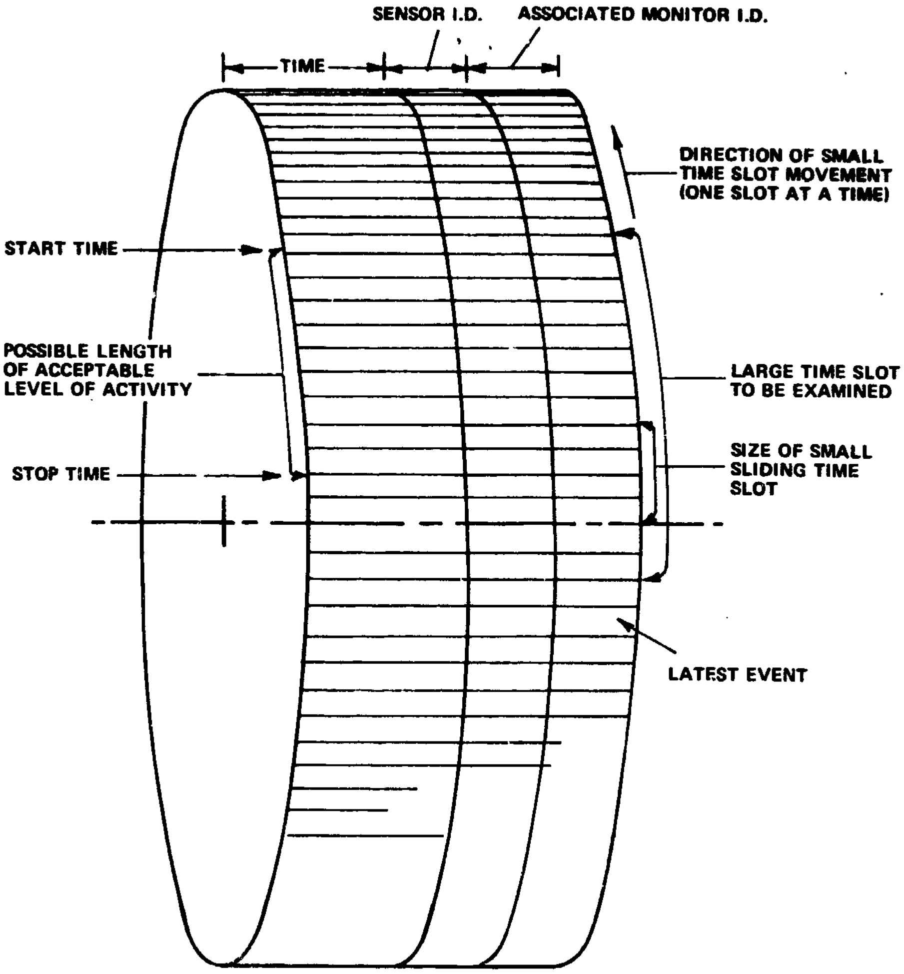
DATA INPUT = TIME, SENSOR/MONITOR ACTIVATED; DATA OUTPUT (NONE)



PURPOSE: TO STORE A SENSOR/MONITOR ACTIVATION EVENT GENERATED BY THE MAIN SIMULATION MODEL.

DATA STORED IS TIME AND SENSOR/MONITOR ID NUMBER (ITIME, JSENSR, MMONTR) INTO A SIMULATED "ROLLING DRUM" STORAGE AREA

Figure 6.4-13 SUBROUTINE - RODRUM MACROFLOW



NOTE: AN ILLUSTRATION OF THE BEHAVIOR OF INSPCT SUBROUTINE IS SHOWN

Figure 6.4-14 DIAGRAM OF ROTATING FILE EVENT RECORD

6.4.2.4.2 CALLIT Subroutine

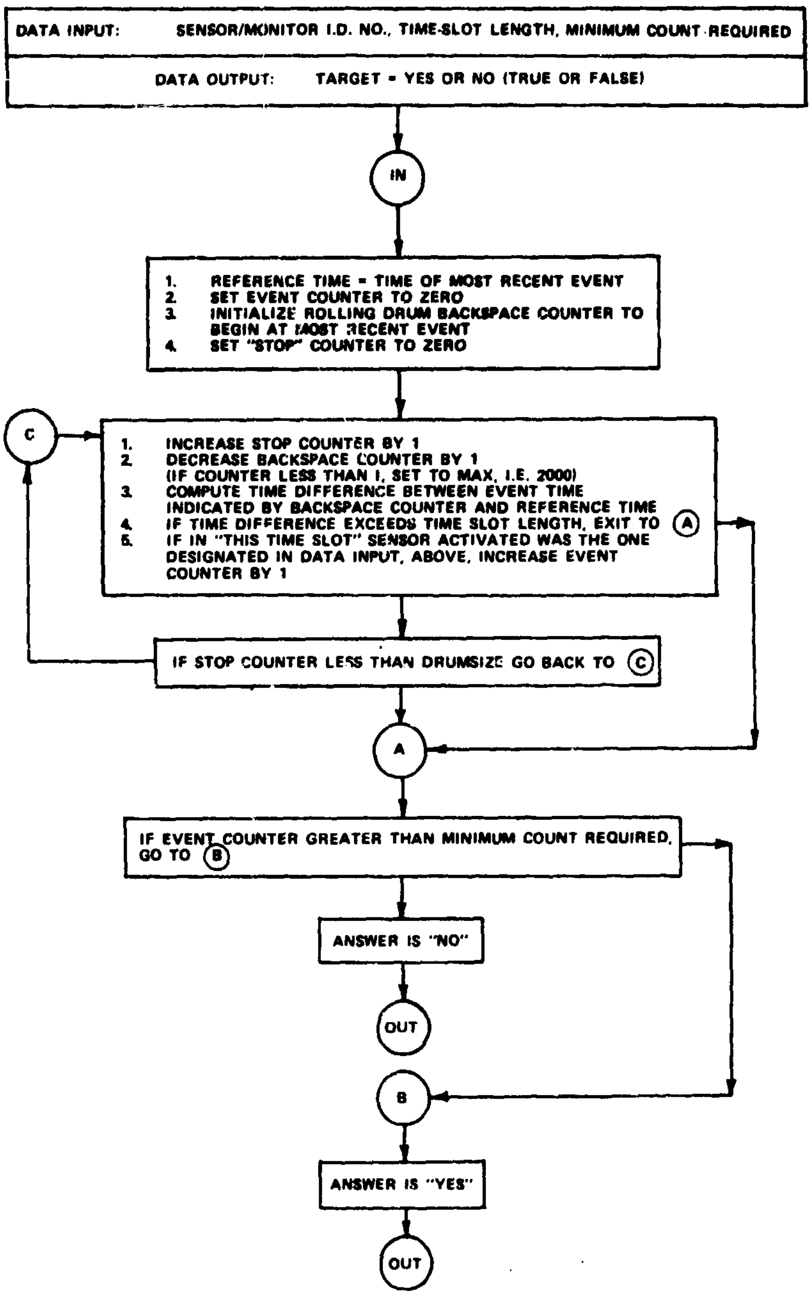
When called by executive subroutine ANLYZE, the purpose of subroutine CALLIT is to determine from stored RODRUM data whether or not a target is indicated on each respective sensor/monitor combination based on the minimum number of activation events falling within fixed time slots. The stored data is obtained from block data subprogram MCHART which is fed by subroutine RODRUM. The required minimum number of activations and the length of the time slot are designated based on decision rules that are planner inputs and therefore, can be varied accordingly. Subroutine CALLIT calls computer function subroutine NMOD as shown previously in Figure 6.4-2, for the purpose of resetting an arbitrary index number to point to the corresponding data in the simulated rolling drum storage of sensor/monitor activation data. A flow diagram of computer subroutine CALLIT is shown in Figure 6.4-15. Since computer function subroutine NMOD has been mentioned above for the first time, it is described next.

6.4.2.4.3 NMOD Subroutine

Subroutine NMOD provides a utility function utilized for restricting search range to the capability of the simulated "rotating drum" in RODRUM and for all of the subroutines which utilize RODRUM. A major purpose is to reset an arbitrary index number to point to the corresponding data in the "rolling drum" storage of sensor/monitor activation data. In addition to subroutine CALLIT, subroutine NMOD is called for use by INSPCT, COUNTR, CRLATE, FSTARG and RESET. A flow diagram of computer function subroutine NMOD is shown in Figure 6.4-16.

6.4.2.4.4 INSPCT Subroutine

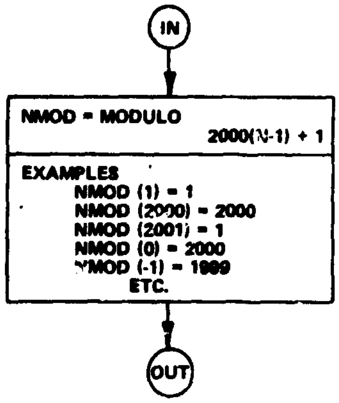
When called by executive subroutine ANLYZE, subroutine INSPCT is used in conjunction with subroutine CALLIT. A past search of relatively long time space on RODRUM is conducted with a sliding time slot of specified length to find the duration (time length), initiation times and stop times of continuous collections of events on respective sensors where the frequency of occurrence equals or exceeds a specified input density (threshold) value based on a specified decision rule. If the threshold density is equaled or exceeded, the subroutine returns start and stop times of continuous activations and the duration of continuous activations which satisfy required density criteria. The subroutine is flexible in that the planner can change the input values (DENREF) of the decision rule to suit his needs. A flow diagram of the computer subroutine INSPCT is shown in Figure 6.4-17.



PURPOSE: A LOGICAL FUNCTION SUBROUTINE TO EVALUATE WHETHER AN EVENT COUNT LEVEL (MINCAL) HAS BEEN EQUALED OR EXCEEDED BY A SENSOR/MONITOR WHOSE I.D. NO. IS (J/M), IN THAT TIME SLOT (ITSLOT) THAT PRECEDES AND INCLUDES THE MOST RECENT EVENT (REGARDLESS OF WHICH SENSOR/MONITOR WAS ACTIVATED MOST RECENTLY.)

Figure 6.4-15 SUBROUTINE - CALLIT MACROFLOW

DATA INPUT:	A NUMBER REPRESENTING A DESIRED RELATIVE ENTRY POINT IN THE SENSOR/MONITOR ACTIVATION DATA BANK
DATA OUTPUT:	ABOVE NUMBER CONVERTED TO LIE IN RANGE 1-2000



PURPOSE: TO RESET AN AR[illegible]RY INDEX NUMBER
TO POINT TO TH[illegible]RESPONDING DATA
IN THE "ROLLIN[illegible]" STORAGE OF
SENSOR/MONITO[illegible]VATION DATA

Figure 6.4-16 SUBROUTINE NMOD MACROFLOW

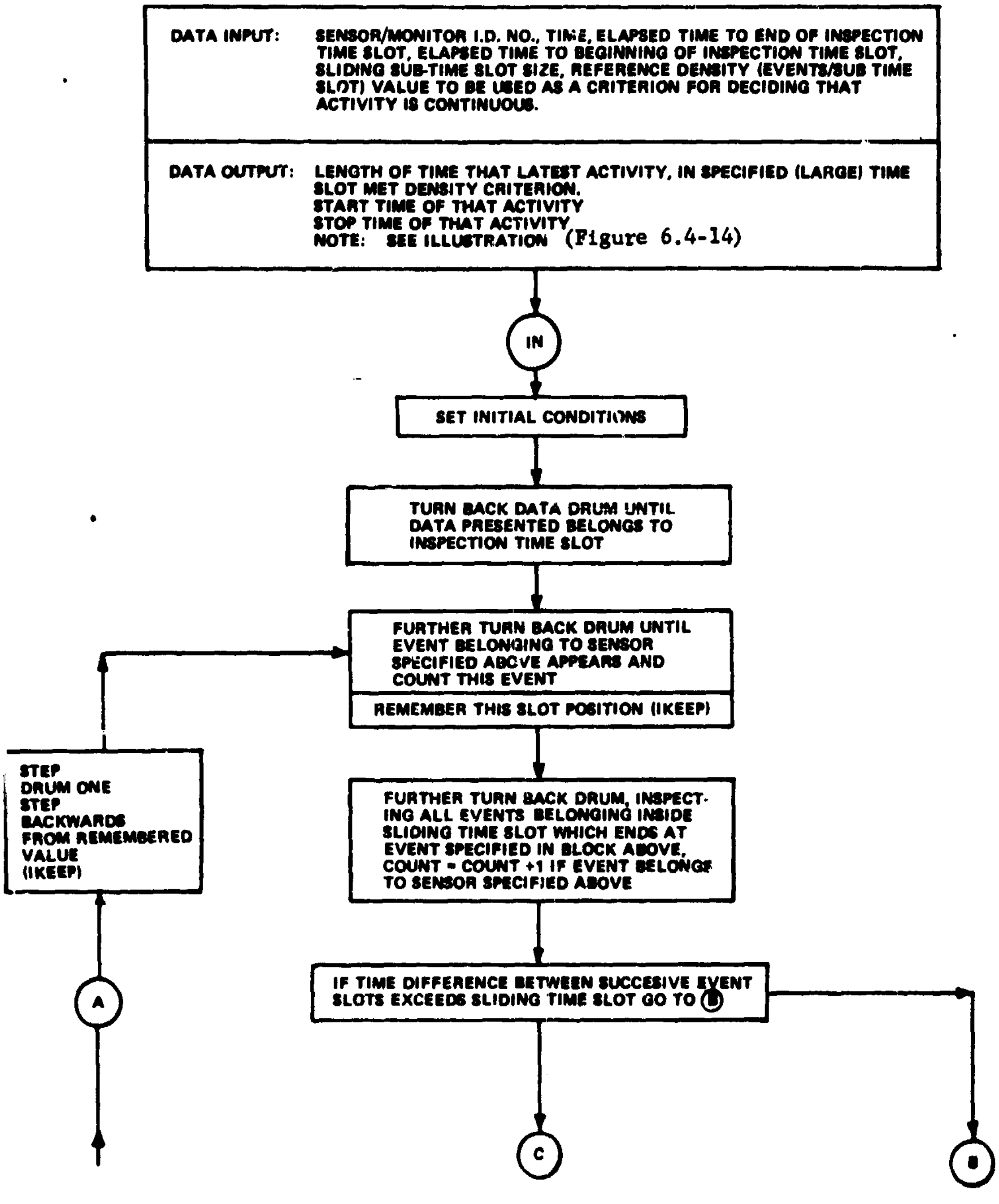
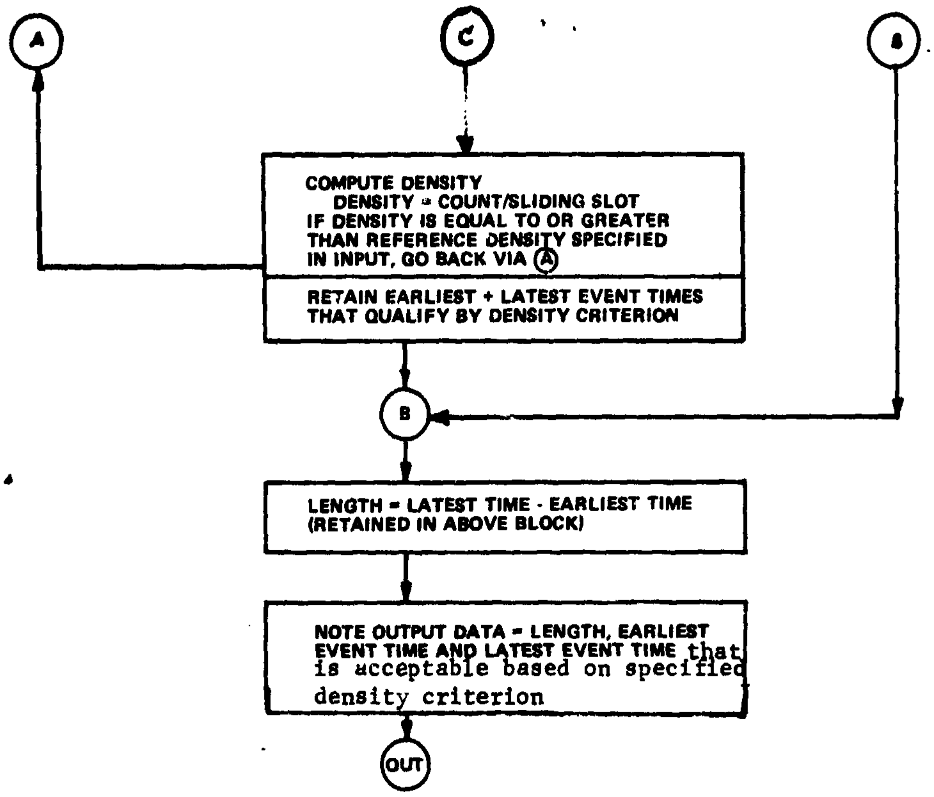


Figure 6.4-17 SUBROUTINE INSPCT MACROFLOW
(Sheet 1 of 2)



PURPOSE: FOR SENSOR MONITOR WHOSE I.D. NO. IS J, M, AT THE ITIME, SEARCH A TIME SPACE BEGINNING AT ITIME-ITB, AND ENDING AT ITIME-ITA, WITH A SLIDING TIME SLOT OF LENGTH ITSLOT, TO FIND THE DURATION (LENGTH) OF THE LATEST CONTINUOUS COLLECTION OF EVENTS WHOSE FREQUENCY OF OCCURRENCE EQUALS OR EXCEEDS A SPECIFIED INPUT VALUE/DENREF). ALSO SPECIFY THE STARTING TIME, JSTART, AND STOPPING TIME, JSTOP, OF THESE EVENTS.

Figure 6.4-17 SUBROUTINE INSPCT MACROFLOW
(Sheet 2 of 2)

6.4.2.4.5 ARRIVL Subroutine

When called by executive subroutine ANLYZE, subroutine ARRIVL determines the estimated time of arrival of the center of a target at preselected firetrap kill points along a trail, and the speed of the target. These are determined based on the sequence and timing of activations obtained from sensor 1 located along a trail at a position 1 and those from sensor 2 located at a position 2. Both PRE-BIAS and POST-BIAS considerations are available in subroutine ARRIVL for more accurately computing target length and estimated time of arrival (ETA) at a selected firetrap kill point position and speed for those cases in which the type of target, estimated sensor detection envelope associated with the target type, and sensor offset distance from a trail are known. When these are unknown, however, PRE-BIAS and POST-BIAS are equal to zero resulting in less accurate estimates of target length and ETAs. PRE-BIAS is the distance from a point on a trail at which initial sensor activation on the leading edge of a target occurs to intersection with the trail of a perpendicular offset from the sensor position to the trail. POST-BIAS is the distance from the intersection of a perpendicular offset with the trail to a point on the trail where the last activation on the trailing edge of a target occurs. A flow diagram of computer Subroutine ARRIVL is shown in Figure 6.4-18.

6.4.2.4.6 JSIETA Subroutine

When called by executive Subroutine ANLYZE, computer function subroutine JSIETA predicts the time of arrival of the center of a target of length (L) at a selected point (x_1, y_1) along a trail. Required inputs include target speed, location of a reference point (x, y) along a trail, the time at which a target passes the reference point and the location (x_1, y_1) of another selected point (e.g., firetrap kill point). This subroutine is used in conjunction with subroutines ARRIVL and LOCATE. A flow diagram of computer function subroutine JSIETA is shown in Figure 6.4-19.

6.4.2.4.7 LOCATE Subroutine

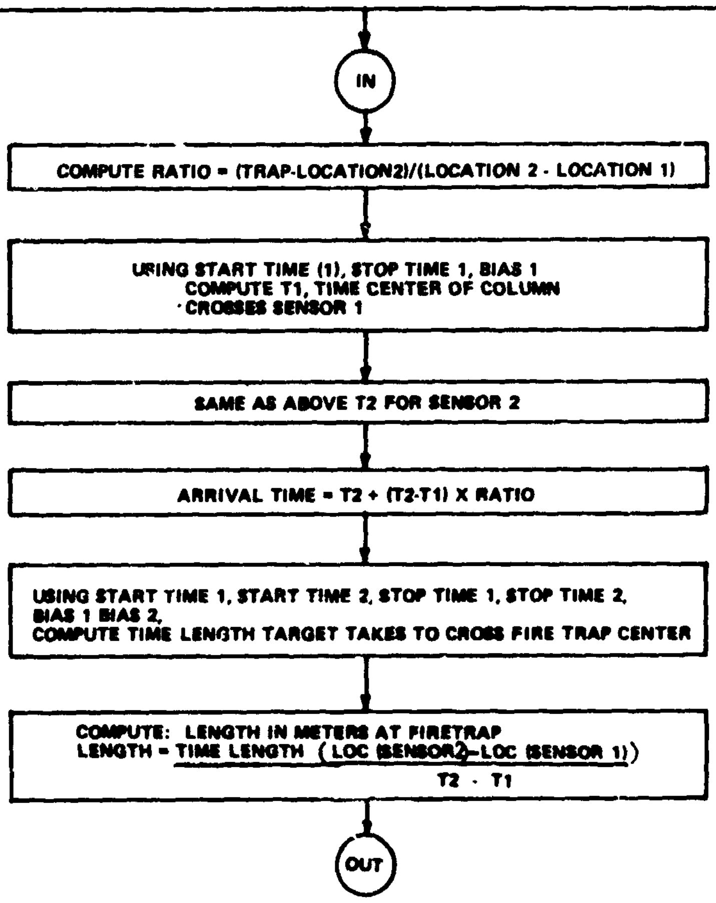
When called by executive subroutine ANLYZE, subroutine LOCATE determines the position (x_1, y_1), of the center of a target along a trail at any arbitrarily specified time. Required inputs include target speed, location of a reference point (x, y), and the time a target passes any specified reference point. This subroutine is used in conjunction with subroutines ARRIVL and JSIETA which have been previously described. A flow diagram of subroutine LOCATE is shown in Figure 6.4-20.

6.4.2.4.8 COUNTR Subroutine

When called by executive subroutine ANLYZE, subroutine COUNTR counts the number of activations received from each sensor as indicated on an associated monitor(s) which occur within a given elapsed time or time slot window. The subroutine returns actual start and stop times of activations and the number of activations that occur within

DATA INPUT:
LOCATION ALONG TRAIL OF CENTER OF SENSOR 1
LOCATION ALONG TRAIL OF CENTER OF SENSOR 2
LOCATION ALONG TRAIL OF CENTER OF FIRE-TRAP
START TIME OF ACTIVATION OF SENSOR 1
STOP TIME OF ACTIVATION OF SENSOR 1
START TIME OF ACTIVATION OF SENSOR 2
STOP TIME OF ACTIVATION OF SENSOR 2
PRE BIAS 1 (PREMATURITY) OF START TIME OF ACTIVATION OF SENSOR/MONITOR 1
PRE BIAS 2 (PREMATURITY) OF START TIME OF ACTIVATION OF SENSOR/MONITOR 2
POST BIAS 1 (POSTMATURITY) OF START TIME OF ACTIVATION OF SENSOR/MONITOR 1
POST BIAS 2 (POSTMATURITY) OF START TIME OF ACTIVATION OF SENSOR/MONITOR 2

DATA OUTPUT: ARRIVAL TIME OF CENTER OF TARGET AT FIRETRAP KILLPOINT,
LENGTH OF TARGET (COLUMN) IN METERS, AND TARGET SPEED, km/HR



COMPUTE RATIO = (TRAP-LOCATION2)/(LOCATION 2 - LOCATION 1)

USING START TIME (1), STOP TIME 1, BIAS 1
COMPUTE T1, TIME CENTER OF COLUMN
CROSSES SENSOR 1

SAME AS ABOVE T2 FOR SENSOR 2

ARRIVAL TIME = T2 + (T2-T1) X RATIO

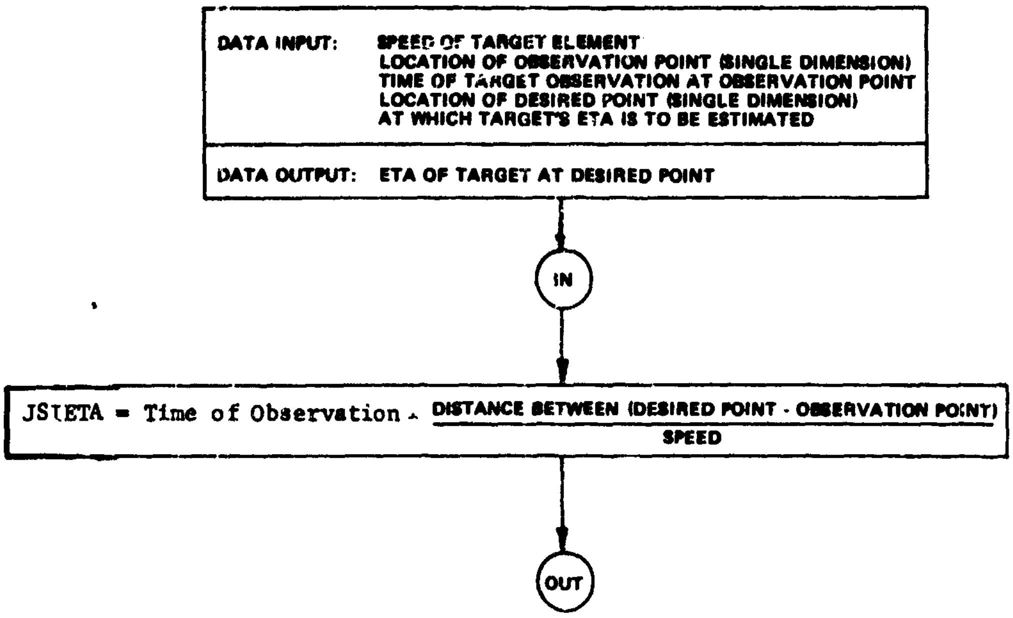
USING START TIME 1, START TIME 2, STOP TIME 1, STOP TIME 2,
BIAS 1 BIAS 2,
COMPUTE TIME LENGTH TARGET TAKES TO CROSS FIRE TRAP CENTER

COMPUTE: LENGTH IN METERS AT FIRETRAP

$$\text{LENGTH} = \frac{\text{TIME LENGTH} \ (\text{LOC (SENSOR2)} - \text{LOC (SENSOR 1)})}{\text{T2} - \text{T1}}$$

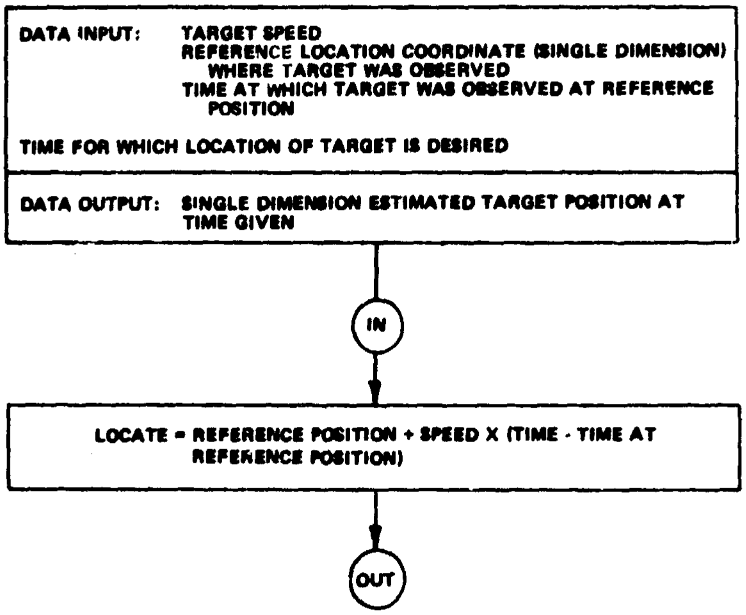
PURPOSE: TO DETERMINE TARGET LENGTH (LNGTH), SPEED (SPED) AND ARRIVAL TIME (ETA) AT FIRETRAP LOCATED AT JS3, BASED ON ACTIVATIONS ON SENSOR 1
LOCATED AT JS1, STARTING AT TIME JSTRT1, STOPPING AT TIME JSTP1, AND ACTIVATIONS ON SENSOR 2, STARTING AT TIME JSTRT2, STOPPING AT TIME JSTP2, KNOWING THAT SENSOR 1 ACTIVATIONS START PREMATURELY OR POSTMATURELY BY JBIAS 1 (SECONDS) AND SENSOR 2 ACTIVATIONS START PREMATURELY OR POSTMATURELY BY JBIAS 2 (SECONDS)

Figure 6.4-18 SUBROUTINE ARRIVL MACROFLOW



PURPOSE: TO ESTIMATE TIME OF ARRIVAL OF A TARGET AT A DESIRED POINT, KNOWING TARGET SPEED, TIME OF TARGET OBSERVATION AT OBSERVATION POINT, AND LOCATION OF OBSERVATION POINT AND DESIRED POINT IN CUMULATIVE DISTANCE COORDINATES ALONG A TRAIL

Figure 6.4-19 SUBROUTINE JSIETA MACROFLOW



PURPOSE: TO LOCATE A TARGET IN SINGLE DIMENSION I.E., ALONG A TRAIL, AT AN ARBITRARILY GIVEN TIME, KNOWING THE TIME, SPEED AND LOCATION THAT A TARGET WAS LAST OBSERVED.

Figure 6.4-20 SUBROUTINE LOCATE MACROFLOW the selected time window. In performing the operations, subroutine COUNTR analyzes sensor/monitor activation events data received from block data subprogram MCHART. Subroutine NMOD is called to index and restrict the range of search of the sensor activation events data in the "rolling drum" storage area. A flow diagram of subroutine COUNTR is shown in Figure 6.4-21.

6.4.2.4.9 CRLATE Subroutine

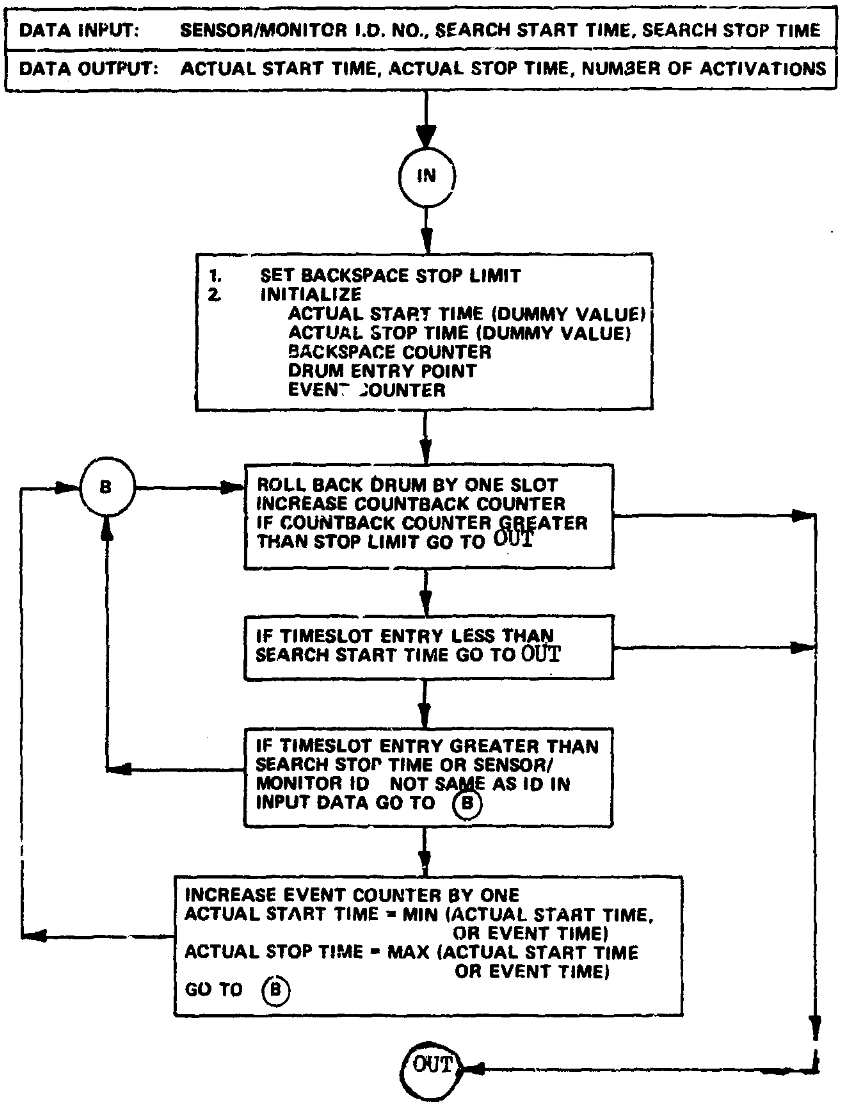
When called by executive subroutine ANLYZE, the purpose of subroutine CRLATE is to determine whether the time of occurrence of activations on a first sensor deployed along a trail correlate on an elapsed time basis with those of a second sensor spaced a specified distance apart considering the possible types of targets encountered and their estimated velocities. In order to perform these correlation functions, subroutine CRLATE must analyze sensor/monitor activation events data which are received from block data subprogram MCHART. Subroutine NMOD is called and utilized to perform the same functions as described previously for subroutine COUNTR. A flow diagram of this logical function subroutine is shown in Figure 6.4-22.

6.4.2.4.10 FSTARG Subroutine

When called by executive subroutine ANLYZE, subroutine FSTARG correlates the number of sensors/monitors having simultaneous or near simultaneous activations. It then determines whether the number of sensors/monitors activated equals or exceeds a specified minimum number (threshold) out of the total number of sensors/monitors (based on specified decision rules). If the threshold is equaled or exceeded, a false target (e.g. aircraft) or false alarm (e.g. seismic disturbance, lightning strike, etc.) is indicated. It is important to note that this subroutine does not differentiate between a false target or false alarm and, in addition, does not identify (who or what) the source of activations. Subroutine FSTARG is flexible in the sense that value of the parameter input (MINCLS) to the decision rule can be changed aswell by the planner. In order to perform these correlation functions, subroutine FSTARG must analyze sensor/monitor activation events data which are received from block data subprogram MCHART. Subroutine NMOD is called and utilized for the same purpose as described previously for subroutine COUNTR. A flow diagram of subroutine FSTARG is shown in Figure 6.4- [illegible]

6.4.2.4.11 RESET Subroutine

When called by executive subroutine ANLYZE, subroutine RESET is used in conjunction with subroutine FSTARG. If a false target or false alarm is indicated based on the simultaneous or near simultaneous activations from a number of sensors in an array (as determined by subroutine FSTARG), subroutine RESET prohibits the reuse of this sensor activation data by flagging it in block data subprogram MCHART. Again, subroutine NMOD is called for the same purpose as described previously for subroutine COUNTR. A flow diagram of subroutine RESET is shown in Figure 6.4-24.



PURPOSE: TO COUNT NUMBER OF ACTIVATIONS ON SENSOR NO. J/MONITOR NO. M COMBINATION IN TIME SLOT BETWEEN JSTART AND JSTOP, YIELDING ACTUAL START TIME OF ACTIVATION, JA, NUMBER OF ACTIVATIONS, KOUNT.

Figure 6.4-21 SUBROUTINE – COUNTR MACROFLOW

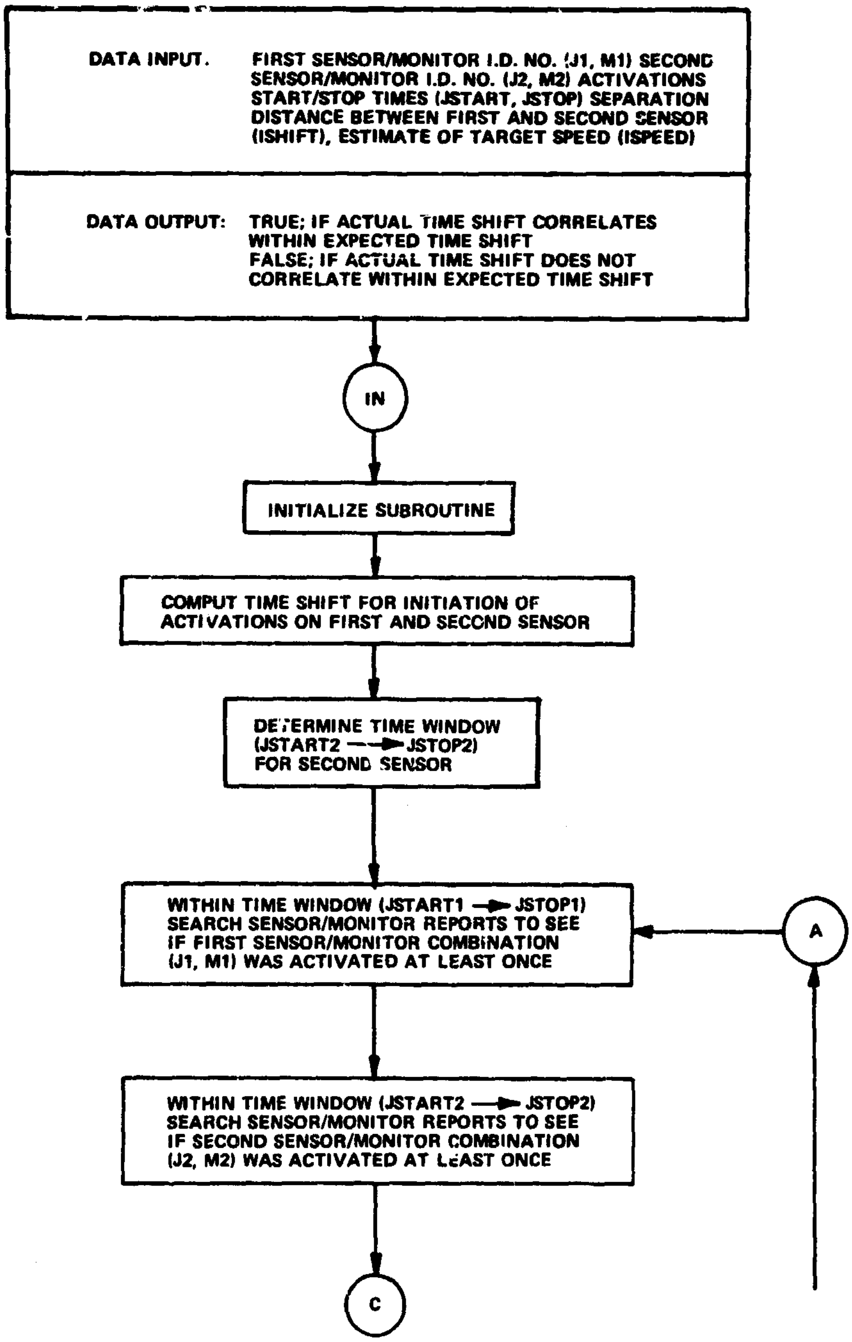
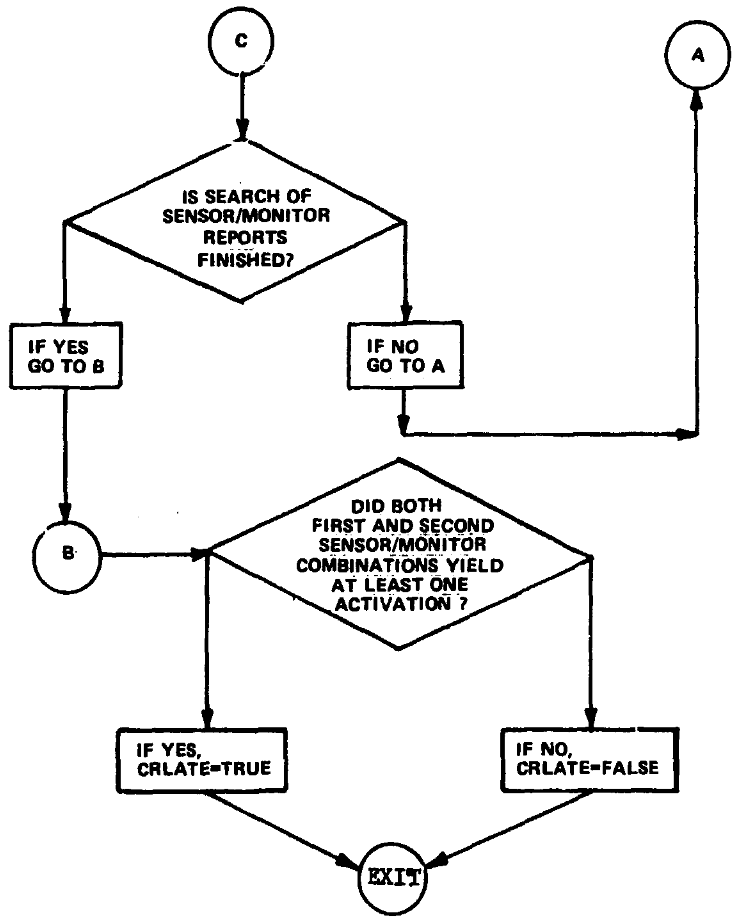


Figure 6.4-22 LOGICAL FUNCTION SUBROUTINE – CRLATE MACROFLOW
(Sheet 1 of 2)



PURPOSE: TO DETERMINE WHETHER A CORRELATION EXISTS BETWEEN TWO DIFFERENT SENSOR/MONITOR ACTIVATION REPORTS CONSIDERING THE RELATIVE LOCATIONS OF THE SENSOR AND TARGET SPEED. IF CORRELATION IS OBTAINED, TRUE IS RETURNED OTHERWISE FALSE IS RETURNED.

Figure 6.4-22 LOGICAL FUNCTION SUBROUTINE CRLATE MACROFLOW (Sheet 2 of 2)

DATA INPUT:	TIME, NUMBER OF SENSORS/MONITORS, RELATIVE BACKWARD START TIME OF FALSE ALARM TIME SLOT, BACKWARD RELATIVE STOP TIME OF FALSE ALARM TIME SLOT, BACKWARD RELATIVE STOP TIME OF ZERO ACTIVATION TIME SLOT, MINIMUM NUMBER OF SENSORS/MONITORS ACTIVATED TO DECIDE ALARM IS FALSE.
DATA OUTPUT:	FALSE ALARM = YES, OR NO (TRUE OR FALSE) NOTE: NO (FALSE) RESULT MEANS ALARM IS NOT FALSE.

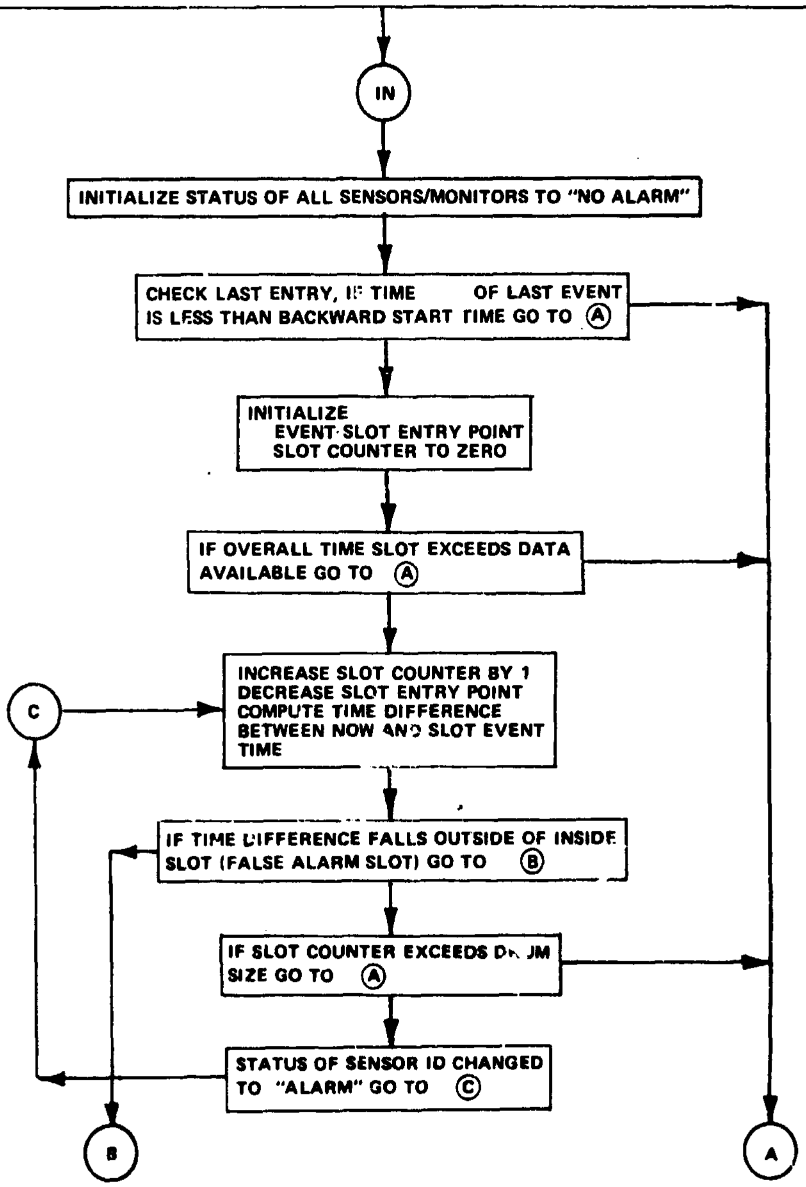
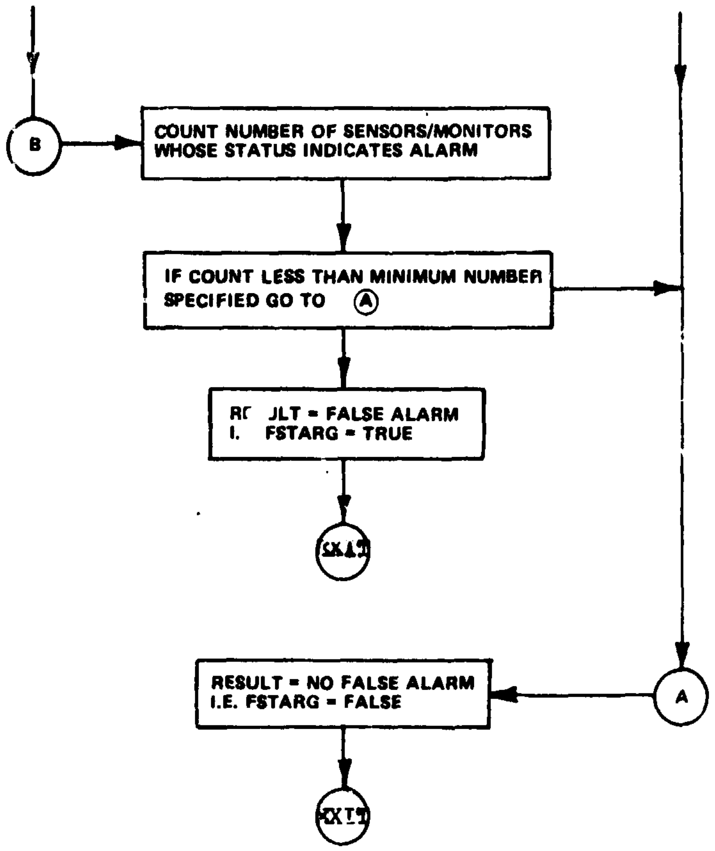


Figure 6.4-23 SUBROUTINE – FSTARG MACROFLOW
(Sheet 1 of 2)



PURPOSE: TO DECIDE WHETHER ACTIVATIONS ON A GROUP OF SENSORS/MONITORS, JMAX/MMAX IN NUMBER, OCCURRING BETWEEN ITIME-ITC AND ITIME CONSTITUTED A FALSE ALARM. CONDITIONS ARE, NO SENSORS MAY BE ACTIVATED BETWEEN ITIME-ITA TO ITIME, AND ITIME-ITC TO ITIME-ITB. ALSO AT LEAST MINCLS SENSORS/MONITORS MUST BE ACTIVATED AT LEAST ONCE BETWEEN ITIME-ITB TO ITIME-ITA. FURTHERMORE, DATA DRUM MUST CONTAIN SUFFICIENT DATA TO "LOOK BACK" TO ITIME-ITC. IF ALL ABOVE CONDITIONS ARE MET, FALSE ALARM=YES IS RETURNED OTHERWISE FALSE ALARM NO IS RETURNED

Figure 6.4-23 SUBROUTINE – FSTARG MACROFLOW
(Sheet 2 of 2)

DATA INPUT:	MONITOR I.D. NUMBER OF MONITOR WHOSE SENSOR/MONITOR ACTIVATION DATA IS TO BE DELETED START TIME OF TIME WINDOW IN WHICH THIS DATA IS TO BE DELETED STOP TIME OF TIME WINDOW IN WHICH THIS DATA IS TO BE DELETED.
DATA OUTPUT:	NONE, HOWEVER, THE SENSOR/MONITOR ACTIVATION DATA SPECIFIED ABOVE IS "DISABLED" IN THE "ROLLING DRUM," AND WILL NOT "SHOW UP" IN ANY DATA EVALUATION SUBROUTINES SUCH AS CALLIT AND INSPCT. DISABLEMENT IS ACCOMPLISHED BY SETTING THE SENSOR I.D. ENTRIES NEGATIVE

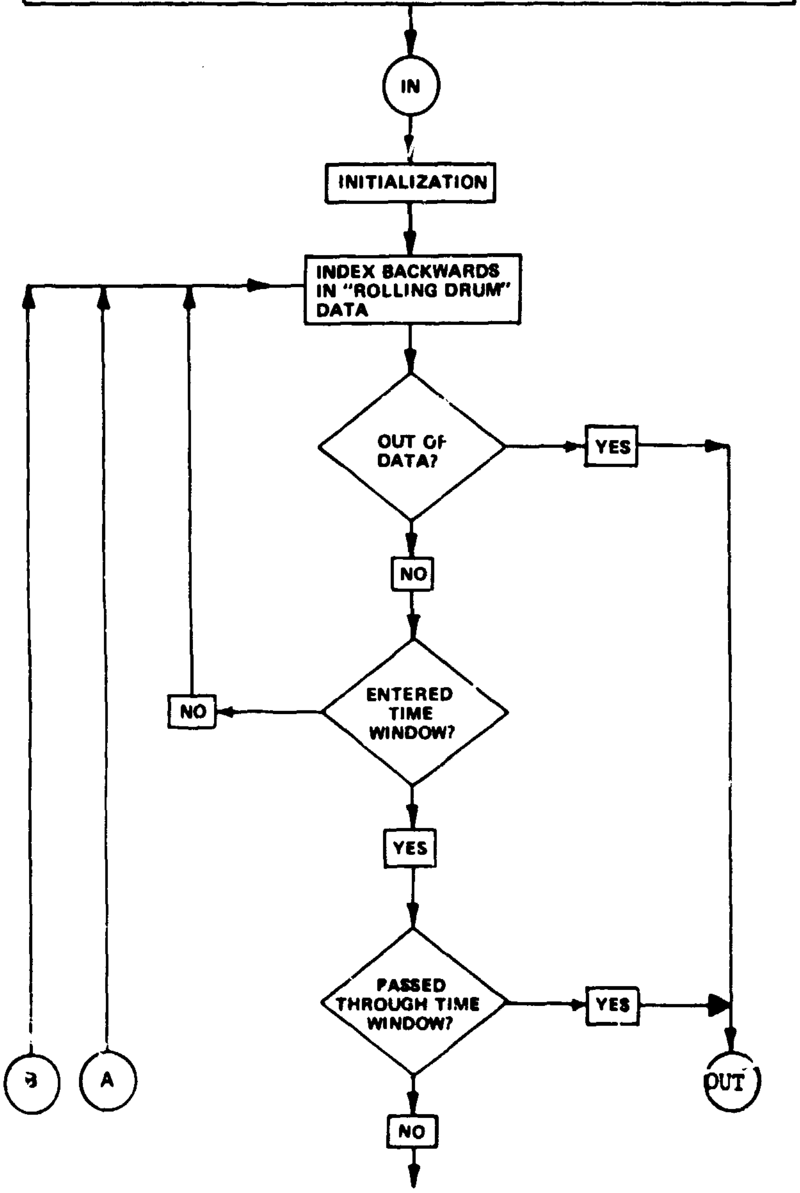
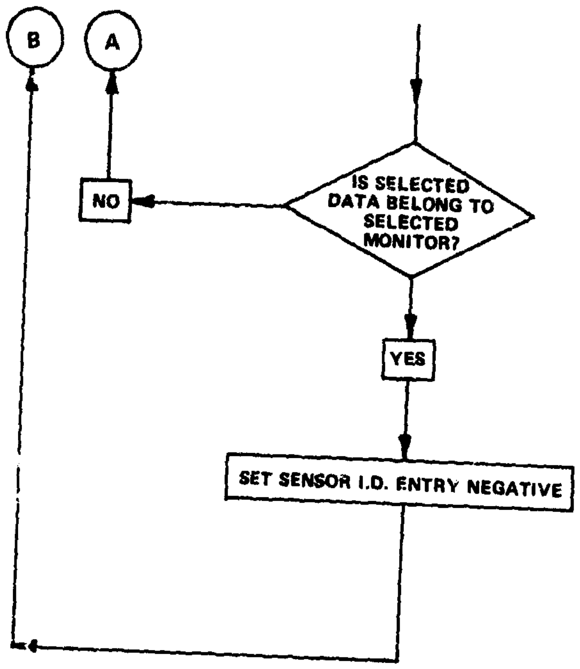


Figure 6.4-24 SUBROUTIN_ RESET MACROFLOW
(Sheet 1 of 2)



PURPOSE: TO RESET SENSOR/MONITOR ACTIVATION DATA FOR A GIVEN MONITOR AND A GIVEN TIME SLOT

Figure 6.4-24 SUBROUTINE RESET MACROFLOW
(Sheet 2 of 2)

6.4.3 Unattended Ground Sensors Analyzed and Modeled

6.4.3.1 Types of UGS Analyzed and Modeled

While the SAM I simulation includes a wide range of sensors and is expandable to an even greater range, those sensors of the remote unattended type have been emphasized for inclusion at this time in the sensor report data processing model. These include the following primary and auxiliary types:

Primary UGS	Auxiliary UGS
Seismic	Passive Infrared
Acoustic	Magnetic
Arfbuoy	Acoustic
Breakwire	

Of the primary UGS employed in the field, the seismic, acoustic, arfbuoy, and breakwire types are modeled. A second set, the Auxiliary UGS, are also modeled. These are auxiliary in the sense that they are add-on items to the primary sensors and include passive infrared, magnetic, and acoustic types. Some types not presently included are balanced pressure, active infrared, and electromagnetic sensors of the UGS class. However, these latter types are not nearly so widely applied as those included in the simulation at this time.

6.4.3.2 Combinations of UGS Analyzed and Modeled

Certain types of information can be derived from single sensors. The amount of information varies somewhat for different types of sensors. Additional information can be determined from combining the information from more than one sensor, using either combinations of different types of sensors, combinations of the same types of sensors, or both.

Various combinations of similar and dissimilar sensor types can be further grouped by an operating procedure where any sensor can report an activation or where both sensors of a two-sensor team must activate before an activation may be reported to the monitor. These two procedures are referred to as the "or" and "and" modes respectively. In order to have an and mode of operation, the sensor must be limited to a common go/no-go logic where a primary and auxiliary relationship, insofar as hardware considerations are concerned, exists. The sensor report data processing model as presently formulated is able to analyze data and formulate target reports for the following sensor combinations:

1. One primary sensor
2. Two primary sensors

3. One collocated pair: of one primary plus one auxiliary sensor
4. Two pairs: of one primary plus one auxiliary sensor.

Of course, any number of repeats of these combinations of sensors in any one scenario can be accommodated in the model.

6.4.3.3 Target Information/Data Derivable from UGS Combinations Modeled

The quantity and quality of target information/data which can be derived depends upon:

1. The type of sensor array employed.
2. The input information available to the monitor operator or decision-maker.

For the data processing model as presently formulated it has been assumed that the input information available to the operator or decision maker consists solely of the activation patterns displayed on the monitor. The target information/data derivable based on these monitor patterns is presented in Table 64-I.

The information presented in Table 6.4-I is indicative of the types of target data which can be derived when sensor detection range is unknown and for the condition in which the type of target (personnel or vehicle) cannot be determined from rules based on characteristics of the monitor activations received from a single sensor. These are believed to be the present limits of derivable target information/data under these conditions and for the sensor arrays shown.

Table 6.4-II indicates the target information data which is derivable for the condition in which detection range is known and it may be possible to determine the target type from rules based on characteristics of the monitor activations received from a single sensor.

These are believed to be the maximum target information data derivable under these conditions and for the sensor arrays shown when utilizing monitor activation patterns only.

It is expected that sensor system classification and identification capability can be considerably improved by correlation of monitor and a'priori information from other (outside) sources. These sources include a'priori information on:

1. Enemy targets (intelligence)
2. Friendly forces and activities

Table 6.4-I

TARGET INFORMATION/DATA PRESENTLY DERIVABLE FROM UGS ARRAYS

SENSOR	PRESENCE OF TARGET	TYPE OF TARGET	DIRECTION OF TARGET MOVEMENT	NUMBER OF TARGET ELEMENTS	TARGET SPEED	TARGET LENGTH	ETA OF TARGET AT FUTURE POSITION
1 PRIMARY	YES*	NO	NO	NO	NO	NO	NO
1 PRIMARY + 1 AUXILIARY (CO-LOCATED)	YES**	NO	NO	YES	NO	NO	NO
AUXI. (OR LOGIC)	YES	NO	NO	YES	NO	NO	NO
TWO PAIRS: 1 PRIMARY + 1 AUXILIARY	YES**	POSSIBLY	YES	YES	YES	YES	YES
2 PRIMARIES	YES***	POSSIBLY	YES	NO	YES WITH INACCURACY	YES WITH INACCURACY	YES WITH INACCURACY

*IF PRIMARY DETECTION CRITERIA IS SATISFIED.

**CONFIRMED TARGET. IF BOTH PRIMARY AND AUXILIARY DETECTION CRITERIA ARE SATISFIED BY EITHER OR BOTH SENSOR PAIRS.

***CONFIRMED TARGET: IF THE PRIMARY DETECTION CRITERIA IS SATISFIED BY BOTH SENSORS

Table 6.4-II

MAXIMUM AMOUNT OF TARGET INFORMATION DATA DERIVABLE FROM UGS ARRAYS

SENSOR ARRAY	PRESENCE OF TARGET	TYPE OF TARGET	DIRECTION OF TARGET MOVEMENT	NUMBER OF TARGET ELEMENTS	TARGET SPEED	TARGET LENGTH	ETA OF TARGET AT FUTURE POSITION
1 PRIMARY	YES	POSSIBLY	NO	POSSIBLY	ACCURATE: POSSIBLY COURSE: YES	POSSIBLY	ACCURATE: POSSIBLY COURSE: YES
1 PRIMARY + 1 AUXILIARY (CO-LOCATED)	YES**	POSSIBLY	NO	YES	YES	YES	YES
TWO PAIRS: 1 PRIMARY + 1 AUXILIARY	YES**	POSSIBLY	YES	YES	YES	YES	YES
2 PRIMARY	YES***	POSSIBLY	YES	POSSIBLY	YES	YES	YES

*IF PRIMARY DETECTION CRITERIA IS SATISFIED.

**CONFIRMED TARGET: IF BOTH PRIMARY AND AUXILIARY DETECTION CRITERIA ARE SATISFIED BY EITHER OR BOTH SENSOR PAIRS.

***CONFIRMED TARGET: IF THE PRIMARY DETECTION CRITERIA IS SATISFIED BY BOTH SENSORS

3. The surrounding environment

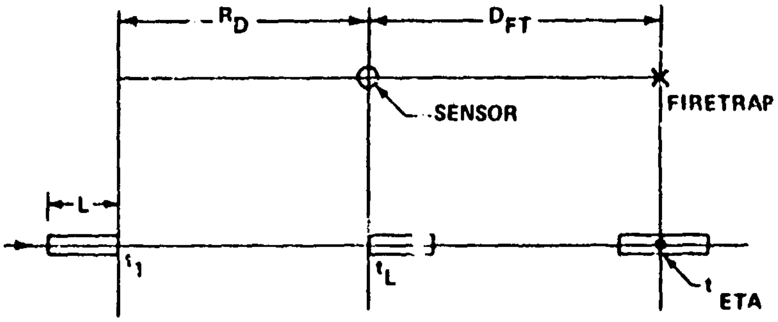
The consideration of these outside sources of information is discussed later in this section of the report.

Derivation of Equations and Decision Rules for Determining Target Information/Data from Sensor Characteristics and Monitor Activations

A target of length L is assumed to pass within the detection range of each of the four types of sensor arrays analyzed. It is presumed in developing the mathematical equations that sensor detection range R_D and possible decision rules for the type of target based on monitor activations are known or derivable. Thus the mathematical relationships shown represent the case in which the maximum target information/data is derivable as indicated previously in Table 6.4-II. To obtain the presently derivable target data case, in which sensor detection range and type of target are unknown, all equations and rules in which sensor detection range R_D is an independent variable are discarded. The mathematical equations and possible decision rules for each of the types of target information/data are presented below for the four arrays analyzed.

Single Seismic Sensor Array

The array geometry for a single seismic sensor when utilized in a firetrap operation is shown in Figure 6.4-25.



L = TARGET LENGTH
R_D = SENSOR DETECTION RANGE
D_{FT} = DISTANCE BETWEEN SENSOR AND FIRETRAP
t_1 = TIME OF FIRST ACTIVATION ON SENSOR
t_L = TIME OF LAST ACTIVATION ON SENSOR
t_{ETA} = ESTIMATED TIME OF ARRIVAL OF CENTER OF TARGET AT FIRETRAP

Figure 6.4 25 ARRAY GEOMETRY FOR SINGLE SEISMIC SENSOR

The presence of a target can be determined if the detection criteria for a seismic sensor is satisfied. The type of target may possibly be determined on the basis of:

1. The relationship of the time interval between the first isolated activation and the first continuous activation to the type of target

   If Δt = 0 to $KMIN$*, the target is classified as personnel.

   If $\Delta t > KMIN$, the target is classified as vehicles.

2. A coarse estimate of target speed, V^*

   If $V^* < M$**, the target is classified as either personnel or vehicles.

   If $V^* > N$***, the target is classified as vehicles.

The direction of target movement cannot be determined. However, the number of elements in a target may possibly be determined if the type of target is known and the relationship between the number of continuous sensor activations and number of target elements is available based on field test data. If, for example, the target is personnel, X continuous sensor activations = Y men. Accurate target speed, V, may possibly be determined if the number of target elements, E, and the separation distance between elements, S, are known. On this basis, the following relationships are:

$$V = \frac{R_D + (E-1)S}{t_L - t_1}$$

If E is small, $V = \dfrac{R_D}{t_L - t_1}$

A coarse estimate of target speed, V^*, can be made on the basis of:

$$V^* = \frac{R_D}{t_L - t_1}$$

---

* KMIN is the elapsed time between 1st isolated activation to the time of the set of continuous activations

** M is velocity critera for classifying target as personnel

***N is velocity critera for classifying target as vehicle

If E and S are known, it is possible to determine target length, L, from the relationship

$$L = (E-1)S$$

The estimated time of arrival, t_{ETA}, of a target at a future position such as a firetrap can accurately be determined by the following relationships if V and L are known:

$$t_{ETA} \text{ (measured from } t_1 \text{)} = \frac{R_D + D_{FT} + \frac{L}{2}}{V}$$

$$t_{ETA} \text{ (measured from } t_0 \text{)} = t_1 + t_{ETA} \text{ (measured from } t_1\text{)}$$

where t_0 = any reference time.

A coarse estimate of t_{ETA} can be made on the basis of the following relationships:

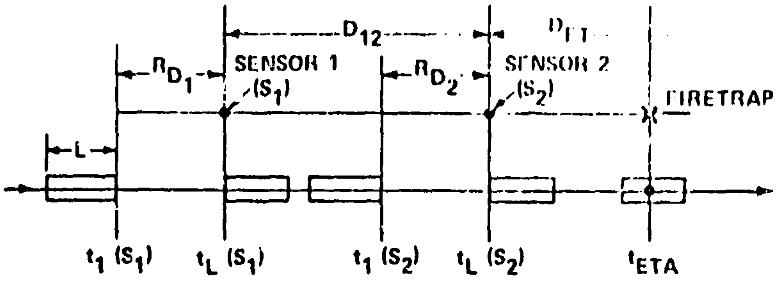
$$t_{ETA} \text{ (measured from } t_1 \text{)} = \frac{R_D + D_{FT}}{V^*}$$

$$t_{ETA} \text{ (measured from } t_0 \text{)} = t_1 + t_{ETA} \text{ (measured from } t_1 \text{)}$$

Referring again to Table 6.4-I, it is important to note that only the presence of a target can be determined from a single seismic sensor if R_D and the type of target are unknown. This is presently the case with respect to R_D. Also the target type is unknown since it is assumed in this paper that information is limited to that which can be obtained from monitor activations only.

Two Seismic Sensor Array

The geometry for a two-seismic sensor array is shown in Figure 6.4-26.



L = TARGET LENGTH

R_{D_1} = SENSOR 1 DETECTION RANGE

R_{D_2} = SENSOR 2 DETECTION RANGE

D_{12} = DISTANCE BETWEEN SENSOR 1 AND SENSOR 2

D_{FT} = DISTANCE BETWEEN SENSOR 2 AND FIRETRAP

t_1 (S_1) AND t_1 (S_2) = TIME OF FIRST ACTIVATION ON SENSOR 1 AND 2 RESPECTIVELY

t_L (S_1) AND t_L (S_2) = TIME OF LAST ACTIVATION ON SENSOR 1 AND 2 RESPECTIVELY

t_{ETA} = ESTIMATED TIME OF ARRIVAL OF CENTER OF TARGET AT FIRETRAP

Figure 6.4-26 GEOMETRY FOR TWO SEISMIC SENSOR ARRAY

Determination of the presence and type of target follows the same rationale as described previously for the single seismic sensor. In addition, the type of target may possibly be determined on the basis of the elapsed time, $t_1(S_2) - t_1(S_1)$, between initiation of activations of the two sensors. If the elapsed time is:

1. Simultaneous or near simultaneous, the activations are classified as a false target.
2. Less than the smallest possible elapsed time of the expected target, the activations are classified as a false alarm.
3. Within the expected elapsed time of the target, the activations are classified as a true or false target.
4. Greater than the expected elapsed time of the target, the activations are classified as a true or false target which has slowed or stopped, two separate targets, or a false alarm.

The direction of target movement can be determined based on the times of the initiation of activations on sensors 1 and 2. The number of target elements may possibly be determined utilizing the same rationale as described previously for the single seismic sensor. Target speed can be determined from either of the following relationships:

Based on the leading target element,

$$V = \frac{R_{D_1} - R_{D_2} + D_{12}}{t_1(S_2) - t_1(S_1)}$$

Based on the last or trailing target element,

$$V = \frac{D_{12}}{t_L(S_2) - t_L(S_1)}$$

Target length can be determined from each of the equations listed below:

$$L_1 = V(t_L(S) - t_1(S_1)) - R_{D_1}$$

$$L_2 = V(t_L(S_2) - t_1(S_2)) - R_{D_2}$$

$$L = \frac{L_1 + L_2}{2}$$

The t_{ETA} of a target at a future position such as a firetrap can be determined from the following relationships based on the leading target element:

t_{ETA} (measured from t_1 (S_2)) $= \dfrac{R_{D_2} + D_{FT} + \frac{L}{2}}{V}$ -

t_{ETA} (measured from t_0) $= t_1(S_2) + t_{ETA}$
(measured from t_1 (S_2))

Relationships based on the last target element are:

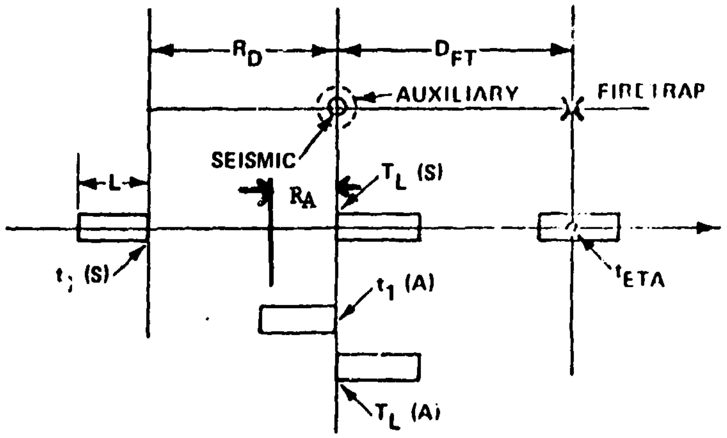
t_{ETA}(measured from t_L (S_2)) $= -\dfrac{D_{FT} - \frac{L}{2}}{V}$

t_{ETA}(measured from t_0) $= t_L(S_2) + t_{ETA}$
(measured from t_L (S_2))

If sensor detection range and type of target are unknown, target presence and direction of movement can still be determined. Also, it is possible to determine target speed, length, and t_{ETA} at a future position with some inaccuracy. Determination of target type may or may not be possible. For example, if the speed of the target is considerably greater than the maximum speed that a man can walk, the target can be classified as a vehicle. If the speed is less, it is uncertain whether the target is a man or vehicle.

One Seismic Sensor Plus One Collocated Auxiliary Sensor Array

The array geometry for one seismic sensor plus one collocated auxiliary sensor is shown in Figure 6.4-27.



L = TARGET LENGTH
R_D = SEISMIC SENSOR DETECTION RANGE
D_{FT} = DISTANCE BETWEEN COLLOCATED SENSORS AND FIRETRAP
t_1 (S) = TIME OF FIRST ACTIVATION ON SEISMIC SENSOR
t_L (S) = TIME OF LAST ACTIVATION ON SEISMIC SENSOR
t_1 (A) = TIME OF FIRST ACTIVATION ON AUXILIARY SENSOR
t_L (A) = TIME OF LAST ACTIVATION ON AUXILIARY SENSOR
t_{ETA} = ESTIMATED TIME OF ARRIVAL OF CENTER OF TARGET AT FIRETRAP
R_A = Auxiliary Sensor Detection Range*

Figure 6.4-27 ARRAY GEOMETRY FOR SINGLE SEISMIC PLUS SINGLE AUXILIARY SENSOR (COLLOCATED)

The presence of a target can be determined if the detection criteria for the seismic sensor is satisfied. Confirmation of the detection is obtained if the detection criteria for the auxiliary sensor is satisfied. The type of target may possibly be determined utilizing the same rationale presented previously for the single seismic sensor. Direction of target movement cannot be determined. The number of target elements is equal to the number of successive activations, $\mathcal{E}$, indicated on the auxiliary sensor that appear to have continuity. Target speed can be estimated from the following relationship:

* R_A is zero, since auxiliary sensor is assumed to be a line sensor.

$$V = \frac{R_D}{(t_L(S) - t_1(S)) - (t_L(A) - t_1(A))}$$

Target length can be determined from the equation below.

$$L = V(t_L(A) - t_1(A))$$

If the separation distance, S, between target elements is known, target length can also be determined from the following equation:

$$L = (E - 1)\,S$$

The t_{ETA} of a target at a future position can be determined from the following equations:

$$t_{ETA} \text{ (measured from } t_1 \ (A)) = \frac{D_{FT} + \frac{L}{2}}{V}$$

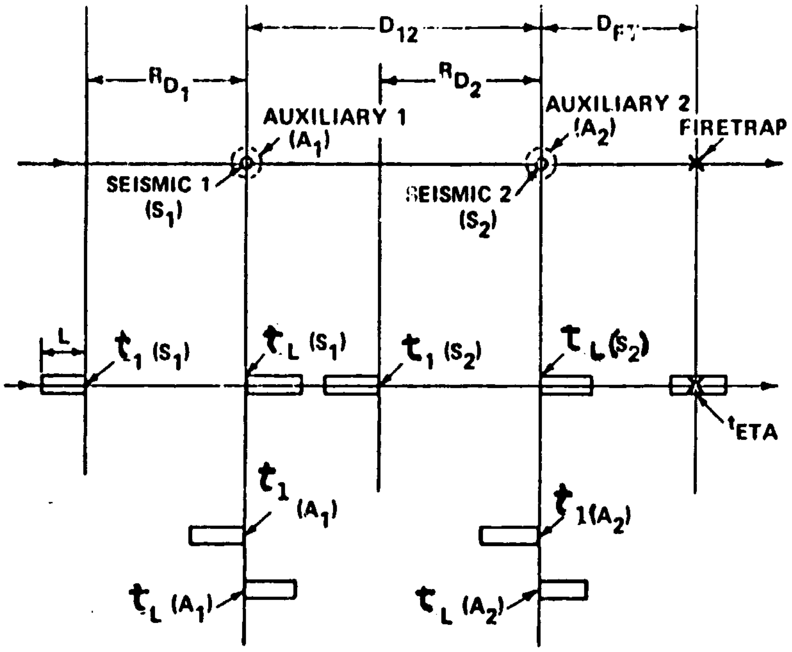
$$t_{ETA} \text{ (measured from } t_0) = t_1(A) + t_{ETA} \text{ (measured from } t_1 \ (A))$$

If detection range of the seismic sensor and type of target are unknown, it is important to note that only the presence of a target and the number of its elements can be determined (refer to Table 6.4-1.)

Array of Two Pairs of One Seismic Sensor Plus One Collocated Auxiliary Sensor

The array geometry for two pairs of one seismic sensor plus one collocated auxiliary sensor is shown in Figure 6.4-28. The presence of a target can be determined if the detection criteria for either seismic sensor is satisfied. Confirmation of the detection is obtained if detection criteria for the auxiliary sensor by either or both pairs is satisfied. Determination of the type of target can follow the same rationale as described previously for the single seismic sensor. The type of target can possibly be determined on the basis of elapsed time, $t_1(A_2) - t_1(A_1)$ between initiation of the activations on the two auxiliary sensors. If elapsed time is:

1. Simultaneous or near-simultaneous, the activations are classified as a false alarm.
2. Less than the smallest possible elapsed time of the expected target, the activations are classified as a false alarm.
3. Within the expected elapsed time of the target, the activations are classified as a true or false target.



L = TARGET LENGTH

R_{D_1} = SEISMIC SENSOR 1 DETECTION RANGE

R_{D_2} = SEISMIC SENSOR 2 DETECTION RANGE

D_{12} = DISTANCE BETWEEN SENSOR PAIRS 1 AND 2

D_{FT} = DISTANCE BETWEEN SENSOR PAIR 2 AND FIRETRAP

$t_1\ (S_1)$ AND $t_2\ (S_2)$ = TIME OF FIRST ACTIVATION ON SEISMIC SENSOR 1 AND 2 RESPECTIVELY

$t_L\ (S_1)$ AND $t_L\ (S_2)$ = TIME OF LAST ACTIVATION ON SEISMIC SENSOR 1 AND 2 RESPECTIVELY

$t_1\ (A_1)$ AND $t_1\ (A_2)$ = TIME OF FIRST ACTIVATION ON AUXILIARY SENSOR 1 AND 2 RESPECTIVELY

$t_L\ (A_1)$ AND $t_L\ (A_2)$ = TIME OF LAST ACTIVATION ON AUXILIARY SENSOR 1 AND 2 RESPECTIVELY

Figure 6.4-28 **GEOMETRY FOR ARRAY OF TWO PAIRS OF ONE SEISMIC SENSOR PLUS ONE COLLOCATED AUXILIARY SENSOR**

Note: Primary sensor is assumed to have AGC and to cease reporting when tail of column is at point of closest approach. Auxiliary sensor is assumed to be a line type sensor (e.g., Magid, Pirid).

4. Greater than the expected elapsed time of the target, the activations are classified as a true or false target which has slowed or stopped, two separate targets or a false alarm.

The direction of target movement can be determined based on the times of initiation on either seismic sensors 1 and 2 or auxiliary sensors 1 and 2. The number of target elements, E , is equal to the greater of the number of activations indicated on auxiliary sensors 1 and 2. Target speed is determined from the following relationship:

$$V = \frac{D_{12}}{t_1(A_2) - t_1(A_1)}$$

Target length can be determined from any of the formulas that follow:

$$L = V \times \text{ the larger of } (t_L(A_1) - (t_1(A_1)) \text{ and }$$

$$(t_L(A_2) - (t_1(A_2))$$

$$L = V(t_L(A_1) - t_1(A_1)), \quad L = V(t_L(A_2))$$

$$- t_1(A_2))$$

$$S = \frac{L}{E \cdot 1}$$

The t_{ETA} of a target at a future position is determined from:

$$t_{ETA} \text{ (measured from } t_1 \text{ } (A_2)) = \frac{D_{FT} + \frac{L}{2}}{V}$$

$$t_{ETA} \text{ (measured from } t_0 \text{) } = t_1 \text{ } (A_2) + t_{ETA}$$

$$\text{(measured from } t_1 \text{ } (A_2))$$

All of the target information presented previously in Table 6.4-I with the exception of type of target can definitely be determined accurately without knowing the detection range of the seismic sensors.

Sensor Operational Situations and Mathematical Simulation

In the mathematical equations which represent the target information/data outputs, it is assumed that target velocity V is unknown. These equations closely represent the operation of the actual sensors. Detection range R_D may possibly be known but it is more likely to be unknown. If it is known, the maximum target data may be derived. If it is unknown, then the target data is limited to that called presently derivable (Table 6.4-I).

Case I: R_D known, V unknown

Case II: R_D unknown, V unknown

In Case I, R_D and the sensor(s) activations are used to derive V and R_D and V are used to obtain t_{ETA}, as shown previously in the derivations of the maximum target data.

In Case II, V cannot be determined from the array activation times if the array consists of a single sensor or co-located pair. An array of two seismics (separated) can yield an imprecise value of V, which can be used to determine an imprecise R_D. These values V and R_D can then be used to calculate an imprecise t_{ETA}. An array of two seismic and auxiliary pairs allows a precise V to be determined, and from that a precise R_D. From R_D and V, a precise t_{ETA} can be calculated.

If the combat situation permits, it is possible that the R_D of a seismic sensor may be determined by calibration at the time of sensor installation. If this is not possible, then it may be feasible to calibrate the seismic sensor detection capability by means of a small noise source of known low intensity implaced near the sensor. This calculated R_D would then be a function of the actual operational environment in which the sensor operates. Changes in the environment would be reflected in periodic calibrations of the sensor. If desired, or required, R_D of the sensor could be obtained at any time. These statements are not indicative of present procedures and operations. Rather, they are presented as possibilities for future study and consideration.

Decision Rules Utilized in Classifying Sensor Activations

The decision rules that are presently utilized in the unattended sensor analysis model in classifying sensor activation patterns are summarized below. These include rules for both single primary UGS and two primary or two collocated pairs of UGS.

The decision rules presently utilized for a single primary UGS are listed as follows:

1. For primary sensors such as the seismic, two or more activations that fall within a specified time period indicate the presence of a target.

2. On the other hand, for primary sensors, such as the Arfbuoy, a single activation indicates the presence of a target.

The following decision rules are presently utilized for two primary or two collocated pairs of UGS in a trail surveillance operation:

1. Simultaneous or near simultaneous, the activations are classified as a false target or false alarm.
2. Less than the smallest possible elapsed time of the expected target, the activations are classified as a false alarm.
3. Within the expected elapsed time of the target, the activations are classified as a true or false target.
4. Greater than the expected elapsed time of the target, the activations are classified as a true or false target which has slowed or stopped, two separate targets, or a false alarm.

6.4.4 Illustrative Example of Unattended Sensor Data Processing Model Target Report

The primary purpose of this section is to present an illustrative example of a typical target report from the model which has been obtained from a run on the IBM 360/65 computer. Before presenting this example however, a typical sensor model and its activation outputs, sample target activation patterns obtained from such a sensor in field trials, and a simulated monitor display of sample sensor false alarm and target activation data streams are briefly discussed. This is done in order to provide the reader with a background from which a better understanding of the model target report can be obtained.

6.4.4.1 Sample Sensor Model and Outputs

In order to illustrate the types of activation responses produced by the sensor models, the performance of the seismic sensor subroutine is shown in Figure 6.4-29.

In the sample problem, a single trooper moves at the rate of 1 meter per second approximately along a straight line path which passes within 5 meters of the sensor position. Thus, the range of closest approach is the ±5 meter position on the ordinate. The background conditions prevailing include a wind speed of 10 Km/hr, zero precipitation rate, no battlefield noise, and a cultural background 20 dB above the microseismic limit. The solid line shows the target level at the sensor for each position in range along the ordinate. The signal level shown rises from -121 dB to approximately -75 dB when the target is 5 meters from the sensor, and then recedes again to a high negative value. The perturbations in the signal strength are due to random variations included on each passage through the sensor routine to simulate the variable nature of the actual propagating medium.

SAMPLE SENSOR MODEL QUTPUT

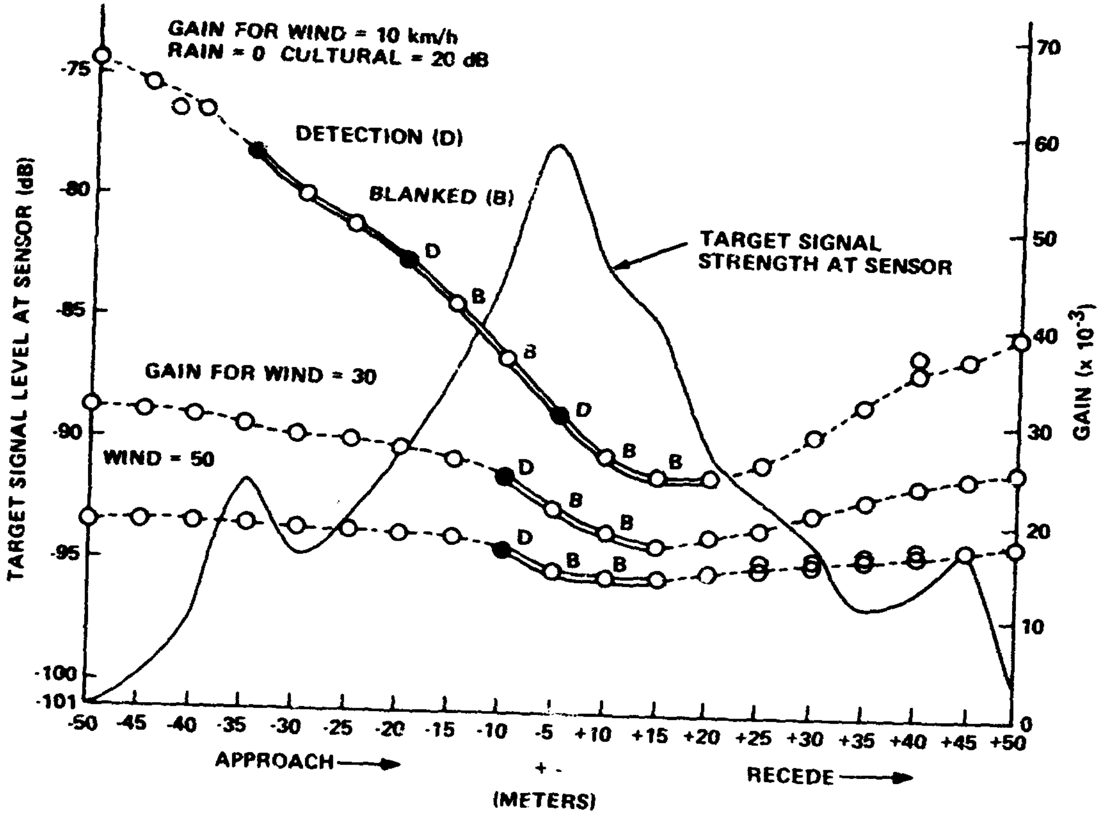


Figure 6.4-29 SAMPLE SENSOR MODEL OUTPUTS

The sensor being simulated is a type which adapts to the background noise level by a variable gain mechanism (Automatic Gain Control) through which output noise level is maintained constant. The upper dashed curve indicates that at the start of this problem the gain was approximately 70,000. Since target signal will affect the long time output of the AGC noise filter, it also will produce an effect on gain. Thus, as the target signal increases, the gain decreases though not in direct proportion. When the product of target signal (in volts) and gain exceeds a specified threshold level, a detection takes place. The points at which detections are observed are shown on the gain curve. There is a 15-second interval between the points because of the logic simulation contained within the model. It can be seen that three detections are observed for the conditions and the sample problem.

If this same problem had been encountered at some other time in the scenario, all conditions being the same except for wind speed which had now risen to the level of 30 Km/hr, the second dashed curve would have been computed. The target signal level would have been the same provided only that the same set of random numbers used in the first problem was employed again. The change in wind speed causes an increase in background noise and the sensor gain is adjusted accordingly starting at a level of approximately 31,000. Note that only a single detection was reported in this case. Similarly, when the wind speed increases to the high level of 50 Km/hr for the same problem, a further decrease in initial gain level is observed to approximately 18,000. Again, only a single detection is reported.

Other types of sensors are modeled in similar form. While in this sensor model a basic 5-second time interval between runs is employed to develop AGC characteristics, other models have entry intervals determined by considerations of gain calculation, signal logic, or other features.

6.4.4.2 Sensor Sample Target Activation Patterns from Field Trials

A comparison of the results described above for a single trooper is made with a sample of field data for a group of men and for a truck in actual field trials in which a sensor of the type described above was tested.* These sample results are presented in Figure 6.4-30 as an illustration of the kinds of target activation patterns that can be expected for this type of sensor.

The top seismic sensor activation pattern is for a 2-1/2 ton truck traveling along a road at 15 miles per hour. The second pattern is shown for the same truck traveling at 7 miles per hour. The third pattern is for a squad of five troopers walking past the sensor. The isolated activations indicated in each case are caused by operation of the AGC. Since the sensor responds to the noisier truck at greater distances, there is more time in which a second or third isolated activation can occur before steadily repeated activations begin. In each case, however, as the targets approach the sensor, a string of steadily repeated activations occur. These terminate

* High Gear Tests run at Eglin AFB, Florida

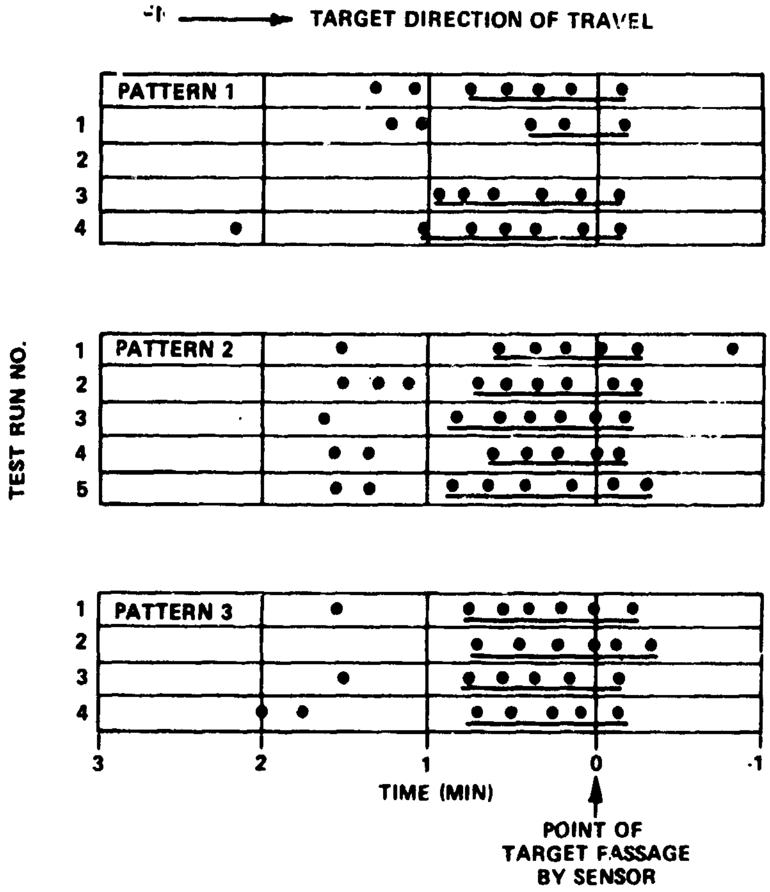


Figure 6.4-30 SENSOR SAMPLE TARGET ACTIVATION PATTERNS

shortly after the targets pass the sensor due to cut off by the AGC. Thus, it is seen that a definite, repetitive activation pattern is presented for both a single vehicle and a team of troops.

It is important to note that the above characteristics are utilized to formulate mathematical relationships for incorporation in the sensor report data analysis model[*] to estimate target velocity, length, and position. For example, the distinct cutoff of the repetitive portion of the activation patterns shown in Figures 6.4-29 and 6.4-30 as the trailing edge of the target (length, ℓ) passes by the sensor is an important observation. Referring to the equations summarized previously for the two-seismic sensor array, this observation is utilized in formulating the mathematical relationships based on the last or trailing element of the target for estimating target velocity, position, length, etc. Having this information, it may then be possible to classify the target under certain conditions. For example, if the target velocity is 15 miles per hour, the target can be classified as a vehicle since the maximum possible velocity of walking troops is much lower.

6.4.4.3 Simulated Monitor Display of Sample Sensor False Alarm and Target Activation Data Streams

Extensive reference has already been made to the false alarm problems in the UGS systems and of need for simulation of that problem in the model. In Figure 6.4-31 is shown the two-hour false alarm history that was developed in the simulation output data stream. Game time in seconds is denoted on the abscissa while the sensor identification numbers are denoted on the ordinate. Approximately 110 reports were obtained from 46 sensors for an average rate of approximately 1 per hour per sensor. In the two-hour period shown, some sensors produced no false alarms, while sensor #1 is seen to produce six false alarms.

The conditions to which each sensor is exposed will vary widely for a given time and set of environmental conditions in the scenario. Because of placement, vegetation, soil moisture, nearness to cultural sources and battle sources, range through foliage, light conditions, temperature and others, the background levels at any particular sensor will differ from that of others. Since in the simulation the variance in background noise as well as background noise level itself are derived from these conditions, false alarm rates for the UGS will vary widely even for sensors of the same type, differing only in emplacement position.

When targets are played in the model, detection times and sensor IDs are recorded. These reports are then merged with the false alarm string into a time sequenced output data that serves as input to the analysis model. The conditions prevailing at the scenario time for the example false alarm output display shown are the following: zero precipitation, wind speed of 7 km/hr, no battlefield background, and culture levels running over a range of 0 to 20 dB with respect to threshold. False alarm rates of higher or lower level would be reported for other conditions.

[*] Unattended

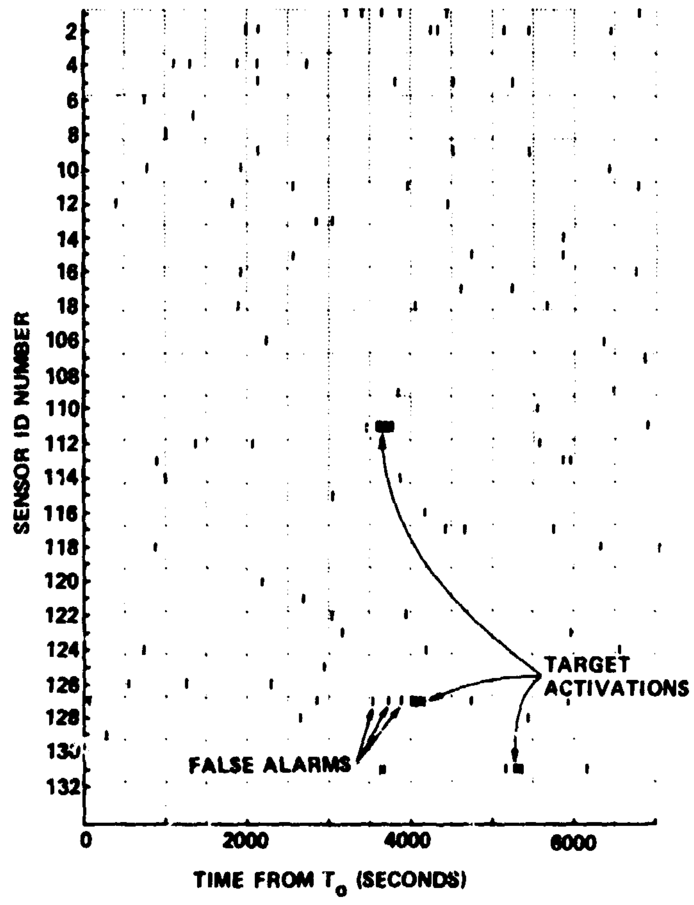


Figure 6.4-31 MONITOR DISPLAY OF SAMPLE SENSOR FALSE ALARM OUTPUT

For the sake of comparison, several steadily repetitive target activation patterns that are typical for a seismic sensor are overlayed on the pattern of false alarms. The target activations which are closely spaced in time stand out among the false alarms for the particular example shown. This may not be the case, however, in a very high false alarm environment. Needless to say, additional analysis utilizing the SAM I simulation model is required in order to obtain answers to this question. If sensors are utilized alone that indicate the presence of a target by one activation, it may be difficult, if not impossible, to differentiate between targets and false alarms. Thus, those combinations of sensors should be used that provide activation patterns that are distinguishable from the background of false alarm activations.

6.4.4.4 Sample Computer Print-Out of Unattended Sensor Data Processing Model Target Report

A sample computer run has been made for a selected tactical situation in order to indicate the format and the output of the model target report. Referring to Figure 6.4-32, a Firetrap operation along a trail consisting of 8 segments and 9 breakpoints (BPs) is analyzed. Firetraps (FT) Nos. 1 through No. 9 are located at each of the trail breakpoints shown. A target consisting of two vehicles each 10 meters long and separated by a distance of 50 meters is moving at a speed of 15 km/hr along the trail toward the first pair of collocated sensors that it passes. These are identified as seismic sensor ID No. 5 working in conjunction with magnetic sensor ID No. 6 in the "and" logic mode of operation. Thus, in this operating mode, a target report will be obtained from only the primary seismic sensor ID No. 5, although both sensors must detect the target before a target can be reported from this pair. The target successively passes acoustic sensor No. 7, seismic sensor ID No. 4, collocated pair seismic sensor ID No. 2, and magnetic sensor ID No. 3, and seismic sensor ID No. 1.

Monitor No. 1 is shown in Figure 6.4-32 to be connected to each of the above sensors. It is also shown as providing estimated times of arrival (ETAs) and speed of the target at the Firetrap positions to the artillery battery. Table 6.4-III summarizes the data input computer print-outs (other than sensor activation time histories) which are required by the model. These include trail ID No. and associated breakpoint locations. The latter are in terms of x, y coordinates measured in meters from a selected reference point ($x=0$, $y=0$). In addition, the cumulative length (s) is given in meters for the trail as each breakpoint is reached starting with breakpoint No. 1. Next, the monitor-to-sensor connections, sensor types, commanders estimate sensor x, y locations in meters, distance to each sensor along the trail in meters as measured from breakpoint 1 and the perpendicular offset as measured in meters from each sensor to the trail are summarized. Finally, the x, y coordinates, offset distances from the trail, and the cumulative distance (s) in meters to each Firetrap are summarized as measured from breakpoint No. 9 (or FT No. 1).

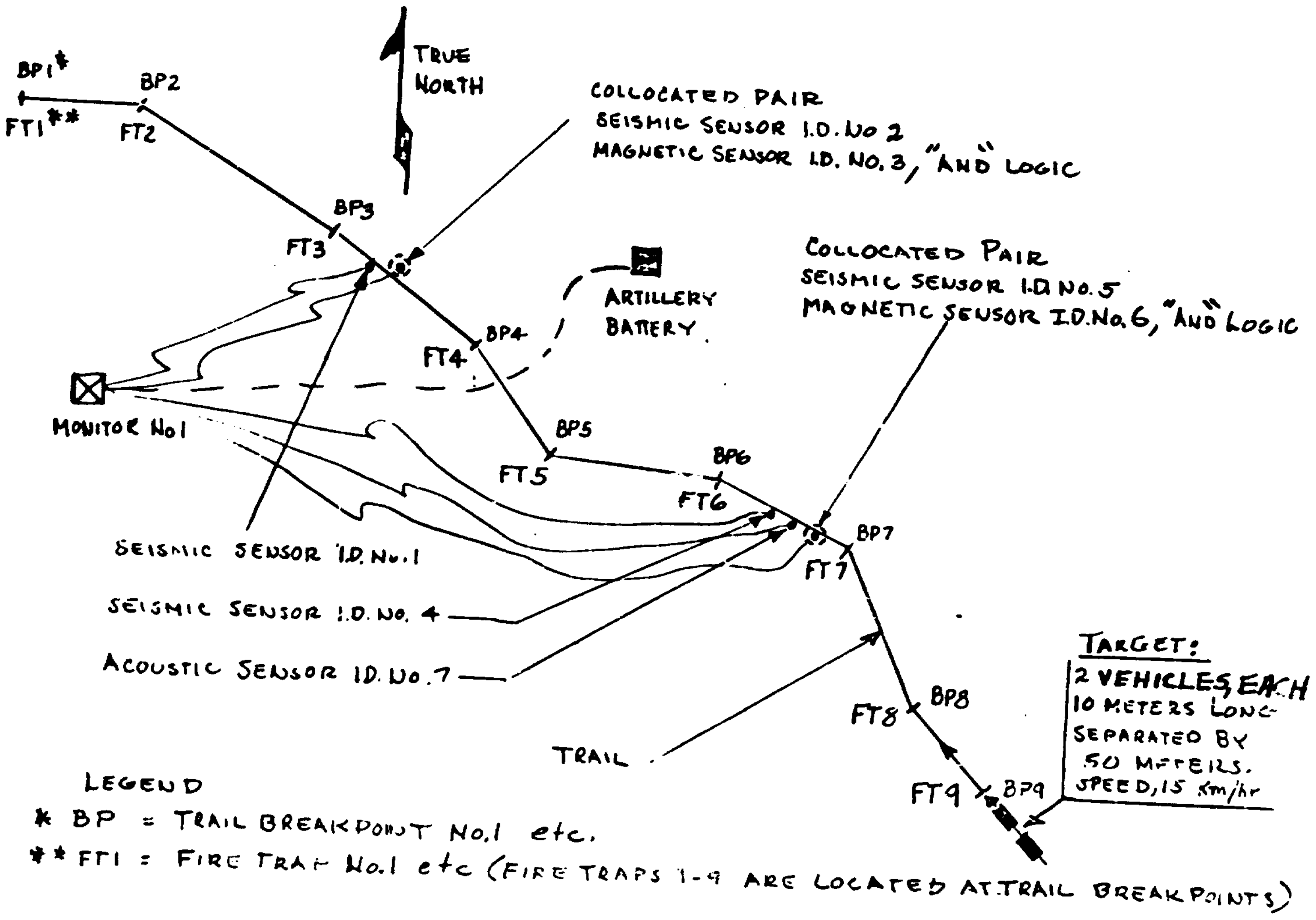


Figure 6.4-32 SENSOR/MONITOR/FIRETRAP DEPLOYMENT FOR TRAIL MISSION

Table 6.4-III
SUMMARY OF INPUT DATA FOR SAMPLE COMPUTER RUN

```
TRAIL DATA
BREAKPOINT    X(MTRS)    Y(MTRS)    S(MTRS)    TRAIL#
    1          56000      99590         0        1
    2          56570      99590       570        1
    3          57510      99000      1680        1
    4          58200      98450      2562        1
    5          58590      97940      3204        1
    6          59400      97850      4019        1
    7          60050      97580      4723        1
    8          60350      96790      5568        1
    9          60750      96400      6127        1


MONITOR#  1 IS CONNECTED TO  5 SENSORS AS FOLLOWS FOR THE PURPOSE OF  TRAIL   SURVEILLANCE:
SENSOR#  1     TYPE=SEISMIC    LOCATED AT X=  57690,  Y=  98830,  S=  1926,  OFFSET= 21
SENSOR#  2     TYPE=SEISMIC    LOCATED AT X=  57825,  Y=  98703,  S=  2111,  OFFSET= 36
SENSOR#  4     TYPE=SEISMIC    LOCATED AT X=  59650,  Y=  97746,  S=  4289,  OFFSET=  0
SENSOR#  5     TYPE=SEISMIC    LOCATED AT X=  59835,  Y=  97669,  S=  4490,  OFFSET=  0
SENSOR#  7     TYPE=ACOUSTIC   LOCATED AT X=  59735,  Y=  97695,  S=  4387,  OFFSET= 15


MONITOR#  1 IS CONNECTED TO  9 FIRETRAPS AS FOLLOWS:
  TRAP#  1     TYPE=ARTIL/RY   LOCATED AT X=  56000,  Y=  99590,  S=     0,  OFFSET=  0
  TRAP#  2     TYPE=ARTIL/RY   LOCATED AT X=  56570,  Y=  99590,  S=   570,  OFFSET=  0
  TRAP#  3     TYPE=ARTIL/RY   LOCATED AT X=  57510,  Y=  99000,  S=  1680,  OFFSET=  0
  TRAP#  4     TYPE=ARTIL/RY   LOCATED AT X=  58200,  Y=  98450,  S=  2562,  OFFSET=  0
  TRAP#  5     TYPE=ARTIL/RY   LOCATED AT X=  58590,  Y=  97940,  S=  3204,  OFFSET=  0
  TRAP#  6     TYPE=ARTIL/RY   LOCATED AT X=  59400,  Y=  97850,  S=  4019,  OFFSET=  0
  TRAP#  7     TYPE=ARTIL/RY   LOCATED AT X=  60050,  Y=  97580,  S=  4723,  OFFSET=  0
  TRAP#  8     TYPE=ARTIL/RY   LOCATED AT X=  60350,  Y=  96790,  S=  5568,  OFFSET=  0
  TRAP#  9     TYPE=ARTIL/RY   LOCATED AT X=  60750,  Y=  96400,  S=  6127,  OFFSET=  0
```

A summary of a sample computer print-out of the model target report is presented in Table 6.4-IV for the trail operation depicted in Figure 6.4-32. Beginning at game play time 72,672 seconds, no detections have occurred as yet on sensor pair IDs No. 5 and No. 6, and monitor No. 1 combination. However, at game play time 72,687 seconds, the first detection occurs on sensor ID No. 5. Detection on this sensor continues until target dropout on sensor ID No. 5 at game play time 72,717 seconds. Thus, JSTART = 72,687 seconds and JSTOP = 72,737 seconds, or a total of 45 seconds that sensor ID No. 5 continued to be activated by the target. During this time, sensor ID No. 5 reported 4 activations to monitor No. 1.

Similarly, sensor ID No. 7 is next to be activated at game play time 72,687 seconds. Target dropout occurred at 72,737 seconds. Thus, sensor ID No. 7 continued to be activated for a period of 50 seconds and reported 4 activations to monitor No. 1. Subroutine ANLYZE indicated that correlation existed between data on sensors ID No. 5 and No. 7. An estimated target speed of 20 km/hr and a target length of 279 meters is computed. Estimated times of arrival ranging from 73,457 seconds to 72,912 seconds are computed at Firetraps No. 1 through No. 5 respectively. Target heading when passing sensors ID No. 5 and No. 7 is a -653 mils relative to true north. The target report presented in Table 6.4-IV continues on in a similar manner for sensors ID No. 4, sensor pair ID No. 2 and No. 3, and sensor ID No. 1 as shown.

The accuracies of these estimates are made by comparing them with ground truth information obtained from the MSM output. This comparison is not presently included in the unattended sensor analysis target report since it is now a stand-alone program which has not been directly linked to the main simulation model. However, a sample comparison is included as follows for sensor combination ID No. 5 and ID No. 7:

Target Parameter	Estimated Value	True Value	Error
Speed	20 km/hr	15 km/hr	5 km/hr
Length	279 meters	70 meters	209 meters
ETA at Trap #2	73,360 sec	73, 634 sec	274 sec
ETA at Trap #1	73,457 sec	73,771 sec	314 sec

Additional comparisons for the other sensor combinations can be made by referring to Table 6.4-IV.

Decision Flow Logic Based on Monitor Activation Patterns and Correlation with Information from Other Sources

Referring to Figure 6.4-33, the work that has been accomplished in the development of an unattended ground sensor report data processing model is based on decision flow logics that are limited by analysis of sensor activation patterns only which are displayed on a monitor. A preliminary

Table 6.4-IV

SAMPLE COMPUTEF PRINTOUT OF UNATTENDED SENSOR ANALYSIS MODEL TARGET REPORT

(Sheet 1 of 3)

```
TIME= 72672       SENSOR#=    5      MONITOR#=  1
INSUFFICIENT DATA TO INDICATE TARGET


TIME= 72687       SENSOR#=    5      MONITOR#=  1
TARGET INDICATED ON SENSOR#  5


TIME= 72697       SENSOR#=    7      MONITOR#=  1
INSUFFICIENT DATA TO INDICATE TARGET


TIME= 72702       SENSOR#=    5      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  5


TIME= 72707       SENSOR#=    7      MONITOR#=  1
TARGET INDICATED ON SENSOR#  7


TIME= 72717       SENSOR#=    5      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  5


TIME= 72722       SENSOR#=    7      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  7


TIME= 72722       SENSOR#=    4      MONITOR#=  1
INSUFFICIENT DATA TO INDICATE TARGET


TIME= 72737       SENSOR#=    7      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  7


TIME= 72737       SENSOR#=    4      MONITOR#=  1
TARGET INDICATED ON SENSOR#  4


TIME= 72752       SENSOR#=    4      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  4


TIME= 72817       SENSOR#=    0      MONITOR#=  0
TARGET DROPOUT ON SENSOR#  5 AT TIME   72717
DURATION=        45, JSTART=   72672, JSTOP=   72717
SENSOR#   5 REPORTED   4 ACTIVATIONS TO MONITOR#  1


TIME= 72837       SENSOR#=    0      MONITOR#=  0
TARGET DROPOUT ON SENSOR#  7 AT TIME=  72737
DURATION=        50, JSTART=   72687, JSTOP=   72737
SENSOR#   7 REPORTED   4 ACTIVATIONS TO MONITOR#  1
CORRELATION EXISTS BETWEEN DATA ON SENSORS   7 AND   5
ESTIMATED TARGET SPEED=-20 KM/HR, TARGET= VEHICLE
TARGET LENGTH= 279 METERS
SET FIRETRAP FOR COORDINATES  56000,  99590:ETA=  73457;     TRAP#=   1
SET FIRETRAP FOR COORDINATES  56570,  99590:ETA=  73360;     TRAP#=   2
SET FIRETRAP FOR COORDINATES  57510,  99000:ETA=  73171;     TRAP#=   3
SET FIRETRAP FOR COORDINATES  58200,  98450:ETA=  73022;     TRAP#=   4
SET FIRETRAP FOR COORDINATES  58590,  97940:ETA=  72912;     TRAP#=   5
```

Table 6.4-IV

SAMPLE COMPUTER PRINTOUT OF UNATTENDED SENSOR ANALYSIS MODEL TARGET REPORT

(Sheet 2 of 3)

```
ESTIMATED TIME TABLE FOR TARGET MOVEMENT
TIME=  73457,  X=  56000,  Y=  99590
TIME=  73331,  X=  56570,  Y=  99590
TIME=  73172,  X=  57510,  Y=  99000
TIME=  73022,  X=  58200,  Y=  98450
TIME=  72913,  X=  58590,  Y=  97940
TIME= 72837TARGET IS NOW AT X=  59032Y=  97891
MOVING IN A DIRECTION OF -653. MILS(RELATIVE TO TRUE NORTH)
TIME=  72775,  X=  59400,  Y=  97850
TIME=  72655,  X=  60050,  Y=  97580
TIME=  72511,  X=  60350,  Y=  96790
TIME=  72417,  X=  60750,  Y=  96400


TIME= 72852      SENSOR#=   0     MONITOR#=  0
TARGET DROPOUT ON SENSOR#  4 AT TIME=  72752
DURATION=       30, JSTART=   72722, JSTOP=   72752
SENSOR#   4 REPORTED   3 ACTIVATIONS TO MONITOR#  1
ESTIMATED TARGET SPEED=-16 KM/HR, TARGET= VEHICLE
TARGET LENGTH= 177 METERS
SET FIRETRAP FOR COORDINATES  56000,  99590:ETA=  73643;     TRAP#=   1
SET FIRETRAP FOR COORDINATES  56570,  99590:ETA=  73523;     TRAP#=   2
SET FIRETRAP FOR COORDINATES  57510,  99000:ETA=  73288;     TRAP#=   3
SET FIRETRAP FOR COORDINATES  58200,  98450:ETA=  73102;     TRAP#=   4
SET FIRETRAP FOR COORDINATES  58590,  97940:ETA=  72966;     TRAP#=   5


ESTIMATED TIME TABLE FOR TARGET MOVEMENT
TIME=  73643,  X=  56000,  Y=  99590
TIME=  73523,  X=  56570,  Y=  99590
TIME=  73288,  X=  57510,  Y=  99000
TIME=  73102,  X=  58200,  Y=  98450
TIME=  72966,  X=  58590,  Y=  97940
TIME= 72952TARGET IS NOW AT X=  59122Y=  97881
MOVING IN A DIRECTION OF -653. MILS(RELATIVE TO TRUE NORTH)
TIME=  72794,  X=  59400,  Y=  97850
TIME=  72645,  X=  60050,  Y=  97580
TIME=  72466,  X=  60350,  Y=  96790
TIME=  72348,  X=  60750,  Y=  96400


TIME= 73240      SENSOR#=   2     MONITOR#=  1
INSUFFICIENT DATA TO INDICATE TARGET


TIME= 73255      SENSOR#=   2     MONITOR#=  1
TARGET INDICATED ON SENSOR#  2


TIME= 73265      SENSOR#=   1     MONITOR#=  1
INSUFFICIENT DATA TO INDICATE TARGET


TIME= 73270      SENSOR#=   2     MONITOR#=  1
TARGET CONTINUED ON SENSOR#  2


TIME= 73285      SENSOR#=   2     MONITOR#=  1
TARGET CONTINUED ON SENSOR#  2


TIME= 73290      SENSOR#=   1     MONITOR#=  1
TARGET INDICATED ON SENSOR#  1
```

Table 6.4-IV

SAMPLE COMPUTER PRINTOUT OF UNATTENDED SENSOR ANALYSIS MODEL TARGET REPORT

(Sheet 3 of 3)

```
TIME= 73300      SENSOR#=   2      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  2


TIME= 73305      SENSOR#=   1      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  1


TIME= 73320      SENSOR#=   1      MONITOR#=  1.
TARGET CONTINUED ON SENSOR#  1


TIME= 73335      SENSOR#=   1      MONITOR#=  1
TARGET CONTINUED ON SENSOR#  1


TIME= 73400      SENSOR#=   0      MONITOR#=  0
TARGET DROPOUT ON SENSOR#  2 AT TIME=  73300
DURATION=       60, JSTART=   73240, JSTOP=   73300
SENSOR#   2 REPORTED   5 ACTIVATIONS TO MONITOR#  1
ESTIMATED TARGET SPEED=-14 KM/HR, TARGET= VEHICE
TARGET LENGTH= 217 METERS
SET FIRETRAP FOR COORDINATES  56000,  99590;ETA=  73780;     TRAP#=   1
SET FIRETRAP FOR COORDINATES  56570,  99590;ETA=  73642;     TRAP#=   2


ESTIMATED TIME TABLE FOR TARGET MOVEMENT
TIME=  73780,  X=  56000,  Y=  99590
TIME=  73643,  X=  56570,  Y=  99590
TIME= 73400TARGET IS NOW AT X=  57416Y=  99059
MOVING IN A DIRECTION OF-1571. MILS(RELATIVE TO TRUE NORTH)
TIME=  73374,  X=  57510,  Y=  99000
TIME=  73161,  X=  58200,  Y=  98450
TIME=  73005,  X=  58590,  Y=  97940
TIME=  72808,  X=  59400,  Y=  97850
TIME=  72639,  X=  60050,  Y=  97580
TIME=  72434,  X=  60350,  Y=  96790
TIME=  72298,  X=  60750,  Y=  96400


TIME= 73435      SENSOR#=   0      MONITOR#=  0
TARGET DROPOUT ON SENSOR#  1 AT TIME=  73335
DURATION=       70, JSTART=   73265, JSTOP=   73335
SENSOR#   1 REPORTED   5 ACTIVATIONS TO MONITOR#  1
ESTIMATED TARGET SPEED=-14 KM/HR, TARGET= VEHICLE
TARGET LENGTH= 251 METERS
SET FIRETRAP FOR COORDINATES  56000,  99590;ETA=  73760;     TRAP#=   1
SET FIRETRAP FOR COORDINATES  56570,  99590;ETA=  73623;     TRAP#=   2


ESTIMATED TIME TABLE FOR TARGET MOVEMENT
TIME=  73760,  X=  56000,  Y=  99590
TIME=  73624,  X=  56570,  Y=  99590
TIME= 73435TARGET IS NOW AT X=  57239Y=  99171
MOVING IN A DIRECTION OF-1571. MILS(RELATIVE TO TRUE NORTH)
TIME=  73359,  X=  57510,  Y=  99000
TIME=  73149,  X=  58200,  Y=  98450
TIME=  72995,  X=  58590,  Y=  97940
TIME=  72800,  X=  59400,  Y=  97850
TIME=  72632,  X=  60050,  Y=  97580
TIME=  72430,  X=  60350,  Y=  96790
TIME=  72297,  X=  60750,  Y=  96400
```

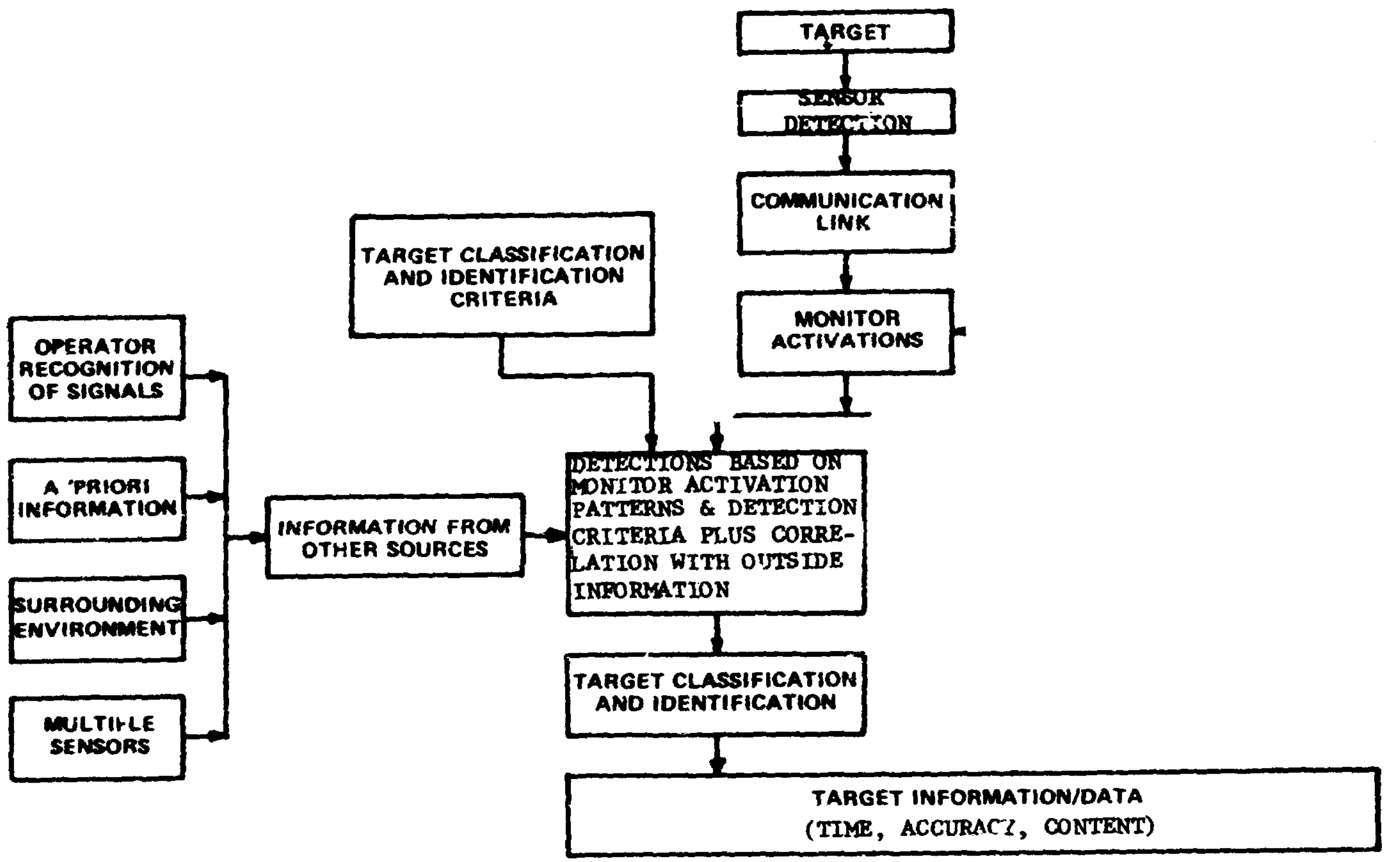


Figure 6.4-33 DECISION FLOW LOGIC BASED ON MONITOR ACTIVATION PATTERNS AND CORRELATION WITH INFORMATION FROM OTHER SOURCES

study has also been accomplished in which basic decision logics have been outlined utilizing sensor activation patterns displayed on a monitor plus correlation with outside information. This information from other sources includes such factors as processing of the raw input signals to the sensor and operator recognition of signals, a priori information, status of surrounding environment, information from sensor arrays in other sectors which are not netted to the monitors and arrays being watched, etc. The possibilities of utilizing some of the logics in the model plus additional logics and subroutines have not been fully explored up to the present time.

CONCLUSIONS

The following principal observations are reached as a result of utilizing the present Unattended Sensor Analysis Model:

1. A single present generation UGS is limited to detection of the presence of a target and/or estimation of the number of target elements.

2. Multiple non-collocated sensors or separated pairs of collocated sensors are required for target classification and certain false target filtering.

3. Target classification may or may not be obtained depending on the particular tactical situation encountered and the types of UGS utilized.

4. Additional outside (non-UGS) information must be added in order to identify targets.

TABLE 6.4-V
UGS ANALYSIS MODEL

USE	VARIABLES	USED BY
Common/MCHART/	NCHMAX, NCHART, NEVENT, JTIME (2000), JRPORT (2000), MONITR (2000)	
	NCHMAX - Maximum array size desired for JTIME, JRPORT, and MONITR. (2000) NCHART - Index number indicating entry slot for JTIME, JRPORT, and MONITR. NEVENT - Cumulative event counter. JTIME - Time of an event report. JRPORT - Sensor ID number associated with an event report. MONITR - Monitor ID number associated with an event report.	ANLYZE CALLIT COUNTR CRLATE FSTARG INSPCT MCHART (block data) NMOD RESET RODRUM
Common/INOUT/	ICARD, IPRINT, IPUNCH	
	ICARD - Device number for card (5) IPRINT - Device number for printer (6) IPUNCH - Device number for card punch (7)	CNNECT INOUT(block data) IILMSM

USE	VARIABLES	USED BY
Common/MONLST/	BGINNG, ICNFIG(100), ISTIME(100), JMSTRT(100), JMSTOP(100), JLIST(1500), JX(500), JY(500), JTYPE(500), JARRAY(500), JMONTS(500), JMONTR(5,500), JS(500,5), JOFFST(500,5), IBPA(100), IBPB(100), IONODE(1000), IBPX(1000), IBPY(1000), IBPS(1000), NTRAIL(1000), KTRAPA(100), KTRAPB(100), IDTRAP(500), KXTRAP(500), KYTRAP(500), KSTRAP(500), KTRAIL(500), DREFS(10,10), BUFFER	
	BGINNG - Code determining whether to call CNNECT (in order to read data in from cards) or not. True - Call False - Don't call (already have data)	ANLYZE CNNECT MONLST (block data)
	ICNFIG(M) Configuration type number for monitor (M)	
	ISTIME(M) Event start time for monitor (M)	
	JMSTRT(M) Minimum # of sensors associated with monitor (M) JMSTRT(M) = 1	
	JMSTOP(M) Maximum # of sensors associated with monitor (M)	
	JLIST(J) Sensor ID # belonging to monitor(M)	
	JX(JLIST(J)) X coordinate of sensor ID belonging to monitor (M)	
	JY(JLIST(J)) Y coordinate of sensor ID belonging to monitor (M)	

USE	VARIABLES	USED BY
	JTYPE(JLIST(J)) Sensor type for sensor ID belonging to Monitor(M)	
	JARRAY(JLIST(J)) Array number from which sensor ID for monitor(M) belongs	
	JMONTS(IDMON) Sensor/monitor combination number for sensor ID belonging to monitor (M)	
	JMONTR(JMONTS(IDMON),IDNO) Monitor number associated with sensor/monitor combination and sensor ID belonging to monitor (M)	
	JS(IDNO, JMONTS(IDNO)) Accumulative distance along the path of sensor associated with sensor/monitor combination and sensor ID belonging to monitor (M)	
	JOFFST(IDNO,JMONTS(IDNO)) Offset distance from the path, of sensor associated with sensor/monitor combination and sensor ID belonging to monitor (M)	
	IBPA(M) Minimum number of geometric nodes associated with monitor (M) (IBPA(M) = 1)	
	IBPB(M) Maximum number of geometric nodes associated with monitor(M)	
	IDNODE(N) ID # of geometric nodes (N) associated with monitor (M)	

USE	VARIABLES	USED BY
	IBPX(N) X coordinate of geometric node(N) associated with monitor (M)	
	IBPY(N) Y coordinate of geometric node (N) associated with monitor (M)	
	IBPS(N) Accumulative distance along the path of geometric node associated with monitor (M) (with respect to the first node on the path)	
	NTRAIL(N) Path number to which geometric node (N) associated with monitor (M) belongs	
	KTRAPA(M) Minimum number of firetraps associated with monitor (M) (KTRAPA(M)) = 1	
	KTRAPB(M) Maximum number of firetraps associated with monitor (M)	
	IDTRAP(K) ID # of firetrap (K) associated with monitor (M)	
	KXTRAP(K) X coordinate of firetrap (K) associated with monitor(M)	
	KYTRAP(K) Y coordinate of firetrap (K) associated with monitor(M)	
	KSTRAP(K) Accumulative distance along the path of firetrap (K) associated with monitor (M). (with respect to the first node on the path)	
	KTRAIL(K) Path number to which firetrap (K) associated with monitor(M), belongs	
	DREFS(I,J) Detection threshold values in impulses per second for sensor type (I) and operating environment (J)	
	BUFFER Intermediate storage area	

6.5 ATTENDED SENSOR ANALYSIS

At the conceptual level, the final logical framework for attended-sensors analysis parallels that for unattended sensors. That is:

- Simulated histories of "raw reports" would be derived within the PRERUN-MSM combination, and the appropriate information placed on an output file (MSMOUT).

- The MSM output file may then be used as input to any number of "analysis" or "message generation" program packages that would simulate the interpretation of raw sensor reports and the generation of corresponding messages that would enter the command structure.

Description of a package for analysis of unattended sensor reports has been given previously (Section 6.4). In this section is a description of an illustrative analysis (or message generation) package for attended sensors, much more limited in scope.

6.5.1 Major Distinctions Between Attended and Unattended Sensor Analysis

For the attended sensor classes considered (radar, thermal viewer and image devices), the human factors elements are much more pronounced than for unattended sensors. Physically, the human element enters into the sensing procedures themselves, into the "raw" reports, and into subsequent analysis. For the sensor classes studied, the attended sensors have the distinction of being scanning sensors. A fully developed model would therefore also have to consider human-dictated adjustments of scanning patterns (e.g., switch from search to track). Finally, the combination of a scanning, attended sensor and its human operators provides multidimensional information (e.g., estimates of target position, speed, composition and number of elements) in contrast to the simple 'yes' or 'no' signals typical of unattended sensors.

Thus, the complexity and variability for attended sensor simulation is a major problem over the range of environmental and battle conditions otherwise treated in the model. Indeed, the data base for reasonably comprehensive modeling does not appear adequate, and near-term expansion of the model appears to hinge, not on programming (coding) per se, but on (a) comprehensive problem definition, (b) major review of existing data sources on human factors in terms of sensor-plus-sensor context, and (c) additional human factors experiments aimed directly at supplementing the current data base.

An elementary approach to the attended sensor analysis package was provided with the CAL-programmed system assessment model. Its general features are described below.

6.5.2 Attended Sensor Analysis Package

A program package for elementary attended sensor analysis was provided that has two intents:

- Demonstration of coding that, while simple, illustrates the general nature of programs to convert "raw" reports to simulated operator messages about targets.

- Demonstration of a linkage from MSM to an output processor program (the basic input to the analysis package is the tape or disk file from MSM called MSMOUT).

6.5.2.1 Emphasis and Scope

Because more information was available on radar operator performance than for other attended sensor types, emphasis was placed on radar sensors. For these sensors, the primary target classes (also the ones most likely to lead to operator errors) are vehicles and personnel. It may be noted that aircraft and munitions are not treated as targets in the initial model for those sensors that can, in fact, distinguish them*, according to the limited warfare scope of this initial model.

The essence of this program package hinges on the combination of radar sensors and vehicle or personnel targets, and the corresponding "working" subprograms, RDRPRS and RDRVEH, are the only ones with non-trivial analysis structures.

For image and thermal viewer sensors, minimal near-dummy routines were provided to illustrate a reasonable mode of linkage for future development. These do, in addition, pass unprocessed reports to the print-out routine so that the corresponding information is not completely deleted.

A similar logic is used for the radar sensor/boat target combination. It is assumed that target type classification is simple for boat targets---if not by doppler signature, then by keying positions to known waterway routes.

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* Note aircraft and munitions signals are important to some unattended sensors, particularly seismic and acoustic, that cannot inherently screen out signals by target differences (e.g., height).

6.5.2.2 Major Qualitative Features of Program Package

With reference to the "emphasis" guidelines above, hence in the context of radar, the major qualitative features of the program package are summarized below.

Input. Primary input comes from the MSM output file called MSMOUT (tape or disk). Raw report data records for the attended sensors are sorted out (i.e., from unwanted records for unattended sensors), deciphered by the executive (main) routine, and then treated by whichever lower level routine is appropriate for the sensor class. Description of the content of the data records on MSM is given in Appendix C (in particular, Figure C-3). Minor input for run identification and for type selection comes from two data cards prepared by the program runner. (See Volume II for card preparation information).

Output. Message text is printed, imagining some of the important content of operator messages in field operations. In present coding, content covers (a) target type, (b) target position, and (c) number of elements in target...according to a list of possible statements that might occur and including the possibility that the operator makes no comment at all about one or more of these parameters.

Effects on Output. Qualitatively, it is assumed that an operator may make a general report, a specific report, or no report on a target parameter. A specific report may or may not be correct

Generally, favorable conditions (high signal to noise, good speed indices) dispose the report towards (a) specific, rather than general or non-existent commitment, and (b) lower probability of error. Unfavorable conditions tend to produce no estimate or vague estimates, with higher probability of error when a specific estimate is made.

The various choices are randomly selected, with probability values given in tables. Selection of the appropriate table and table entry is based upon (a) actual target type*, and (b) signal-to-noise ratio. In addition, a special case was made for personnel and vehicles having a speed (radial velocity) in the vicinity of 1.3 meters/second--that is, for fast-moving personnel and slow-moving vehicles. According to available data**, operators have a high probability of classifying vehicles as personnel and vice-versa in such situations, an implication that apparent speed is a dominating influence on an operator's interpretation of target type.

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* Vehicles and personnel only. As mentioned previously, analysis for boats is limited to a near-dummy routine.

** "Operator Proficiency in Interpreting Ground Surveillance Radar Signals (AN/TPS-33)", A. Kraemer, D. Easley, A. Miller, P. Stevenson, HumRRO Technical Report 90, June 1964

6.5.2.3 Program Structure

The total program package comprises a main (executive) program and 7 supporting subprograms directly oriented to the physical problem. Also used is a utility function-type subprogram, URN, that provides uniform random numbers. (This routine is also used in PRERUN, MSM, and other auxiliary program packages.) One common area, RAWRPT, is used to transmit the raw report record (from MSMOUT) to all subroutines requiring such data.

A list of the subprograms and brief descriptions are given in Figure 6.5-1. An English text macroflow diagram of the overall program structure is given in Figure 6.5-2.

The main program reads records from MSMOUT file one by one. A record that does not apply to an attended sensor is bypassed. If a record corresponding to one of the three classes of attended sensors is located, two steps are taken:

o Planner control data from cards specifies which classes of sensors are to be treated (e.g., planner may select only radar). If planner has rejected the type corresponding to the immediate record, the next record is read.

o If the planner has selected the sensor type corresponding to the immediate record, the data are left in common area /RAWRPT/, and the main program passes control to:

RDRMSG	for radar sensor
IMGMSG	for image sensor
THVMSG	for thermal viewer sensor.

These act as level 2 executive routines, each responsible for its particular sensor type.

True analysis is not performed in the original program package for image or thermal viewer sensors. The corresponding executive routines, IMGMSG and THVMSG, exist in dummy form and merely pass input data to the output printer.

Radar sensor reports are supervised by RDRMSG. It decodes the target type indicator (FORTRAN variable ITGTTP). If the code is invalid, a diagnostic is printed and the record is bypassed. If the code is valid, control is passed to the appropriate working routine as follows:

ASMAIN	Main program.
RDRMSG	Executive routine for radar sensors.
RDRVEH	Working routine for radar sensors, vehicle targets.
RDRPRS	Working routine for radar sensors, personnel targets.
RPTMSG	Print routine for simulated report messages.

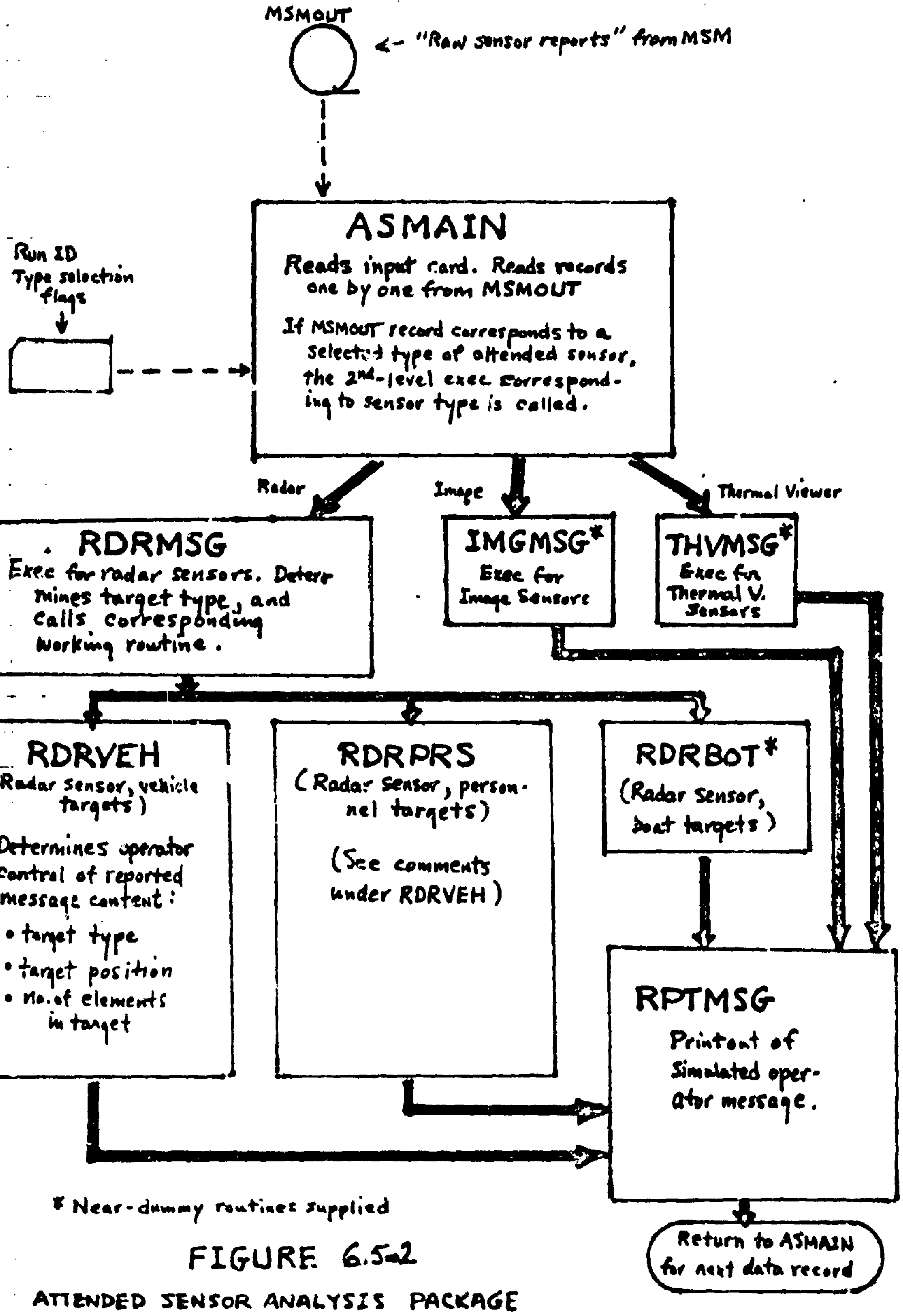
The following routines are provided as near dummy routines. Although full program linkages exist for illustrative purposes, and in order that information is not completely missing from printed output, no real "analysis" is performed.

IMGMSG	Executive routine for image type sensor.
THVMSG	Executive routine for thermal viewer sensors.
RDRBOT	Working routine for radar sensors, boat targets.

The following function type subprogram is a utility program, not unique to the sensor analysis package:

URN	Uniform random number generator.

Figure 6.5-1 SUBPROGRAMS WITHIN ATTENDED SENSOR ANALYSIS PACKAGE



* Near-dummy routines supplied

FIGURE 6.5-2

ATTENDED SENSOR ANALYSIS PACKAGE SUBPROGRAM FLOW DIAGRAM

ITGTTP	Target Type	Routine Called
1	Personnel	RDRPRS
2	Vehicles	RDRVEH
3	Boats	RDRBOT

The essential operations of the package reside in RDRPRS (radar sensor, personnel target) and RDRVEH (radar sensor, vehicle target). Logical structures of these two routines are nearly identical. Brief discussion of RDRVEH, given below, therefore applies generally to RDRPRS. Commented program listings and AUTOFLOWS (supplied separately, Volume III) provide additional detail.

6.5.2.4 Summary of RDRVEH Logic

A macroflow diagram of RDRPRS operation is given in Figure 6.5.3. The qualitative aspects of the logic follow results published in HumRRO Technical Report 90 (see full reference in previous footnote). Description in some cases uses numerical values of probability parameters. It is to be understood that exact numerical values may be readily changed, and do not influence the basic logic. Values provided are, in most cases, quite tentative.

6.5.2.4.1 Target type classification

The initial block of RDRVEH coding applies to determining what an operator might decide about target type. Reference may be made to the partial flow diagram of Figure 6.5-4.

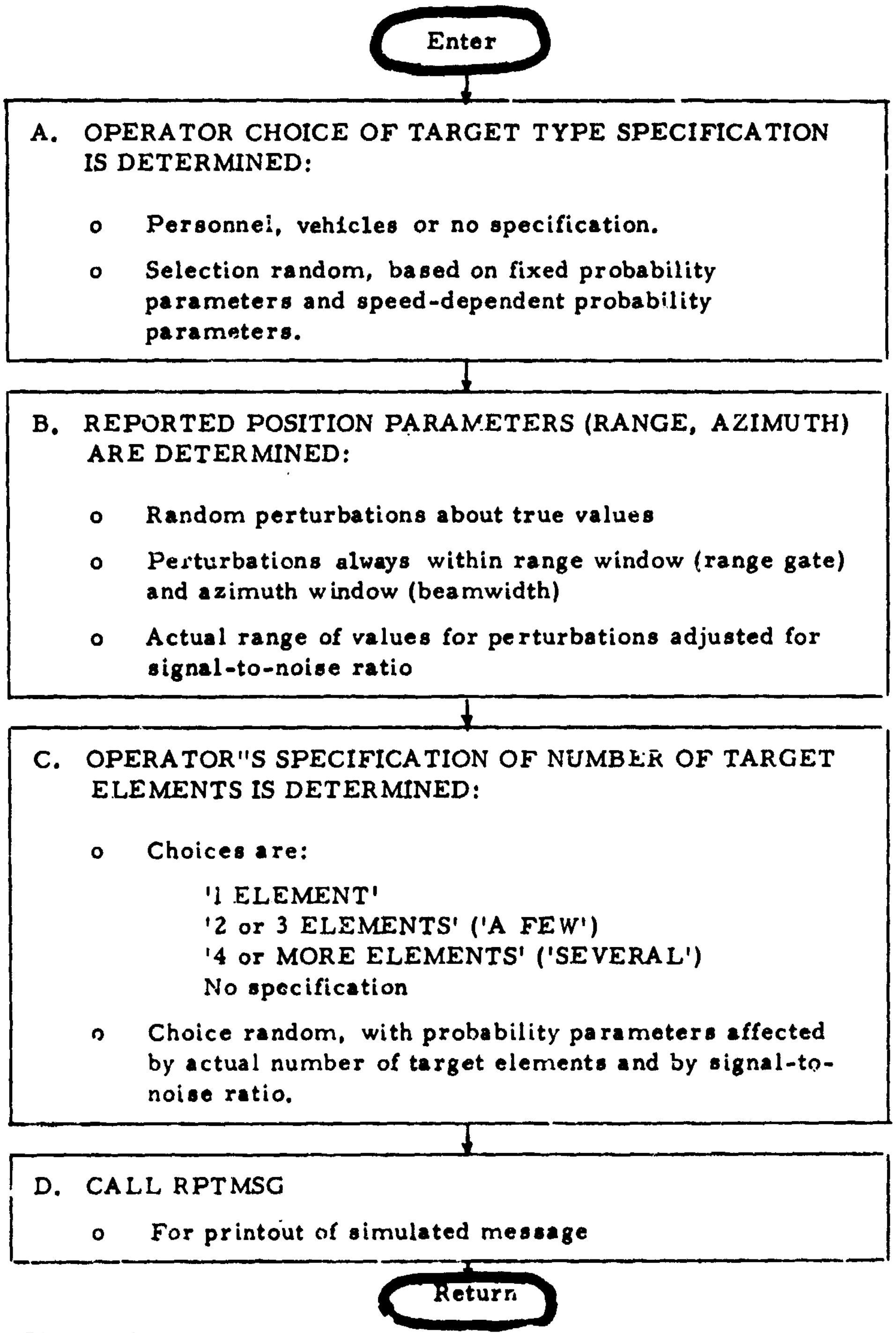
o Some small percentage of the time (8%), regardless of conditions, operators tend to make no statement about target type. If the program determines that commitment would be made, the following step is reached.

o A special case is made for slow-moving vehicles.* According to the literature, slow-moving vehicles are incorrectly classified as personnel (given that any classification estimate is made at all) about 50% of the time.

For slow-moving vehicles (below 1.35 meters/second), this is the last step of classification logic.

---

* In RDRPRS, for personnel targets, the analogous situation corresponds to fast-moving personnel, often misclassified as vehicles.



A. OPERATOR CHOICE OF TARGET TYPE SPECIFICATION IS DETERMINED:

- Personnel, vehicles or no specification.
- Selection random, based on fixed probability parameters and speed-dependent probability parameters.

B. REPORTED POSITION PARAMETERS (RANGE, AZIMUTH) ARE DETERMINED:

- Random perturbations about true values
- Perturbations always within range window (range gate) and azimuth window (beamwidth)
- Actual range of values for perturbations adjusted for signal-to-noise ratio

C. OPERATOR"S SPECIFICATION OF NUMBER OF TARGET ELEMENTS IS DETERMINED:

- Choices are:

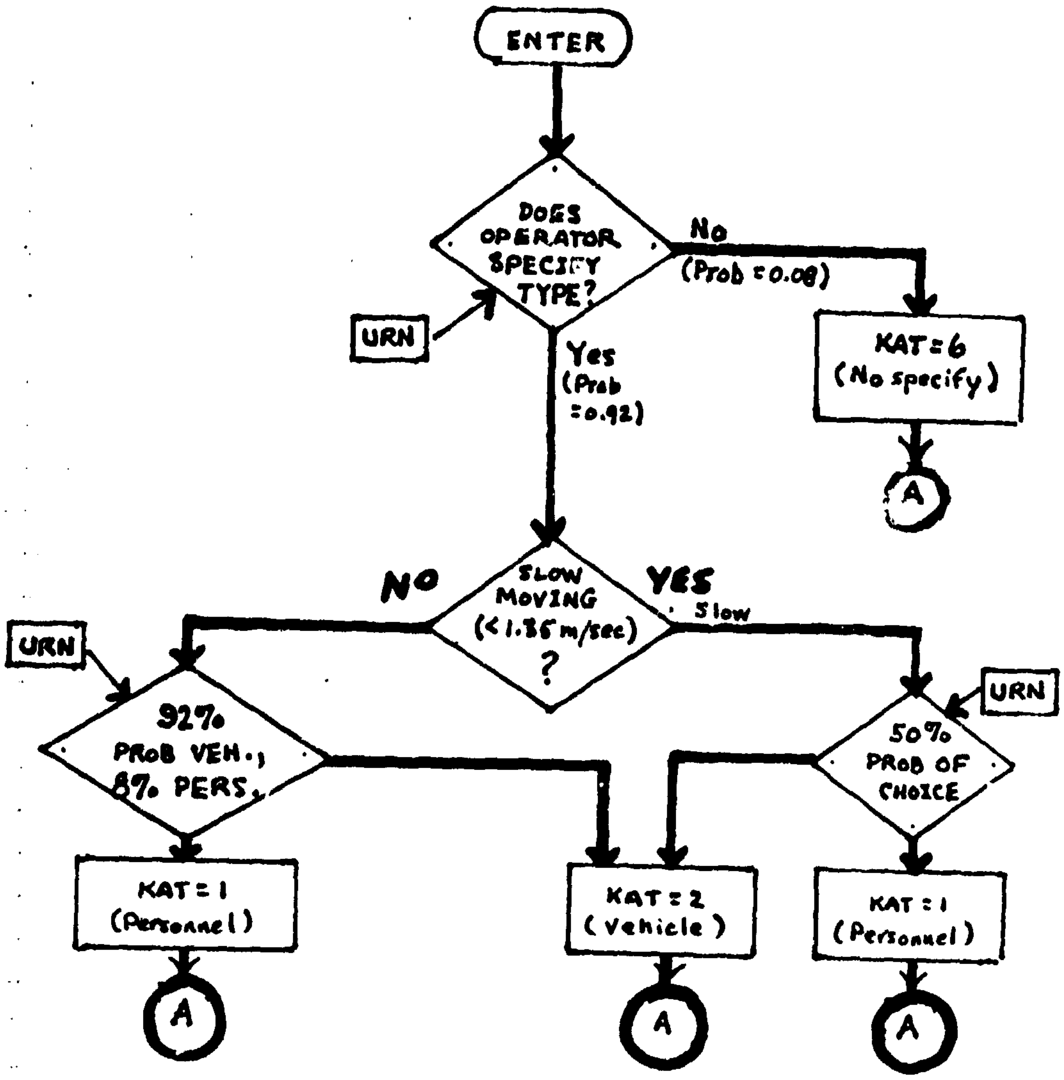
  '1 ELEMENT'
  '2 or 3 ELEMENTS' ('A FEW')
  '4 or MORE ELEMENTS' ('SEVERAL')
  No specification

- Choice random, with probability parameters affected by actual number of target elements and by signal-to-noise ratio.

D. CALL RPTMSG

- For printout of simulated message

Figure. 6.5-3 MACROFLOW FOR SUBROUTINE RDRVEH



Notes: URN: Uniform Random No. Generator
See Fig. 6.5-5 for continuation

Figure 6.5-4. PARTIAL FLOW DIAGRAM — TARGET TYPE SPECIFICATION WITHIN RDRVEH

- o For fast-moving vehicles, operators are quite accurate in correctly classifying type, but do make occasional misclassifications of vehicles as personnel. The program assigns a fixed probability (92%) to correct classification and the complement (8%) to the incorrect specification as personnel.

6.5.2.4.2 Target position:

The program assumes that the operator will always report location information. Current version expresses this information in terms of target range and azimuth relative to the sensor... that is, in radar coordinates.

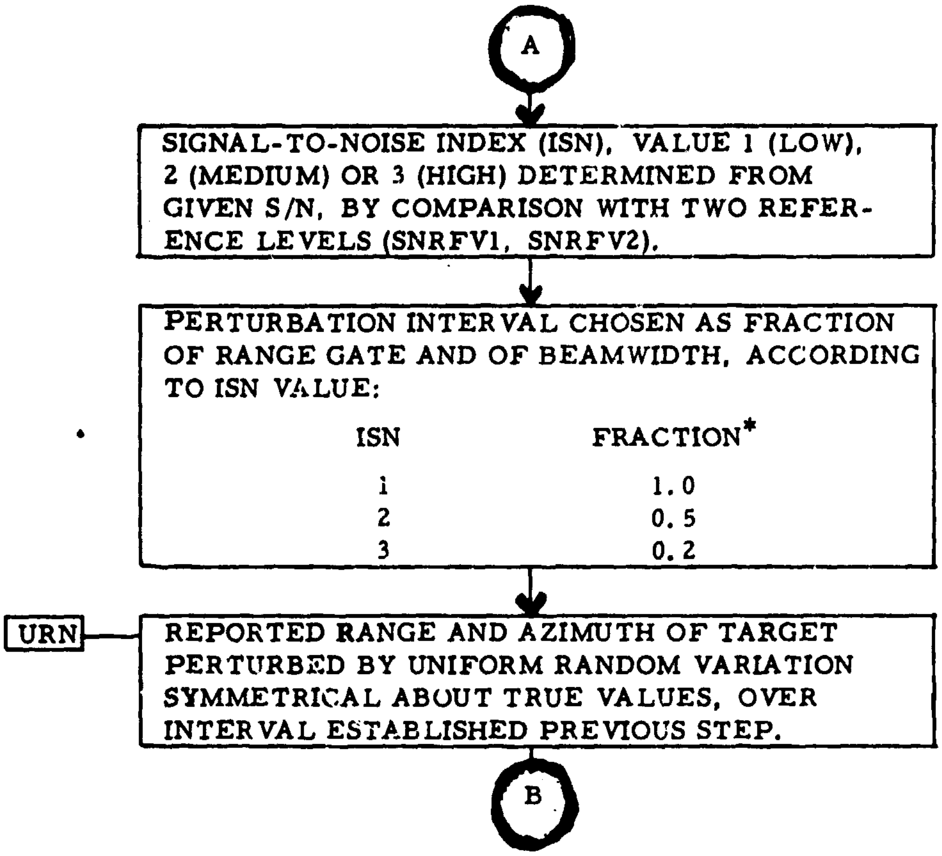
However, it is assumed that the coordinates transmitted will vary from the true coordinates by a random amount that depends upon signal-to-noise (S/N) ratio. The table below relates to current coding, in which S/N is quantized into three descriptive levels (low, medium and high). The random variation is assumed to be a percentage of the range gate or beamwidth as follows (recall, exact numerical values are illustrative, though reasonable, but do not influence the basic logic):

	Variations Allowed Over This Fraction of	
S/N	Range Gate	Beamwidth
Low (< 0.5 dB)	100%	100%
Med. (0.5-1.5 dB)	50%	50%
High (> 1.5 dB)	20%	20%

Figure 6.5-5 gives a partial flow diagram for this block of RDRVEH.

6.5.2.4.3 Number of elements in target:

Present coding, although limited in scope, does reflect basic qualitative features of the operator's problem of estimating the number of elements in a target. The routine (RDRVEH or RDRPRS) provides for four possible message texts from the operator concerning number of target elements:



SIGNAL-TO-NOISE INDEX (ISN), VALUE 1 (LOW), 2 (MEDIUM) OR 3 (HIGH) DETERMINED FROM GIVEN S/N, BY COMPARISON WITH TWO REFERENCE LEVELS (SNRFV1, SNRFV2).

PERTURBATION INTERVAL CHOSEN AS FRACTION OF RANGE GATE AND OF BEAMWIDTH, ACCORDING TO ISN VALUE:

ISN	FRACTION*
1	1.0
2	0.5
3	0.2

REPORTED RANGE AND AZIMUTH OF TARGET PERTURBED BY UNIFORM RANDOM VARIATION SYMMETRICAL ABOUT TRUE VALUES, OVER INTERVAL ESTABLISHED PREVIOUS STEP.

---

* Numerical values set by data statements. FORTRAN variables are RVARV (for fraction of range gate) and AZVARV (for fraction of beamwidth).

Figure 6.5-5 PARTIAL FLOW DIAGRAM FOR REPORTED RANGE AND AZIMUTH WITHIN RDRVEH

Code (KINDEX)	Text
1	'A TARGET' (' TARGET ELEMENT')
2	'A FEW TARGET ELEMENTS' (2 or 3)
3	'SEVERAL TARGET ELEMENTS' (4 or more)
4	Operator does not specify number of target elements

Program selection of the KINDEX code (hence message) depends most strongly upon the actual number of target elements, more weakly upon the signal-to-noise ratio. The partial flow diagram of Figure 6.5-6 may be referenced.

First, the non-specify possibility (KINDEX = 4) may be selected, with a random test against probability values (PUNSVQ table) determined by signal-to-noise. Qualitatively, a low signal-to-noise tends to cause the operator to omit a count variable in his report. If KINDEX is 4 according to this test, the following steps are bypassed.

Second (if this step is reached), one of the values 1, 2 or 3 will be selected for the KINDEX. The value is selected randomly, but with probabilities that depend upon the actual number of elements in the target. For example, there will be a strong tendency for the report to specify one target element if, in fact, there is one target element and to specify "several - 4 or more" if the actual number of elements is greater than 4.

First, the actual number of target elements is mapped into a 3-level index, IKOUNT, as follows:

IKOUNT	True Number of Target Elements
1	1
2	2 or 3
3	4 or more

Given IKOUNT, a uniform random number is referenced against appropriate entries in a preset probability table, PQ (IKOUNT, KINDEX), with the following definition:

PQ (IKOUNT, KINDEX) = Probability that the result is KINDEX, given a value for IKOUNT.

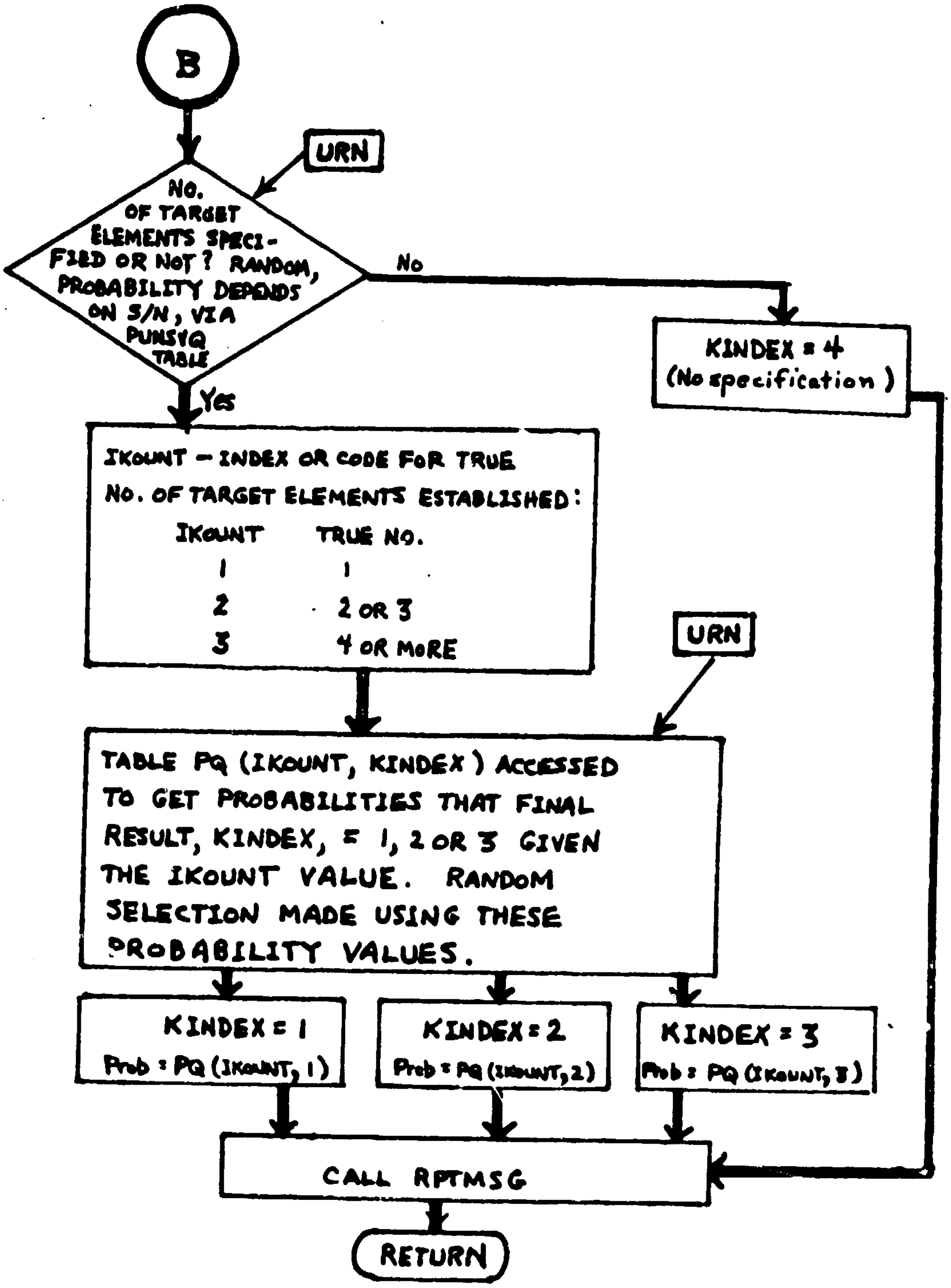


Figure 6.5-6 PARTIAL FLOW DIAGRAM – FOR SPECIFICATION OF NO. OF TARGET ELEMENTS, RDRVEH

For example, PQ (1, 2) is the probability that the operator will report "2 or 3" target elements (KINDEX = 2), if the target has, in fact, one target element (IKOUNT = 1). Because some choice (1, 2 or 3) is made for KINDEX, PQ satisfies the obvious requirement:

$$PQ\ (IKOUNT,\ 1) + PQ\ (IKOUNT,\ 2) + PQ\ (IKOUNT,\ 3) = 1.0$$

for every possible IKOUNT value. It should perhpas be noted that these PQ values are conditional, in that they apply <u>only</u> <u>when</u> the possibility of non-specification (KINDEX = 4) has been previously rejected. Thus:

$$\text{Prob (KINDEX} = 2 \text{ if true number of target elements} = 1)$$
$$\text{Prob (KINDEX} \neq 4) \times \text{Prob (KINDEX} = 2, \text{ given target element)}$$
$$= \text{Prob (KINDEX} \neq 4) \times PQ\ (1,\ 2).$$

Qualitatively, the numbers in the probability table PQ are oriented to:

- highest probability of correct count code
- next highest probability of being off by 1 in the count code
- lowest probability of being off by 2 in the count code

6.5.2.5 RPTMSG: Printout Routine

After a working routine (such as RDRVEH) has established target position values, and codes for target type and for number of elements, RPTMSG is called to provide printout of a simulated message. In this routine, also, are the conversions of azimuth angles (radians, mathematical convention, used internally) to bearing in mils. A typical message printout might be:

```
DAY 1  TIME 1433:20  REPORT FROM SENSOR 132(*)
TARGET AT RANGE  1455 METERS, BEARING  452 MILS
TYPE OF TARGET PERSONNEL
SEVERAL ELEMENTS
```

TABLE 6.5-I

ATTENDED SENSOR ANALYSIS MODEL COMMON AREAS

USE	VARIABLE	USED BY
Common/RAWRPT/	UNUSED(S), IDSNSR, IDARAY, ORGCD1, ORGCD2, IMOVE, IDAY, ICLK24, ISEC, XSNSR, YSNSR, SSPEED, IDTGT, KDCODE, XTGT, YTGT, RANGE, AZ, SNOIS, PDET, ISCAN, BMWDTH, RGATE, ITGTTP, NOELEM, VRADL, STYP1, STYP2, FDOPLR	
	UNUSED(S) - The first five words of this common area are not used. IDSNSR - ID of the sensor. IDARAY - ID of array to which sensor belongs. ORGCD1, ORGCD2 - Two words. Organization to which sensor belongs. IMOVE - Move code for sensor: negative - airborne; zero - stationary; positive - ground moving IDAY - Integer value for day of game 0, 1, etc., of detection ICLK24, ISEC - Twenty-four hour clock giving hours, minutes & seconds of detection respectively. XSNSR - X coordinate of sensor. YSNSR - Y coordinate of sensor. SSPEED - Speed of the sensor (m/sec)	RDRMSG RDRPRS RDRVEH RDRDOT IMGMSG THVMSG

USE	VARIABLE	USED BY
	IDTGT - ID of the target.	
	KDCODE - Target code: 1 - Red Tgt 2 - Blue Tgt 3 - False Tgt 4 - False Alarm	
	XTGT - X coordinate of target	
	YTGT - Y coordinate of target	
	RANGE - Range of target from sensor	
	AZ - Bearing of the target (mils clockwise from north)	
	SNOIS - Signal to noise ratio of sensor	
	PDET - Probability of detection	
	ISCAN - Code describing what scan routine was used. SCAN 1 or SCAN 2.	
	BMWDTH - Beam width of sensor	
	RGATE - Rangegate of sensor	
	ITGTTP - Target type	
	NOELEM - Number of elements in the target	
	VRADL - Radial velocity of target	
	STYP1, STYP2 - Specific type of sensor (alphanumeric)	
	FDOPLR - Doppler Frequency of Target	

TACTICAL COMMUNICATIONS MODEL

6.6

6.6.1 Purpose.

The purpose of the Tactical Communications Model is to utilize a set of computer programs to simulate the flow of STANO messages through a tactical communications network.

6.6.2 Scope.

TACCOM consists of a main program with eleven supporting subroutines, two of which are utility subprograms. It contains approximately 900 source statements, has a total length of 186,376 bytes, prints approximately 60,000 lines, takes about 22.66 minutes to run and uses about 1.11 minutes of CPU time on an IBM 360-65 computer.

6.6.3 Objectives.

The main objective of the TACCOM model is to determine the timeliness of messages which are sent through a tactical communications net. This timeliness is to be measured in terms of delays which the messages incur. These delays include initial and final operator delay, net changeover delay and delays caused by STANO and non-STANO messages.

6.6.4 Assumptions.

The following assumptions are implicit in the Tactical Communications Model:

All non-STANO messages in the queue over 15 minutes in time history for both the transmitter and receiver nodes of the STANO message will be deleted from the flow. (This time may be changed as a parameter.)

A message can flow only up or down or horizontal.

A message is considered "entered into" or "presented out of" the communications net only after occurrence of the initial and final operator delays.

Operator delay is sampled randomly from a normal distribution with mean 85 seconds and standard deviation 25 seconds. (Means and standard deviations may be changed as a system parameter and in the future may be changed to variables dependent on the location of the message and the net being transmitted on).

When a message is being processed from one location to another, all the available nets will be tried. If an available net is not being used (no queue), the message will be transmitted to its receiver location and a new set of available nets will be determined at that location for the next link. If all the available nets are being used, the message will continue to try to get through to its receiver location on the last available net tried.

A maximum of 50 random non-STANO messages can be generated at the transmitter and receiver nodes any time 15 minutes prior to the present game time of the STANO message. (This number may be changed as a system parameter).

Non-STANO messages are assumed present during the processing of the STANO message in order to create a possible delay upon the STANO message for the purpose of simulating the daily flow of messages during the game. Thus, non-STANO delays are calculated as if the non-STANO messages are being constantly processed.

Any message with a precedence of two or less is considered to have high precedence. See paragraph 6.6.5.3, number 2, for an explanation of message precedences.

6.6.5 TACCOM Planner Inputs

6.6.5.1

Data Set #	Name	Contents
I	TABLE A	A chronological list of STANO messages
II	PRECEDENCE	A list of the message precedences, net preferences and path ID's for each message.
III	COMMOROUTE	A description of the path followed by each message.
IV	NET CYCLE CHANGE-OVER DELAYS	Net changeover delay statistics. See para. 6.6.6.4
V	COMMOTRAFIK	Non-STANO communication traffic statistics (rates & lengths)
VI	TRAFIKMODS	Time dependent modifiers of the above non-STANO message rates and lengths
VII	BYPASS DATA SET	Provides input for play or bypass of operator and net cycle delay.

6.6.5.2 TABLE A (Data Set I), is set up to handle 200 messages. This is an arbitrary limitation and may be modified by changing the dimensions of TABLE A and TABLE B in all programs of the model, and by changing the first executable statement, fourth executable statement from the last, and second executable statement before Statement #72 in subroutine TACCOM. TABLE A contains information on new messages, while TABLE B contains information on messages in process.

The present model operates from data cards and reads in up to 200 message cards for processing at a time. As a future expansion, it may be more reasonable to provide an executive package and put these messages on disc. This will be particularly true if a direct linkage is established between the MSM and the other output processing submodels. The information in TABLE A (Data Set I) is described as follows:

Column 1: ITIME -- This is the time (in sequence) the monitor operator determines a sensor report has occurred. (In seconds of game time from game time zero)

Column 2: MSGNUM -- This is the message number (in sequence) of this message. Each message will have a distinct message number which can be cross-referenced to the message output from the sensor analysis models to get the actual message content.

Column 3: IDMON -- This is the ID of the monitor from which this sensor report is coming from. This number should be the same as that used in PRERUN for this monitor.

Column 4: MESSAGE TYPE -- This is a number from one to 100 assigned by the planner to give the specific description of the message which is being sent. The data in the Precedence Data Set is arranged and extracted by message type and subroutine PRCDNT keys off of this message type.

Column 5: MESSAGE LENGTH -- This is the length in seconds of the message being sent. The message length should be considerably longer between higher echelons than lower echelons.

6.6.5.3 The PRECEDENCE DATA SET (II) is prepared by the planner for message precedences and net preferences for up to 100 message types and contains the following items:

MSGTYP -- Message type (1-100). This is the message type of this particular message described in the TABLE A Data Set.

MSGPRC -- Message Precedence Code. The specific message precedences which may be used in the model are:

Flash or Category Z. (1)
Emergency or Category Y (2)
Operational Immediate or Category O (3)
Priority or Category P (4)
Routine or Category R (5)
Deferred or Category M (6)

Any message with a message precedence of two or less is considered to have high precedence.

IPATH -- This is the Path Identification number of the route of this particular message. It is possible for two or more of the same or different messages to be sent from the same location, but along a different route. IPATH differentiates between a message going along one route and the same type or different message going along another route.

NETPRF -- This is the Net Preference code for this message. Four different nets are provided for. The design of the model is such that any radio net may be represented since frequencies, coding or other individual net characteristics are not treated. The four nets considered as most frequently used at brigade and below are:

Command Operations Net (RATT)
Command Operations Net (FM)
Intelligence Net (FM)
Fire Support Net (FM)

Specifications of a four digit code provide net preferences for each message (first digit is primary net, second digit is secondary net, etc.)

LTIME -- This is a time variable to allow for future expansion in the model so that messages may be identified with MSM game time in order to have the message types, precedence, and routing be more closely tied to the scenario.

6.6.5.4 COMMO ROUTE Data Set III is input by the planner and is provided to describe the particular route which each message will follow through the TACCOM Net. The particular items of this data set are:

ROUTE NUMBER -- This is the IPATH number passed from the Precedence Data Set and is the ID of this route.

MONLOC -- This is the location designation of the monitor from which the message is sent. Platoon designations are a hundreds number, company a tens number, battalion a units number, and brigade is 1000. Thus for example, 321 is 3d platoon 2d company, 1st battalion of the brigade 1000. The capacity of the design allows for 1 brigade, 9 battalions, 35 companies and 155 platoons.

NODES -- This is the nodal connection code for the flow of this message along this path. A nodes code (NENTRY Numbers) is used to indicate echelons as follows: 1-brigade, 2-battalion, 4-company, 6-platoon. Thus 6421 means the message starts at platoon and goes through company and battalion to brigade, while 1206 means the message starts at brigade and goes through battalion to a platoon (skipping company).

IHORIZ -- This is the message flow direction code for this message. IHORIZ = 0 means the message is going vertically; for example, battalion to company. IHORIZ = 1 means the message is going horizontally; for example, platoon to platoon.

IROOT -- This is the lowest echelon along this path for this particular message. For a message going horizontally, IROOT is the destination unit of this message. If a message goes from 123 to 23, 123 would be the IROOT.

6.6.5.5 The Net Cycle Changeover Delay Times Data Set (IV) allows the planner to specify various density statistics to be used for the four nets. Included are means and standard deviations of normal densities for net cycle changeover times for echelon levels transmitting up or down. This data set is not used unless so indicated in Input/Bypass Data Set (VII).

6.6.5.6 The COMMOTRAFIK Data Set (V) is prepared by the planner to indicate non-STANO communication traffic statistics to be used. Maximum and minimum (nominal) message rates and lengths are to be supplied for each message precedence echelon, flow direction and net.

6.6.5.7 The TRAFIKMODS Data Set(VI)is prepared by the planner to identify the time dependent modifiers of the COMMOTRAFIK supplied message rates and lengths. Percent message rate and message length inputs may be specified to be in effect at specific game times for each message precedence, echelon, flow direction and net.

6.6.5.8 The final Planner Input, Bypass Data Set(VII) provides for input for play or bypass of operator delay times and net cycling delay times.

The use of these planner data sets will be elaborated upon during the discussion of the model operation

6.6.6 Message Delays

As has been indicated, the model is structured around the determination of a time history for each STANO message entering the communications system. Four types of delays are encountered in communications of this type and are simulated in the model. They are:

Operator delays.
Queues due to non-STANO traffic at each node
Queues due to STANO traffic at each node
Net changeover delays

Before proceeding to a discussion of the model subroutines, some discussion of these delays is appropriate.

6.6.6.1 Operator Delays. Operator delays (exclusive of queuing) occur at each node the message encounters during its flow through the communications net. There are a maximum of eight (8) times at which operator delays may be simulated; two (2) each at brigade, battalion, company, and platoon. The choice as to whether or not to play these delays is a planner option. If the planner indicates that the game will not play any operator time delays (by input of a zero for game variable KOPERT), neither the operator delays in receiving or transmitting the message at any node will be played. However, an input of 1 for KOPERT indicates that the simulation will not bypass operator time delays at any node and will sample from a normal distribution with a mean of 85 seconds and a standard deviation of 25 seconds. Further, if the value obtained is such that the operator delay is less than ten (10) seconds or greater than 160 seconds, i.e., outside of the three sigma range, then the value will be rejected and a new sample drawn. Introduction of operator delay is included as program statements, and, if it is desired to change the above normal distribution parameters, the following statements may be changed (statement 35 in TACCOM, statement 49 in MSGQUE for initial, and statement 35 in MSGQUE for final).

The initial operator delay is included to account for the time during which the man monitoring the reports from the sensor introduces the material to the tactical communications net. This does not include any queuing problems but is basically the time for processing of the message, any coding that might be required, formatting, and getting the message to the point at which it can be introduced to the tactical communications net. The final operator delay is to allow for the decoding if required, the writing and formatting that may be required, and delivery to its destination for presentation to the addressee, e.g., a tactical operations center.

6.6.6.2 Interaction with Non-STANO Messages. STANO messages are defined for the purposes of the Tactical Communications Model as those messages which are input and whose time histories are to be traced through the model. They are assumed to contain activity detected by STANO devices. The non-STANO messages to be simulated are derived in a random fashion by having the planner input statistics for their message rates and lengths. The non-STANO messages represent the basic communications traffic over the nets. There is also an allowance for up to six categories of message precedence; not all six need be played. Both STANO and non-STANO messages are assigned precedences.

Non-STANO messages are generated at the transmitter and receiver nodes no more than 15 minutes prior to the present game time of the STANO message. The STANO message is assumed to be waiting at this time because of certain delays. As soon as the next possible processing time (NEXTYM) of a non-STANO message is greater than or equal to the time of the STANO message, a queue will be developed and the appropriate non-STANO delays will be calculated. For every case where the NEXTYM of the next non-STANO message is less than the present game time of the STANO message, a non-STANO message will be subtracted from the queue to show that it has been processed through the communications net.

If the time plus length of any of the remaining non-STANO messages at the transmitter or receiver overlaps the STANO message and it's present game time is greater than the present game time of the STANO message, then there will be no non-STANO delay incurred by the STANO message for that particular non-STANO message.

As soon as the time plus length of any of the remaining non-STANO messages overlaps the STANO message, is located at the receiver location of the STANO message, and its present game time is less than the present game time of the STANO message, then the STANO message will be automatically delayed. This will cause a non-STANO message to be added to the queue while adding the appropriate delay to the STANO message. If the non-STANO message is located at the transmitter location of the STANO message and its present game time is less than the present game time of the STANO message, then the STANO message will be delayed if the non-STANO message is of higher precedence only.

6.6.6.3 Interaction with Other STANO Messages. When a STANO message is sent between two nodes the transmit and receive times (that is, the next time that the message can be transmitted or received) are recorded. However, such a message will not be processed immediately because the indicated transmit/receive times are in the future with regard to present game running time. These later transmit/receive times result from such delays as operator delays, queuing, and net changeovers if required, which, when added to message origination time, put the transmit/receive time at a future time. In the intervening time between game time and this message's transmit time, other STANO messages of higher precedence may arrive at the same transmitter location and happen to be flowing in the same direction. This will cause a further delay in the original STANO message, while the earlier arriving, higher precedence traffic is processed. Other STANO messages which arrive at a different transmitter location or happen to be flowing in a different direction (the delay may be at another location) will cause the STANO message to be automatically delayed because the messages are physically separated in this state and message precedences cannot be compared automatically. The same basic process for calculating the non-STANO delay is used for processing the STANO delay.

6.6.6.4 Net Changeover Delays. The net changeover delays are those delays encountered in changing the message from one tactical communications net to another. The planner may play up to four net preferences. A basic assumption in the model is that when a message is introduced into the Tactical Communications Model it will be sent over the first preferred net. Thus, the message is entered and a determination is made to see if that net is available between the first point (i.e., the entry point) and the second point which may be either an intermediate or terminal node. If the message encounters a delay because non-STANO and STANO traffic of higher precedence is being transmitted, the model will try to send the message over the next preferred net. If there is no next preferred net, the message will enter into the queue for the previous net. If, however, an alternate net is specified and the planner chooses to play net changeover delays, then a random number is drawn based upon a normal distribution where the parameters for the distribution are contained in the planner input data set for net cycle delays. In this data set, the input of the mean and standard deviation is allowed for each of the six nodes simulated in the model. Thus the planner may allow for different cycle times at different echelons, and flow directions. In addition, separate data sets may be input for the four different nets simulated. Thus the planner may input a total of 48 different values, 24 means and 24 standard deviations, six of each for each net By sampling from the normally distributed random numbers, the net changeover delay is determined. This time is added to the present time for that message in its cycle so that the message is introduced to the next preferred net at the previous time plus a net changeover delay time. The determination of whether a queue exists in this new net is made based upon this new time. When the message does get transmitted to its receiver location and this is not the final location, a new set of available nets will be determined based on the nodes the message must go between.

6.6.7 TACCOM OUTPUTS

The Tactical Communications Model generates six types of outputs:

A time history of all messages from time zero to the end of the simulation. (See Figure 6.6-1)

A listing of all messages presented including the message number, transmitter location, time entered into net, receiver location, time presented to receiver location, the path taken, precedence of the message, total delays incurred, and message length. (See Figure 6.6-2)

A listing of the total net delays for each message presented by link and also a listing of the transmitter and receiver times minus their associated net delay times at each of these links. (See Figure 6.6-3)

Total initial and final operator delays for each message presented. (See Figure 6.6-4)

Total STANO delays for each message presented by link. (See Figure 6.6-4)

Total non-STANO delays for each message presented by link. (See Figure 6.6-5)

6.6.8 MODEL DESCRIPTION

6.6.8.1 The Tactical Communications Model consists of 11 subroutines* which are listed as follows:

DUMXTC (Main Program)
TACCOM
LODQUE
LSDRT
PRCDNT
ROUTE
MSGQUE
MAPPER
BUPDAT
BSORT
XSORT
TACOUT

*DUMXTC and TACCOM are the two executive routines which control the whole model. The general flow of the Tactical Communications Model in Figure 6.6-6 is based on these.

```
      MESSAGE NUMBER =       22    PRECEDENCE =      3
      IDMON =    17      PATH  =      20
      GAME TIME     =              1720
KDUMP1
NETPRE=          4.            3.           2.            0.NENTRY=          0.             2.          4.            0.LOCMCN=
LOCA=            0.LOCR=            0.LOCEXT=           21.IPATH=           20.IDMON=           17.LENMSG=           20.IOPTDY=         10
KEND

THE FOLLOWING STAND MESSAGES MAY CAUSE DELAY OR BE DELAYED

         TIME/PRECD          ROW
           10323              4
           10393              6
           21882             16

 THE RANDOMLY GENERATED NON-STAND MESSAGES AT THE TRANSMITTER  AND RECEIVER NODES FOR THIS MESSAGE ARE
        MSGLEN    MSGRATE    IRN     MARRIV     KOUNT    NODE
          20         0        42     177811         1          1
          20         1        76     174421         2          1
          21         4         6     181431         3          1
           2         4        58     176241         4          1
          27         3        93     172751         5          1
          28         1        23     179761         6          1
          20         0               179811         7          1
          20         1               179521         8          1
          21         4               181631         9          1
           2         4               179141        10          1
          27         3               180651        11          1
          28         1               180361        12          1
          20         0               178911        13          1
          20         1               177521        14          1
          17         4               177431        15          1
           1         4               181941        16          1
          27         3               181951        17          1
          28         2               179161        18          1
          20         0               176311        19          1
          20         1               180021        20          1
          21         4               176291        21          1
           2         4               176841        22          1
          27         3               180851        23          1
          28         1               180241        24          1
          20         0               176611        25          1
          20         1               176821        26          1
          17         4               180351        27          1
           1         4               179241        28          1
          27         3               176451        29          1
          28         2               179761        30          1
          20         0        21     179912        31          2
          20         1        74     174622        32          2
          17         4        75     174532        33          2
           1         4        17     180342        34          2
          27         3         7     181752        35          2
          28         2        46     177462        36          2
   AT THE NET :      4
      MESSAGE NO.    22 HELD UP IN QUEUE BETWEEN MONITOR     1 AND MONITOR     21ALONG PATH NUMBER         20 .
NUMBER OF MESSAGES IN LINE BEFORE MESSAGE NUMBER    22
AT  TRANSMITTER LOCATION    17 IS     2
THIS MESSAGE WAS DISPATCHED AT        1720 SECONDS.
THE NEXT POSSIBLE TIME THAT IT CAN BE TRANSMITTED     DUE TO THE QUEUE IS       1841 SECONDS
NUMBER OF MESSAGES IN LINE BEFORE MESSAGE NUMBER    22
AT   RECEIVER LOCATION   21 IS     0
THIS MESSAGE WAS DISPATCHED AT        1720 SECONDS.
THE NEXT POSSIBLE TIME THAT IT CAN BE RECEIVED  DUE TO THE QUEUE IS       1820 SECONDS

MESSAGE NUMBER    22 HAS INCURRED          46 SECONDS         OF NET CHANGEOVER DELAY

THE FOLLOWING STAND MESSAGES MAY CAUSE DELAY OR BE DELAYED

         TIME/PRECD          ROW
           10323              4
           10393              6

THE RANDOMLY GENERATED NON-STAND MESSAGES AT THE TRANSMITTER  AND RECEIVER NODES FOR THIS MESSAGE ARE
        MSGLEN    MSGRATE    IRN     MARRIV     KOUNT    NODE
          16         0        97     172611         1          1
          16         0        76     176121         2          1
          16         2        87     174231         3          1
           1         2        70     177141         4          1
          23         2        22     185151         5          1
          24         1        65     177961         6          1
          16         0        96     172712         7          2
          16         0        87     174222         8          2
          13         3        48     180732         9          2
           1         2        22     185142        10          2
          23         2        88     174152        11          2
          24         1        62     178462        12          2

    MESSAGE NUMBER    22 PRECEDENCE NUMBER    3 WAS DISPATCHED AT       1720 SECONDS FROM MONITOR NUMBER         17
ALONG PATH      NUMBER    20 IT REMAINED IN TRANSMITTER QUEUE UNTIL       1887 SECONDS.
    IT ARRIVED AT ITS DESTINATION AT       1887 SECONDS.
MESSAGE NUMBER    22 HAS INCURRED          48 SECONDS OF      FINAL OPERATOR DELAY
NR=         18
ITABLE(NR,1)=         1780
N=          22
TACCOM TABLE
     1887    1035       1       1      21      20      22       0       0       1       3    1841    1889       2      45       0
        0       0       0       0       0       0       0      21       0       0       0       0       1       1       0       0
        4       0       0    1720       1      21      20    1820       0       0       0       3       4     100      48      17
```

Figure 6.6-1 MESSAGE HISTORY

1 MESSAGE NUMBER	FROM UNIT	AT AT TIME	ALONG PATH	TO UNIT	PRESENTED AT TIME	PRECEDENT	TOTAL DELAYS (SECONDS)	MESSAGE LENGTH (SECONDS)
1	111	510	1	11	730	FLASH	210	10
2	11	620	2	1	927	EMERGENCY	287	20
5	121	736	5	21	978	EMERGENCY	234	8
9	131	960	9	31	1146	EMERGENCY	174	12
10	31	967	10	1	1261	EMERGENCY	274	20
13	311	1267	13	11	1517	EMERGENCY	238	12
8	21	820	8	1000	1522	FLASH	672	30
15	321	1322	14	21	1565	EMERGENCY	228	15
19	341	1567	17	41	1783	EMERGENCY	204	12
12	31	1260	12	1000	1800	FLASH	515	25
21	411	1716	19	11	1880	EMERGENCY	155	9
20	41	1649	18	1	2000	EMERGENCY	326	25
14	11	1299	4	1000	2034	FLASH	700	35
25	431	1870	22	31	2055	EMERGENCY	175	10
18	1000	1560	16	31	2149	FLASH	559	30
27	41	1917	24	441	2076	EMERGENCY	147	12
29	611	2002	26	11	2223	EMERGENCY	213	8
32	121	2088	5	21	2315	EMERGENCY	217	10
35	131	2170	9	31	2346	FLASH	164	12
38	141	2207	29	41	2364	EMERGENCY	147	10
16	21	1415	8	1000	2476	EMERGENCY	1021	40
24	21	1818	8	1000	2556	FLASH	708	30
26	1000	1871	23	41	2694	FLASH	789	34
44	11	2470	32	41	2789	EMERGENCY	304	15
52	121	2626	34	621	2783	EMERGENCY	147	10
53	621	2635	35	21	2872	EMERGENCY	222	15
47	31	2528	33	21	2933	EMERGENCY	390	15
42	31	2446	12	1000	2973	FLASH	502	25
4[illegible]	21	2326	31	31	2941	EMERGENCY	605	10
39	41	2227	30	1000	3022	FLASH	760	35
40	1000	2320	23	41	3196	FLASH	846	30
37	1000	2197	16	31	3186	FLASH	961	28
36	31	2173	12	1000	3213	FLASH	1005	35
43	1000	2457	28	21	3216	FLASH	729	30
63	341	3070	38	541	3181	EMERGENCY	101	10
30	11	2016	4	1000	3278	FLASH	1232	30
58	41	2599	30	1000	3292	FLASH	668	25
65	421	3046	36	621	3265	EMERGENCY	209	10
48	21	2574	8	1000	3372	FLASH	762	36
45	41	2471	10	1000	3290	FLASH	789	30
33	21	2110	8	1000	3353	FLASH	1208	35
60	1000	2797	27	11	3337	FLASH	515	25
71	321	3192	16	21	3410	EMERGENCY	208	10
66	1000	2497	27	11	3475	FLASH	913	25
59	41	2791	30	1000	3499	FLASH	678	30
74	431	3346	22	31	3521	EMERGENCY	164	11
77	111	3398	35	211	3496	EMERGENCY	88	10
69	11	3097	4	1000	3583	FLASH	461	25
57	11	2752	4	1000	3518	FLASH	741	25
79	121	3502	41	321	3685	FLASH	168	15

Figure 6.6-2 MESSAGE SUMMARY DATA

```
1
                                                  ---------------- NET DELAYS -----------
MESSAGE   ----------- LINK 1 -----------   ----------- LINK 2 -----------   ----------- LINK 3 -----------
NUMBER

          XMTRQ    RCVRQ    NET   CYCLE     XMTRQ    RCVRQ    NET   CYCLE     XMTRQ    RCVRQ    NET   CYCLE
          (SEC)    (SEC)          (SEC)     (SEC)    (SEC)          (SEC)     (SEC)    (SEC)          (SEC)
   1        594      720     2       0
   2        790      846     4      63
   5        860      970     2       0
   9       1036     1134     2       0
  10       1129     1203     3      38
  13       1390     1505     2       0
   8        985     1096     3      31      1347     1396     3      96
  15       1445     1550     2       0
  19       1662     1771     2       0
  17       1344     1466     2      53      1696     1775     1       0
  21       1811     1871     2       0
  20       1818     1912     3      63
  14       1592     1673     3      92      1918     1999     1       0
  25       1940     2045     2       0
  18       1687     1789     2      93      1994     2119     2       0
  27       2010     2084     2       0
  29       2151     2215     2       0
  32       2182     2305     2       0
  35       2268     2334     2       0
  38       2276     2354     2       0
  16       1566     1685     1      56      2170     2275     4     161
  24       1890     1958     3      86      2278     2309     4     217
  26       2190     2288     4     188      2597     2640     2       0
  44       2622     2706     4      68
  52       2705     2775     2       0
  53       2731     2857     2       0
  47       2755     2868     4      70
  42       2589     2655     2      64      2837     2948     1       0
  41       2785     2875     4      56
  39       2417     2496     3      80      2905     2987     1       0
  40       2554     2648     4     246      3010     3131     3      35
  37       2500     2650     1     139      2964     3070     4      88
  36       2518     2599     1      92      2953     3051     4     147
  43       2586     2681     4      60      2940     3067     4     119
  67       3126     3171     2       0
  30       2540     2632     3     108      3004     3088     4     160
  50       2509     2886     2      47      3112     3201     2      66
  65       3204     3255     2       0
  48       2702     2766     4       0      3053     3100     4     156
  49       2750     2801     3      71      3136     3180     2      80
  33       2682     2768     1      82      3080     3158     4     160
  60       2961     3035     2     115      3250     3312     2       0
  71       3294     3400     2       0
  46       2718     2849     4     [illegible]      3370     3410     2       0
  90       2961     2998     2      45      3222     3358     2     111
  76       3474     3510     2       0
  77       3431     3486     2       0
  59       3204     3275     4       0      3457     3558     1       0
  57       2919     2980     4     135      3363     3394     2      95
  79       3417     3670     2       0
                                          ---------------- NET DELAYS -----------
```

Figure 6.6-3 MESSAGE SUMMARY NET DELAY DATA

1

MESSAGE NUMBER	INITIAL OPERATOR DELAY (SEC)	FINAL OPERATOR DELAY (SEC)	---------- STANO DELAYS ---------- LINK 1 (SEC)	LINK 2 (SEC)	LINK 3 (SEC)
1	84	126	0		
2	86	96	0		
5	70	110	0		
8	76	98	0		
10	128	76	0		
13	104	115	0		
9	224	163	0	0	
15	97	105	0		
19	82	109	0		
12	138	205	70	0	
21	65	60	30		
20	76	94	30		
14	210	162	0	0	
25	70	105	0		
18	148	227	0	0	
27	93	54	0		
29	149	66	0		
32	94	123	0		
35	78	86	0		
38	56	78	0		
16	172	224	70	94	
26	112	99	0	0	
24	107	161	138	35	
44	38	94	65		
52	79	68	0		
53	96	126	0		
47	90	93	45		
42	171	177	30	0	
41	97	90	95		
39	170	161	260	0	
40	140	235	[illegible]	0	
37	151	196	124	0	
36	179	149	135	50	
43	178	172	0	25	
67	56	45	0		
30	167	136	175	25	
50	263	170	66	0	
68	93	91	30		
48	180	189	65	0	
45	222	95	118	55	
33	117	144	371	45	
60	168	147	30	0	
71	102	108	0		
66	285	211	65	0	
59	244	173	0	0	
74	78	86	0		
77	33	55	0		
69	268	170	0	0	
57	221	96	30	0	
79	102	93	0		

Figure 6.6-4 MESSAGE SUMMARY STANO DELAY DATA

```
------------- NON STAND DELAYS -------------



 MESSAGE      LINK 1      LINK 2      LINK 3
  NUMBER      (SEC)       (SEC)       (SEC)

      1           0
      2          46
      5          54
      9           0
     10          34
     13          19
      8          35          92
     15          26
     19          13
     12          20           0
     21           0
     20          63
     14         201           0
     25           0
     18          61           0
     27           0
     29           0
     32           0
     35           0
     38          13
     16          15         185
     24          37         127
     26         126           0
     44          49
     52           0
     53           0
     47          92
     42          35           0
     41         267
     39          54           0
     40         102          30
     37         189          46
     36         125          93
     43          50          95
     67           0
     30         286         125
     50          16          15
     65          20
     48           0         136
     45          71          67
     33         147          87
     60          30           0
     71           0
     66         114           0
     59          30          45
     74           0
     77           0
     69           0           0
     57          93          64
     79          13
```

Figure 6.6-5   MESSAGE SUMMARY NON-STAND DELAY DATA

Eight Common Areas are needed in the model:

MSGCAR
MODIFY
MESSGS
COMROT
MSSTYP
LOADSA
CYCLE
OPSHUN

MSGCAR contains the COMMOTRAFIK data which are read into the model. This consists of the minimum and maximum rates and lengths of non-STANO messages and each message precedence, echelon, net and flow direction.

MODIFY contains the TRAFIKMODS Data read into the model, which consists of the rate and length modifiers for the non-STANO message traffic.

MESSGS contains the two TABLES A and B used in the model.

COMROT contains data on the path description of each STANO message, namely, the route number, the monitor location, node description codes, flow description codes and lowest echelon for each STANO message going through the communications net.

MSSTYP contains the message precedences, path numbers and net preferences for each STANO message going through the communications net.

LOADSA contains the storage area ISTORE which holds all the unique echelon designations played in the model. It also holds the queues developed in the model by echelon designation, message precedence and net, and a count (STRCNT) of the unique echelon locations in ISTORE.

CYCLE contains the net cycle delay statistics for each net and flow direction between each echelon.

Finally, OPSHUN contains:

Bypass codes for playing operator and net delays (KOPERT, NETCYC)

Number of precedence and route data cards (IPREC, NRTCNT).

Number of time sections in the model after which the non-STANO message rate and length modifiers to the COMMOTRAFIK data will be applied (KTIME).

Code 1,2 describing a message being processed from TABLE A or TABLE B (ITABA).

The number of messages to be played in the model (NMESG).

6.6.8.2 Figure 6.6-6 shows a macro-flow of the Tactical Communications Model. As was previously stated, the model consists of eleven subroutines. Detailed descriptions and flow charts for the most important of these subroutines are contained in the following paragraphs.

The TACCOM subroutine itself is the executive program which directs the message processing through the other subroutines as appropriate. It also computes certain values such as the INTIME for the message, the monitor ID (IDMON), message length (LENMSG) and operator delays (IOPTDY).

There are two major working blocks of data which are used to drive the model -- TABLES A and B.

TABLE A, prepared by the planner, is the information on new messages, i.e., STANO messages which have not yet entered the tactical communications model. These messages are arranged chronologically according to the times at which they will enter the system. The program reads the first message from TABLE A (that is, the next message in chronological order). This message then is processed through TACCOM and its subordinate subroutines. This message no longer exists in TABLE A. Any further reference to this message is made by using TABLE B, since TABLE B contains information on messages in process.

In order to determine the next message to be processed, a test is made in TACCOM between the next message in TABLE A and the highest precedence message in TABLE B with the lowest game time. The highest precedence message of the two with the lowest game time will be the next message to be processed. If they are both of the same precedence and also have the same game time, then the message from TABLE B will be processed next since it is already in the net. This test appears in the listing of subroutine TACCOM between statements 91 and 20.

TABLE B is a temporary storage area for information on messages enroute from an entry point to a final destination. When each of these messages reaches its final destination, it is exited from TABLE B and summary data about the message is written onto the disk.

Forty-eight items of information are kept in TABLE B in order to have a complete time history of each message being processed. A description of these items is given in Table 6.6-I.

6.6.8.3 PRCDNT and ROUTE Subroutines

Each new message to be processed, based on its origin time, comes from TABLE A. These messages are first processed through subroutines PRCDNT and ROUTE. Messages that have entered TABLE B, do not require further processing in these subroutines.

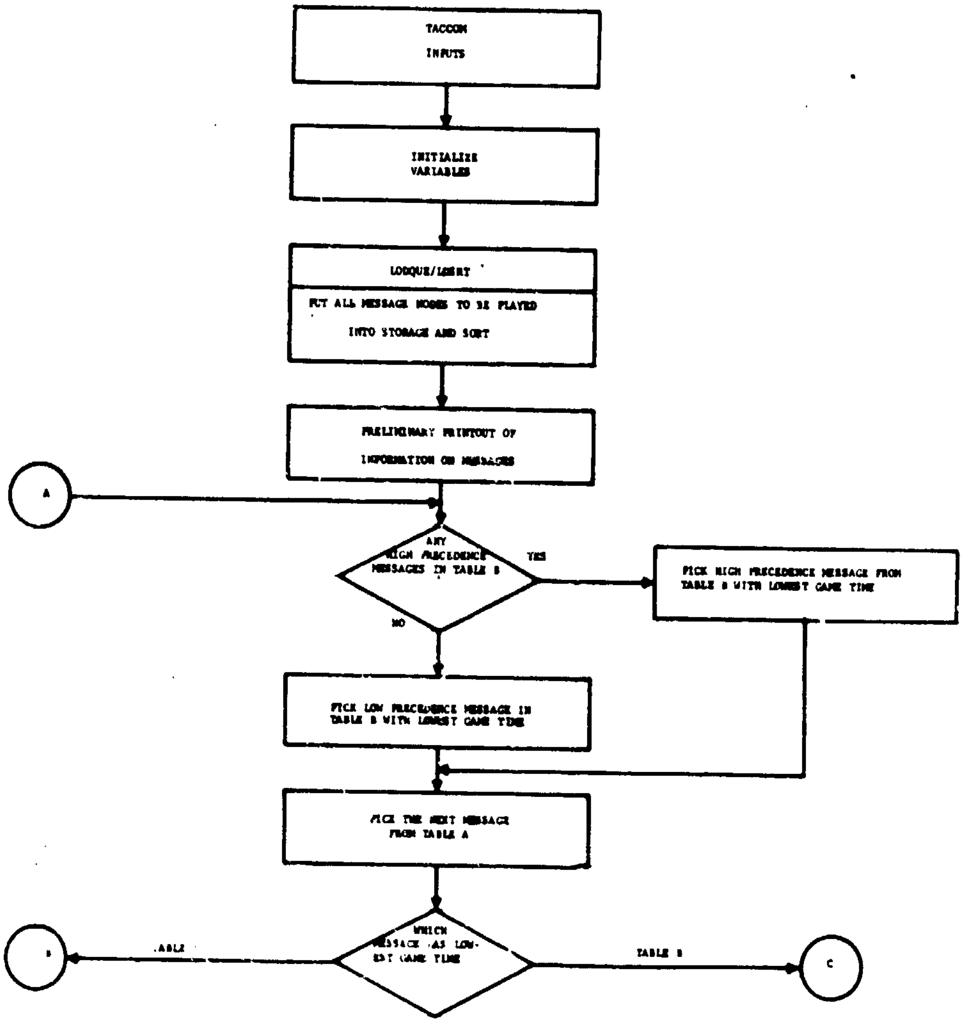


FIGURE 6.6-6 ACCOM SUBROUTINE MACROFLOW
(Sheet 1 of 3)

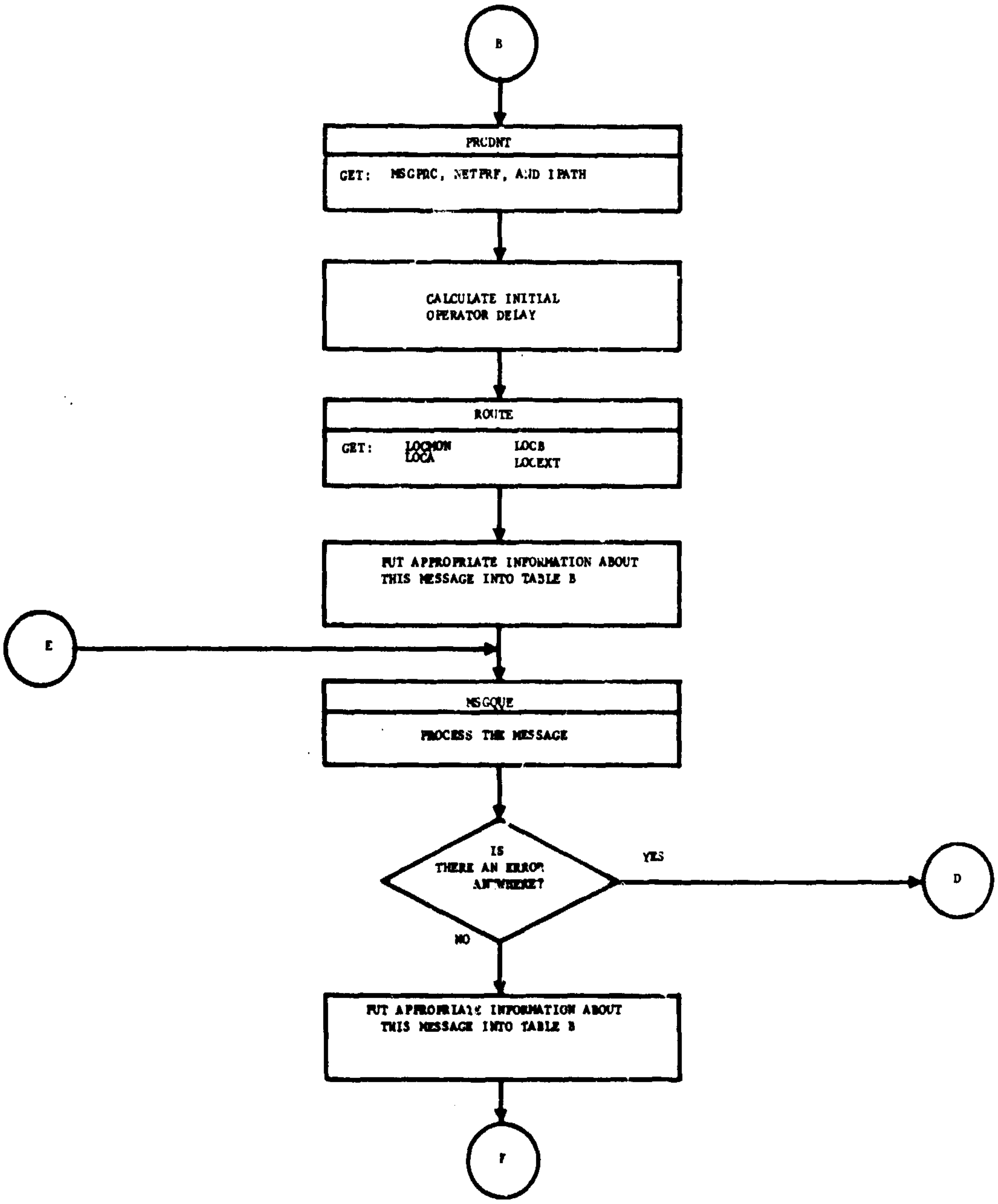


FIGURE 6.6-6 TACCOM SUBROUTINE MACROFLOW
(Sheet 2 of 3)

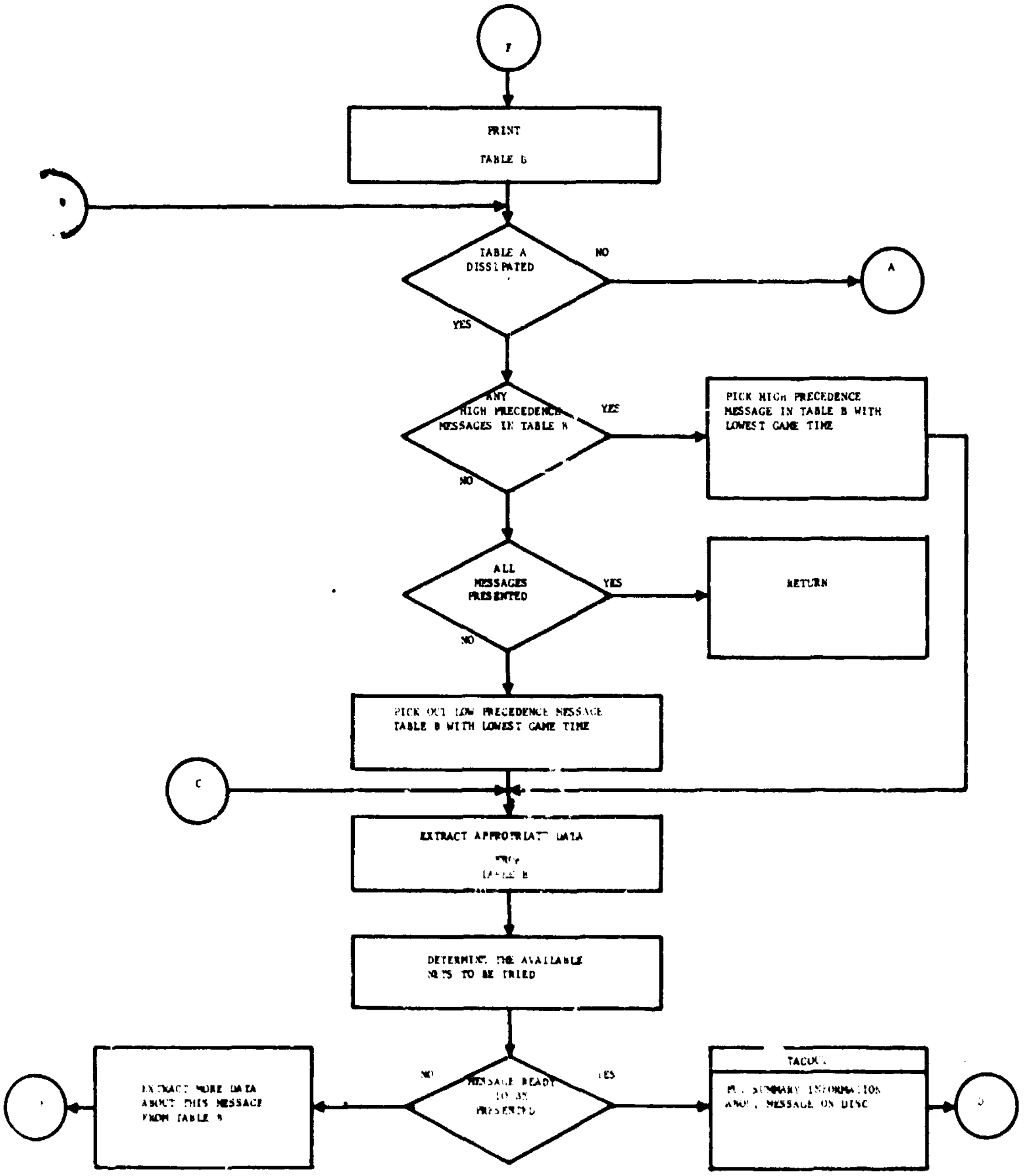


FIGURE 6.6-5 TACCOM SUBROUTINE SYNOPSIS
Sheet 3 of 3

TABLE 6.6-I

TABLE B

COLUMN	NAME	VARIABLE	DESCRIPTION
1	Transmitter Time	XMTYM	The next available time that this message can be transmitted.
2	Receiver Time	RCVTYM	The next available time that this message can be received.
3	Maximum number of Links	KMX	The maximum number of links this message is going through. Up to three links are allowed.
4	Transmitter Location	LOCTMT	The unit designation for the associated transmitter time in Column 1.
5	Receiver Location	LOCRCV	The unit designation for the associated receiver time in Column 2.
6	Message Length	LENMSG	The length of the STANO message being processed.
7	Message Number	MSGNUM	The unique message number of this STANO message which comes from TABLE-A.
8	First Intermediate Node Location	LOCA	A message may have up to three links. The end points of the links are the nodes. Therefore, there may be up to four nodes. The first node is the monitor node. The fourth node, or last node if less then four nodes, is the exit node. If four nodes are used, the two intermediate nodes are called LOCA and LOCB. Hence LOCA is the unit designation for the A node.

TABLE 8 (Contd)

COLUMN	NAME	VARIABLE	DESCRIPTION
9	Second Intermediate Node Location	LOCB	The unit designation of the second intermediate node.
10	Investigation Link	LINK	The link which the STANO message is trying to be transmitted on.
11	Message Precedence	MSGPRC	The model allows for the play of up to six message precedences. These are designated in the model as 1 for the highest precedence and 6 for the lowest precedence.
12	-	-	Transmitter time of the message minus the net delay time for link number 1.
13	-	-	Receiver time of the message minus the net delay time for link number 1.
14	Net Used	NET	Net used in link number 1,i.e., the net associated with the transmitter and receiver available for this message.
15	Net Delay	NET DLY	Net changeover delay incurred by the STANO msg along link number 1.
16-19	-	-	Same as Columns 12-15 except for link number 2.
20-23	-	-	Same as Columns 12-15 except for link number 3.
24-26	Non-STANO Delay	-	Total non-STANO delay incurred by the STANO message for link 1, 2, & 3 respectively.

TABLE B (Contd)

COLUMN	NAME	VARIABLE	DESCRIPTION
27	-	-	Blank for further use.
28	-	NOQ	Code showing whether the STANO message has made it through its previous link. 1 = No, 0 = Yes.
29	-	IF	This is the index in the storage area ISTORE (800) where the ground location LOCTMT is stored.
30	-	JTO	Same as Column 29 except for LOCRCV.
31-34	Node Designation Code	NENTRY	The node designation code for the flow of this STANO message.
35	-	-	Blank for Future use.
36	Origination Time of Message.	INTIME	The game time of the STANO message when the monitor operator gets a detection from the sensor.
37	Monitor Location	LOCMON	Unit designation of the monitor location.
38	Exit Node Location	LOCEXT	Unit designation of the point at which the information will be presented and where it will exit from the communications net.
39	Path Number	IPATH	The path number along which the STANO message is traveling.
40	Message Entry Time	MSGENT	The actual entry time of the STANO message into the communications net at whatever location it might presently be. This time takes into account the initial and final operator delays.

TABLE B(Contd)

COLUMN	NAME	VARIABLE	DESCRIPTION
41-43	STANO Delays	-	The total STANO delay incurred by the STANO message for links 1, 2, and 3 respectively.
44-45	Flow Description Codes for Direction of Message Travel	IFROM ITO	These represent the flow codes at each link for the STANO message being processed. As previously stated, the model allows up to a maximum of three communications links in an up/down or horizontal manner. The nodes between these links can be considered as both transmitting and receiving nodes. The IFROM and ITO codes indicate which way the message is flowing. these codes are numbered 1 through 6 where: 1 = Brigade Down 2 = Battalion Up 3 = Battalion Down 4 = Company Up 5 = Company Down 6 = Platoon Up
46	Total Initial Operator Delays	-	The total initial operator delays incurred by this STANO message through all of its nodes.
47	Total Final Operator Delays	-	Same as Column 46 except for final operator delay.
48	Monitor ID	IDMON	The ID of the monitor at which the message originated.

6.6.8.4 PRCDNT

The purpose of this subroutine is to extract from the precedence data set the appropriate values for the message precedence, net preference, and path number for each message based on its message type. A flow diagram of subroutine PRCDNT is shown in Figure 6.6-7.

6.6.8.5 ROUTE

The purpose of this subroutine is to prepare information for subroutine MSGQUE. This information includes the unit designations for the monitor, the presentation or final location, and the two intermediate nodes for the message over its designated route. The inputs for this subroutine are the Route Data Set prepared by the planner. Route is accessed by the path numbers obtained from subroutine PRCDNT.

From the NODE description code for each message in common area COMROT, ROUTE prepares the individual NENTRY numbers which describe the flow of the message. There are a maximum of four of these numbers, where 6 indicates a platoon is involved; 4 indicates a company is involved; 2 indicates a battalion is involved, and 1 indicates a brigade is involved. From the NENTRY numbers prepared, ROUTE then calculates the maximum number of links the message must go through (a link being a path between a transmit and receive node). ROUTE then gets the location of the monitor from Common COMROT for this message and then determines whether the message is flowing up, down or horizontal.

ROUTE then goes through the process of determining the two intermediate locations and presentation location for the message. Two restrictions are set forth at this time. First, a message cannot flow down from Platoon. Secondly, a message cannot flow up from Brigade. A general flow of the ROUTE subroutine is shown in Figure 6.6-8.

6.6.8.6 LODQUE

The purpose of this subroutine is to set up the common area LOADSA. As previously stated, LOADSA contains the storage area(ISTORE), which holds the echelon ground locations to be played in the model. It also holds the queue developed in the model according to each echelon unit played, net and message precedence. It is the storage locations of these echelon units in the storage area (ISTORE), which will be used as index values to develop the queues at each echelon. A general flow of LODQUE is given in Figure 6.6-9.

6.6.8.7 LDSRT

Subroutine LDSRT is used to sort and order the echelon ground locations in the storage area ISTORE. LDSRT also deletes any repeated echelon ground locations so that there will not be more than one index for a queue which points to the same echelon location. A general flow of LDSRT is given in Figure 6.6-10.

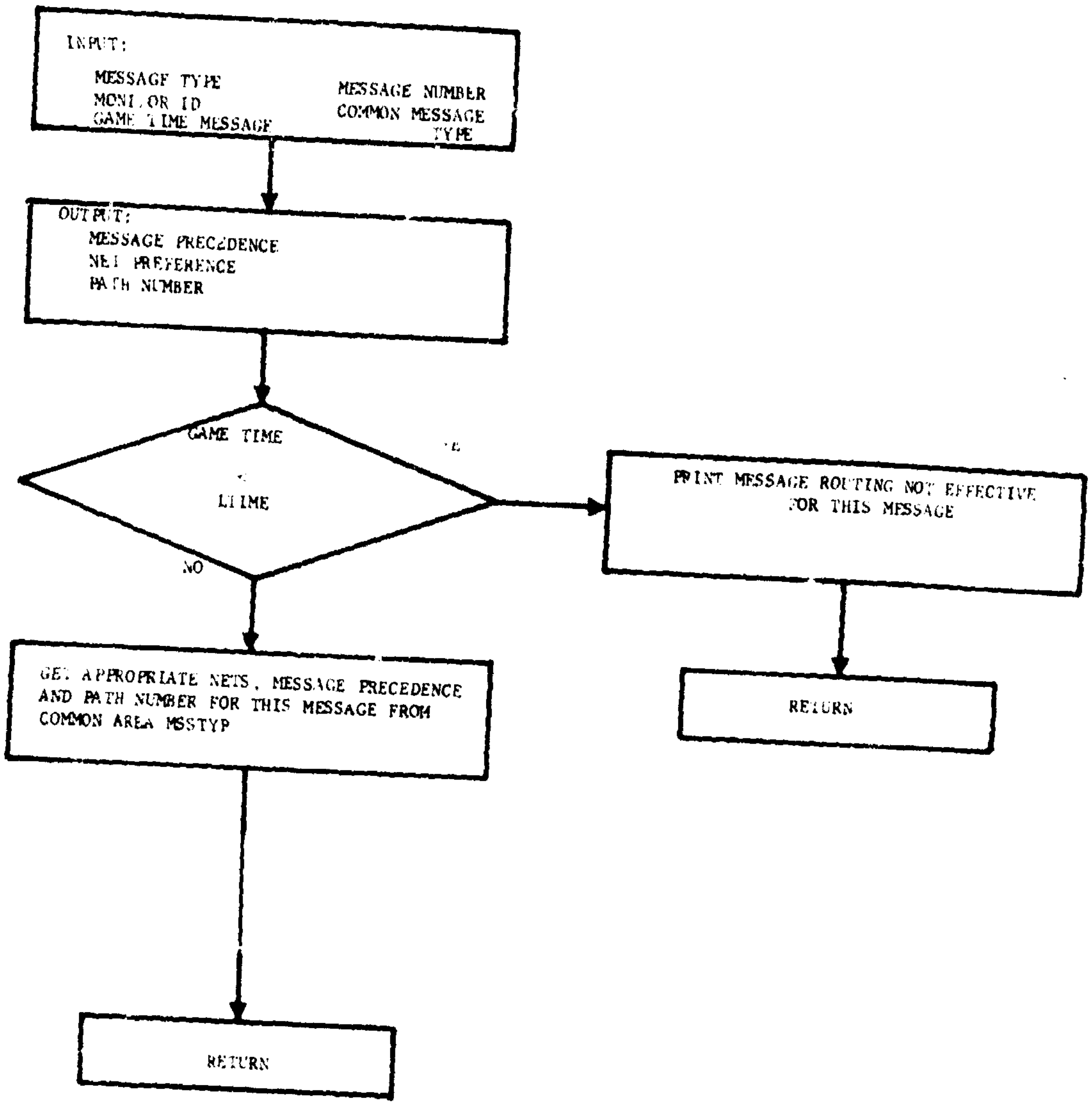
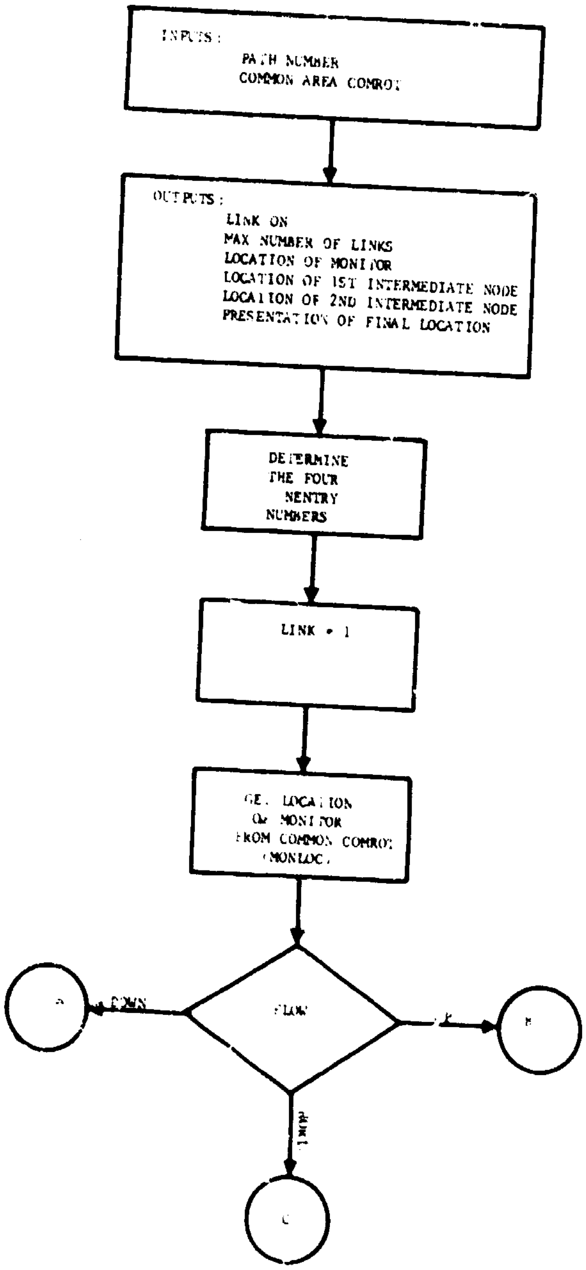
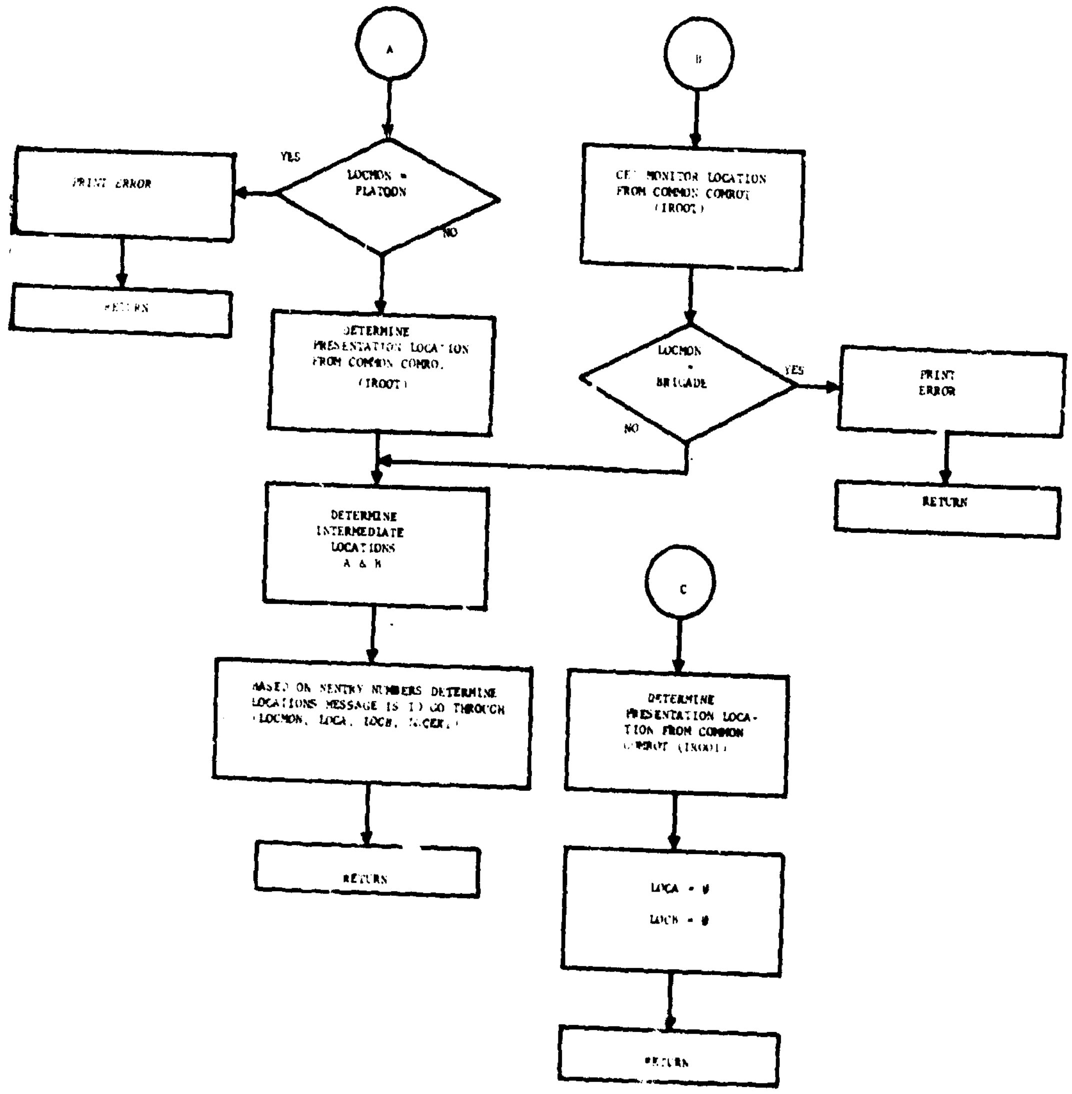


FIGURE 6.6-7 PRCDNT SUBROUTINE MACROFLOW


INPUTS:
PATH NUMBER
COMMON AREA CONTROL
OUTPUTS:
LINK ON
MAX NUMBER OF LINKS
LOCATION OF MONITOR
LOCATION OF 1ST INTERMEDIATE NODE
LOCATION OF 2ND INTERMEDIATE NODE
PRESENTATION OF FINAL LOCATION
DETERMINE THE FOUR NENTRY NUMBERS
LINK = 1
GET LOCATION OF MONITOR FROM COMMON CONTROL (MONLOC)
FLOW
DOWN
UP
LEVEL
A
B
C

[illegible]
[illegible]


A
LOCMON = PLATOON
YES
NO
PRINT ERROR
RETURN
DETERMINE PRESENTATION LOCATION FROM COMMON COMRO. (IROOT)
B
GET MONITOR LOCATION FROM COMMON COMROT (IROOT)
LOCMON = BRIGADE
YES
NO
PRINT ERROR
RETURN
DETERMINE INTERMEDIATE LOCATIONS A & B
BASED ON SENTRY NUMBERS DETERMINE LOCATIONS MESSAGE IS TO GO THROUGH (LOCMON, LOCA, LOCB, [illegible])
RETURN
C
DETERMINE PRESENTATION LOCATION FROM COMMON COMROT (IROOT)
LOCA = 0
LOCB = 0
RETURN

[illegible]
Sheet 2 of 2

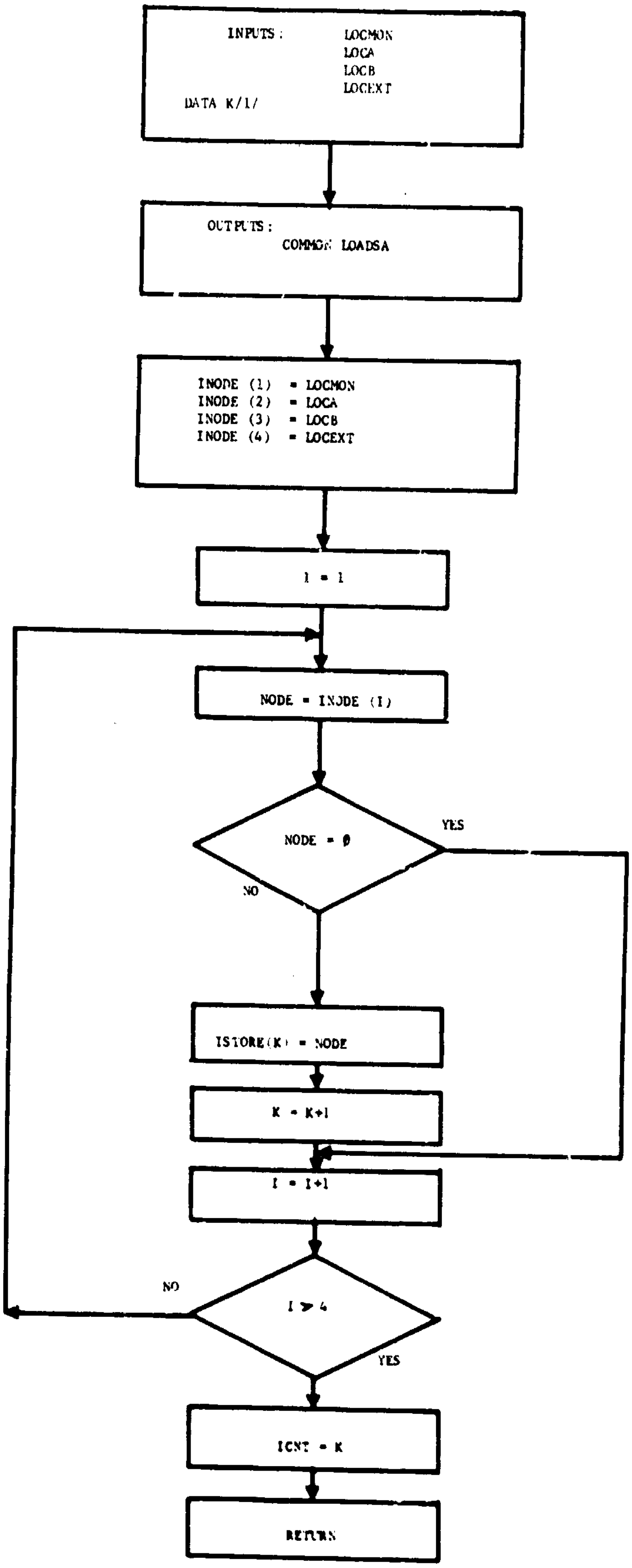


FIGURE 6.6-9 LODQUE SUBROUTINE MACROFLOW

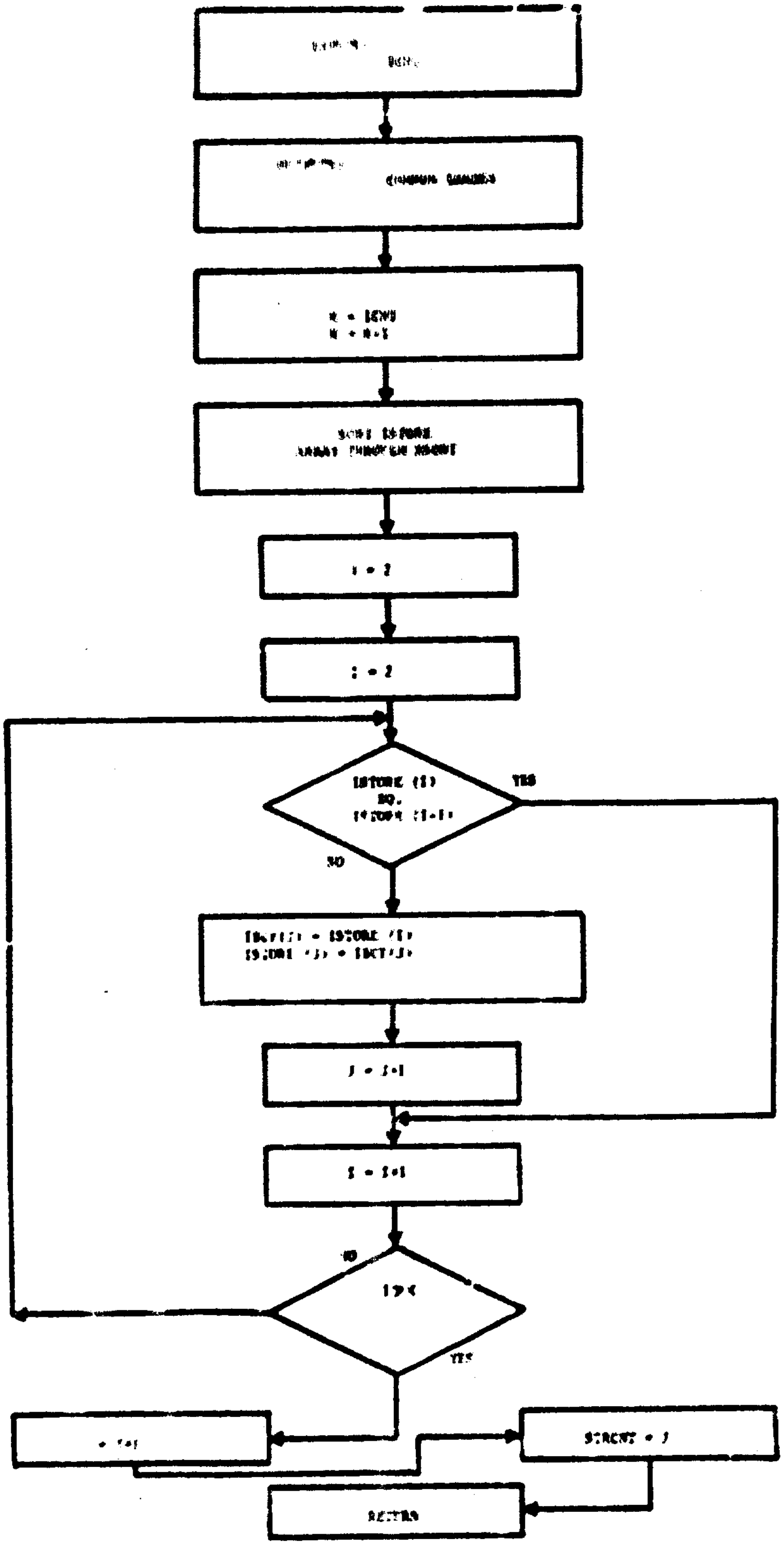


FIGURE 6.6-10 LBRT SUBROUTINE MACROFLOW

6.6.8.8 MAPPER

Before giving any discussion of subroutine MSGQUE, it is necessary to discuss subroutine MAPPER and how it interacts with MSGQUE. Subroutine MAPPER, when called by MSGQUE, uses the ground locations of the message transmitter and receiver plus the storage area ISTORE in common area LOADSA to determine one of the three indexes used for the queues at the transmitter and receiver of the message. These indexes will be the storage locations in the area ISTORE where the transmitter and receiver ground locations lie. Because of the interaction of each STANO message with non-STANO traffic, delays might occur at either the transmitter or receiver nodes or both. Each queue holds the number of non-STANO messages which are in line with the message presently trying to be processed. There are three indexes by which each queue is described. These are: 1) the indexes from subroutine MAPPER; 2) the net the message is on, and 3) the message precedence for the message. Thus INQ (IF, J, Net) will hold the number of non-STANO messages which are in line with the message coming from location (IF) with message precedence (J) and being transmitted over (Net). Subroutine MAPPER also determines for any message the time in at the transmitter and receiver of the last messages entering these queues. These times INQ(IF, 7, NET) and INQ (JTO, 7, NET)) are used to determine the difference between the time of the STANO message and the times of the last message in the transmitter and receiver queue. If this time is greater than 15 minutes at either the transmitter or receiver, the queues for that transmitter or receiver will be cleared. It is assumed in the model that it takes approximately 15 minutes for all of the messages in the queue to be sent. This process prevents any STANO message coming in later than 15 minutes after the last message in any queue from encountering non-STANO messages from that queue. A general flow of subroutine MAPPER is given in Figure 6.6-11.

6.6.8.9 MSGQUE

All messages, whether new from TABLE A or in-process from TABLE B are processed through subroutine MSGQUE each time they endeavor to pass over a communications link (between two nodes). Subroutine MSGQUE may be thought of as the heart of the Tactical Communications Model. It is in subroutine MSGQUE that the planner input non-STANO traffic statistics are used to determine the queues existing at the transmitter and/or receiver nodes of a link, and, if so, the length of the queue, i.e., the number of non-STANO messages in the queue for that location, precedence and net, and the amount of non-STANO delay incurred by the STANO message due to the queue.

For a message coming from TABLE A, subroutine MSGQUE will first determine the net to be chosen and if this is the last available net, a code (LASNET) will be set so that no net delay will be calculated after the message is processed. The same processing steps will be taken for a message coming from TABLE B which is at a new location (has been transmitted through its previous link) however, an initial operator delay is calculated. It will then calculate the flow codes for this message. These are explained in the description of Table B, Table 6.6-I, in Columns 44 and 45.

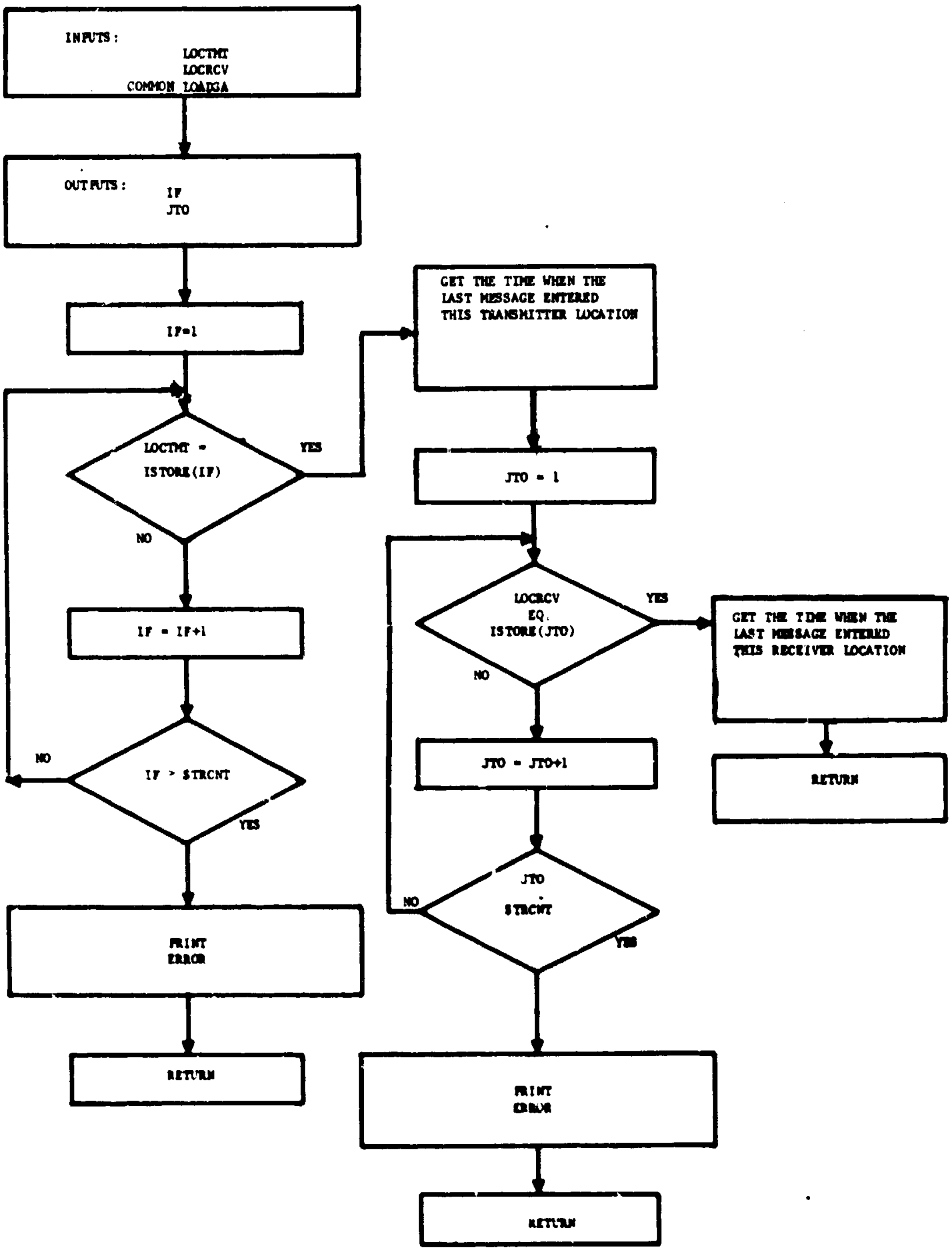


FIGURE 6.6-11 MAPPER SUBROUTINE MACROFLOW

Subroutine MAPPER is then called to determine the indexes for the queue and the times in at the transmitter and receiver locations of the last messages in these queues. MSGQUE then will determine for this message, through the planner input for non-STANO statistical data, the message lengths and message rates for the random non-STANO messages to be generated.

After MSGQUE has finished setting up the initial situation for this message to be processed, it will then determine the difference between the present game time of the STANO message and the times in of the last messages in the queues at this transmitter and receiver. If this time difference at the transmitter or receiver is greater than 15 minutes, then all of the messages in queue at that transmitter or receiver will be cleared. If it is not, subroutine BUPDAT will be called to calculate the STANO message delays for this message. If there are any STANO delays incurred, they will be added to the present time of the STANO message. The non-STANO messages will then be generated and from these messages a determination will be made to see if the STANO message must go into a queue. (The next possible processing time of the next non-STANO message is greater than or equal to the present game time of the STANO message.) If the message does not have to go into queue, a message will be printed out that the STANO message has been presented to its next location.

If the message does have to go into queue, the appropriate non-STANO message delays in the form of messages added to the queue, and times, will be calculated and added to the current time of the message. If any non-STANO delays exist, and there are other nets available, the STANO message will try to get through on them, and print out the amount of net changeover delay incurred for each switch to another net. If no other nets are available a code will be set to show that the message did not make it through this link on any of the available nets and must remain in queue. MSGQUE will then return to TACCOM placing the necessary data in TABLE B for the message to be processed again some time later in the model through the same link and on the previous or last available net tried.

If no non-STANO delays exist, a message will be printed out that the message has been presented to its receiver location giving the message number, precedence, dispatch time (initial game time), monitor ID, path number, time leaving the transmitter queue, and arrival time at its destination. The final operator delay at the receiver location is then calculated, printed out, and added to the arrival time of the message, and a code is set to show that this message did make it through this link. MSGQUE will then return to TACCOM in the same manner as done previously; however, the next time, the message will be processed through its next link on a new set of available nets. If it was on its last link, the message will be presented at its final description.

For messages coming from TABLE B which have not made it through their previous link, the processing to set up the initial situation is bypassed because all the data needed for this case have already been generated.

Besides using the common areas MSGCAN, LOADSA, MESSGS, CYCLE, OFSHUN, COMROT, and MODIFY, MSGQUE also uses the following inputs:

NENTRY	Nodal points for echelon locations
LINK	Link the message is presently on
MSGPRC	Message precedence of the message
NETS	Array of available nets for the message
ITIME	Present time of the message
IDMON	ID of monitor at which message
LINKMX	Maximum number of links on the path for this message
LOCTMT	Ground location of the transmitter for this message
LOCRCV	Ground location of the receiver for this message
LENMSG	Length of the message (in seconds)
MSGNUM	Message number

A general flow of subroutine MSGQUE is shown in Figure 6.6-12.

6.6.8.10 BUPDAT

TACCOM next calls subroutine BUPDAT. This subroutine handles the delay to one STANO message caused by other STANO messages or vice versa.

In order for a STANO delay to occur certain conditions are necessary but not sufficient:

Both messages must be on the same net, <u>or</u>

Both messages must be at the same location and flowing in the same direction.

There must be a time overlap between the two messages.

When these conditions are met, then we can say that there is a possibility that there will be a STANO delay incurred, either by this STANO message or by another one. The delay incurred depends first on the time, location and flow of the messages and second, on their particular message precedences. These delays are calculated in basically the same manner as non-STANO delays. A general flow of subroutine BUPDAT is given in Figure 6.6-13, and a description of how the STANO delays are calculated is given on page 6-131, paragraph 6.6.6.3.

6.6.8.11 Subroutine TACOUT

The final subroutine in the Tactical Communications Model is the output subroutine TACOUT. Every time a message from TABLE B is ready to be presented, it is written on disk by this subroutine. At the end of the simulation when all the messages are finished being processed, TACOUT prints the summary information as explained in paragraph 6.6.7 in the format shown in Figures 6.6-1 through 6.6-5.

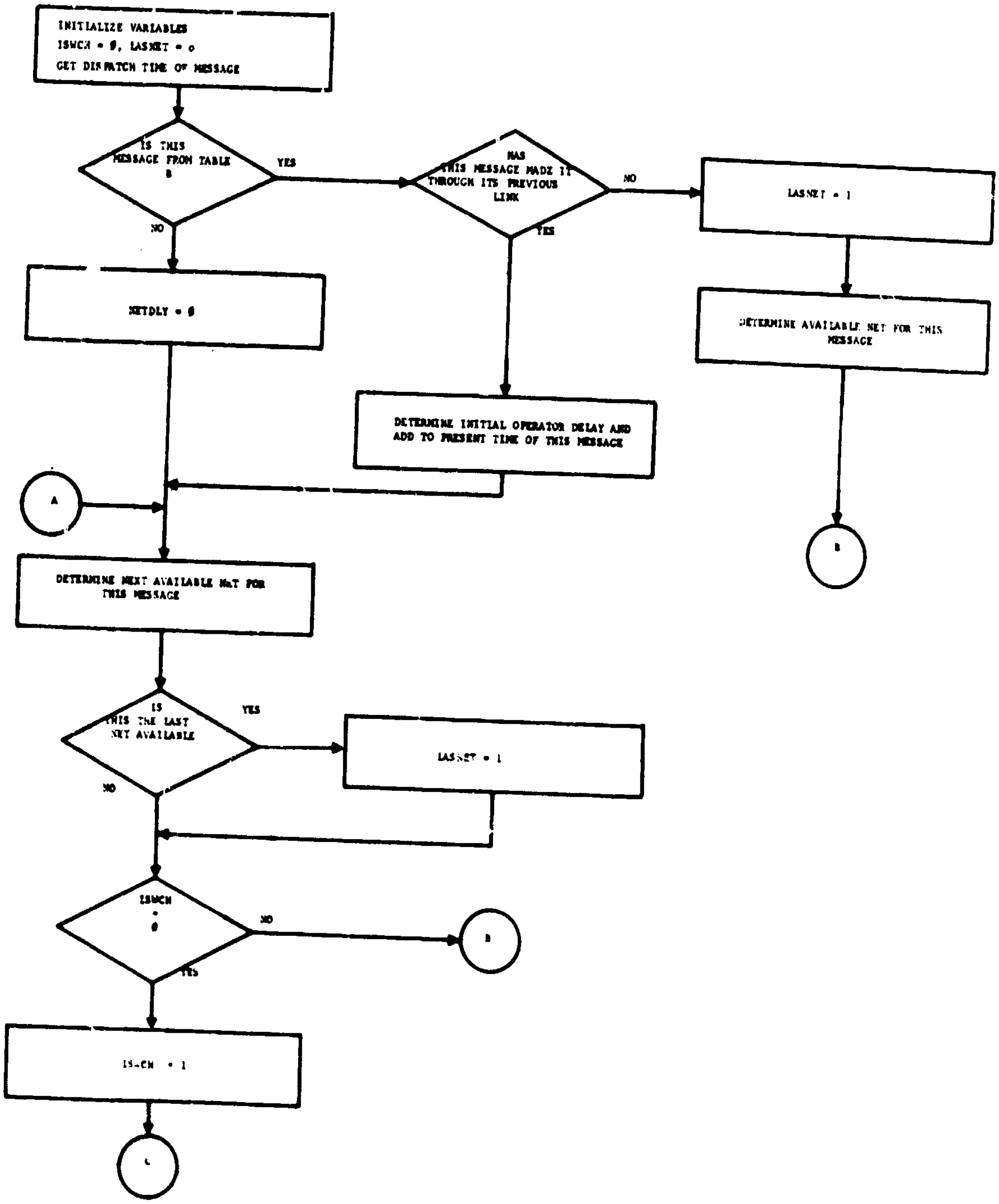


FIGURE 6.0-12 [illegible] SUBROUTINE MACROFLOW
(Sheet 1 of 6)

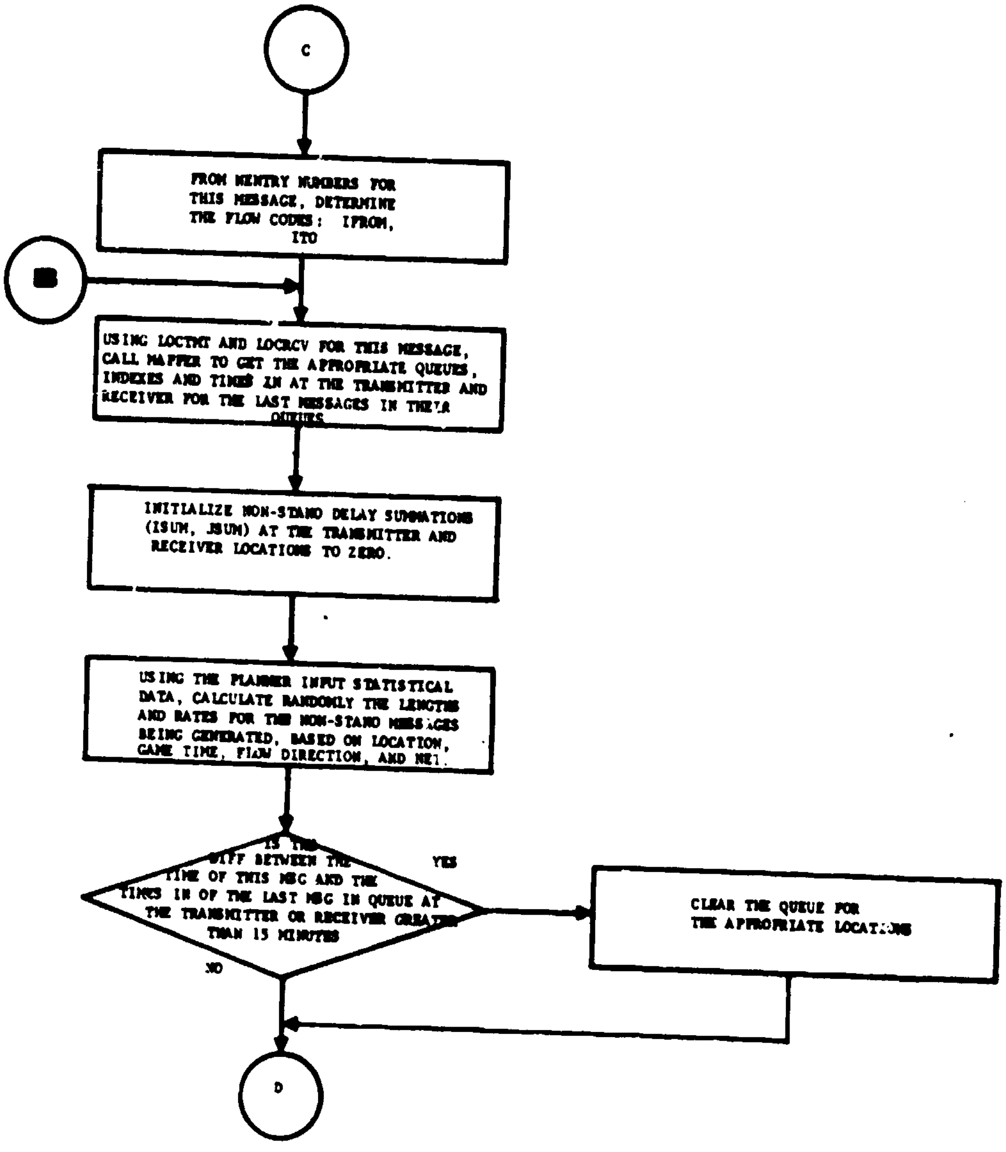


FIGURE 6.6-12 MSGQUE SUBROUTINE MACROFLOW
(Sheet 2 of 4)

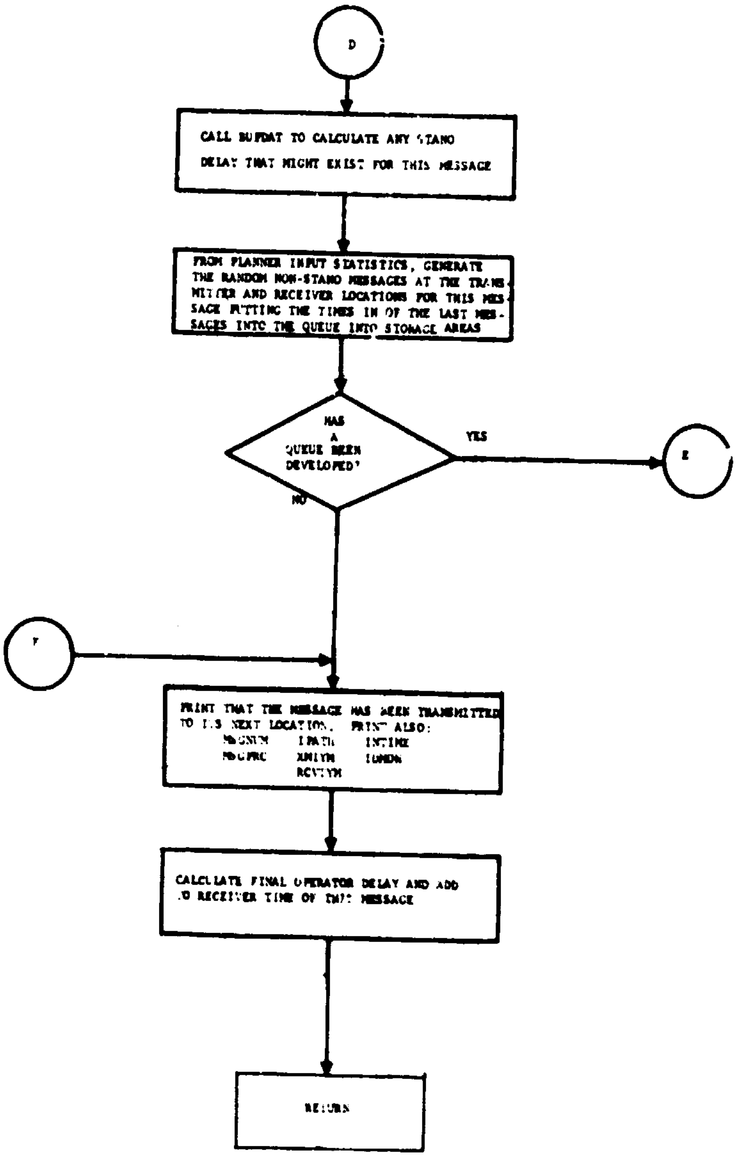


FIGURE 6.6-13 MSQUE SUBROUTINE MACROFLOW
(Sheet 3 of 6)

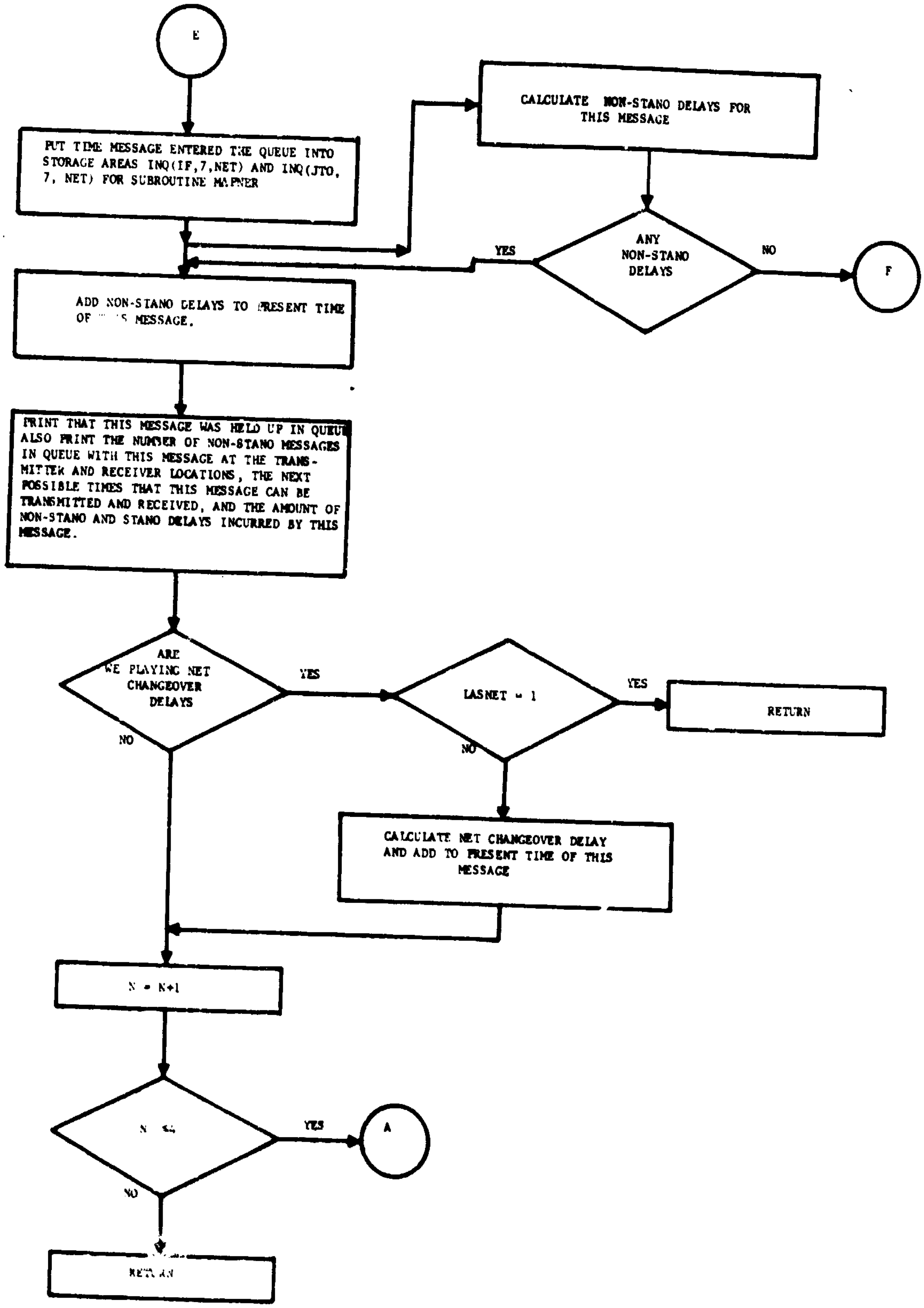


FIGURE 6.6-12 MSGQUE SUBROUTINE MACROFLOW
(Sheet 4 of 4)

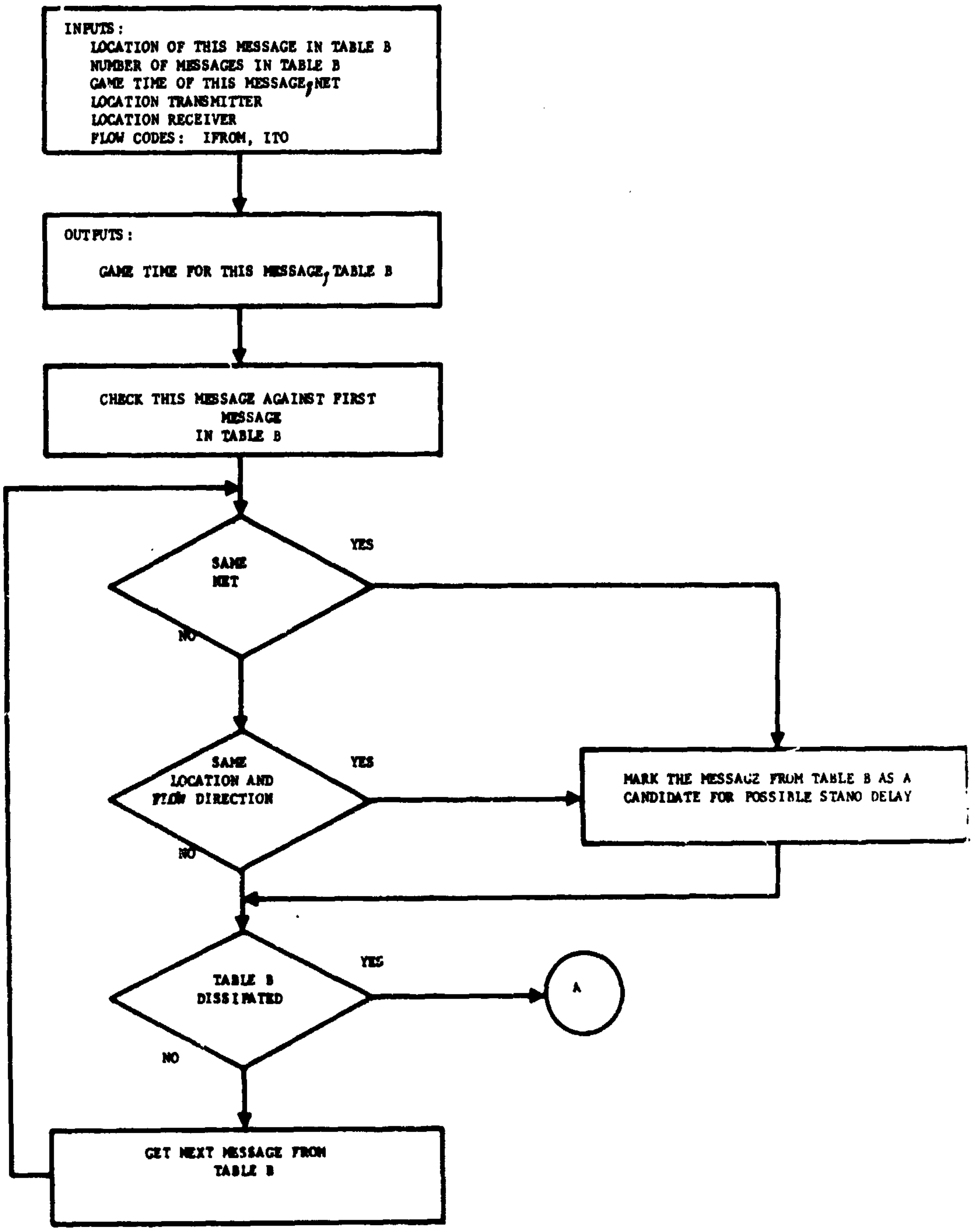


FIGURE 6.6-13 BUFDAT SUBROUTINE MACROFLOW
(Sheet 1 of 2)

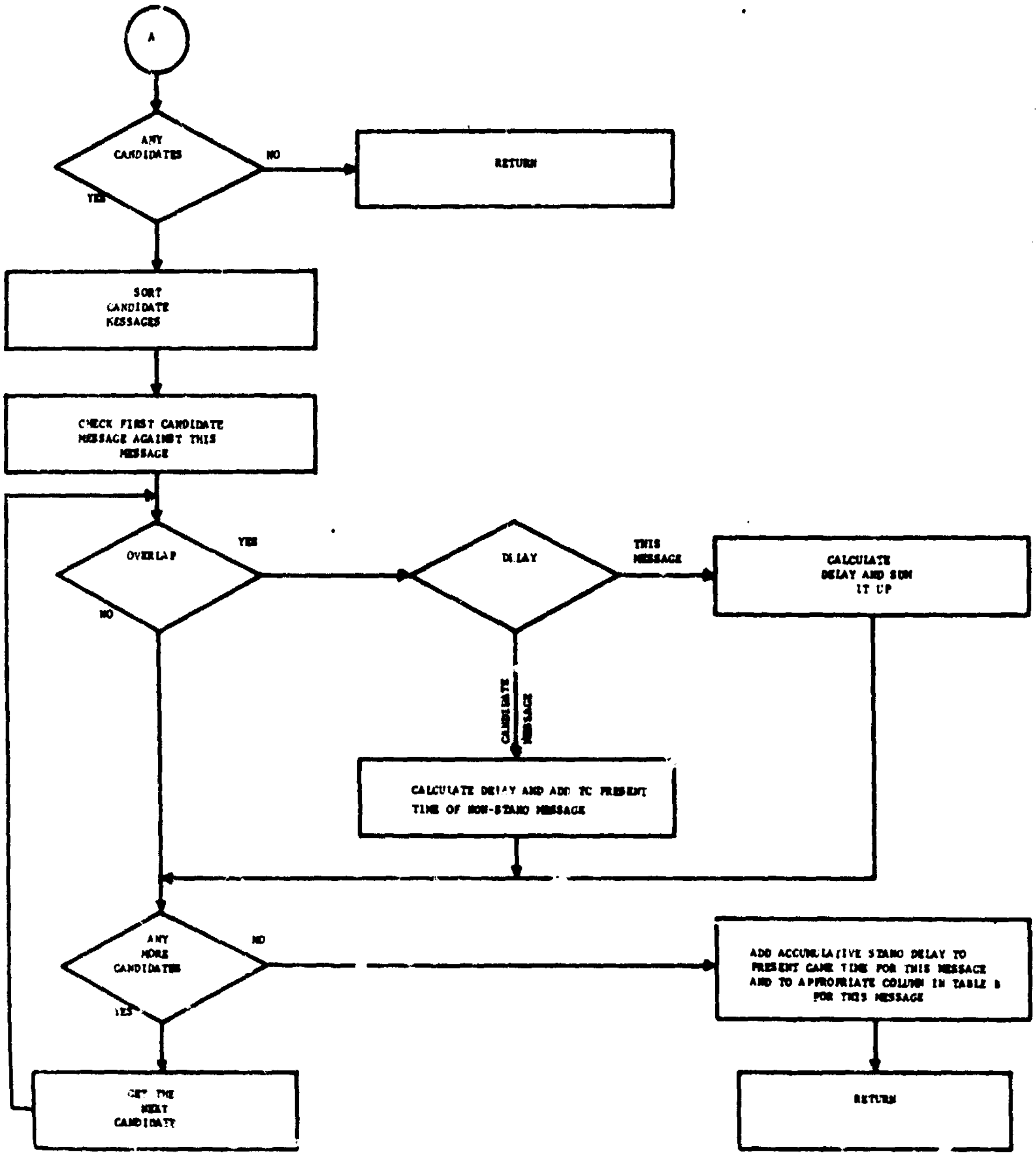


FIGURE 6.6-13 BUPDAT SUBROUTINE MACROFLOW
(Sheet 2 of 2)

TABLE 6.6-II

TACTICAL COMMUNICATIONS MODEL COMMON AREAS

USE	VARIABLES	USED BY
Common/MSGCAR/	MINRAT(6,6,4), MAXRAT(6,6,4), MINLEN (6,6,4), MAXLEN(6,6,4)	
	MINRAT(6,6,4) - Minimum number of non-STANO message attempts per hr, by precedence, flow direction, and net. MAXRAT(6,6,4) - Maximum number of non-STANO message attempts per hr, by precedence, flow direction, and net. MINLEN (6,6,4) - Minimum lengths of non-STANO messages to be generated, by precedence, flow direction and net. MAXLIN (6,6,4) - Maximum lengths of non-STANO messages to be generated, by precedence, flow direction and net.	DUMTXC MSGQUE
Common/MODIFY/	KTYM(50), MODRAT(6,6,4,50), MODLEN(6,6,4,50)	
	KTYM(50) - game times at which these modifiers begin to be effective.	DUMTXC MSGQUE

USE	VARIABLES	USED BY
	MODRAT(6,6,4,50) - Modification of non-STANO message rates at KTYM. MODLEN(6,6,4,50) - Modification of non-STANO message lengths at KTYM.	
Common/MESSGS/	ITABLA(200,5), ITABLB(200,48)	
	ITABLA(200,5) - A chronological list and initial description of STANO messages. ITABLB (200,48) - A temporary storage area for information on messages enroute from an entry point to a final destination.	DUMTXC TACCOM MSGQUE BUFDAT TACOUT
Common/CGROT/	MONLOC(100), NODES(100), IHORZ(100), IROOT(100)	
	MONLOC(100) - The monitor location where the STANO message is initiated. NODES(100) - Code describing flow of the STANO message through the tactical communications net. IHORZ(100) - Code describing horizontal or vertical flow of the message through the tactical communications net. 0 - Vertical (Plt - Co) 1 - Horizontal (Plt - Plt) IROOT(100) - The lowest echelon along the path for a particular STANO message. For horizontal flow, the destination unit of this message.	DUMTXC TACCOM ROUTE MSGQUE

USE	VARIABLES	USED BY
Common/MSSTYP/	MSGPRE(100), KPATH(100), NETPRE(100), LTIME(100)	
	MSGPRE(100) - Message precedence of the STANO message	DUMTXC TACCOM PRCDNT
	KPATH(100) - Path ID on which the message is flowing	
	NETPRE(100) - Net Preference Code for the STANO message along its path. A four digit code specifying 4 different nets.	
	LTIME(100) - Time variable so that messages may be identified with MSM game time in order to have the message types,precedences and routing be more closely tied to the scenario.	
Common/LOADSA/	ISTORE (800), INQ(200,6,4), STRCNT	
	ISTORE(800) - Storage area for the unique echelon locations played in the model.	DUMTXC TACCOM LDSRT MSGQUE MAPPER
	INQ(200,6,4) - The queue developed in the model for each STANO message, by echelon, message precedence & net.	
	STRCNT - Count of the unique echelon locations in ISTORE (800)	

USE	VARIABLE	USED BY
Common/CYCLE/	MECYCL(4,6), SIGCYC(4,6)	
	MECYCL(4,6) - The mean net changeover delay for each net and flow direction between each echelon. SIGCYC(4,6) - The standard deviation for net changeover delay for each net and flow direction between each echelon.	DUMTXC MSGQUE
Common/CPSHUN/	KOPERT, NETCYC, IPREC,NRTCNT, KTIME, ITABA, NMESG	
	KOPERT - Bypass code for playing operator delays. 0 = no play 1 = play NETCYC - Bypass code for playing net changeover delays. 0 = no play 1 = play IPREC - Number of precedence data cards. NRTCNT - Number of Route data cards KTIME - Number of time sections in the model after which the non-STANO message rate and length modifiers to the COMMOTRAFIK data will be applied.	DUMTXC TACCOM MSGQUE

USE	VARIABLE	USED BY
	ITABA - Code for describing a message being processed from TABLE A or TABLE B. 1 = Table A 0 = Table B **NMESG** - The number of messages to be played in the mdl.	

APPENDIX A

SAMPLE PRERUN OUTPUTS

The following sections describe how to interpret the output of PRERUN. Any of the output can be suppressed by inputting NPRINT = 0 in PRERUN Step 0.

1.1 PRERUN Step 0. The following tables and data lists are printed out in PRERUN Step 0.

Title	Reference for Definition of Fields
Headers	Vol II, page F-4 - printed with no change
Arrays	Vol II, page F-5,- printed with no change
Position Error Parameters	Vol II, page F-11- printed with no change
Sensors	Vol II, page F-16- printed with no change
Sensor Parameter Set	Vol II, page F-20- printed with no change except as noted

Note: Field 10 will appear as four asterisks if Sector coverage is used. Field 9 will not be printed.

Firetrap Kill Point Systems	Vol II, page F-29- printed with no change
Monitors	Vol II, page F-32- printed with no change
Monitor Parameter Set	Vol II, page F-39- printed with no change
Relays	Vol II, page F-39- printed with no change
Relay Reliability Parameter	Vol II, page F-39- printed with no change
Data Links	Vol II, page F-45- printed with no change
Receiver/Transmitter Parameter	Vol II, page F-48- printed with no change

Note: Fields 7 and 8, and 15 and 16 have no space between them.

Path Vol II, page F-52- Same as Input, with following differences: Only "ATH" will be printed from PATH. No space between items 7 and 8. Item 12 starts on line 2 and has no decimal point between it and item 13. Trailing zeros indicate that less than 9 legs are used.

Force Type Parameter	Vol II, page F-56- printed with no change
Coverage/Scan Parameter	Vol II, page F-60- printed with no change
NAV System Hyperb PRNV1	Vol II, page F-64- printed with no change
NAV System Rhotheta PRNV2	Vol II, page F-67- printed with no change
NAV System Doppler PRNV3	Vol II, page F-70- printed with no change
NAV System normal dist PRNV4	Vol II, page F-73- printed with no change
STASCAN Arrays	Vol II, page F-76- printed with no change
MOVE Arrays	Vol II, page F-80- printed with no change
Forces (Blue)	Vol II, page F-85- printed with no change
Forces (Red)	Vol II, page F-88- printed with no change

Battle PIEVT Table	Vol II, page F-91- printed with no change
Battle RSEVT Table	Vol II, page F-98- printed with no change
Battle XCLUA	Vol II, page F-102 printed with no change
Battle FSPTB Table	Vol II, page F-105 printed with no change
Culture PCEVT Table	Vol II, page F-108 printed with no change
Culture RCEVT Table	Vol II, page F-114 printed with no change
Culture SNFDX-Y Table	Vol II, page F-118 printed with no change

Note: In all cases, rounding errors will result if a number is read in and printed out in a different format from that used in the input. For example, the CULTURE PCEVT TABLE, Item 10. For CEVID type 2, if the value of activity level is 1.5; it will be printed out as 2., even though it will be properly stored in the machines.

1.2 PRERUN Step 1. PRERUN Step 1 contains PREMN1 and 14 subroutines which it calls. Of these 15 subprograms, only two, UPDN8 and UPDN6 have any printed output. The output of UPDN8 will appear as follows:

```
RELAY UP-DOWN TIMES

Time            Code

3 ←Ⓐ
    0 ←Ⓑ
                -2 ⎫
13456           -4 ⎬ ←Ⓒ
15786           -1 ⎪
18230           -6 ⎭
```

NOTE: A Identifies the relay, in this case relay number 3.

B An actual time an event occurs, whether planned or unplanned, and whether a relay goes up (becomes operational) or goes down (ceases to be operational).

C Code to tell case of up/down as follows:

-1 Reemplace (up)
-2 Normal up (up)
-3 Abort (down)
-4 Reliability failure (down)
-5 Life failure (down)
-6 Normal down (down)

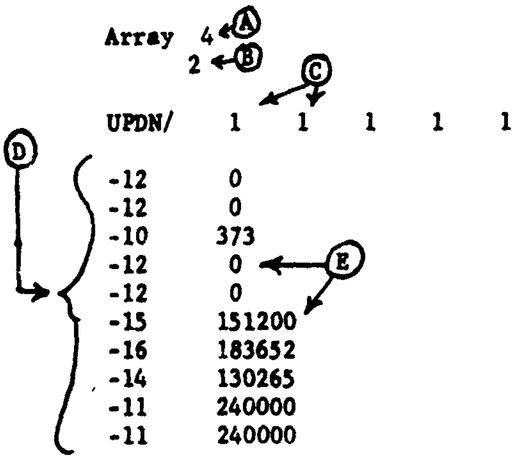
The output of UFDN 6 will apppear as follows:

```
Monitor
ID   No.   Planned Up   Planned Down    Actual Up     Actual Down Counter
      1          0 Ⓐ      151200 ←Ⓑ         0              151200
      2     151199 ←       151200        151199       Ⓓ      151200
      3        350          63215           350          →  17038
      3        350          63215      Ⓒ→ 19532              63215
```

NOTE: A and B. Planned up and down time have been converted from planner input values to seconds from start of game.

C and D. Difference between planned and actual down times result from randomness introduced through planner input Set 7, items 3, 4, and 5. Initial up time will always be the same as the planned up time.

1.3. PRERUN Step 2. PRERUN Step 2 contains PREMN2 and 10 subroutines which it calls. Of these 11 subprograms, only UPDN3, UPDN19, and PREMN2 have any printed output. The output of UPDN3 and UPDN19 will appear as follows:



```
Array  4
      2

UPDN/   1     1     1     1     1

-12     0
-12     0
-10     373
-12     0
-12     0
-15     151200
-16     183652
-14     130265
-11     240000
-11     240000
```

Explanation:

A: Array under consideration

B: Twice the number of Up/Down Cycles experienced by this array during the game. If a sensor array were emplaced and then reemplaced twice because of equipment failures, this number would be <u>6</u>.

C: Number of up/down cycles per sensor in the array.

D: Code to indicate cause of each sensor going up or going down. If the first number in item C had been 2, then the first two entries would pertain to the first sensor. The same applies to the first two down times. Up times for all sensors are listed first followed by down times. Codes used include the following:

- 8 Couldn't emplace enough sensors during a mission (down) see items 24, 25, and 26, Data Set I, pages F-5 and 6, Volume II.
- 9 Falls below acceptable number of sensors (down). same reference as above.
- 10 Maintenance (Up); may not have been down, since this can be preventive maintenance.
- 11 Normal or planned down time (down)
- 12 Normal or planned up time (up)
- 13 Abort (down) UGS arrays only
- 14 Equipment reliability failure (down)
- 15 Life of battery has been exceeded (down)
- 16 The auxiliary sensor is unable to report since the primary sensor is down.
- 17 The sensor failed to survive emplacement (down)
- 18 The sensor came up at a time later than the end of game time

The Output of PREN2 will appear as follows:

```
       UPDN

        0.        151200.
        0.        151200.
        0.        151200.
Ⓐ ───►  0.         73268.        84376.          151200.
        0.        151200.
       376.        13000.        18324.          134260.
```

Explanation: Each sensor has a single line showing alternately up and down times. Line A, for example, concerns sensor 4. Sensor 4 came up at 0. seconds, went down at 73268, then came back up at 84376 and went down again at 151200 seconds.

1.4 PRERUN Step 3. PRERUN Step 3 contains PREMN3 and 15 subroutines called directly or indirectly. Of these, only PSNP, PSNP19, and PREMN3 have printed output. PSNP19 and PSNP have identical output as follows:

```
SNER
  A    B    C    D    E    F    G    H              I

  1.   3.   1.   0.   0.   0.   0.   0.   10750.    11450.
  2.   3.   2.   0.   0.   0.   0.   0.   10750.    11450.
  3.   3.   3.   0.   0.   0.   0.   0.   10750.    11450.
  4.   3.   4.   0.   0.   0.   0.   0.   10750.    11450.
  5.   3.   5.   0.   0.   0.   0.   0.   10750.    11450.

          J              K     L     M     N     O            P            Q
  12320.    10100.      1.    1.    10.   91.-0.710  12340.7  10125.5  1.0
  12200.    10000.      1.    1.    10.   91.-0.785  12182.6   9984.5  1.0
  12100.     9900.      1.    1.    10.   91.-0.854  12102.3   9911.4  1.0
  12020.     9800.      1.    1.    10.   91.-0.915  11958.7   9855.3  1.0
  11950.     9700.      1.    1.    10.   91.-0.970  11931.4   9754.7  1.0
```

SNER: Table name

A: Sensor number

B: Method of emplacement code (i.e.,1 . = hand emplaced; 2. = hand emplaced using path as references; 3 = airdrop; 4 = artillery or mortar)NOTE: This differs from emplacement technique code used in item 11 of Data Sets I and XIX. New code is assigned in the program.

C: Number of the sensor within the particular array.

D: 0 - if map errors are not being played, 1. if they are. (From Prerun Step 0, NPLAY)

E. Either a code or a parameter value concerning location errors. If location errors are being played and the sensors are hand emplaced (or they are being delivered by unobserved artillery), then E is the value of one standard deviation of location error. Otherwise the value will be 0.

F: If the sensors are hand emplaced, and the sensor is not the first sensor in the array, and relative errors are being played, then number will be the relative location error in percent of base (first sensor) error. Otherwise value will be 0.

G. If sensor is hand emplaced, set to 0.
If air delivered (±3 in column B) number denotes type of navigation system on aircraft (0 = "perfect," 1 = Hyperbolic, 2 = Rho-Theta, 3 = Doppler, 4 = Gaussian errors assumed).
If artillery delivered (± 4 in column B) number denotes weapon type (1 = 155mm; 2 = 105mm; 3 = 8, "4 = 81mm, 5 = 4.2")

H. If artillery emplaced, number = 1. Any other delivery means, number is 0.

I. If sensor field is <u>not</u> hand emplaced, these are the X and Y coordinates of either the gun which fired it in, or the point of origin of the aircraft which dropped it. If the sensor is hand emplaced, values will be 0, unless the sensor is an auxiliary sensor in which case a 1. will be in the first field.

J. X and Y coordinates of desired sensor location.

K. 1. indicates airdrop errors are being played, 0 indicates they are not. (applies only to air delivered sensors)

L. If the sensor is airdropped, set to 1 if helicopter delivered, 2 if dropped from a fixed wing aircraft. If delivered by unobserved artillery, value is set to 1.

M. Speed of aircraft, if airdropped sensor, otherwise 0.

N. Altitude of aircraft (meters), if airdropped sensor; otherwise 0.

O. An angle. This angle is derived by taking the $\tan^{-1}$ of $\frac{DY}{DX}$ where DY and DX are the differences in the Y and X directions respectively of:

(1) Aircraft start point and desired sensor position in case of air dropped sensors <u>or</u>

(2) Gun position and desired sensor position in case of artillery or mortar delivered sensor <u>or</u>

(3) Start and end points of path leg along which the sensor is to be emplaced <u>or</u>

(4) A line connecting the South-West corner of the play area with the desired sensor location in the case of sensors emplaced in the open.

NOTE: Format may preclude printing out entire angle.

P. Ground truth position of each sensor, to nearest .1 meter.

Q. Version of navigation system (within the category shown in G above), if airdropped sensor. Otherwise, 0. See item 3, AIRDROP, page F-11, Volume II.

PREMN3 has output as follows:

```
      0.      1250.    11000.    12532.       60.   172800.
      0.      1250.    11000.    12582.       60.   172800.
      0.      1250.    11000.    12842.       60.   172800.
   4569.      2638.    11439.    13403.       60.   172800.
   4569.      2638.    11482.    13428.       60.   172800.
   4569.      2638.    11525.    13453.       60.   172800.
   4569.      2638.    12224.    13840.       60.   172800.
   4569.  Ⓐ   2638.    12278. Ⓑ  13906.       60. Ⓒ 172800.
   4569.      2638.    12342.    13951.       60.   172800.
   4569.      2638.    12883.    14237.       60.   172800.
   4569.      2638.    12927.    14262.       60.   172800.
   4569.      2638.    12970.    14287.       60.   172800.
   4569.      2638.    13293.    14474.       60.   172800.
   4569.      2638.    13293.    14474.       60.   172800.
   4569.      2638.    13995.    14879.       60.   172800.
   4569.      2638.    14562.    15207.       60.   172800.
      0.         0.    15755.    16145.       60.   172800.
      0.         0.    15781.    16119.       60.   172800.
      0.         0.    15754.    16146.       60.   172800.
    931.      1612.    16077.    16667.       60.   172800.
    931.      1612.    16077.    16667.       60.   172800.
      0.      1500.    16475.    17869.       60.   172800.
```

A: DX and DY - For sensors emplaced with respect to a leg of a path, the first column is the distance between the end points of the leg in the East-West direction. The second column is the distance between end points in the North-South direction. For sensors emplaced using only UTM coordinates in Data Set III, these numbers will be 0.

B: X_1 and Y_1 - The first ground truth location of each sensor. Same as Item P in PSNP19, and PSNP explanation above.

C: T_1 and T_2 - The first up and down time of the sensor.

NOTE: Each sensor has a single line. If a single sensor is relocated or goes up and down more than once, new columns will be printed to the right of the first column showing subsequent location and up/down times. X_2 and Y_2, T_3 and T_4.

1.5 PRERUN Step 4. There is no printed output from this step.

1.6 PRERUN Step 5. Consists of TRNPAR which calls TRNPRI. TRNPR1 calls seven (7) subroutines. Thirteen Tables are printed out by TRNPR1. These tables are headed by a MSM file number and the location on disc in set JTFWDF where the table starts. Columns correspond to data extracted from planner inputs from data sets described in Appendix F, Volume 2. Explanations follow and are keyed to items in the data sets.

MSM 1 - Arrays - UGS Start Location = 1

A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	UGS	1	3	1	1	1	1	0	0	0	0	0	0
2	UGS	1	1	4	2	1	2	2	3	0	0	0	0
3	UGS	1	3	5	2	1	4	2	5	0	0	1	1
4	UGS	1	3	8	1	1	6	0	0	0	0	1	1
5	UGS	1	3	11	2	1	7	2	8	0	0	0	0
6	UGS	1	2	14	1	1	9	0	0	0	0	0	0
7	UGS	1	1	16	1	1	0	0	0	0	0	0	0
8	UGS	1	1	17	1	1	10	0	0	0	0	0	0
9	UGS	1	3	18	1	1	11	0	0	0	0	0	0
10	UGS	1	2	21	1	1	12	0	0	0	0	0	0
11	UGS	1	1	23	1	1	13	0	0	0	0	0	0
12	UGS	1	2	24	1	2	14	0	0	0	0	0	0
13	UGS	1	2	26	1	2	15	0	0	0	0	0	0
14	UGS	1	2	28	1	2	16	0	0	0	0	0	0
15	UGS	1	1	30	1	1	0	0	0	0	0	0	0
16	UGS	1	2	31	1	2	17	0	0	0	0	0	0
17	UGS	1	2	33	1	2	18	0	0	0	0	0	0
18	UGS	1	2	35	1	2	19	0	0	0	0	0	0

A: ID of array (item 1, page F-5)
B: Generic type (item 2, page F-5)
C: Organization (item 3, page F-5)
D: Number of sensors in array (item 4, page F-5)
E: ID of first sensor in array (item 5, page F-5)
F: Number of monitors associated with array (item 13, page F-5)
G: ID of first (primary monitor) (item 14, page F-5)
H: ID of data link to 1st monitor(item 15, page F-5)
I: ID of second monitor (item 16, page F-5)
J: ID of data link to second monitor (item 17, page F-5)
K: ID of third monitor (item 18, page F-5)
L: ID of data link to third monitor (item 19, page F-5)
M: ID of artillery ambush (firetrap) (item 22, page F-5)
N: Buffer

MSM 2 - Arrays - STASCAN Start Location = 272

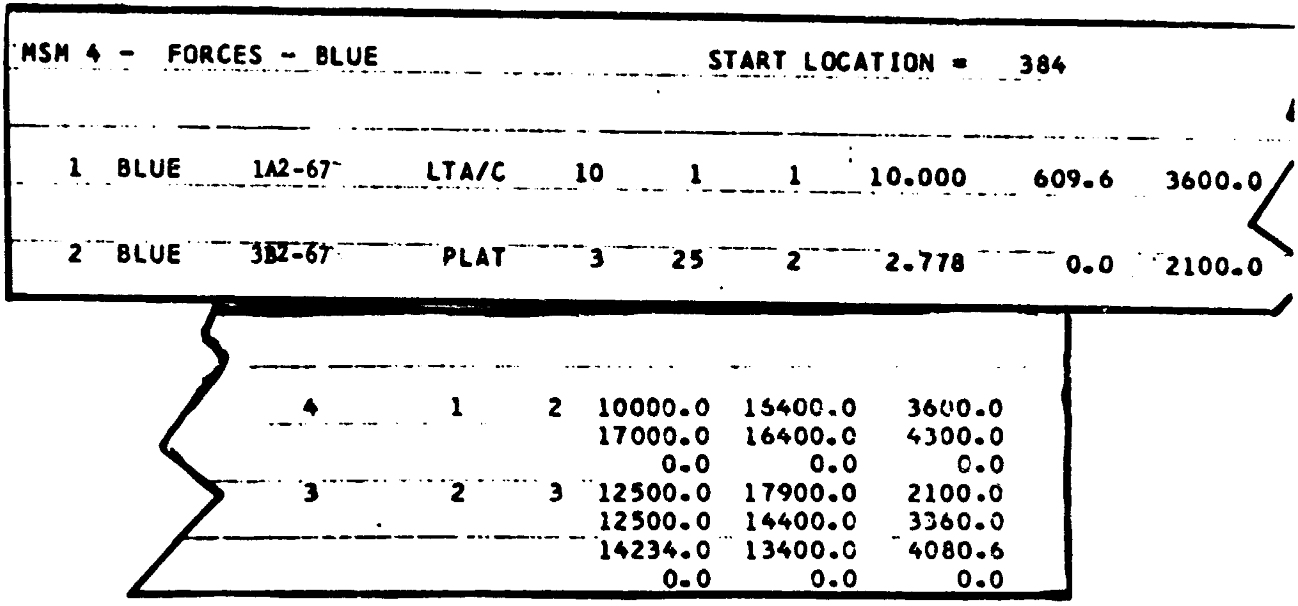
19	VISS	1	1	37	0	0
20	VISS	1	1	38	0	0
21	VISS	1	1	39	0	0
22	VISS	1	1	40	0	0
23	VISS	1	1	41	0	0
24	VISS	1	1	42	0	0
25	VISS	1	1	43	0	0
26	VISS	1	1	44	0	0
27	VISS	1	1	45	0	0
28	VISS	1	1	46	0	0
29	VISS	1	1	47	0	0
30	VISS	1	1	48	0	0

See Table D-2, page D-21, Volume I, Part II.
See also Para 4, page D-8, Volume I, Part II.
See also Data Set XIX, Page F-76, Volume II

MSM 3 - Arrays - MOVING Start Location = 369

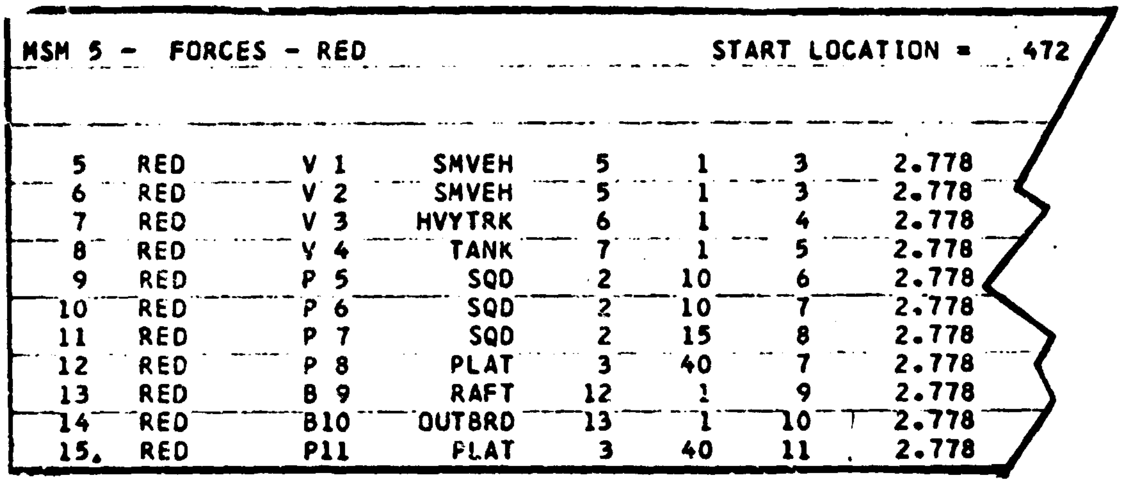
31	MOVE	1A2-67	2	49	1	1
32	MOVE	3B2-67	2	51	2	1

See Table D-3, page D-22, Volume I, Part II.
See also para 4, pages D-8 and D-9, Volume I, Part II.
See also Data Set XX, page F-80, Volume II

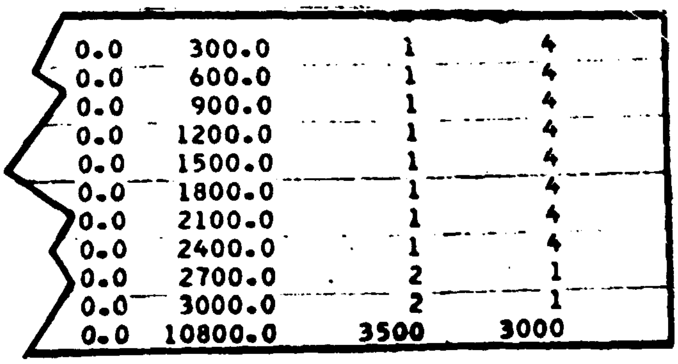


```
MSM 4 - FORCES - BLUE                              START LOCATION =   384

  1  BLUE    1A2-67      LTA/C     10      1      1    10.000     609.6    3600.0

  2  BLUE    3B2-67      PLAT       3     25      2     2.778       0.0    2100.0

            4          1       2   10000.0   15400.0    3600.0
                                   17000.0   16400.0    4300.0
                                       0.0       0.0       0.0
            3          2       3   12500.0   17900.0    2100.0
                                   12500.0   14400.0    3360.0
                                   14234.0   13400.0    4080.6
                                       0.0       0.0       0.0
```

See Table D-4, page D-23, Volume I, Part II.
See also Para 6, page D-9, Volume I, Part II.
See also Data Set XXI, page F-84, Volume II.



```
MSM 5 -  FORCES - RED                          START LOCATION =   472


  5   RED          V 1     SMVEH      5      1       3      2.778
  6   RED          V 2     SMVEH      5      1       3      2.778
  7   RED          V 3    HVYTRK      6      1       4      2.778
  8   RED          V 4      TANK      7      1       5      2.778
  9   RED          P 5       SQD      2     10       6      2.778
 10   RED          P 6       SQD      2     10       7      2.778
 11   RED          P 7       SQD      2     15       8      2.778
 12   RED          P 8      PLAT      3     40       7      2.778
 13   RED          B 9      RAFT     12      1       9      2.778
 14   RED          B10    OUTBRD     13      1      10      2.778
 15.  RED          P11      PLAT      3     40      11      2.778
```



```
0.0     300.0            1        4
0.0     600.0            1        4
0.0     900.0            1        4
0.0    1200.0            1        4
0.0    1500.0            1        4
0.0    1800.0            1        4
0.0    2100.0            1        4
0.0    2400.0            1        4
0.0    2700.0            2        1
0.0    3000.0            2        1
0.0   10800.0         3500     3000
```

See Table D-5, page D-25, Volume I, Part II.
See also Para 7, Page D-10, Volume I, Part II.
See also Data Set XXII, Page F-88, Volume II.

MSM 6 - SENSORS START LOCATION = 627

29	14	ACOUSTIC	8	2	12005.2	12400.0	0.0	1.5708	1	0	0
30	15	BREAKWIR	15	4	10977.8	16350.0	-50.0	1.5708	0	0	0
31	16	SEISMIC	2	0	10000.0	11900.0	0.0	1.5708	0	0	0
32	16	SEISMIC	2	0	10000.0	11900.0	0.0	1.5708	0	0	0
33	17	SEISMIC	2	0	10000.0	11900.0	0.0	1.5708	0	0	0
34	17	SEISMIC	2	0	10000.0	11900.0	0.0	1.5708	0	0	0
35	18	SEISMIC	2	0	10000.0	11900.0	0.0	1.5708	0	0	0
36	18	SEISMIC	2	0	10000.0	11900.0	0.0	1.5708	0	0	0
37	19	THERMVEW	7	0	14000.0	14850.0	0.0	1.5708	0	6	0
38	20	THERMVEW	7	1	13603.1	14641.4	-10.0	-4.1891	0	6	0

See Table D-6, page D-27, Volume I, Part II.
See also Para 8, page D-11, Volume I, Part II.
See also Data Set III, Page F-16, Volume II.

Note: Column numbers correspond to word descriptions in Table D-6, except for column 3 which is sensor type rather than code.

```
MSM 7 -  SENSOR DESCRIPTION PARAMETERS    START LOCATION =  1304

  1   SEISMIC       ADSID 0.864E 08 0.864E 07 0.0            0     0  1.00
                   A DSID    0     0        0.0          0.0        0.0       0.0
                                            0.0      0.0            0.0****** 0

  2   SEISMIC     MINISID 0.864E 08 0.864E 07 0.0            0     0  1.00
                 MIN ISID    0     0        0.0          0.0        0.0       0.
                                            0.0      0.0            0.0****** 0

  3   ARFBUOY     NBB-CIR 0.864E 08 0.864E 07 0.0            0     0  1.00
                  NBB -CIR   1     1       50.0          0.0        0.0     500.
                                            0.0      0.0            0.0****** 0

  4 PASSIVIR        PIRID 0.864E 08 0.864E 07 0.0            0     0  1.00
                   P IRID    0     0        0.0          0.0        0.0       0.
                                            0.0      0.0            0.0****** 0
```

```
9999.0      6.283         0.0      30.0      100.0     2000.0
    0     0.0         0.0         0.0        0.0        0.0
0  0  0  0  0  0  0  0  0

9999.0      6.283         0.0      30.0      100.0     2000.0
    0     0.0         0.0         0.0        0.0        0.0
0  0  0  0  0  0  0  0  0

9999.0      6.283         0.0      25.0       25.0        0.0
    0     0.0         0.0         0.0        0.0        0.0
0  0  0  0  0  0  0  0  0

 -25.0       0.0          1.0      50.0       50.0        0.0
    0     0.0         0.0         0.0        0.0        0.0
0  0  0  0  0  0  0  0  0
```

See Table D-7, page D-30, Volume I, Part II.
See also para 9, page D-15, Volume I, Part II.
See also Data Set IV, page F-20, Volume II

Note: The line of 6 asterisks in the example constitute fields 35 and 36 in Table D-7. Upon correction of a format error this will correctly show the coordinates of the searchlight (if used) in game coordinates. The last 8 zeros have no present meaning. Space is being reserved if future sensors require additional sensor parameters.

```
MSM 8 -  FIRETRAPS


    1     1         0    172800     1
```

```
START LOCATION =  2271


  2    2000.0     0       0.0      0     0
```

See Table D-8, page D-35, Volume I, Part II.
See also para 10, page D-16, Volume I, Part II.
See also Data Set V, page F-29, Volume II.

```
MSM 9 -  MONITORS


  1     UGS1        1   14500.0   17400.0
  2     UGS2        1   14500.0   14400.0
```

```
START LOCATION =  2283


   0    172800      1     2
   0    172800      1     2
```

See Data Set VI, page F-32, Volume II, times in seconds.

MSM10 - DATA LINKS START LOCATION = 2306

1	1	1	1	2	0
2	2	1	1	2	0
3	2	2	0	0	0
4	3	1	1	2	0
5	3	2	1	2	0
6	4	1	0	0	0
7	5	1	0	0	0
8	5	2	0	0	0
9	6	1	2	2	1

See Data Set X, page F-45, Volume II, times in seconds.

MSM11 - PATH DATA

PATH	C	1	4	11000.0	11900.0
PATH	C	2	1	10000.0	12400.0
PATH	B	3	2	12500.0	17900.0
PATH	B	4	1	10000.0	16400.0

START LOCATION = 2421

1.0000	1.0000	1	11000.0	13150.0
1.0000	1.0000	1	15569.0	15788.0
1.0000	1.0000	1	16500.0	17400.0
1.0000	1.0000	1	16500.0	18900.0
1.0000	1.0000	5	14000.0	12400.0
1.0000	1.0000	1	12500.0	14400.0
1.0000	1.0000	1	14234.0	13400.0
1.0000	1.0000	9	17000.0	16400.0

See Table D-11, page D-38, Volume I, Part II.
See also para 13, page D-18, Volume I, Part II.

MSM12 - FORCE TYPE PARAMETERS START LOCATION = 2486

1	1	1	0.0	0	0	0
2	1	1	1.00	2	2	1
3	1	0	10.00	0	0	0
4	1	0	10.00	0	0	0
5	1	1	10.00	0	0	0
6	0	0	2.00	2	1	1
7	1	0	2.00	1	1	2
8	1	0	2.00	3	1	2
9	0	0	0.0	0	0	0
10	1	0	0.0	0	0	0
11	1	0	5.00	3	1	1

See Table D-12, page D-39, Volume I, Part II.
See also para 14, page D-19, Volume I, Part II.
See also Data Set XII, page F-56, Volume II.

MSM13 - COVERAGE/SCAN PARAMETERS START LOCATION = 2564

1	3	1000.0	1000.0	0.0	1000.0	0	0.0	0.0	0.0	0.	APD9
2	3	500.0	500.0	0.0	-500.0	0	0.0	0.0	0.0	0.	A/CSLS
3	3	500.0	550.0	250.000	-175.0	0	0.0	0.0	0.0	0.	MOVSLS
4	3	500.0	650.0	250.000	225.0	0	0.0	0.0	0.0	0.	MOVEYE
5	1	0.0	0.0	0.0	0.0	2	300.000	0.079	0.044	0.	PPS9
6	1	0.0	0.0	1.571	0.0	0	0.182	50.000	75.000	0.	IMG&THER
7	1	0.0	0.0	0.785	0.0	0	0.182	50.000	75.000	0.	SLT&SLS

See Data Set XIV, page F-60, Volume II.

1.7 PRERUN Step 6. PRERUN Step 6 contains PREMN6 and 19 subprograms. Printed output consists primarily of a listing of the planner and designer input data sets. Sample output is shown below:

```
SCHAR

 12.00  0.50  0.75  1.00  0.10  0.90  0.80  0.10  0.30  0.80  0.80  0.40
 42.00  0.50  0.75  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00  1.00
```

See page I-20, Volume II. Note that rows and columns have been exchanged.

```
ROUTX

  9400. 9400.10700.10550.     0.     0.     0.     0.     0.     0.     3.     1.
 15600.14800.15200.15150.16300.16550.17500.     0.     0.     0.     6.     1.
 15600.14650.14900.14200.     0.     0.     0.     0.     0.     0.     3.     1.
  5500. 5500. 7950.     0.     0.     0.     0.     0.     0.     0.     2.     1.
  5900. 6800. 7150. 7800. 8150.     0.     0.     0.     0.     0.     4.     1.
  6200. 6900. 7700. 8500. 8800.     0.******     0.     0.     0.     4.     1.
 13200.13100.11600.10750.     0.     0.******     0.     0.     0.     3.     1.
 13200.13100.11600.12150.11400.     0.     0.     0.     0.     0.     4.     1.
  6200. 6900. 7700. 8500. 8800. 9100.     0.     0.     0.     0.     5.     1.
  8800. 8450.     0.     0.     0.     0.     0.     0.     0.     0.     1.     1.
  5500. 5500. 7950. 8000. 8200.     0.     0.     0.     0.     0.     4.     1.
```

```
ROUTY

  7400. 8000. 8300. 9100.     0.     0.     0.     0.    -0.     5.     3.     1.
  8900. 9900.10400.11200.12550.14550.14700.     0.     0.******     6.     1.
 17200.16050.15100.14500.     0.     0.     0.     0.     0.******     3.     1.
 11600.11100.10200.     0.     0.     0.     0.     0.    -0.     0.     2.     1.
 11600.11550.11300.11200.10350.     0.     0.     0.    -0.     0.     4.     1.
 11950.12000.12600.12600.10400.     0.     0.     0.     0.******     4.     1.
  7700. 9600. 9800.11200.     0.     0.     0.     0.     0.     1.     3.     1.
  7700. 9600. 9800.10700.11100.     0.     0.     0.******     0.     4.     1.
 11950.12000.12600.12600.10400. 9950.     0.     0.******    -0.     5.     1.
```

These two tables are from labeled common area, "ROUTE" and contain the first 20 paths from planner data set XII, page F-52, Volume II. Since these are used to locate paths for battle and culture events, the 20x12 dimension of this matrix may need to be expanded for larger scenarios. The last column in the table denotes the type of path (see footnote, page F-52). The 11th column shows the number of legs on the path. There will be one more node than legs and the first 10 fields (columns) are reserved for the X (ROUTX) or Y (ROUTY) coordinate of the nodes. Only those numbers that represent nodal points have any meaning. The non-sensical values printed out in the remaining spaces result from not initializing the matrix area before overwriting.

```
IPSPED

 61.  3.  6.  9.
 72.  2.  5. 10.
```

See para 5.4.3.4b, page 5-153, Volume I, Part II. See also Table I-24, Volume II, Appendix I.

```
CACAL

 91.200.400.800.
 92.200.400.800.
```

See para 5.4.3.4c, page 5-153, Volume I, Part II. See also Table I-25, Volume II, Appendix I.

```
CEVCEA

 12.   30.   60.
 42.   30.   60.
```

See Table I-26, Volume II. Appendix I. See also para 5.4.3.4d, page 5-153, Volume I, Part II. In order to extend the sensor types past what is shown (sensor type 1 is all seismic sensors and sensor type 2 is all acoustic sensors) additional definition and extension is required in Subroutine CULTBK.

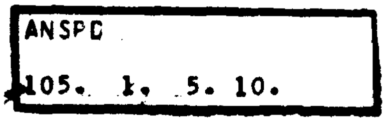
```
SNFDX

105. 16000. 16500. 10000. 10000. 10000. 10000
105. 17000. 17500. 10000. 10000. 10000. 10000.
```

```
**************         0.        0.        0.        0.       2.
      0.***********************************                   2.
```

```
SNFDY

105. 17400. 17900. 11900. 11900. 11900. 11900
105. 18400. 18900. 11900. 11900. 11900. 11900.
```

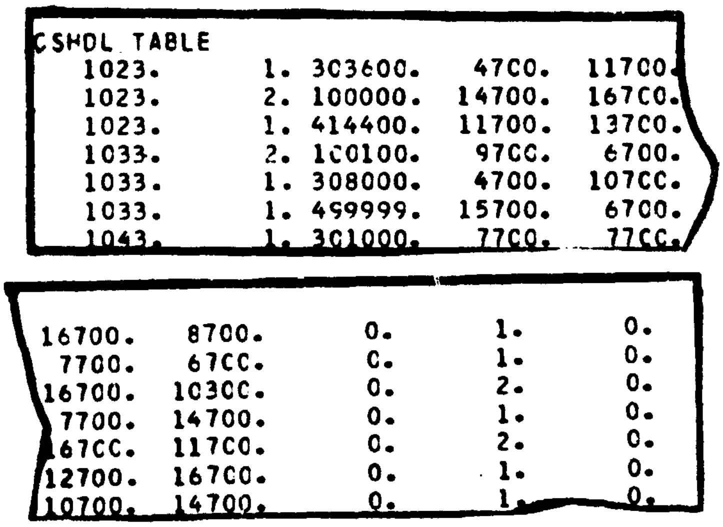
```
*********************          1.**************           2.
*******      0.       0.       0.       0.       0.       2.
```

These tables are obtained from the planner input Data Set XXIX (see page F-118), Volume II and page 5-152, Volume I, Part II). SNFDX and SNFDY tables are outgrowths of the master Data Set XXIX. The first column is the cultural event type and class being used. The last column shows the number of columns to the left of the first column that are meaningful. Up to six columns can be used (3 sensor fields.) The 2d, 4th and 6th columns show the South (SNFDX) or West (SNFDY) boundary of the sensor field while the 3d, 5th, and 7th columns show the North (SNFDX) or East (SNFDY) boundary. The 8-13th columns have no significance. Columns 2-7 are initially given the value of the Southwest corner of the play area and this number will show in those fields not used for exclusion areas.



```
ANSPC
105.  1.  5. 10.
```

See Table I-27, page I-22 Volume II and para 5.4.3.4e, page 5-153, Volume I, Part II.



```
CSHDL TABLE
   1023.        1. 303600.   4700.  11700.
   1023.        2. 100000.  14700.  16700.
   1023.        1. 414400.  11700.  13700.
   1033.        2. 100100.   9700.   6700.
   1033.        1. 308000.   4700.  10700.
   1033.        1. 499999.  15700.   6700.
   1043.        1. 301000.   7700.   7700.
```

```
16700.   8700.       0.       1.       0.
 7700.   6700.       0.       1.       0.
16700.  10300.       0.       2.       0.
 7700.  14700.       0.       1.       0.
16700.  11700.       0.       2.       0.
12700.  16700.       0.       1.       0.
10700.  14700.       0.       1.       0.
```

CSHDL consists of the planner input table PCEVT (see data set XXVII, page F-108, Volume II). Columns 1-10 of the printout are the same as items 2 - 11 of the data set.

```
123. ISHR        2
423. ISHR        2
123. ISHR        2
423. ISHR        2
123. ISHR        2
423. ISHR        2
123. ISHR        2
423. ISHR        2
```

If values are not entered in required tables, or if inconsistencies are found, values are assigned by default and a list of the type shown here is printed out. These entries are normally made as each sensor - CEVID is indexed through a do-loop in subroutine CULTBK.

```
CEVD    113.
CEVD    113.
CEVD    113.
CEVD    113.
CEVD    113.
```

```
TABLE CLTBGR

  0.10000000E 01     -0.98563585E 01     -0.98563585E 01
  0.20000000E 01     -0.98770628E 01     -0.98770628E 01
  0.30000000E 01     -0.99099855E 01     -0.99099855E 01
  0.40000000E 01     -0.99542694E 01     -0.99542694E 01
  0.50000000E 01     -0.10004425E 02     -0.10004425E 02
  0.60000000E 01     -0.70547132E 01     -0.70547132E 01
  0.70000000E 01     -0.70471048E 01     -0.70471048E 01
```

```
-0.98563585E 01     -0.98563585E 01
-0.98770628E 01     -0.98770628E 01
-0.99099855E 01     -0.99099855E 01
-0.99542694E 01     -0.99542694E 01
-0.10004425E 02     -0.10004425E 02
-0.70547132E 01     -0.70547132E 01
-0.70471048E 01     -0.70471048E 01
```

Column 1: Sensor number

Columns 2, 3, 4, 5 Contain the culture background level in each quarter day in dB.

```
FCWPN
 31.  2.  4.  8. 60. 30. 15.120. 60. 15.  1.  2.  3.  0.  0.  0.
 32.  1.  3.  5. 60. 30. 15.120. 60. 15.  3.  3.  1.  0.  0.  0.
 52.  1.  3.  5. 60. 30. 15.120. 60. 15.  2.  6.  6.  1.  0.  0.
 53.  1.  3.  5. 60. 30. 15.120. 60. 15.  2.  6.  2.  1.  0.  0.
121.  1.  1.  1.  0.  0.  0.  0.  0.  0.  1.  1.  1.  0.  0.  0.
```

See Para 5.4.2.4, page 5-146, Volume I, Part II and Table I-12, page I-13, Volume II.

```
FSPTB
      6000.       5500.        521.    10521.         0.
      6100.       5600.        521.        0.         0.
      6200.       5700.        521.        0.         0.
      6300.       5800.        521.        0.         0.
```

```
        0.         0.         0.         0.
        0.         0.         0.         0.
        0.         0.         0.         0.
        0.         0.         0.         0.
```

See page 5-145, Volume I, Part II and Data Set XXVI, Page F-105, Volume II. Note Item 1 of the Data Set is not printed out.

```
FBWPN
     52.     41.     41.     42.     42.     42.     42.
     53.     42.     42.     42.     42.     42.     42.
```

```
     43.     43.     43.     43.     43.     43.
     43.     44.     44.     44.     44.     44.
```

See page 5.4.2.4c, page 5-146, Volume I, Part II and Table I-13, page I-14, Volume II.

```
RNGBN
         200.
         500.
        1000.
        2000.
        4000.
        7000.
       10000.
       14000.
       18000.
       24000.
       30000.
       50000.
```

See page 5-147, Volume I, Part II and Table I-14, page I-14, Volume II.

```
WRLIM
      31.       100.       26CC.       32.
     800.      560C.

ACSPD
    1711.        25.         20.        5C.
    1721.        25.         25.        9C.

ACALT
     1CC.       700.         15.
     1CC.       700.         25.
```

See Pages 5-147 and 5-148, para f, g, h, Volume I, Part II.

XCLUA TABLE

```
(2) 0.(13)1810.        (15)0.     (12) 1721.  (13)  1810.    (15)    0.
(12)1721.  (8)521.   (10)1510.    (8)   521.   (9)  1210.    (11)1530.
 (7) 310.  (4) 0.    (6)     4.   (3) 17500.   (4)     0.    (6)     4.
(3)16000.  (14)0.    (16)    0.               (14)     0.    (16)    0.
          (9) 1210.  (11)1530.                (10)  1510.
          (5)18900.  (7)  310.                 (5) 17400.
                     (2)16000.
```

See Data Set XXV, page F-102, Volume II. Items in brackets correspond to item numbers in Data Set XXV. Data are repeated for number of exclusion areas used.

```
SAFTY
         311.        20.        20C.        25C.
         321.        3C.        410.        510.
         521.        3C.        180.        22C.
         531.        5C.        35C.        43C.
        1211.        10.         50.         5C.
```

See Table I-11, page I-12, Volume II (note that rows and columns have been exchanged) and Para 5.4.2.4a,page 5-146, Volume I, Part II.

```
ROUTX
     9400.       9400.     10700.
    15600.      14800.     15200.
    15600.      14650.     14900.
     5500.       5500.      7950.
     5900        6800       7150
```

See explanation above for ROUTE X and ROUTE Y - This list is reprinted with no change.

```
ROUTY
     7400.       8000.      830
     8900.       9900.
    17200.      16050.
    11600.      1
    11600.
    1195
```

```
       VSPED
              181.          3.          10.          20.
              182.          3.          10.          20.
```

```
       CNVOY
              181.          1.           2.           4.
              182.          1.           2.           3.
```

```
1.          2.          4.          1.          2.
1.          2.          4.          1.          2.
```

```
    SPACE
          181.         20.         30.         50.        100.
          182.         30.         40.         50.        100.
```

See Tables I-19, I-20, I-21, pages I-17 and I-18, Volume II.

```
 NOMAS
   21.  0.10  0.30  0.0
   22.  0.10  0.30  0.0
   31.  0.10  0.30  0.0
   32.  0.20  0.40  0.0
   41.  0.10  0.30  0.0
   42.  0.10  0.30  0.0
   43.  0.20  0.40  0.0
   44.  0.20  0.40  0.0
   52.  0.20  0.40  0.0
   53.  0.30  0.50  0.0
  121.  0.10  0.30  0.0
  132.  0.30  0.50  0.0
  171.  0.20  0.40  0.0
  172.  0.30  0.50  0.0
  181.  0.30  0.50  0.0
  182.  0.40  0.60  0.0
```

See Table I-22, page I-19, Volume II.

```
 SCHOL TABLE
      310.          1. 312600.   8400.    9800.  10550.   9100.
      310.          1. 312900.  10600.   11400.  10550.   9200.
      310.          2. 111700.   8400.    9800.   9400.   7400.
      310.          2. 111700.   8400.    9800.   7050.  10050.
      311.          1. 312720.  10700.    8900.   8400.   9800.
      311.          1. 312960.  10500.    9300.  10500.  11200.
      321.          1. 313080.  10500.    9100.  10620.  11220.
      321.          1. 313800.  10500.    8700.  10620.  11220.
      311.          2. 111760.   7000.   10000.   8400.   9800.
      321.          2. 112000.   9500.    7700.  10620.  11220.
      321.          2. 112900.   7500.   11700.  10620.  11220.
      110.          1. 400000.  10550.   11700.      0.      0.
      110.          1. 400300.  11100.   11500.      0.      0.
      110.          1. 410200.  10750.   11200.      0.      0.
```

```
  2261.      20.      210.      10.      25.      2.      0.
  2201.      20.      210.      10.      20.      2.      0.
  2600.      25.      210.      10.       4.      2.      0.
  1373.      18.      210.      10.       4.      2.      0.
  2470.      24.      211.      20.      30.      1.      0.
  1900.      19.      211.      20.      30.      4.      0.
  2123.      45.      221.       8.      10.      1.      0.
  2523.      48.      221.       6.      10.      2.      0.
  1414.      15.      211.      50.       5.      2.      0.
  3694.      62.      221.      10.       3.      4.      0.
  3157.      55.      221.      10.      10.      2.      0.
     0.       0.        0.      40.      15.      1.      0.
     0.       0.        0.      20.      15.      1.      0.
     0.       0.        0.     120.       5.      1.      0.
```

See page F-91, Volume II, User's Manual, Item No's 2-15.

If first word of output is a floating point number followed by "FCWPN," this means that the firing characteristics of the weapon used in this event were taken from the FCWPN Table on page I-13, Volume II, User's Manual, instead of using weapon characteristics explicitly stated by the planner input.

```
ACOUSTIC SENSORS

        0.        0.        0.        0.        0.        0.
        0.        0.        0.       19.        0.        0.
        0.        0.        0.       24.        0.        0.
        0.        0.        0.        0.        0.        0.
```

```
   0.        0.        0.        0.        0.        0.
   1.        0.        0.        0.        0.        0.
   0.        0.        0.        0.        1.        1.
   0.        0.        0.        0.        0.        0.
```

```
SEISMIC SENSORS

        0.        0.        0.        0.        0.        0.
        1.        0.        0.       48.        1.        0.
        0.        1.        1.       57.        1.        0.
        0.        0.        0.        0.        0.        0.
```

```
        0.        0.        0.        0.        0.        0.
        2.        0.        0.        1.        1.        1.
        0.        0.        0.        0.        2.        1.
        0.        0.        0.        0.        0.        0.
```

These two tables contain the battle background threshold levels in volts for the acoustic and seismic sensors before the random battle events are introduced. Each row contains twelve numbers representing the threshold levels for each of twelve hours for that day. The first two rows represent the first day (24 hours) and the next two rows represent the second day (next 24 hours), etc.

See page F-98, Data Set XXIV, Volume II for Battle RSEVT Table.

This table contains information on the random battle events played in the scenario. It has exactly the same format as SCHDL previously described.

```
TARGETS
    -118.   4700.  11700.  46800.  16700.   8700.  71539.
    -218.  14700.  16700.  86400.   7700.   6700.  98607.
    -318.  11700.  13700.  79200.  16700.  10300.  83231.
    -419.   9700.   6700.  86500.   7700.  14700.  94746.
    -519.   4700.  10700.  51200.  16700.  11700.  59228.
    -619.  15700.   6700. 164799.  12700.  16700. 185680.
    -719.   7700.   7700.  44200.  10700.  14700.  51816.
    -819.  12700.   6700.  91400.   9700.  16700.  96620.
    -919.  11700.   8700.  68400.  15700.  16700.  86289.
   -1019.   4700.  11700.  63200.  12700.   6700. 110370.
   -1119.   4700.  11700.  64802.  16700.   9700. 105354.
   -1219.   4700.  11700.  86402.  16700.  11900. 110405.
   -1316.  10550.   9100.  55780.  10550.   9100.  55960.
   -1415.   8400.   9800.  55800.   8400.   9800.  55980.
   -1516.  10550.   9200.  56080.  10550.   9200.  56260.
   -1615.  10600.  11400.  56100.  10600.  11400.  56280.
```

```
1.        0.        0.      201023       0.       1.
1.        0.        0.      201023       0.       1.
2.        0.        0.      201023       0.       1.
1.        0.        0.      201033       0.       1.
2.        0.        0.      201033       0.       1.
1.        0.        0.      201033       0.       1.
1.        0.        0.      201043       0.       1.
2.        0.        0.      201043       0.       1.
1.        0.        0.      201043       0.       1.
0.        0.        0.      201053       0.       1.
0.        0.        0.      201053       0.       1.
1.        0.        0.      201053       0.       1.
0.        0.        0.      200210       0.       1.
0.        0.        0.      100310       0.       1.
0.        0.        0.      200210       0.       1.
0.        0.        0.      100310       0.       1.
```

See pages B-7 through B-8, Volume I, Part II. The following additional information is necessary to completely interpret all words:

Word 1 - The digits preceeding the target identifiers are sequence numbers indicating the order in which the targets were generated. The leading minus sign indicates it is a "False Target."

Word 11 - The last digit indicates the type of target: 3 = Culture, 0 = Battle Enemy, 1 = Battle Friendly.

Word 13 - This word is a 1 or 0 depending on whether the target is attempting to avoid detection (1 = Yes, 0 = No)

```
ACOUSTIC SENSORS

   -200.     -200.     -200.     -200.     -200.     -200.
     -4.     -200.     -200.       13.       -4.     -200.
   -200.       -4.       -4.       14.       -4.     -200.
   -200.     -200.     -200.     -200.     -200.     -200.
```

```
   -200.     -200.     -200.     -200.     -200.     -200.
     -1.     -200.     -200.       -4.       -4.       -4.
   -200.     -200.     -200.     -200.       -0.       -1.
   -200.     -200.     -200.     -200.     -200.     -200.
```

```
SEISMIC SENSORS

   -200.     -200.     -200.     -200.     -200.     -200.
     -0.     -200.     -200.       17.       -0.     -200.
   -200.       -0.       -0.       18.       -0.     -200.
   -200.     -200.     -200.     -200.     -200.     -200.
```

```
   -200.     -200.     -200.     -200.     -200.     -200.
      3.     -200.     -200.       -0.       -0.       -0.
   -200.     -200.     -200.     -200.        2.        1.
   -200.     -200.     -200.     -200.     -200.     -200.
```

These tables are exactly the same as the Acoustic and Seismic tables described previously, however, they represent the battle background threshold values for the acoustic and seismic sensors in dB's after the random battle events are introduced.

1.8. PRERUN Step 7. There is no printout from this step except for diagnostic error messages.

1.9. PRERUN Step 8. There are several types of printout from PRERUN Step 8. The data shown below that comes from battle or culture can be distinguished by a minus sign in the first column. The meaning of each item in the first 12 columns is defined on page B-7, Volume I, Part II. The data concerns false targets.

BLUE AND RED FORCES STEP 8

```
1026.  13100.   9600.  36360.  13200.   7700.  38262.
1027.  11400.  11110.  34500.  11394.  11110.  35040.
1028.  11200.  17700.  37800.  10950.  16000.  40893.
2028.  10950.  16000.  40893.  11600.  15900.  41840.
3028.  11600.  15900.  41840.  11700.  15150.  43396.
4028.  11700.  15150.  43396.  10650.  14700.  45746.
5028.  10650.  14700.  45746.  10600.  14170.  46842.
```

```
1.00   1   0.0        12551   19.00    0.0
0.01   1   0.0        12565    4.95    0.0
0.56   1   0.0        12579   50.00    0.0
0.69   1   0.0        12579   50.00    0.0
0.49   1   0.0        12579   50.00    0.0
0.49   1   0.0        12579   50.00    0.0
0.49   1   0.0        12579   50.00    0.0
```

The following data concern Red and Blue Forces. Each column is defined below:

1 2 3 4 5 6

7 8 9 10 11 12

1. First digit is the leg of the path this force is on, if the force is moving. If the force is not moving there will be no leading zeros printed out and only the ID of the force will be shown.

2. For stationary targets, the X coordinate of the force location. For moving targets, the X coordinate of the first node of this leg.

3. Same as 2. except for the Y coordinate.

4. Start operations time for stationary targets. Time at which target gets to first node on this leg, for moving targets.

5. Zero for stationary targets. X coordinate of last node on this leg for moving targets.

6. Same as 5, except for Y coordinate.

7. Zero for stationary targets. Arrival time at this last node on this leg for moving targets.

8. Zero for stationary targets. Nominal speed along this leg for moving targets.

9. Ferrous metal indicator code. 1 = ferrous metal present, 0 = no ferrous metal present.

10. Altitude of the target. Zero if no altitude.

11. Storage location of force data subset plus 4.

12. Time length of the target for moving targets. Zero for stationary targets.

1.10. PRERUN Step 9: There are two types of output from this step, the second of which is optional. An example of the first output is shown below:

```
1  2          3          4          5

3
   221       -519      12021      12031
   221       3019      32574      32595
   221       3026      33386      33401


2  233       1056      52414      52534
   233       1068      53325      54675
```

1. The number of times that line-of-sight occurred between the target and sensor.

2. Sensor ID.

3. Target ID. Negative target ID indicates a target from battle and culture.

4. Earliest possible detection time of the target at this moment.

5. Latest possible detection time of the target at this moment.

The second output from PRERUN Step 9 is optional and gives a detailed description of what is actually happening between the sensor and target. It is used for debugging purposes.

1.11. PRERUN Step 10: There is basically one printout from this step but there are two types of information printed out. The first type of information is the earliest and latest possible detection information on the non-LOS sensor-target interrogations. The second is the same except it contains LOS sensor-target interactions which have line-of-sight. An example of the printout of both of these types is shown below:

```
 1                    2              3              4

114                -13609          65103          65177
114  Non - LOS     -13910          57027          57041
114                -14208          80554          80886
  0                     0              0              0
145                  -719           3294           3309
151    LOS           1055          52513          52918
152                  1055          52711          52981
157                  -719           3237           3267
```

1. Sensor ID

2. Target ID. Negative ID's are targets from battle and culture.

3. Earliest possible detection time.

4. Latest possible detection time.

1.12. PRERUN Step 11. This step collects and merges all events of all types that have been generated and stored in previous PRERUN steps. Specific references in Volume I, Part II for the format of event sublists are as follows:

Event Type	Pages
1	B-6 to B-8
2	B-9
3	B-10
4,5,6,7	B-11
8	B-12
9	B-13
10	B-14

In the printout both fixed point and floating point format are used for the listing of all events. Thus the fixed point format is listed first for an event and this is followed by floating point, and then the applicable format will be used.

1.13. PRERUN Step 12: This Step takes all the merged events, blocks them for MSM, and stores them on disc.

APPENDIX B
SIMULATION EVENTS

1. INTRODUCTION

The dynamic linkage between PRERUN and MSM is a time ordered sequence of <u>events</u>, the titles and general meanings of which are listed in Table B-1. These events (strictly speaking, the word lists for these events) are prepared by PRERUN, blocked into records containing not more than 901 words, and placed into a (disk or tape) data set currently named "EVENT1". The MSM executive routine EXEC1B then reads these events and causes them to be executed, one by one, until the special end-of-events flag is encountered.

This Appendix addresses details of event list structuring, with emphasis on the exact structure of sub-lists for each of the 11 event types.

The reader may note that the general concept underlying the linkage by <u>events</u> is compatible with potential program growth. That is, there is no preestablished limit on the number of different event types, and the word list for any event type may be of indefinite length and, except for the first few words, may be of any convenient format or content.

TABLE B-1

EVENT TYPE SUMMARY

TYPE CODE	TITLE	NO. OF WORDS PER SUBLIST*
1	SENSOR INTERROGATE	Min 6 *
2	SENSOR FALSE ALARM	4
3	SENSOR PARAMETER CHANGE	6 to 9**
4	SENSOR UP/DOWN	5
5	MONITOR UP/DOWN	5
6	DATA LINK UP/DOWN	5
7	FIRETRAP UP/DOWN	5
8	ARRAY UP/DOWN	5
9	BATTLEFIELD ILLUMINATION	10
10	SENSOR REPOSITION	6
99	END-OF-EVENT-SEQUENCE FLAG	1

* Events type 1 have no explicit upper limit on length of sublists. The minimum value corresponds to a single red or blue force considered as a sensor target.

** For events type 3, the stated limits correspond to changing from one to four sensor parameters, as was required for the sensor routines within the original SAM. There is no basic limit to the maximum number, however.

2. THE DATA SET "EVENTI"

The disk or tape data set "EVENTI" is written by PRERUN, used as input to MSM. It is blocked into logical records of at most 901 words: a word count variable (NW), and at most 900 words of event information. The corresponding read statement within MSM is of the form:

```
READ (IUNIT)   NW, (LIST(I), I=1,NW)
```

with, of course, a comparable write statement in PRERUN.

A record always contains full event lists. Since event lists are of variable length, the actual number of event words in a record is typically a few words short of the maximum of 900, and may be very small for the very last record of the set.

In MSM, a storage area of 900 words is reserved for event information. The events in this area are executed, one by one (until a special end-of-events flag is encountered), with interruptions as necessary for reading a new block [illegible] of information. [illegible] Read control is based on comparison of the internal list pointer with the word count variable, NW. It may be noted that the blocking allows MSM to execute an indefinite number of events in the sense that the number of events is not limited by MSM storage.

B.1 TIME ORDERING

Events are prepared by PRERUN in a time ordered sequence, according to the following logic:

(a) For an event associated with a time interval (both a begin and an end time), sorting is based on the begin time.

(b) The only criterion for "tie-breaking", that is, deciding which event should be placed first in the sequence when the key times are identical, is the following:

> "point-in-time" events should precede "interval-of-time" events, if the key times are identical.

B.2 EVENTS AT t = 0

Certain initialization steps within MSM are expected to be entered via the event list. These steps may require a series of events at initial game time (t = 0) in the following cases:

(a) Initial values of operational sensor parameters are expected to be set by appropriate events of type 3 (Sensor Parameter Change).

(b) In MSM, up/down flags for sensors, monitors etc. are initialized to "off" or "down." If any such elements are specified to begin operations at beginning of simulation, appropriate events (of types 4, 5, 6, 7 or 8) must be provided at initial game time*.

---

* These considerations are the motivation for the "tie breaking" logic under Section B.1. System elements must be turned on prior to any requests for operations.

2.3 FORMATS OF EVENT SUBLISTS

Formats of sublists for the 11 different types of events (see Table B-1) are given in the following pages. Some of these lists are of fixed length; some are of variable length. Although formats can differ greatly, these lists do have a consistent format for the first few words:

Word 1:	Event type code	(1 through 10, or 99)
Word 2:	LNGTHS:	length of the sublist
Word 3:	IDxxxx:	ID of the system element associated with the event (e.g., ID of a sensor, monitor, ...)
Word 4:	ITIM	For a point-in-time event, this is the associated (integer, seconds) time value. For an interval-of-time event, this is the beginning time value.
Word 5:		For interval-of-time events, this word provides the end time.

The value of LNGTHS corresponds to the concept of variable length sublists, that can be packed "back to back". That is, storage space corresponding to the largest possible list length does not have to be reserved. LNGTHS is used as the increment to an event list pointer within MSM, as control passes from one event sublist to the next.

Time sorting within PREFUN is based on the time value in word number 4. As MSM receives and executes events, the value in word number 4 will either be identical to the previous value, or greater.

FORMAT OF EVENT SUBLIST FOR EVENT TYPE 1

(SENSOR INTERROGATE: ANY TARGET COMBINATION)

WORD		
1.	ITYPEV	event type code = 1 for this type event
2.	LNGTHS	length of this sublist (number of words)
3.	IDSNSR	ID of sensor
4.	ITIM1	(integer) time, beginning of interrogate interval
5.	ITIM2	(") " end " " "
6.	NRBTGS	number of red and blue targets (forces) to be considered simultaneously within sensor coverage
7. 8. . . .		ID numbers of red and blue targets to be treated. Number of items in this block = NRBTGS
k.	NFTGTS	Number of false targets also present (if NRBTGS = 0, then all targets are false targets)
K+1. and following		If false targets are indicated (NFTGTS > 0), then a block of parameters will appear for each false target. Each block will contain 12 words of parameter values. The total number of words in this area will therefore be 12 times NFTGTS; the total number of blocks will be NFTGTS. Format for each 12-word block shown on following page.

Event type 1, continued:

FALSE TARGETS:

For each false target implied by the NFTGTS count, the following block of 12 parameters will be provided:

WORD*		
1	IDTGT	(see note *)
2	X	Coordinates and time, at initial node of line segment
3	Y	
4	T	
5	X	Coordinates and time, at terminal node of line segment**
6	Y	
7	T	
8	SPEED	False target speed, if applicable
9	IMAGN	1 if target has magnetic material, 0 if not.
10	ALT	Altitude of target
11	IDCODE	(see note *)
12	TLNGTH	Target length

---

* Two types of target identifiers are provided. In the initial SAM, MSM uses only the last two digits of the integer in word number 1 (preceding digits have no significance to MSM). These two digits give a number 1 through 19, corresponding to a target type-and-strength designation given by the table on the following page.

The last four digits of the integer in word number 11 provide the four digit EVID or CEVID code, as defined in documentation for the Battle and Cultural routines, respectively. With program expansion, particularly in terms of expanded resolution of sensor routines with respect to different target types and strength levels, linkage of the full EVID or CEVID code exists to MSM.

** For a point event (e.g., artillery fire), words 5-7 will duplicate words 2-4 in position and time.

Event type 1, continued:

NUMERICAL CODES 1 - 19 FOR TARGET TYPES

1	INDIV	11	JETA/C
2	SQD	12	RAFT
3	PLAT	13	OUTBRD
4	CO	14	PTBOAT
5	SMVEH	15	LT AMMO
6	HVYTRK	16	MED AMMO
7	TANK	17	HVY AMMO
8	TRAIN	18	SMANIM
9	HELO	19	LGANIM
10	LTA/C		

General Comments on Basic List:

1. The value of LNGTHS in general

   LNGTHS = 7 + NRBTGS + 12*NFTGTS (1)

2. If there are no RB targets (Red or Blue forces), the list of RB identities will be empty, and word 7 will contain the variable NFTGTS.

   If there are RB targets, but no false targets, then MSM will accept either of the following two forms:

   - The value 0 is entered in the last word, for the variable NFTGTS, and LNGTHS has the value given by (1) above, or
   - The sublist is simply terminated after the last RB target ID, and LNGTHS is modified accordingly (i.e., it will have a value one less than given by expression (1); more explicitly:

     LNGTHS = 6 + NRBTGS.

3. PRERUN passes, for RB targets, an extended ID format. The so-called "target ID code" for RB targets is of the form:

   (actual ID) + 1000*(leg number).

   For example, target number 29 on leg 5 (of its associated path) would be identified by the code 5029 .

FORMAT OF EVENT SUBLIST FOR EVENT TYPE 2

[SENSOR FALSE ALARM]

WORD		
1.	ITYPEV	event type code = 2 for this event type
2.	LNGTHS	length of this sublist (number of words) = 4
3.	IDSNSR	ID number of sensor
4.	ITIMFA	time value false alarm to be reported; analogous to the variable ITIMI in other event sublists.

Comments

False alarms are generally considered (at this date) only for unattended sensors that have only a "report" or "non-report" status -- that is, isolated-in-time detections with no other information such as range or bearing.

FORMAT OF EVENT SUBLIST FOR EVENT TYPE 3

(CHANGE SENSOR PARAMETERS)

Note: This event type provides for changes in sensor operational parameters that change with environment, and that require PRERUN execution of background routines for calculations of these changes. See comments below. See event type 4 for changes in the up/down or on/off flags for sensors.

WORD

1.	ITYPEV	event type code = 3 for this type event
2.	LNOTHS	length of this sublist
3.	IDSNSR	ID of sensor for which changes are to be made
4.	ITIM	(integer) time at which changes to be made
5.	NPARCH	number of parameters to be changed
6. . . .		Values of parameters (replace values currently in MSM storage)

COMMENTS

1. Value of LNOTHS = 5 + NPARCH

2. As of this date, maximum value of NPARCH = 4 (for PIRID sensors), and minimum value = 1 (for ARFBUOY and THERMAL sensors). Thus, maximum and minimum values of LNOTHS are 9 and 6, respectively.

3. Sensor types are related to this event type as follows:

RADAR	not applicable
IMAGE	not applicable
MAGNETIC	not applicable
THERMAL	one parameter (TEMPEV), frequently changed
SEISMIC ACOUSTIC	three parameters (GEQUIL,THRESH,VNOISE), frequently changed. List to be prepared in that order.
PIRID	four parameters (EXPAN, FIELD, TEMPEV, WATTBK) frequently changed. List to be prepared in that order.
ARFBUOY	one parameter (AREADN) -- passed in EVENT type 2 list only once, for initialization.

FORMAT OF EVENT SUBLISTS FOR EVENT TYPES 4, 5, 6 AND 7

EVENT TYPE 4: CHANGE UP/DOWN STATUS OF SENSOR *

" " 5: CHANGE UP/DOWN STATUS OF MONITOR *

" " 6: CHANGE UP/DOWN STATUS OF DATA LINK*

" " 7: CHANGE UP/DOWN STATUS OF FIRETRAP*

Note: The formats for these four event types are identical. The MSM determines whether sensor, monitor, data link or firetrap ID appears in word 3 by the event type number.

WORD		
1.	ITYPEV	event type code (= 4,5,6 or 7)
2.	LNGTHS	length of this sublist (number of words) = 5
3.	IDELEM	ID of the element (i.e., sensor, monitor, data link or firetrap) implied by event type code
4.	ITIM	(integer) time at which up/down flag to be set
5.	IUPFLG	= 0 if component to be set to "down" status = 1 if component to be set to "up" status

---

COMMENT

The 0 vs 1 convention follows current rule of thumb for programming that "0" implies "no" (in this case, no operation), and "1" implies "yes" (in this case, 'yes, element is operating').

* Reasons for up/down status changes are provided as PRERUN outputs. MSM requires and receives from PRERUN only final status values (i.e., "up" or "down").

FORMAT OF EVENT SUBLIST FOR EVENT TYPE 8

(ARRAY EMPLACEMENT)

This event follows the format for event types 4, 5, 6 and 7, and has much the same meaning. It is used differently, however, within MSM, in that this event only is used for printing a "significant event" in the output stream (array __ emplaced).

WORD		
1.	ITYPEV	event type code = 8 for this type event
2.	LNGTHS	length of this sublist (number of words) = 5
3.	IDARAY	ID of the array
4.	ITIM	(integer) time, this event to be recorded
5.	IAFLAG	= 0 for 'ARRAY OPERATION TERMINATED' = 1 for 'ARRAY EMPLACED'

FORMAT OF EVENT SUBLIST FOR EVENT TYPE 9

(BATTLEFIELD ILLUMINATION)

WORD		
1.	ITYPEV	event type code (= 9)
2.	LNGTHS	length of this sublist (=10)
3.	xxx	(not used by MSM)
4.	ITIM1	time illumination begins
5.	ITIM2	time illumination ends
6.	X	Coordinates of illumination source
7.	Y	
8.	H	altitude above ground of source
9.	AINTNS	intensity of light source
10.	MODE	indicator to sensor routines of type of illumination

Notes:

1. X, Y and H units: meters
2. See documentation of sensor routines (Volume I, Section 3) for full definition of AINTNS and MODE variables.

FORMAT OF EVENT SUBLIST FOR EVENT TYPE 10

(SENSOR REPOSITION)

WORD		
1.	ITYPEV	event type code (=10)
2.	LNGTHS	length of this sublist (= 6)
3.	IDSNSR	ID of sensor being repositioned
4.	ITIM	integer game time for event execution
5.	X	new coordinates (real, meters,
6.	Y	game values) for sensor

Notes:

1. This event is not required for the <u>initial</u> values of sensor coordinates, which are considered to be system parameters. It is required for reemplacement, if such occurs during the game, when location errors may cause a change in actual sensor coordinates even though the nominal (game play) values are identical.

FORMAT OF EVENT SUBLIST FOR SPECIAL EVENT 99
(END OF EVENT SEQUENCE)

WORD

1. ITYPEV event type code = 99

NOTES:

This "event" flags the end of the sequence of events from PRERUN. When encountered by MSM, normal execution of events ceases, and terminal operations preceding a full program stop are initiated.

This is the only event type for which the sublist is less than four words.

APPENDIX C
MSM OUTPUT LIST STRUCTURES AND DEFINITIONS

Contents

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ILLUSTRATIVE COMPUTER PRINTOUT

APPENDIX C

MSM OUTPUT LIST STRUCTURES AND DEFINITIONS

1. INTRODUCTION

MSM output occurs on two channels. Printed output, covering a variety of information categories, provides an immediately accessible listing of detailed game simulation results and a system results summary. Binary output file MSMOUT, written on tape or disk*, provides a computer readable data base that may be used as input for one or more post-MSM analysis programs.

This appendix provides details of output content of both channels, including -- in the case of printer output -- illustrative full-page excerpts from output generated during an actual simulation run.

2. TIME SEQUENCING

For both channels a sequence of sensor report information is a major output category. These reports will occur in approximate but not in exact time sequence. Reports for any one sensor, however, will occur in exact time sequence.

---

* FORTRAN coding for the binary write specifies unit device number 70. Association with physical device, including the tape-vs-disk option, is accomplished with Job Control Language on most modern large computers. If the FORTRAN-specified device number itself must be changed, the unit device number is given by a DATA statement (in each subprogram writing binary output) for the variable IOUT70.

3. BINARY OUTPUT FILE: MSMOUT

3.1 Basic Structure of MSMOUT

The binary output file ("MSMOUT") provided by MSM on tape or disk incorporates the major growth-compatibility features that were designed into the input events file (see Appendix B). That is:

(a) The file comprises a set of lists (logical records), one for each specific item of output information, in approximate time sequence.

(b) The first word of each list provides an <u>event type code</u> (in this case, an output event type code) that may be used for sorting or program branching.

(c) The second word of each list provides the word count for the list.

Thus, the conceptual structure is compatible with potential additions to the number of output event types, and with either (a) changes in content and number of data provided for current event types, or (b) completely free choice of list lengths for future event types. Inclusion of list length within the list itself also simplifies the reading and storage allocation procedures, for any post-MSM processing program that may use MSMOUT.

The remainder of this Section describes the specific choices of event types, and of corresponding list content, made in initial MSM coding.

3.2 Output Event Types

In initial MSM coding, 11 distinct output event types are provided. These fall into four general information categories, plus an end-of-events flag. The general categories, and the MSM subprograms directly responsible for the corresponding write operations, are:

System parameters	EXEC1
Sensor-to-monitor reports by unattended (UGS) sensors	UGSOUT
Reports from scanning (attended) sensors	SCNOUT
UGSARRAY and firetrap start and stop operations times	EX2UPD
End of Events Flag	EX2HLT

A list of the 11 output event types, by title and assigned event number, is given in Table C-1.

3.3 Output Event Type 100

Output event type 100 -- system parameters -- is unique. First, it is always the first event (record) of MSMOUT. Second, an event of this type is written only once. Third, the associated list length is very large -- of the order of 20000 words.

Content of the corresponding event list comprises the pointer and system parameter arrays for the labeled common area /BIGSTR/, preceded by certain "bookkeeping" data. Exact list structure is defined in Fig. C-1.

Placement of system parameter data, and associated pointer tables, within MSMOUT provides the potential for post-MSM programs to (a) execute analysis procedures, much along the lines used within MSM, that would not be possible without system parameter data, and (b) to utilize, if necessary, many of the MSM subprograms.

On the other hand, a post-MSM program that does not require system parameter data may bypass the lengthy event type 100 list (with a dummy READ statement), and avoid the problems of providing storage for 20000 or so values.

3.4 Output Event Types 1 Through 9

Following the initial type 100 output event, an indefinite number of sensor report events (types 1 through 9) may occur in any order. Event types in this general class are numbered in exact correspondence with the numerical codes for sensors used internally within MSM:

1	Seismic	U
2	Acoustic	U
3	Magnetic	U
4	ARFBUOY	U
5	Passive Infrared	U
6	Radar	S
7	Image	S
8	Thermal Viewer	S
9	Breakwire	U

Those flagged with the letter U are unattended (UGS) sensors. Reports from these are all written with the same list format, described in Fig. C-2. The subroutine directly responsible for writing these reports is UGSOUT.

Those flagged with the letter S are scanning (attended) sensors. Reports from these are all written with the same list format, described in Figure C-3. The subroutine directly responsible for writing these reports is SCNOUT.

List formats for attended and unattended sensor reports are partially matched, in the sense that variables that would have the same meaning in either context are written in the same list positions. The fact that both types of lists have the same word count, however, has no significance. There is, in fact, no fundamental reason why each event type could not have a unique list length, if the need were indicated in program extensions. Indeed, the list length for a fixed event type need not be held constant.*

3.5 Output Event Types 10 and 11

Event types 10 and 11 report on the firetrap and UGSARRAY start and stop operations times respectively. The list structure for these events are shown in Figure C-4. The subroutine responsible for writing these events is EX2UPD.

3.6 Output Event Type 99

The end of informational output events is indicated by the special event code 99. The trivial event list structure is shown in Figure C-5. The subroutine responsible for writing this output event is EX2HLT.

4. PRINTED OUTPUT

Information in a number of categories is printed during the course of MSM operations. Brief explanation is given in Section 4 .1 of printout considered relatively minor. The three categories considered important are discussed individually in Sections 4.2, 4.3 and 4.4, respectively. For the important categories and most of the minor categories, illustrative output -- reproductions of computer printout for an actual simulation run -- are provided and referenced at the appropriate points.

---

*For example, list length might vary according to the number of targets within the sensor response field.

Table C-2 lists all categories of printed information, and the names of the MSM subroutines directly responsible for the corresponding WRITE executions.

4.1 Minor Printout

Classified as minor printout are the following:

(a) Header card images
(b) Storage map for system parameters
(c) Dump (listing) of system parameter data
(d) Notations on:
    Precipitation start or stop
    Array emplacement/cease operations
    Start/stop of firetrap operations
(e) System "snapshots"

Information in these categories would generally be accessible from other sources (e.g., planner data listings, previous printout by PRERUN), but is placed in proper time sequence in the printed-data stream for user convenience.

The very first page of MSM printout provides a direct alphanumeric image of the 18 planner supplied header cards. An example is shown in Fig. C-6. Attached to subsequent bulky printer output, this page serves to fully identify the run.

Fig. C-7 demonstrates a storage map listing for system parameters. This printout is prepared by EXECIA, and is essentially duplicated if the provided DUMPMS routine is used. Section 2.2.6 and Appendix D provide information as to the meanings of the various storage categories.

No example is shown of system parameter listings. These listings provide detail of interest only to a programmer, in the context of debugging or verifying detailed program operations. Inclusion of this printout was intended for exploratory phases of program operation only.

Examples of some of the notational printouts are shown in Fig. C-9. The scenario did not provide for precipitation, so no examples of precipitation start or stop notations appear.

System "snapshot" refers generally to a listing of active elements of the scenario at a fixed instant of time. The snapshot routine provided, EX2SNP, provides a listing of active sensors and associated information, as illustrated in Fig. C- 8. In programs initially supplied, a system snapshot was requested of EX2SNP by subroutine EXEC1B at the end of every two hours of game time.

4.2 UGS Sensor-to-Monitor Reports

When simulation results indicate that a detection report by an UGS sensor would be received by at least one monitor*, a two-line summary of that report and associated game truth information is printed by subroutine UGSOUT. A number of examples appear within Figs. C-9, 10 and 11. for several sensor types. Table C-3 provides definitions and clarifications for abbreviations within the format.

---

* Sensor "up" status is checked before UGSOUT receives a nominal detection report. UGSOUT then checks, for each monitor associated with the sensor, whether the monitor and the associated sensor-to-monitor data link are also "up". No report can be written, either on the printer or on the binary output file, unless a valid combination of sensor, data link and monitor exists for at least one monitor. In the case of sensors connected in an AND-logic mode, a report further requires that both sensors detect at approximately the same time.

4.3 Reports by Scanning (Attended) Sensors

When simulation results indicate that a detection* would have occurred during the normal scanning cycle of an attended sensor, a three-line summary of that detection and associated game truth information is printed by subroutine SCNOUT. Examples appear within Figs. C-9, 10, and 11 Included are reports from sensors that are stationary, are associated with a moving ground force, or are airborne. Table C-4 provides definitions and clarifications for abbreviations within the format.

4.4 System Summary

When the normal sequence of simulation operations has ceased, subroutine EX2HLT prepares a three-page summary of overall system results, based on 128 system counters**. Some of these results have "physical" significance (e.g., detection counts); some have significance only in the context of computer operations (e.g., number of calls to classes of subroutines).

Content of system summary output is identified by titles within the actual printout. Illustrative printout is shown in Figs. C-12 through C-14.

---

* Two criteria will have been met. First, the target will have been within an illumination cell of the sensor's scan. Second, the sensor routine will have established "detection," based on signal strength and the noise environment.

** Counters are stored in labeled common area /SYSCNT/. See Section 2.2.6, this Volume.

In Figure C-12, "Calls to Sensors," refers to calls to sensor subroutines. In Figure C-13, "Sensor Interrogate Event" refers to a time period for interrogating a sensor. During this "event," of time period, a sensor may be called many times,once or perhaps not at all if subsidiary check indicates sensor is off.

In Figure C-14, counts refer to the number of calls to the EX3--- routines. A single call to an EX3--- routine creates one or more calls to sensor routines, depending upon the time interval. In the case of the scanning sensors, the EX3 --- routine will not call the sensor routine until and unless scan coverage is verified. To a first approximation, the number of calls to EX3 --- routines should agree with the number of sensor interrogate type Events. The difference (in the example shown in Figures C-12 through C-14 there are 385 calls to EX3--- routines and 392 corresponding sensor interrogate Events) occurs because Events fed to MSM may occasionally correspond to sensors that are down. In such cases, an Event is rejected at the EX2--- level and no corresponding call to an EX3--- routine occurs.

Code No.	Title	Word Count, Each List	List Written By Subroutine:
1	Seismic detection	33	UGSOUT
2	Acoustic detection	33	UGSOUT
3	Magnetic detection	33	UGSOUT
4	Arfbuoy detection	33	UGSOUT
5	Passive infrared detection	33	UGSOUT
6	Radar detection	33	SCNOUT
7	Image-sensor detection	33	SCNOUT
8	Thermal viewer detection	33	SCNOUT
9	Breakwire detection	33	UGSOUT
10	Firetrip start/stop operations	7	EX2UPD
11	UGSARRAY start/stop operations	7	EX2UPD
100	System Parameters	20345	EXEC1
99	End-of-events flag	3	EX2HLT

TABLE C-1

BINARY OUTPUT EVENT TYPES

Information Category	Printed by Subroutine:
(MAJOR)	
Sensor-to-Monitor Reports by UGS Sensors	UGSOUT
Reports by Scanning (Attended) Sensors	SCNOUT
System Summary	EX2HLT
(MINOR)	
Listing of Header Cards (Page 1 of Printout)	EXEC1
Storage Map for System Parameters	EXEC1A
Dump (Listing) of System Parameters	DUMPMS
One-line Notations:	
Precipitation Start/Stop	EXEC1B
Array Start/Stop Operations	EX2UPD
Firetrap Start/Stop Operations	EX2UPD
System "Snapshots"	EX2SNP

TABLE C-2

CATEGORIES OF PRINTED INFORMATION

TABLE C-3

UGS SENSOR REPORTS: EXPLANATION OF PRINTER OUTPUT

Item

1 Time, in external units. Day count begins with 0. Leading zeros not printed for clock (e.g., clock time 0108:24 prints as 108:24).

2 Sensor ID number, and type

3 Array ID and type.

4 Monitor ID or ID's. Sensor may be assigned to up to three monitors, of which one is considered primary. Space is provided for three monitor ID numbers -- one under "PRI," two under "OTHER."

If a monitor is defined, and receives signal, the ID number is printed. If secondary monitors are not defined, fields are left blank. If any monitor, primary or secondary, is defined but cannot receive sensor signal (either monitor or data link down), three asterisks will be printed in the ID field to flag the implied system malfunction.

5 A firetrap ID number will be printed if (a) a firetrap has been associated with the sensor array, and if (b) that firetrap is currently operational. Otherwise, the field is left blank.

6 The message 'CONFIRMED BY SENSOR ___', with an ID number replacing the underlined area, is printed if the report is from a sensor connected in an AND-logic mode, and AND-confirmation exists. For other UGS sensors, this field is left blank.

Under the heading, GAME TRUTH INFORMATION, these abbreviations and comments apply:

7 'DET 0FA 0RT 1BT 0FT'

and similar notation gives counts of general target types simultaneously affecting sensor detection. In this example, there are 0 False Alarms, 0 Red Targets, 1 Blue Target and 0 False Targets.

8 The second line gives information only for the primary target. Only seismic and acoustic sensors have potential for multiple targets, where the distinction between 'primary target' and 'only target' applies.

(continued, next page)

TABLE C-3, continued

8, continued

Selection of a 'primary' target from a list of targets is partially arbitrary, but the following criteria are applied:

(a) if a red target is present, the first (in the input list) is chosen as primary

(b) if no red target is present, but there is at least one blue target, the first blue target is considered primary

(c) if no red or blue targets exist, but there is a false target, the first false target is chosen as primary

(d) for the other possibility -- false alarm -- the second line has no relevance.

For sensors having significant area coverage (e.g., seismic, acoustic), target coordinates refer to the leading element of the target... the normal internal specification of target positions. For sensors having very small coverage, however, positions refer to the point at which detection occurs.

Coordinates are in meters, relative to the origin corner (SW corner) of the scenario.

TABLE C-4

SCANNING SENSOR REPORTS: EXPLANATION OF PRINTER OUTPUT

For reports from scanning (attended) sensors, a three-line printer summary is generated. Comments are given below.

1. Information on the left third or so of the page has same significance as for UGS sensor reports (Table C-3), except that:
   - (a) array types are 'STA', for stationary scanning sensors; 'MVG' for ground moving sensors; 'AIR' for airborne sensors.
   - (b) Monitor ID's and firetrap ID's are not relevant. Under the 'MONITORS' title, however, the Blue Force ID is noted for moving sensors.

2. Target bearing and range are game truth values, in "external," or military units (meters, mils). For radar sensors, S/N is the signal to noise ratio in db; for image and thermal viewer sensors, the number printed is comparable to signal to noise: see program listings. 'PD' is probability of detection, as specified by the sensor routines. 'BW' is beamwidth (mils), and 'RG' is range gate (meters): meaningful for sector scan of types 1 or 2. For moving rectangle scan, the analogous information is 'RW', rectangle width (cross-track dimension), and 'RL', rectangle length (along-track dimension), both in meters.

3. The abbreviation 'L.E.' on the first line, right hand side of page, stands for 'Leading Element'.

4. Target ID code for red and blue targets is a packed number (as used internally) of the form.

   (actual target ID) + 1000*(leg number)

   where leg number refers, of course, to whatever path has been specified for the target. For example:

   TGT IDCODE 2010

   refers to target ID 10, on leg number 2.
   Target ID code for False Targets is a packed number of the form

   (CEVID number + 200000) or
   (EVID number + 100000)

   Leading 2 indicates a culture event, leading 1 indicates a battle event.

TABLE C-4, continued

5. Target speed and (absolute value of) relative radial velocity are in units of meters/second.
6. NO. ELEM. gives number of elements in target.
7. TARGET TYPE CODE refers to generic target type:

   1 personnel (or animals)
   2 vehicles
   3 aircraft
   4 munitions
   5 boats

8. SCAN gives scan type. Sector scans may be of logical types 1 or 2 (see program comments for subroutines SCAN1 and SCAN2 for full description). The third possibility is 'MVG,' moving rectangle.

   Reference has already been made (comment number 2) about the corresponding variables BW and RG for sector scans, and RW and RL for moving rectangle.

Word		
1	IEV	Event type code (= 100)
2	LEV	Length (word count) of list (=20345)
3		Zero values;
4		no information
5-17		Thirteen values of array LJUMP
18-30		Thirteen values of array NDSMSM
31-45		Fifteen values of array IPBIGS
46-245		200 values of array IPBLU
246-345		100 values of array IPPATH
346-20345		20000 values of array MSMPAR

Arrays LJUMP, NDSMSM, IPBIGS, IPBLU, IPPATH and MSMPAR collectively form common area /BIGSTR/... system parameters and associated pointer tables. See Section 2.2.6 and Appendix D for definitions and content.

Figure C-1

LIST STRUCTURE: EVENT TYPE 100

Word		
1	IEV	Event type code (=1,2,3,4,5 or 9*)
2	LEV	List length (word count) = 33
3	KNTOEV	Sequential output event count
4	ITIMDT	Integer game time for detection
5	ITIMDT	Same
6	IDSNSR	ID number of sensor
7	IDARAY	ID of associated array
8 9	ORGCOD	Two words: alphanumeric organization code as specified in planner cards
10		Not used
11 12 13	IDAY ICLK24 ISEC	Integers specifying "external" time: day of game (0,1,...), 24 hour clock, and seconds.
14 15	XSNSR YSNSR	Game coordinates of sensor (x, y respectively). Game truth.
16		Not used
17	IDPTGT	ID code of primary target
18	KDCODE	Index for primary target type: 1 for red force; 2 for blue force; 3 for false target; 4 for false alarm.
19 20	XPTGT YPTGT	Game truth coordinates of primary target at time of detection.
21	RPTGT	Distance: sensor to primary target
22	NMONS	Number of monitors assigned to sensor
23 24 25	IDMON1 IDMON2 IDMON3	ID numbers of assigned monitors, except: 0 if ID not applicable; ID value set negative if monitor cannot receive signal.
26	IDCONF	ID of confirming (AND-logic) sensor, if appl.
27	IDFTRP	ID of firetrap associated with sensor (value is 0 if no firetrap defined, or if firetrap is defined but not currently in operation)
28 29 30	NRTGTS NBTGTS NFTGTS	Respectively, number of red, blue and false targets simultaneously affecting sensor response
31 32	SNTYP	Two words; alphanumeric designation of sensor type, as provided by planner cards
33		Not used

* According to sensor type

FIGURE C-2. LIST STRUCTURE: UGS SENSOR REPORTS

Word #		
1	IEV	Event type code (=6, 7 or 8*)
2	LEV	List length (word count) = 33
3	KNTOEV	Sequential output event count
4	ITIMDT	Integer game time for detection
5	ITIMND	Time "input event" ends**
		Words 6 through 15 same as for UGS sensors, Fig. C-2, except for word 10:
10	IMOVE	= 0 for stationary sensor; = +ID of associated blue force if ground moving; = -ID of blue force if airborne moving.
16	SPEED[illegible]	Sensor platform speed (0 for stationary)
		Words 17 through 21 same as for UGS sensors.
22	AZTGT	Azimuth angle of target (radians; mathematical convention for "0" and positive dir'n)
23	SGNOIS	Signal/noise ratio, or equivalent depending upon sensor type. See program listings.
24	PDET	Probability of detection (value provided by sensor routine)
25	ISCAN	=3 for moving rectangle; =1 or 2 for sector scan logics of types 1, 2 respectively
26	WORD26	= Beamwidth (radians) if ISCAN = 1 or 2 = Rectangle cross-track dimension, ISCAN = 3
27	WORD27	= Range gate if ISCAN = 1 or 2 = Along-track dimension if ISCAN = 3
28	ITGTTP	Target type code, 1 through 5
29	NOELEM	Number of elements in target
30	VRADL	Magnitude of radial velocity (relative)
31 32	SNTYP	Two words: alphanumeric designation of sensor type, as provided by planner cards
33	ILXTRA	Not meaningful except for image type sensors. For those, ILXTRA = 0 if no battlefield illumination devices are active, >0 otherwise.

* According to sensor type

** A lower bound on the time that target is within nominal coverage area of sensor.

FIGURE C-3. LIST STRUCTURE: SENSOR REPORTS

Word		
1	IEV	Event type code (= 10,11)
2	LEV	List length (word count) = 7
3	KNTOEV	Sequential output event count
4	ITIME	Game time in seconds
5	ITIME	Game time in seconds
6	ID	ID of firetrap or UGSARRAY
7	IUP	Up or down designation code =(down = - ITIME, up = 1)

FIGURE C-4. LIST STRUCTURE: FIRETRAP AND UGSARRAY START/STOP OPERATIONS

Word		
1	IEV	Event type code (= 99)
2	LEV	List length (word count) = 3
3		= integer 99999 (dummy time value)

Figure C-5. LIST STRUCTURE: EVENT TYPE 99

```
                                                                                PAGE  1

                         BEGINNING OF MSM PROCESSING

TITLE:  SAM I, ACCEPTANCE RUN                                                  HEADER 1
RUN NUMBER: 1                                                                  HEADER 2
AREA IDENTITY CODE: 1 (SOUTH VIETNAM)                                          HEADER 3
MAPS: VIETNAM, 1:50000, SHEETS 6441 I, SERIES L7014                            HEADER 4
COORDINATES SW CORNER PLAY AREA: -10000,-11900                                 HEADER 5
COORDINATES NE CORNER PLAY AREA:  07500, 07000                                 HEADER 6
GAME START TIME:   29 MAY 1969, 0000 HOURS                                     HEADER 7
DURATION OF GAME:  02 DAYS, 00 HOURS, 00 MINUTES                               HEADER 8
PSM ERRORS:   MAP(0)  LOC(0)RELOC(0)  NAV(0)  ARTY(1)  AIRD(1)                 HEADER 9
TOTAL UGS:      ARRAYS( 18)   SENSORS( 36)                                     HEADER10
TOTAL RAD/VIS:ARRAYS( 12)   SENSORS( 12)                                       HEADER11
TOTAL MOVE:     ARRAYS(  2)   SENSORS(  4)                                     HEADER12
TOTAL UGS MONITORS:  (  2)                                                     HEADER13
TOTAL UGS RELAYS:    (  2)                                                     HEADER14
TOTAL RED FORCES:    ( 11)                                                     HEADER15
TOTAL BLUE FORCES:   (  4)                                                     HEADER16
FIRST RAND. NO.REF: (              0)
SECOND RAND.NO.REF: (              0)
```

Figure C-6   HEADER CARD IMAGES

```
SAM I, ACCEPTANCE RUN                              RUN NUMBER: 1                      PAGE  3

                 LISTING OF CONTENTS OF LABELED COMMON /BIGSTR/
                           (PARAMETER STORAGE -- MSM)

  MSM#     POINTER   NUMBER OF   WORD COUNT   TOTAL
 NUMBER     VALUE       SETS      EACH SET    WORDS           TYPE
                                                            DESCRIPTOR

    1          1         18          15         270     UGS ARRAYS
    2        271         12           8          96     STASCAN ARRAYS
    3        367          2           8          16     MOVARRAYS
    4        383          4           0          87     BLUE FORCES
    5        470         11          14         154     RED FORCES
    6        624         52          24        1248     SENSORS
    7       1872         21          38         798     SENSOR DESCR PAR
    8       2670          1          10          10     FIRETRAPS
    9       2680          2          11          22     MONITORS
   10       2702         19           7         133     DATA LINKS
   11       2835          4           0          64     PATHS
   12       2899         11           7          77     FORCE TYPE PAR
   13       2976          7          10          70     COVERAGE/SCAN

NOTE.  COLUMN 4 NOT APPLICABLE FOR MSM4 (BLUE FORCES) OR MSM11 (PATHS).
WORD COUNT PER SET IS VARIABLE FROM 15 TO 42 FOR MSM4, FROM 6 TO 51
FOR MSM11. SEE FOLLOWING PAGE.
```

Figure C-7   STORAGE MAP

```
SAM I, ACCEPTANCE RUN                     RUN NUMBER: 1                  PAGE 49



                        SUMMARY OF ACTIVE SENSORS/ARRAYS
               AT GAME TIME   7200 SECONDS (DAY  0, CLOCK  2001

         SENSOR  TYPE     ARRAY  GAME COORDINATES     FOR MOVING ARRAY,
           ID              ID       X        Y        ASSOCIATED BLUE FORCE

            1  SEISMIC      1    11000.   12400.
            2  SEISMIC      1    11000.   12450.
            3  SEISMIC      1    11000.   12500.

            4  ARFBUOY      2    11000.   12900.

            5  SEISMIC      3    11433.   13400.
            6  SEISMIC      3    11476.   13425.
            7  SEISMIC      3    11520.   13450.

            8  SEISMIC      4    12282.   13928.
            9  SEISMIC      4    12353.   13904.
           10  SEISMIC      4    12374.   13954.

           11  SEISMIC      5    12819.   14200.
           12  SEISMIC      5    12852.   14225.
           13  SEISMIC      5    12905.   14250.

           14  SEISMIC      6    13338.   14500.
           15  MAGNETIC     6    13338.   14500.

           17  ARFBUOY      8    14464.   15150.

           18  SEISMIC      9    15770.   16130.
           19  SEISMIC      9    15729.   16171.
           20  SEISMIC      9    15720.   16160.

           21  SEISMIC     10    16069.   16554.
           22  ACOUSTIC    10    16069.   16654.

           23  PASSIVIR    11    16475.   17900.

           24  SEISMIC     12    16500.   18150.
           25  SEISMIC     12    16500.   18200.

           26  SEISMIC     13    16500.   18400.
           27  ACOUSTIC    13    16500.   18400.
```

Figure C-8   SYSTEM SNAPSHOT

```
   SAM I, ACCEPTANCE RUN                 RUN NUMBER: 1             PAGE 20

  REPORTS BY SENSORS

   T I M E      SENSOR     ARRAY     MONITORS FTRP 'GAME PLAY' REPORT, OR    * * * * * * * * G A M E   T R U T H * * * * * * * *
  DD HHMM SS    ID TYPE   ID TYP   PRI OTHER   ID   AVAILABLE INFORMATION   *              I N F O R M A T I O N              *

                  BEGINNING OF EVENT PROCESSING

    0     0     FIRETRAP ID  1 BEGINS OPERATIONS
    0     1     ARRAY ID   1 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   2 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   3 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   4 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   5 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   7 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   8 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID   9 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID  10 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID  11 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID  12 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID  13 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID  14 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0     1     ARRAY ID  15 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0   2:49    23 PIR     11 UGS   1                                    SENSOR X,Y  16475, 17900  DET 1FA  ORT  OBT  OFT
                                                                         PRI TGT ID =      0  AT      0.        0. DIST =   0
    0   4:41     9 SEIS     4 UGS   1          1                         SENSOR X,Y  12352, 13904  DET 1FA  ORT  OBT  OFT
                                                                         PRI TGT ID =      0  AT      0.        0. DIST =   0
    0   4:42     3 SEIS     1 UGS   1                                    SENSOR X,Y  11000, 12500  DET 1FA  ORT  OBT  OFT
                                                                         PRI TGT ID =      0  AT      0.        0. DIST =   0
    0     6     ARRAY ID   6 AND AT LEAST ONE ASSOCIATED MONITOR NOW OPERATIONAL
    0   7:54     1 SEIS     1 UGS   1                                    SENSOR X,Y  11000, 12400  DET OFA  1RT  OBT  OFT
                                                                         PRI TGT ID =      5  AT  10999, 12383, DIST =  16
    0   5:12     2 SEIS     1 UGS   1                                    SENSOR X,Y  11000, 12450  DET OFA  1RT  OBT  OFT
                                                                         PRI TGT ID =      5  AT  10999, 12433, DIST =  16
    0   8:30     3 SEIS     1 UGS   1                                    SENSOR X,Y  11000, 12500  DET OFA  1RT  OBT  OFT
                                                                         PRI TGT ID =      5  AT  10999, 12483, DIST =  16
    0   8:50    29 ACOU    14 UGS   2                                    SENSOR X,Y  12000, 12400  DET 1FA  ORT  OBT  OFT
                                                                         PRI TGT ID =      0  AT      0.        0. DIST =   0
    0  10:20    23 PIR     11 UGS   1                                    SENSOR X,Y  16475, 17900  DET 1FA  ORT  OBT  OFT
                                                                         PRI TGT ID =      0  AT      0.        0. DIST =   0
    0  10:57     4 ARFB     2 UGS   1  2                                 SENSOR X,Y  11000, 12900  DET OFA  1RT  OBT  OFT
                                                                         PRI TGT ID =      5  AT  11000, 12900, DIST =   0
    0  10:59     4 ARFB     2 UGS   1  2                                 SENSOR X,Y  11000, 12900  DET OFA  1RT  OBT  OFT
                                                                         PRI TGT ID =      5  AT  11500, 12900, DIST =   0
    0  11: 7     4 ARFB     2 UGS   1  2                                 SENSOR X,Y  11000, 12900  DET OFA  1RT  OBT  OFT
                                                                         PRI TGT ID =      5  AT  11000, 12900, DIST =   0
    0  11:51     1 SEIS     1 UGS   1                                    SENSOR X,Y  11000, 12400  DET 1FA  ORT  OBT  OFT
                                                                         PRI TGT ID =      0  AT      0.        0. DIST =   0
```

Figure C-9 SENSOR REPORTS (A)

```
[illegible] I, ACCEPTANCE RUN                  RUN NUMBER  1              PAGE 34

REPORTS BY SENSORS

 T I M E     SENSOR    ARRAY    MONITORS FTRP 'GAME PLAY' REPORT, OR   * * * * * * * * * G A M E   T R U T H * * * * * * * * * *
DD HHMM SS  ID TYPE   ID TYP  PRI OTHER  ID    AVAILABLE INFORMATION   *                 I N F O R M A T I O N               *

 0   51:46    9 SEIS    4 UGS   1          1                            SENSOR X,Y  12352, 13904  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      11  AT  12337, 13922, DIST =  23
 0   51:53   10 SEIS    4 UGS   1          1                            SENSOR X,Y  12373, 13953  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      11  AT  12354, 13931, DIST =  29
 0   52: 8   10 SEIS    4 UGS   1          1                            SENSOR X,Y  12373, 13953  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      11  AT  12390, 13952, DIST =  16
 0   53:52   45 IMAG   27 STA                  TARGET DET BEARING 5505, SENSOR X,Y  13500, 14400  TARGET L.E. X,Y  13362, 14513
                                               RANGE  178, S/N  -30.6 DB TGT IDCODE   2010, SPEED   2.78, NO. ELEM. 10, VRADL   1.03
                                               PD 1.00,BW   184, RG   75 TARGET TYPE CODE  1    SCAN 2
 0   53:12   20 SEIS    9 UGS   1                                       SENSOR X,Y  15720, 16179  DET 1FA  ORT  CBT  OFT
                                                                        PRI TGT ID =       0  AT       0,      0, DIST =   0
 0   53:41   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OLT  OFT
                                                                        PRI TGT ID =      10  AT  13335, 14496, DIST =   2
 0   53:4    14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   53:43   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  CFT
                                                                        PRI TGT ID =      10  AT  13338, 14500, DIST =   0
 0   53:46   14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   53:44   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13343, 14502, DIST =   5
 0   53:46   14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  CBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   53:46   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  CFT
                                                                        PRI TGT ID =      10  AT  13345, 14504, DIST =   8
 0   53:46   14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   53:47   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13350, 14506, DIST =  13
 0   53:46   14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   53:49   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13352, 14508, DIST =  16
 0   53:46   14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   53:50   15 MAGN    6 UGS   1                CONFIRMED BY SENSOR 14 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13357, 14511, DIST =  22
 0   53:46   14 SEIS    6 UGS   1                CONFIRMED BY SENSOR 15 SENSOR X,Y  13338, 14500  DET OFA  1RT  OBT  OFT
                                                                        PRI TGT ID =      10  AT  13347, 14505, DIST =  11
 0   55:17   48 RDAR   30 STA                  TARGET DET BEARING 5301, SENSOR X,Y  14000, 14400  TARGET L.E. X,Y  13565, 14631
                                               RANGE  491, S/N   14.9 DB TGT IDCODE   2010, SPEED   2.73, NO. ELEM. 10, VRADL   1.11
                                               PD 0.65,BW    44, RG  300 TARGET TYPE CODE  1    SCAN 1
 0   56:29   52 IMAG   32 NVG  BLUE FORCE      TARGET DET BEARING 2764, SENSOR X,Y  12479, 14692  TARGET L.E. X,Y  12729, 14149
                                   2           RANGE  553, S/N    0.7 DB TGT IDCODE   2011, SPEED   2.78, NO. ELEM. 15, VRADL   2.33
                                               PD 0.86,KW   650, KL  500 TARGET TYPE CODE  1    SCAN N/R
```

Figure C-10   SENSOR REPORTS (B)

```
  SAN 1, ACCEPTANCE RUN                    RUN NUMBER: 1               PAGE 42

  REPORTS BY SENSORS

   T I M E     SENSOR    ARRAY    MONITORS FTRP 'GAME PLAY' REPORT, OR   * * * * * * * * G A M E   T R U T H * * * * * * * *
 DD HHMM SS    ID TYPE   ID TYP  PRI OTHER  ID   AVAILABLE INFORMATION    *             I N F O R M A T I O N              *

   0  108:24   22 ACOU   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  ORT  1BT  OFT
                                                                          PRI TGT ID =      1  AT  15040, 16399, DIST =1059
   0  108:39   22 ACOU   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  ORT  1BT  OFT
                                                                          PRI TGT ID =      1  AT  15190, 16399, DIST = 915
   0  108:59   22 ACOU   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  ORT  1BT  OFT
                                                                          PRI TGT ID =      1  AT  15390, 16399, DIST = 725
   0  109:14   22 ACOU   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  ORT  1BT  OFT
                                                                          PRI TGT ID =      1  AT  15540, 16399, DIST = 586
   0  109:34   22 ACOU   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  ORT  1BT  OFT
                                                                          PRI TGT ID =      1  AT  15740, 16399, DIST = 415
   0  109:49   22 ACOU   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  ORT  1BT  OFT
                                                                          PRI TGT ID =      1  AT  15890, 16399, DIST = 310
   0  105:51   20 SEIS    9 UGS   1                                       SENSOR X,Y  15720, 16179  DET 1FA  ORT  0BT  OFT
                                                                          PRI TGT ID =      0  AT      0,     0, DIST =   0
   0  109:29   47 RDAR   29 STA                  TARGET DET BEARING   58, SENSOR X,Y  14000, 14400  TARGET L.E. X,Y  14028, 14896
                                                 RANGE  499, S/N   21.2 DB TGT IDCODE    2012, SPEED   2.78, NO. ELEM. 40, VRADL   1.37
                                                 PD 0.90,BW    44, RG  300 TARGET TYPE CODE  1   SCAN 1
   0  108:51   47 RDAR   29 STA                  TARGET DET BEARING  155, SENSOR X,Y  14000, 14400  TARGET L.E. X,Y  14081, 14929
                                                 RANGE  535, S/N   21.3 DB TGT IDCODE    2012, SPEED   2.78, NO. ELEM. 40, VRADL   2.21
                                                 PD 0.90,BW    44, RG  300 TARGET TYPE CODE  1   SCAN 1
   0  107:23   23 PIR    11 UGS   1                                       SENSOR X,Y  16475, 17900  DET 1FA  ORT  0BT  OFT
                                                                          PRI TGT ID =      0  AT      0,     0, DIST =   0
   0  108:39   47 THMV   19 STA                  TARGET DET BEARING  713, SENSOR X,Y  14000, 14850  TARGET L.E. X,Y  14052, 14912
                                                 RANGE   81, S/N    0.8 DB TGT IDCODE    2012, SPEED   2.78, NO. ELEM. 40, VRADL   2.53
                                                 PD 1.00,BW   184, RG   75 TARGET TYPE CODE  1   SCAN 2
   0  109: 5   25 SEIS   12 UGS   2                                       SENSOR X,Y  16500, 18200  DET 1FA  ORT  0BT  OFT
                                                                          PRI TGT ID =      0  AT      0,     0, DIST =   0
   0  109: 9   50 IMAG   31 AIR  BLUE FORCE      TARGET DET BEARING 3070, SENSOR X,Y  15490, 16399  TARGET L.E. X,Y  15568, 15787
                                      1          RANGE  617, S/N    0.5 DB TGT IDCODE    2010, SPEED   2.78, NO. ELEM. 10, VRADL   1.91
                                                 PD 0.41,RW   500, RL  500 TARGET TYPE CODE  1   SCAN MVR
   0  109:43   24 SEIS   12 UGS   2                                       SENSOR X,Y  16500, 18150  DET OFA  1RT  1BT  OFT
                                                                          PRI TGT ID =      7  AT  16499, 18132, DIST =  17
   0  110:15   50 IMAG   31 AIR  BLUE FORCE      TARGET DET BEARING 3154, SENSOR X,Y  15550, 16399  TARGET L.E. X,Y  15576, 15601
                                      1          RANGE  598, S/N    0.5 DB TGT IDCODE    3010, SPEED   2.78, NO. ELEM. 10, VRADL   2.81
                                                 PD 0.35,RW   500, RL  500 TARGET TYPE CODE  1   SCAN MVR
   0  110: 1   25 SEIS   12 UGS   2                                       SENSOR X,Y  16500, 18200  DET OFA  1RT  1BT  OFT
                                                                          PRI TGT ID =      7  AT  16499, 18182, DIST =  17
   0  109:56   49 RDAR   31 AIR  BLUE FORCE      TARGET DET BEARING  502, SENSOR X,Y  15960, 16399  TARGET L.E. X,Y  16467, 17343
                                      1          RANGE 1071, S/N   34.3 DB TGT IDCODE    3008, SPEED   2.78, NO. ELEM.  1, VRADL   2.22
                                                 PD 0.99,RW  1000, RL 1000 TARGET TYPE CODE  2   SCAN MVR
   0  110:19   49 RDAR   31 AIR  BLUE FORCE      TARGET DET BEARING  305, SENSOR X,Y  16190, 16399  TARGET L.E. X,Y  16499, 17398
                                      1          RANGE 1045, S/N   34.0 DB TGT IDCODE    3008, SPEED   2.78, NO. ELEM.  1, VRADL   0.57
                                                 PD 0.99,RW  1000, RL 1000 TARGET TYPE CODE  2   SCAN MVR
   0  109:59   21 SEIS   10 UGS   1                                       SENSOR X,Y  16069, 16653  DET OFA  1RT  1BT  OFT
                                                                          PRI TGT ID =      9  AT  16054, 16629, DIST =  28
```

Figure C-11 SENSOR REPORTS (C)

```
SAM J. ACCEPTANCE RUN                    RUN NUMBER: 1                    PAGE192

                                        TERMINATION OF MSM PROCESSING

                              SUMMARY OF SIMULATION RESULTS (SYSTEM COUNTERS) FOLLOWS

                              NO. OF CALLS TO SENSORS         NO. OF DETECTIONS          NO. OF    TOTAL          NO. OF CALLS
SENSOR TYPE     NO. IN       VS. INPUT TARGET TYPE         VS. INPUT TARGET TYPE         FALSE     NO. OF      TO SCAN ROUTINES
 (MOVE CAT.     GAME        RED   BLUE  FALSE  TOTAL       RED   BLUE  FALSE  TOTAL      ALARMS    REPORTS      SCAN1    SCAN2

SEISMIC          27        1683    308    122   2113       224    29     10    263       1251      1514
ACOUSTIC          3         189     55     83    332        60    16     19     95        196       291
MAGNETIC          1         206      0      0    206         7     0      0      7          0         7
AIRBUOY           2         198      0      0    198       148     0      0    149          2       150
PASSIVIR          1           0      0      0      0         0     0      0      0        256       256
BREAKWIR          2           1      0      0      1         1     0      0      1          0         1

RADAR             3          51      0      0     51        33     0      0     33                   33        10866       0
  STATIONARY      2          44      0      0     44        26     0      0     26                   26
  AIRBORNE        1           7      0      0      7         7     0      0      7                    7

IMAGE            11          34      0      0     34        27     0      0     27                   27            0    7210
  STATIONARY      8          15      0      0     15        15     0      0     15                   15
  MOVING (GND)    2          11      0      0     11        10     0      0     10                   10
  AIRBORNE        1           8      0      0      8         2     0      0      2                    2

THERMVEW          2           7      0      0      7         7     0      0      7                    7            0     309
  STATIONARY      2           7      0      0      7         7     0      0      7                    7
  MOVING (GND)    0           0      0      0      0         0     0      0      0                    0
  AIRBORNE        0           0      0      0      0         0     0      0      0                    0

* TOTALS *       52        2369    363    210   2942       507    45     29    581       1705      2286        10866    7519
```

Figure C-12 SYSTEM SUMMARY, FIRST PAGE

```
SAM I, ACCEPTANCE RUN                     RUN NUMBER: 1                PAGE193


                  COUNTS OF INPUT 'EVENTS' BY TYPE

                        T Y P E                    COUNT

                  1 SENSOR INTERROGATE               392
                  2 SENSOR FALSE ALARM              2637
                  3 SENSOR PARAMETER CHANGE          133
                  4 SENSOR UP/DOWN                    92
                  5 MONITOR UP/DOWN                    4
                  6 DATA LINK UP/DOWN                 40
                  7 FIRETRAP BEGIN/END                 2
                  8 ARRAY EMPLACE/CEASE               34
                  9 BATTLEFIELD ILLUMINATION           2
                 10 SENSOR REPOSITION                  0

                             TOTAL                  3336


             SENSOR REPORTS BY CATEGORY OF PRIMARY 'TARGET'

                 RED FORCES                  507
                 BLUE FORCES                  45
                 FALSE TARGETS                29
                 FALSE ALARMS               1705
                       SENSOR REPORTS,
                         TOTAL NUMBER       2286

             WHEN MULTIPLE TARGETS AFFECTING SENSOR
             DETECTIONS ARE COUNTED ACCORDING TO THE
             MULTIPLICITY, THE VALUES BECOME:
                 RED FORCES                  507
                 BLUE FORCES                  55
                 FALSE TARGETS                29
                 FALSE ALARMS               1705

                        TOTAL               2296
```

Figure C-13   SYSTEM SUMMARY, SECOND PAGE

```
     SAM I. ACCEPTANCE RUN                              RUN NUMBER: 1                  PAGE194



                          COUNTS OF CALLS TO SENSOR EXEC
                            ROUTINES (EX3... SERIES)

                          1 EX3SAC    (SEISMIC)      205
                          2 EX3SAC    (ACOUSTIC)      38
                          3 EX3MAG    (MAGNETIC)       8
                          4 EX3ARF    (ARFBUOY)       16
                          5 EX3PIR    (PASSIVIR)       0
                          6 EX3RDR    (RADAR)         33
                          7 EX3IMG    (IMAGE)         68
                          8 EX3THV    (THERMVEW)      16
                          9 EX3BKW    (BREAKWIR)       1

                                       TOTAL     385



                     TERMINAL VALUES OF REFERENCE STATES FOR THE TWO
                     SYSTEM RANDOM NUMBER GENERATORS ARE:
                            URN (UNIFORM)  1381907106
                            GRN (GAUSSIAN) 1586020418



                     ******************** MSM PROCESSING TERMINATED ********************
```

Figure C-14 SYSTEM SUMMARY, THIRD PAGE

APPENDIX D

MSW STORAGE: SYSTEM PARAMETERS

APPENDIX D

TABLE OF CONTENTS

TABLES:

Tables D-1 through D-13 give list contents for categories MSM1 through MSM13, respectively.

APPENDIX D

I. INTRODUCTION

This Appendix supplements a general discussion in Section 2.2.6 of this Volume. The primary content is a set of tables that define sublist structures -- lengths, names or definitions of variables, etc. -- for the 13 partitions or data categories of storage area MSMPAR in which system parameter data are stored.

The primary source of system parameter data for MSM is the data file 'JTFWDF' generated by PRERUN. These data, in turn, originated with what is termed here the "planner data sets" (scenario specification). There are 29 such sets, described in detail in Volume II, Appendix F; of these 29, MSM receives edited versions of 13.

Subroutine EXEC1A, a so-called level I executive routine of MSM, has control of reading data from the PRERUN-generated file; in some cases provide editing in the form of adding words, changing words, and/or setting initial parameter values; allocating storage to parameter lists according to a contiguous-packing logic that minimizes overall storage requirements; transferring lists to the allocated storage slots; and setting one or more pointer table values that are used for access to these stored data.

Labeled common area /BIGSTR/ holds storage array MSMPAR, in which system parameters are stored, and it holds the various pointer tables.

Thus, the important elements of MSM, in the context of this Appendix, are the primary data set, 'JTFWDF'; the primary subprogram, EXECIA; and the associated storage area, labeled common /BIGSTR/ and its storage arrays. This Appendix is not intended to be completely self-sufficient in the coverage of these elements, for which additional information may be found as follows:

JTFWDF Data File: PRERUN documentation in general, Volumes I and II. Related information on planner data sets is, as mentioned, given in Appendix F of Volume II.

Subroutine EXECIA: Exact details of editing and storage control may be determined from program listing and AUTOFLOW diagrams, Volume III. Program listings are documented internally with program comments. A brief summary may be found in Volume I, Section 2.2.3.

Common /BIGSTR/: Overview material in Section 2.2.6.2 of this Volume is particularly appropriate.

Of related, albeit secondary, interest are the subroutines PARPTR, PARVLU, ARRPTR, ARRVLU, TGTPTR and TGTVLU, that explicitly are designed to access system parameter data from storage area MSMPAR. Summary discussions are given in Section 2.2.3 of this volume; details may be extracted from internally-documented program listings.

Finally, the content descriptions for the various tables are sometimes given in terms of variable names, rather than in terms of "physical" description. This use of names is used, in particular, in connection with MSM6 ("SENSORS" data) and MSM7 ("SENSOR DESCRIPTOR" data). Reference to either the sensor routines *per se*, or their corresponding EX3... executive routines, is implied for the reader who would have reached this level of detail.

2. SUMMARY OF INPUT AND STORAGE LOGIC

Parameters are stored on disk file 'UTFWDF' as a sequence of variable length binary records. The corresponding READ statement in MSM is of the form:

```
READ (2)  NW, (LIST(I), I=1,NW)
```

where LIST is either:

(a) a set of parameter values for one system element (for example, one sensor; one PATHS sublist) -- in which case NW will be the number of parameter values that PRERUN has written in the list*,

or

(b) a dummy list of one word, containing the integer 9999 -- in which case NW will have the value 1.

It may be noted that 13 different categories of information are provided (that will correspond with MSM1 through MSM13 conceptual partitions of MSMPAR), and that the number of elements or subsets within any one category is completely arbitrary**. That is, not only may variations in list lengths within a category exist, but the number of lists within a category is also variable.

The dummy list, then, is the flag provided for the end of data for one category. When it is encountered, the branching logic within EXEC1A is altered, and a new index is selected for the pointer table that locates the beginnings of the 13 partitions.

A distinct possibility with limited scenarios is the absence of one or more data categories. If no scanning sen-

---

* As discussed in detail later, the "NW" value does not necessarily agree with the word count of final stored list.

** Except for an ultimate storage limit for the complete set of data.

sors are specified, for example, there will be no data sets in the COVERAGE/SCAN category. This possibility is handled, at the input level, by two (or more) dummy 9999-type records being written in sequence. The corresponding category is recognized as empty, and no storage is allocated.

EXECIA recognizes the end of system parameter data by monitoring the number of 9999-type records read. When the 13th one is encountered, read operations are terminated.

Assuming the LIST is of type (a), that is, a bona fide parameter list, EXECIA will determine how many words of storage are required, determine from a pointer index where the next free area of storage begins, and transfer the block of data to storage. Prior to this, it may:

(a) Change some of the PRERUN-supplied values

(b) Add words to the list supplied by PRERUN

(c) Initialize one or more of the added words.

The editing just referred to (items a, b, c) is in some cases delayed, when the information required has yet to be read from the data file.

The final result, after all EXECIA operations have ceased, is a set of parameter lists in storage in 13 categories, and a set of pointer values that are required to locate specific data when needed. The following 13 sections of this Appendix primarily describe the content of the final forms of the stored sublists, on a category by category basis.

3. MSMI: UGSARRAYS*

MSMI is the partition of MSMPAR reserved for parameters of UGSARRAYS. Passed to MSM are 14 of the original 32 items for each UGSARRAY. Since one alphanumeric item requires two computer words, the number of words passed is 15.

EXECIA does no editing on these data. The 15 words received from PRERUN are transferred directly to storage. Table D-1 gives the content of the 15-word list for each UGSARRAY, as it would exist in storage.

4. MSM2: STASCAN ARRAYS**

MSM2 is the partition of MSMPAR reserved for parameters of STASCAN (Stationary Scanning) ARRAYS. Passed to MSM are 7 of the original 19 data items. Since one of the alphanumeric items requires two computer words, the number of words passed is 8.

EXECIA does no editing on these data. The 8 words received from PRERUN are transferred directly to storage. Table D-2 gives the content of the 8-word list for each STASCAN ARRAY, as it would exist in storage.

5. MSM3: MOVARRAYS***

MSM3 is the partition of MSMPAR reserved for parameters of MOVARRAYS (moving sensor platforms). Passed to MSM are 6 of the original 12 data items. Since one of the alphanumeric items requires two computer words, the number of words passed is 7.

---

* Analogous to planner data set I. See Volume II.

** Data Set XIX. See Volume II.

*** Data Set XX. See Volume II.

EXECIA does not change any of these 7 words. It does, however, add an eighth word, that is given an integer value that specifies whether the moving array is airborne or ground. Table D-3 gives the content of the 8-word list for each MOVARRAY, as it would exist in storage after all editing operations.

6. MSM4: BLUE FORCES*

MSM4 is the partition of MSMPAR reserved for parameters of BLUE FORCES. The original planner data set contains 12 items, that would, if passed as is, require 14 computer words. PRERUN, however, passes to MSM BLUE FORCE lists that have been extended and partially edited, and that are variable length -- from 18 to 45 words per list.

EXEC1A does no further editing, in the sense of adding or changing words. However, special storage allocation logic is used. It was considered undesirably wasteful of storage space to allocate for each list the maximum possible length of 45 words. Instead, these lists are packed "back to back" in storage, and a pointer value is associated with each list. The corresponding pointer table, IPBLU, is filled in by EXEC1A as it transfers lists to storage**.

Table D-4 gives the content of a BLUE FORCE list, as it would exist in storage.

---

* Planner Data Set XXI. See Volume II.

** In particular, IPBLU(K) gives the pointer value (subscript of MSMPAR) for the K'th BLUE FORCE.

7. MSM5: RED FORCES*

MSM5 is the partition of MSMPAR reserved for parameters of RED FORCES. The original planner data set contains 12 items (14 words).

PRERUN passes 14 words to MSM. These differ slightly from the original 14.

EXECIA does no further editing of the 14 words received from PRERUN, and transfers them directly to storage. Table D-5 gives the contents of a RED FORCE list, as it exists in storage.

It may be noted that storage lists for BLUE FORCES and RED FORCES agree in content and structure for the first 14 words. However, RED FORCE positions are keyed to PATH data appearing elsewhere in storage (MSM11), which are used in position evaluation. In contrast, although BLUE FORCE positions are nominally keyed to PATH data, the perturbations simulated in PRERUN for such effects as navigation errors make exact calculations from the original PATHS data impossible. Thus, for BLUE FORCES, independent path information is appended to the BLUE FORCE list (the fifteenth word and all those following) by PRERUN.

---

* Planner Data Set XXII. See Volume II.

8. MSM6: SENSORS[*]

MSM6 is the partition of MSMPAR reserved for parameters of SENSORS[**]. The original planner set data for one sensor consists of 12 data items, corresponding to 13 computer words (the one alphanumeric information item, sensor type, requiring two words for storage). PRERUN passes these 13 words to MSM in essentially the same form as the original planner data, but edited slightly in terms of providing consistent internal units for variables and providing game truth values of x and y for the position parameters[***].

The final form of a sensor list in MSMPAR, however, reflects major editing by EXECIA. For Example, twenty four words are allocated for each sensor list. Briefly, editing procedures within EXECIA take the form:

(a) altering 2 of the 13 words supplied by PRERUN

(b) adding words 14, 15 for two variables that have the same meaning for every sensor type

(c) adding a maximum of 9 words of information, beginning with word no. 16; the exact number of meaningful words, and the corresponding meanings of these words, vary according to sensor type.

---

[*] Planner Data Set III. See Volume II.

[**] Note distinction between SENSORS (MSM6) and SENSOR DESCRIPTORS (MSM7). The former refers to information that varies from sensor to sensor; the latter gives parameters that tend to be common to a number of sensors.

[***] PRERUN supplies x,y values corresponding to initial emplacement. If a sensor is reemplaced, these values may be dynamically altered during simulation by an event type 10 (see Appendix B).

Table D-6 gives the content of a SENSORS list, as it would exist in storage after editing is complete. The first 15 words are essentially independent of sensor generic type. Words 16 on do depend upon sensor generic type, although not all types use the full allocation of 24 words*. Thus, the last page of Table D-6 is given in a different format from the preceding pages... partially in terms of categorization by sensor type, and also with variables defined only in terms of FORTRAN names used in the sensor or EX3... routines.

A few comments on the editing logic and on the choice of storage block size (24 words) may be appropriate. During simulation, sensor routines are called very many times -- enough that speed efficiency becomes an important consideration. If an abbreviated list of SENSOR parameters were stored (e.g., the original 13 words from PRERUN), then each call to a sensor routine would imply executive routine support in accessing other parameter lists -- usually via a trace of ID numbers and pointer values to determine which lists are applicable. This approach is valid but tends to be inefficient with respect to computing speed.

An extreme approach in the opposite direction would have a list stored, for <u>each</u> sensor, that is completely self-sufficient in describing every aspect of the sensor. Then speed is gained, for only one block access is required during a sensor interrogate event. But, in view of the fact that many hundreds of sensors may be present in a scenario, each word added to a SENSOR list may imply hundreds of words of additional storage.

---

* At the time storage control was being planned, the possibility of using variable lengths lists, as was done for BLUE FORCES and for PATHS, was considered as a means to save wasted space. The choice of a fixed list length of SENSORS was marginal. The added complexity, and the space required for an additional set of pointers, <u>might</u> be found justifiable in event of major program changes.

The choice made is a compromise between the two extremes. With 24 words available for each sensor, there is room to store many parameters (obtained from subsidiary parameter categories, especially SENSOR DESCRIPTORS) on a sensor by sensor basis. Thus, for those data within the 24-word list, the table search and data transfer problem becomes a one-time-only event within EXECIA editing, in contrast to a similar set of operations performed at every call to a sensor routine.

It may be noted that 24 words is not sufficiently large to eliminate dynamic table searching for all sensor types. But it is large enough to "handle" all information for all UGS sensors, and partially reduces dynamic searches for the scanning sensors.

Part I of Table D-6 has a few features, not accounted for in the original planner data descriptions. Words 3 and 4, as supplied to MSM by PRERUN, contain in two computer words an alphanumeric designation of sensor type (e.g., 'ACOUSTIC' or ' RADAR'). For operational efficiency, a numeric code is much simpler to use than a two-word alphanumeric block. Thus, EXECIA maps the alphanumeric information into numeric information as follows:

1	Seismic
2	Acoustic
3	Magnetic
4	ARFBUOY
5	Passive infrared
6	Radar
7	Image
8	Thermal viewer
9	Breakwire

This numeric indicator, of course, requires only one word of storage. It is placed into word no. 3, erasing the first four alphanumeric characters originally supplied. Free for some other use is word no. 4 (which originally held the last four alphanumeric characters). EXECIA fills this word with a variable called IMOVE, the numeric value of which is based on a search via ID parameters of other tables. This variable indicates the motion status of the sensor, and possibly a blue force ID, as follows:

Type of Motion	IMOVE Value
Stationary	0
Moving, ground	+ID of corresponding BLUE FORCE
Moving, airborne	-ID of corresponding BLUE FORCE

Word no. 14 (IUPFLG) is an up/down flag -- 0 for down, 1 for up -- that is initialized to zero. Word no. 15 (IUT) is set to 0 for moving sensors; but for stationary sensors, EXECIA determines the IUT value -- the index for unit terrain type -- that is associated with the sensor position.

9. MSM7: SENSOR DESCRIPTORS*

MSM7 is the partition of MSMPAR reserved for parameters called SENSOR DESCRIPTORS. The corresponding planner data set contains 37 data items, three of which (alphanumeric) require two words of storage. MSM uses the first 35 items, or 38 words, and 38 words are allocated to each SENSOR DESCRIPTOR list.

The only editing of MSM7 data by EXECIA is concerned with a subtle problem of variable types (integer vs. real), and arises only for two sensor types: radar and ARFBUOY.

In the original sensor descriptor lists read by PRERUN, the implied variable type -- integer or real -- is generally consistent for any one item. For three of the items (items 17, 18 and 22 of planner data set), the implied variable type is not consistent and must be determined by other references. For items 17 and 18, for example, the specified parameters tend to be of integer type, and are stored in this (implied) form by PRERUN; but for radar sensors only, the floating point or real equivalent of this integer is intended for use by sensor routine RADAR. EXECIA searches MSM7 data subsets, and for those pertaining to radar makes the integer to floating point conversion for two variables (PRIMFR, CLIMFR).

---

* Data Set IV. See Volume II.

A similar situation exists for ARFBUOY descriptors. The variable NBMBLT (number of bomblets) arrives from PRERUN in floating point form. EXECIA searches MSM7 data subsets, and for those pertaining to ARFBUOY sensors makes the floating point to integer conversion.

Table D-7 gives the content of a SENSOR DESCRIPTOR parameter list, as it would exist in MSMPAR storage. This table is nearly identical to that for planner data set IV (Appendix F, Volume II), but reflects changes to internal units, deletion of the last two items (not used in MSM), and a change in the counting index from item number to word number (the two differing because two words are occasionally required to store one alphanumeric "item").

10. MSM8: FIRETRAPS*

MSM8 is the partition of MSMPAR reserved for parameters of FIRETRAPS. The original data set, comprising 9 words, is passed to MSM by PRERUN. An additional word, number 10, is added for an up/down flag indicator initialized to 0 (down); and 10 words are allocated in storage for each FIRETRAP list. Table D-8 shows the content for each FIRETRAP list.

---

* Data Set V. See Volume II

11. MSM9: MONITORS*

MSM9 is the partition of MSMPAR reserved for MONITORS lists. The original data set comprised 9 items, with implied word count of 11 (two "items" being alphanumeric, requiring two storage words each). PRERUN passes these 11 words to MSM, differing from original planner values only in the units for planned up and down times. The 11th word (originally an ID for a receiver/transmitter parameter set) is used within MSM as an up/down indicator (initialized to 0, or down). Eleven words of storage are allocated for each MONITORS list. Content of a MONITOR list as it would exist in MSMPAR storage is given in Table D-9.

12. MSM10: DATA LINKS**

MSM10 is the partition of MSMPAR reserved for DATA LINKS lists. The original data set comprised 6 items, in 6 computer words. MSM receives these 6 words from PRERUN, adds a seventh word as an up/down indicator (initialized to 0, or down), and allocates 7 words per DATA LINKS list. Content of a DATA LINKS list as it would exist in MSMPAR storage is given in Table D-10.

---

* Planner Set VI. See Volume II.

** Planner Set X, See Volume II.

13. MSMII: PATHS[*]

MSMII is the partition of MSMPAR reserved for PATHS data lists. EXECIA does not change or edit any of the values for these lists, but merely allocates the PRERUN supplied values to MSMPAR storage.

PATHS data, like BLUE FORCES data, do receive special treatment however. A PATH list may vary in length from 6 words (for a single point) to 51 words (for a path with the maximum of nine legs). To circumvent the waste of storage that would occur if the maximum, 51 words, were reserved for each PATHS list, pointer tables are established for the lists, which are packed "back to back" in MSMPAR. In particular, the table IPPATH is filled by EXECIA with appropriate pointer values[**].

Table D-II gives the content of a PATHS list, as it would exist in MSMPAR storage.

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[*] Data Set XII. See Volume II

[**] IPPATH(K) gives the pointer value (subscript of MSMPAR) to the beginning of the list for path number K.

14. MSM12: FORCE TYPE PARAMETERS*

MSM12 is the partition of MSMPAR reserved for FORCE TYPE PARAMETER lists. The original planner data set contains 12 items (12 computer words), of which MSM is given the first 7 by PRERUN. EXEC1A makes no changes or additions to these lists, and allocates 7 words of storage in MSMPAR to each such list. Table D-12 gives the content of a FORCE TYPE PARAMETERS list, as it would exist in MSMPAR storage.

15. MSM13: COVERAGE/SCAN PARAMETERS**

MSM13 is the partition of MSMPAR reserved for COVERAGE/SCAN PARAMETER lists. The original planner data set contains 12 items (12 computer words). MSM uses the first 10 of these without alteration, and EXEC1A allocates 10 words of storage in MSMPAR to each list. Table D-13 gives the content of a COVERAGE/SCAN PARAMETER list, as it would exist in MSMPAR storage.

---

* Data Set XIII. See Volume II.

** Data Set XIV. See Volume II.

TABLE D-1

MSMI LIST CONTENT (UGSARRAYS)

WORD

1. ID of array

2. Generic type: alphanumeric = 'UGS'

3. } Organization: alphanumeric, arbitrary (from planner input cards), 2 words (~2A4 format)
4. }

5. No. of sensors in array

6. ID of first sensor

7. No. of monitors associated with array

8. ID of first (primary) monitor

9. ID of corresponding data link

10. ID of second monitor

11. ID of corresponding data link

12. ID of third monitor

13. ID of corresponding data link

14. Array associated with firetrap? (0=no; 1=yes)

15. ID of associated firetrap system, if any

TABLE D-2

MSM2 LIST CONTENT (STASCAN ARRAYS)

WORD

1. ID of array
2. Generic type: alphanumeric = 'VISS'
3. } Organisation: alphanumeric,
4. } two computer words (~ 2A4 format)
5. No. of sensors in array
6. ID of first sensor
7. Array associated with firetrap? (0=no; 1=yes)
8. ID of associated firetrap, if any

Notes:

For MSM2, EXEC1A places into storage 8 words per data set, exactly as given to MSM by PRERUN.

7 "items" in 8 computer words. All words integers except alphanumeric in words 2, 3 and 4.

TABLE D-3

MSM3 LIST CONTENT (MOVARRAYS)

WORD

1. ID of array

2. Generic type: alphanumeric = 'MOVE'

3. Organization: alphanumeric,
4. two computer words (2A4 format)

5. Number of sensors in array

6. ID of first sensor

7. Alias ID as blue force

EXEC1A places 8 words into storage for each MSM3 subset (each moving array.) The first 7 words are directly from PRERUN, as listed above. The 8th word is added within EXEC1A editing procedures:

8. 0 if arrays move on ground
   1 if array is airborne

TABLE C-4

MSM4 LIST CONTENT (BLUE FORCES)

WORD

1. ID of force

2. Generic type (= alphanumeric 'BLUE')

3. Organization: 8 characters alphanumeric in
4. two computer words (2A4 format)

5. Category: 8 characters alphanumeric in two com-
6. puter words (2A4 format); one of the following continuous list of 19 items:

(1) ' INDIV'
(2) ' SQD'
(3) ' PLAT'
(4) ' CO'
(5) ' SMVEH'
(6) ' HVYVEH'
(7) ' TANK'
(8) ' TRAIN'
(9) ' HELO'
(10) ' LTA/C'
(11) ' JETA/C'
(12) ' RAFT'
(13) ' OUTBRD'
(14) ' PTBOAT'
(15)* LT AMMO
(16)* MD AMMO
(17)* HVY AMMO
(18)** SMANIM
(19)* LGANIM

Note: the alphanumeric content in these two words is not used in initial MSM program, and would probably be used later, if at all, only for alphanumeric print-out. The numeric code in the following word is used for actual MSM program computation and logic.

7. Numeric code (1 through 19) corresponding to the choice above.

8. Number of elements in target

9. ID of force type parameter set

10. Nominal speed (real; meters/sec)

11. Altitude (real; meters; =0 for ground forces)

* Generated as False Targets in BATTLE and CULTURE, not obtained from Planner Set XXI.

** Generated as Background noise in CULTURE, not obtained from Planner Input Data Set XXI.

TABLE D-4, continued

WORD

12. Start operations time (real; seconds since start of game)

WORD	For stationary blue force	For moving blue force
13.	X (real; meters)	ID of route
14.	Y (real; meters)	N_sN_e

Note: N_s = node of indicated route at which force starts
N_e = node at which force ends

N_sN_e indicates packed word = $10*N_s + N_e$

Note: Determination of stationary or moving (hence, of interpretation of words 13 and 14 in MSM) comes from word 10 (0 speed implies stationary force).

15. NLEGS: number of legs in defined route (path). Note: corresponding nodes (NLEGS+1 in number) are denoted below as nodes 0 (start) through NLEGS (end)

16. x_o
17. y_o
18. t_o
19. x_1
20. y_1
21. t_1
⋮
x_{NLEGS}
y_{NLEGS}
t_{NLEGS}

Beginning with word 16, a total of (NLEGS+1) triplets of x, y and t values at the nodes... game truth. All variables real -- coordinates x and y in meters, time t in seconds since start of game.

Total word count for a complete blue forces sublist is 15 + 3*(NLEGS+1). Maximum value, corresponding to 9 legs, is therefore 45.

TABLE D-5

MSM5 LIST CONTENT (RED FORCES)

WORD

1. ID of force

2. Generic type (= alphanumeric 'BLUE')

3. Organization: 8 characters alphanumeric in
4. two computer words (2A4 format)

5. Category: 8 characters alphanumeric in two com-
6. puter words (2A4 format); one of following:

(1) ' INDIV'
(2) ' SQD'
(3) ' PLAT'
(4) ' CO'
(5) ' SMVEH'
(6) ' HVYVEH'
(7) ' TANK'
(8) ' TRAIN'
(9) ' HELO'
(10) ' LTA/C'
(11) ' JETA/C'
(12) ' RAFT'
(13) ' OUTBRD'
(14) ' PTBOAT'
(15)* LT AMMO
(16)* MD AMMO
(17)* HVY AMMO
(18)** SMANIM
(19)* LGANIM

Note: the alphanumeric content in these two w [illegible] is not used in initial MSM program, and would probably be used later, if at all, only for alphanumeric printout. The numeric code in the following word is used for actual MSM program computation and logic.

7. Numeric code (1 through 19) corresponding to the choice above.

8. Number of elements in target

9. ID of force type parameter set

10. Nominal speed (real; meters/sec)

11. Altitude (real; meters; =0 for ground forces)

* Generated as false targets in BATTLE and CULTURE, not obtained from planner input data set XXI.

** Generated as background noise in CULTURE, not obtained from planner input Data Set XXI.

TABLE D-5, continued

WORD

12. Start operations time (real; seconds since start of game)

	For stationary red force	For moving red force
13.	X (real; meters)	ID of route
14.	Y (real; meters)	N_sN_e

Note: N_s = node of indicated route at which force starts

N_e = node at which force ends

N_sN_e indicates packed word = $10*N_s + N_e$

Note: Determination of stationary or moving (hence, of interpretation of words 13 and 14 in MSM) comes from word 10 (0 speed implies stationary force).

TABLE D-6

MSM6 LIST CONTENT (SENSORS)

<u>WORD</u>

1. ID of this sensor

2. ID of array containing this sensor

3. Numeric indicator for sensor type: 1 seismic; 2 acoustic; 3 magnetic; 4 ARFBUOY ; 5 passive infrared; 6 radar; 7 image; 8 thermal viewer; and 9 breakwire.

4. IMOVE Movement code: = 0 for stationary sensor; = +ID of corresponding BLUE FORCE for ground moving; = -ID of corresponding BLUE FORCE for airborne.

   (Note: As received from PRERUN, words 3 and 4 contained a two-word alphanumeric sensor type designation)

5. ID of Sensor Descriptor Parameter Set

6. Integer: 0 for open location
   or
   ID of path if "path" type location

   (that is, same as item 5 of planner data set III)

7. XSENS x-coordinate, <u>ground truth</u>, of sensor (real)

8. YSENS y-coordinate, <u>ground truth</u>, of sensor (real)

   *Note: correspond to items 6, 7 of planner data III, but (a) should be ground truth values (after emplacement errors inserted), and (b) if planner specified the alternate forms for "path" location, his information must be translated into actual x,y coordinates.

9. OFFSET offset from path in meters; real; leave 0 in this word if offset has no meaning for the particular sensor

10. ORIENT Orientation angle, if applicable. Same as item 9 of planner data III, except converted to mathematical angles (radians; positive = counterclockwise from x-axis)

TABLE D-6, continued

WORD

11. Integer to specify whether primary or auxiliary sensor

    0 = PRIMARY
    1 = AUXILIARY

    *Note: planner input is alphanumeric 'PRI' or 'AUX': PRERUN to translate to 0,1.

12. ID of Coverage/Scan Parameter Set (0 if no such set assigned to sensor)

13. Integer to specify whether AND logic to be used:

    0 = not used
    1 = AND logic is used

14. IUPFLG Up/down flag (0 = down, 1 = up)

15. IUT Unit terrain index

Note: Words 14, 15 not supplied by PRERUN. EXECIA initializes up/down flag to 0. IUT is evaluated in EXECIA for stationary sensors; set to 0 for moving sensors.

TABLE D-6, continued

Word No.	Seismic and Acoustic	Magnetic	ARFBUOY	Passive Infrared	Image	Thermal Viewer
16.	GEQUIL	TLTC	AREADN	EXPAN	ITIMEP	TEMPEV
17.	THRESH	THRESH	IMAG	FIELD	ICLEAR	FOCALL
18.	VNOISE	(n.a.)	IGEOM	TEMPEV	IVISUAL	RESOL
19.	ITIMLR	(n.a.)	DIMMAX	WATTBK	ITYPE	FNUMBR
20.	ITIMLE	(n.a.)	WIDTH	(n.a.)	TIMCON	IAIR
21.	GAIN	(n.a.)	(n.a.)	(n.a.)	FOCALL	(n.a.)
22.	GINLST	(n.a.)	(n.a.)	(n.a.)	XMTF	(n.a.)
23.	IFIXGN	(n.a.)	(n.a.)	(n.a.)	FNUMBR	(n.a.)
24.	(n.a.)	(n.a.)	(n.a.)	(n.a.)	ISERCH	(n.a.)

Note: (n.a.) means not applicable
For radar and breakwire sensors, there is no applicable information in words 16 through 24.

TABLE D-7

MSM7 LIST CONTENT (SENSOR DESCRIPTORS)

WORD	
1.	ID of this parameter set
2., 3.	Generic type of sensor [alphanumeric; 2 words]
4., 5.	Specific type/model [alphanumeric; 2 words]
6.	MTBF (mean time between failures)*
7.	MBLT (mean battery life time)*
8.	Standard deviation for battery life time*
9.	Does this sensor have a self-destruct capability or not? [1 if it does; blank if not]*
10.	Auxiliary or primary sensor [1 if auxiliary, 0 if primary]
11.	Probability of emplacement survival*

For Items 10 through 15, See Note 1.

	Sensors with Sector Coverage	Sensors with Rectangular Coverage
12.	enter 9999	Cross-track component of vector from sensor to rectangle center. + if to left, - if to right with respect to direction of movement of sensor platform or from lower number node if stationary (meters).
13.	Maximum coverage angle for this equipment (radians)	Along-track component of vector from sensor to rectangle center. + if forward, - if rearward with respect to direction of movement of sensor platform or from lower number node if stationary (meters).
14.	Minimum range capability of this equipment (meters).	Maximum along-track length of rectangle against any target (meters).
15.	Maximum range capability of this equipment against personnel (meters)	Cross-track dimension of rectangle against personnel (meters).

---

*Not used in MSM

TABLE D-7, continued

16.	Maximum range capability of this equipment against vehicles and boats (meters).	Cross-track dimension of rectangle against vehicles and boats (meters).
17.	Maximum range capability of this equipment against aircraft and munitions (meters).	Cross-track dimension of rectangle against aircraft and munitions (meters).
18., 19.	Specific type/model of generic type of sensor for which parameter set applies, whichever is most useful to user. This item is for reference only. (alphanumeric, 2 computer words)	

20.

a. Radar — Precipitation improvement factor code (PRIMFR).

1	no precipitation improvement played
2	precipitation improvement played

b. Imaging device

0	or blank for human eye or binocular
1	image intensification device (or daylight TV

c. **ARFBUOY**

0	or blank for Magnetic Button Bomblets (MBB)
1	Noiseless Button Bomblets (NBB)

d. Thermal Viewer

Left blank

e. Magnetic Devices

Left blank

f. Seismic — Gain level code (IFIXGN)

0	or blank for automatic gain control (AGC should be used for MINISID, MICROSID, ADSID III and MODS)
1-5	Specific gain settings desired, PSID
6	gain settings computed and set at lowest setting above background noise level, PSID
Negative No.	gain settings fixed for game

TABLE D-7, continued

21.	a.	Radar		Clutter improvement factor (CLIMFR)
			1	clutter improvement not played
			2	clutter improvement played
	b.	Image device		
			blank	If Item 17 is blank or 0 (eye or binocular)
			0	If Item 17 is set at 1 (image intensification device); used at night
			1	daylight (daylight TV) (Word 19 is set to 1)
	c.	**ARFBUOY**		Geometry of bomblet pattern
			1	open circle
			2	open line
			3	along road or trail
	d.	Thermal		Leave blank
	e.	Magnetic		Leave blank
22.	a.	Radar		Wavelength, meters (RAMBDA)
	b.	Image device		
			blank	human eye or binocular
			integer	enter time constant (TIMCON for image intensification devices (seconds))
				Must be consistent with Word 19
	c.	ARFBUOY		Diameter of seeded area, if circle; or length of longest side of rectangle, if rectangle (meters), (DIMMAX)
	d.	Thermal		Leave blank
	e.	Magnetic		Leave blank
23.	a.	Radar		Filter band thermal noise, (FNKTB)
	b.	Image device		
			focal length	(FOCALL) if equipment is an image intensifier (mm)
			1.5	human eyes (DEVCAL)
			0.01	binoculars (DEVCAL)

TABLE D-7, continued

	c.	ARFBUOY	Enter width of seeded area (meters), for rectangle area, (WIDTH), blank for circular area.
	d.	Thermal	Focal length (mm) (FOCALL)
	e.	Magnetic	Leave blank
24.	a.	Radar	Radar characteristics (RADCAR)[watts(meter)^2]
	Note:		RADCAR is a composite of peak power, transmitter antenna gain, transmitter losses, receiver antenna gain, receiver losses, wavelength squared and a constant.
	b.	Image device	
		=	Value of average resolution, (XMTF) if equipment is an image intensifier
		=	0.5 for human eyes (area of aperture (ALPHA), (mm^2)
	c.	ARFBUOY	blank
	d.	Thermal	Resolution of detector element (radians) (RESOL)
	e.	Magnetic	Threshold, gauss [Note E-6] - (THRESH)
25.	a.	Radar	Scan rate (SCANRT) rad/sec
	b.	Image	f-number if equipment is image intensifier, (FNUMBR) is the focal length divided by the diameter of aperture. 1.0 for human eye, magnification factor (AMAG) 7.0 for 7x50 binoculars, magnification factor (AMAG)
	c.	ARFBUOY	Number of bomblets, (NBMBLT)
	d.	Thermal	f-number (focal length divided by diameter of aperture diameter) (FNUMBR)

TABLE D-7, continued

26. a. Radar — Code for radars, (ICOH)

0	or blank for coherent
1	noncoherent

b. Image — Code for direct searchlight, (ISERCH)

0	no searchlight
1	clear searchlight
2	searchlight with pink filter

Note: If searchlight used, (ISERCH =1 or 2), then additional searchlight parameters are provided below.

27. Azimuth beamwidth (BEAMAZ), mils

28. Elevation beam angle (BEAMEL), mils

29. Range gate (RGATE), meters

30. Standard deviation for radar instability (clutter power) (SIGSTB)

31. Filter lower cutoff frequency (FCUTLO), Hz

32. Filter upper cutoff frequency (FCUTHI), Hz

33. Antenna or aircraft height (HGTANT) = feet above ground (if aircraft, this entry should be the same as Item 12 in the Forces input).

34. Probability of False Alarm (PFA) (actual value, not percent)

Items 35 through 38 apply only for image sensors with searchlight (ISERCH = 1, 2, Word 26)

35. XSRCH — Coordinates of searchlight location

36. YSRCH

37. BWIDTH, searchlight beamwidth, degrees

38. CPOWER, searchlight candlepower

TABLE D-8

MSM8 LIST CONTENT (FIRETRAPS)

WORD

1. ID of this firetrap system
2. ID of associated route
3. Planned time, begin op'ns (integer; time in secs into game)
4. Planned time, cease op'ns (" " " " " ")
5. Number of kill points in system (1 or 2)
6. Leg number on the route, first kill point
7. Distance along that leg (real)
8. Leg number on the route, second kill point
9. Distance along that leg (real)
10. IUP: Up/down flag (0 = down, 1 = up)

TABLE D-9

MSMS LIST CONTENT (MONITORS)

WORD	
1	ID of this monitor
2, 3	Generic type (alphanumeric; 2 words)
4, 5	Organization (alphanumeric; 2 words)
6	x, meters (real)
7	y, meters (real)
8	Planned up time (integer, seconds into game)
9	Planned down time (integer, seconds into game)
10	ID for monitor parameter set
11	Up/down flag (0 = down, 1 = up)

TABLE D-10

MSM10 LIST CONTENT (DATA LINKS)

WORD		
1.	ID of this data link	
2.	ID of associated array	
3.	ID of associated monitor	
4.	Number of relays:	
	0	no relays, radio link
	1	one relay (radio transmission both legs)
	2	two relays (radio transmission all legs)
5.	ID of first relay (one closest to array), if applicable	
6.	ID of second relay (one closest to monitor), if applicable	
7.	Up/down flag (0 = down, 1 = up)	

TABLE D-11

MSMII LIST CONTENT (PATHS)

WORD	
1.	Alphanumeric 'PATH'
2.	Input source (C = control, B = blue, R = Red); alphanumeric
3.	Route ID
4.	Number of legs*
5.	X-coordinate of first node (node 0), meters
6.	Y-coordinate of first node (node 0), meters
	Note: Location input on stationary items stop here
7.	Forward speed factor for first leg
8.	Reverse speed factor for first leg
9.	Leg type**
10.	X-coordinate of second node (node 1), meters
11.	Y-coordinate of second node (node 1), meters
12.	Forward speed factor for second leg
13.	Reverse speed factor for second leg
14.	Leg type
15.	X-coordinate of third node (node 2), meters
16.	Y-coordinate of third node (node 2), meters

The five parameters (as for items 7 - 11, or 12 - 16) are repeated for additional legs, up to a maximum nine legs (or ten nodes). For maximum number of legs (9), number of items will be 51. For minimum number of legs (0; i.e., stationary point at node 0), number of items will be 6.

---

* Nodes are numbered 0, 1, ..., 9 and legs are numbered 1, 2, ..., 9 where leg 1 is between nodes 0, 1, etc.

** Leg types are specified for each leg by the code: 0 = cross country, 1 = (unimproved) trail, 2 = unimproved road, 3 = gravel road 4 = hard surface road, 5 = water, 6 = railroad, 7 = airstrip, 8 = coastline and 9 = airroute.

TABLE D-12

MSM12 LIST CONTENT (FORCE TYPE PARAMETERS)

WORD		
1.	ID of parameter set	
2.	Ferrous metal present	
	1	yes
	2	no
3.	Visual security descriptor	
	0	attempting concealment
	1	normal
4.	Spacing between elements, meters	
5.	Formation descriptor (personnel only, otherwise blank)	
	1	file
	2	column of two's
	3	randomly within circular area
6.	Weight descriptor (personnel only, otherwise blank)	
	1	light or medium weight men
	2	heavy weight men
7.	Acoustic descriptor (personnel only, otherwise blank)	
	1	silent
	2	talking

TABLE D-13

MSM13 LIST CONTENT (COVERAGE/SCAN PARAMETERS)

WORD		
1.	ID of this parameter set	
2.	Coverage/scan code	
	1	sector/scan
	2	sector/non-scan
	3	moving rectangle
	4	stationary rectangle

Note: If 2, 3 or 4 is entered for Item 2, i.e., not scanning, then Items 7, 8, 9 and 10 are left blank.

WORD	Sector (1 and 2)	Rectangle (3 and 4)
3.	Minimum range selected (RMIN), meters	Along-track dimension (ILONG)-meters
4.	Maximum range selected (RMAX), meters	Cross-track dimension (IWIDE)-meters
5.	Coverage angle selected (CVANGL), radians	Along-track component of vector from sensor to rectangle's center; + if forward - if rearward with respect to direction of movement of sensor platform, (IATD), meters
6.	Blank	Cross-track component of vector from sensor to rectangle's center; + if to left - if to right, (ICTD), meters

Note: Items 3, 4, 5 and/or 6 are left blank if the equipment coverage limits given in the Sensor Descriptor Parameter Sets (IV) are to be used.

WORD	Scan in Azimuth*	Scan in Range**
7.	NREPRI, number of repetitions per range increment	0 or blank

---

* Corresponds to SCAN 1 subroutine in MSM

** Corresponds to SCAN 2 subroutine in MSM

TABLE D-13, continued

8.	RINCR, range increment, meters	AZINC, azimuth increment, radians
9.	OMEGA, scan rate, rad/sec	DRDT, scan rate, meters/sec
10.	BEAMW, beamwidth, rad	RGATE, range gate, meters

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