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Final Report

COMBINED RECONNAISSANCE, SURVEILLANCE AND SIGINT MODEL (CRESS)

Volume II: User's Handbook

By: J. R. PAYNE, G. W. MOSELEY, S. W. ELIESON, JR., B. J. RIPPLE, C. D. HEROLD, J. G. RUBENSON

Prepared for:

INSTITUTE OF LAND COMBAT
UNITED STATES ARMY
COMBAT DEVELOPMENTS COMMAND
DEPARTMENT OF THE ARMY

CONTRACT DA-49-092- ARO-10

STANFORD RESEARCH INSTITUTE

MENLO PARK, CALIFORNIA

November 1968

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SRI Project 5205

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ABSTRACT

This volume supplements Volume I of the SRI final report "Combined Reconnaissance, Surveillance, and SIGINT Model (CRESS)" by providing a detailed description of the model, explicit instructions for using it, formats for the data, and some of the required data. The description includes models for photographic, IR, radar, visual, TV, PNVD, laser, and SIGINT sensors. These sensor models provide the core for the three major models (aerial, ground, and SIGINT) that constitute CRESS.

Methods of providing for the effects of navigation error, aircraft attrition caused by enemy ground AA weapons, attrition of ground observation posts, equipment failure, terrain masking, cloud coverage, vegetation coverage, camouflage, misrecognition and misidentification of target elements, false targets, multisensor interpretation, various report criteria, delay times for reports, and time-ordering of reports and of grouping elements into possible area targets are also described. Instructions for collecting, collating, and processing of the data necessary for running the computer programs are included, as are instructions for analyzing the computer output.

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GLOSSARY

Target	Any collection of objects that are to be processed together, usually a designated military unit such as a tank platoon or a rifle company
Target Element Type (Target Object Type)	Any one of the type of things of which a target is composed (e.g., T-62 tank, 105-mm Howitzer, radio set R104).
Detection	Target element detection is the determination of the presence of a nonnatural object and the estimation of its general characteristics (e.g., linear target, medium land object, FM voice signal at 38.00 MHz). Detection can be accomplished by the sensor operator or by an offline analyst who searches through the raw data (image interpreter).
Recognition	Target element recognition is the determination of the presence of an object with a sufficient level of detail to enable the object to be classified as belonging to a group of similar object types (e.g., small animal, wheeled vehicle, tracked vehicle).
Identification	(1) Target element identification is the determination of the presence of an object with a sufficient level of detail to enable the object to be classified by type (e.g., man, 2-1/2 ton truck, T-62 tank, radio set R104). (2) Target identification is the identification of a target through the identification of a characteristic set of elements of the target.

Hearability	**The ability of an electromagnetic emitter to produce a signal at a specified remote location that is sufficiently greater than the background noise to be detectable.**
SIGINT	**A generic term including the technical and intelligence information derived from foreign communications by other than the intended recipients (COMINT), or from foreign noncommunications electromagnetic radiations emanating from other than nuclear detonation or radioactive sources (ELINT).**

Conventions for forms to be filled in for keypunching

1. The first row will have one of the three entries A, I, or R for each column of information

   A denotes alphanumeric information. Entries must be left-justified.

   I denotes an integer type number. Entries must be right-justified. Blank entries are converted to 0 by the computer

   R denotes a real type number. Entries must contain a decimal point and should be right-justified. Blank entries are converted to 0.0 by the computer.

2. The second row will contain the rightmost card column for each form column of numeric information. It will contain the leftmost card column for each form column of alphanumeric information (/ indicates the start of a new card).

3. The third row will contain the headings for the form columns of information.

4. At least one sample of realistic entries will be furnished.

5. The FORTRAN format will be given at the bottom of the form. See Fig. 23 as an example of these conventions.

I INTRODUCTION

This volume presents detailed discussions of CRESS and each of its three major submodels: CRESS-A for airborne collateral sensor systems; CRESS-G for ground based collateral sensor systems; and CRESS-S for SIGINT collection systems.

To use CRESS, or any one of its submodels, requires strict compliance with the directions given for data preparation. Although it is theoretically possible to use CRESS by simply following the directions for use, in practice it will be necessary to become familiar with the capabilities and limitations of CRESS by reading both this volume which contains detailed descriptions of the models and the directions for their use, and Volume I of this report which contains some supplementary information in its summary description of CRESS.

In addition to the descriptions of CRESS and each of its submodels, Section II contains instructions and examples for each type of required input data, and samples,* with explanations of each type of computer output. Section III contains instructions for organizing the data for computer processing, and discusses the analysis of the simulated reconnaissance and surveillance data contained in the computer output. Appendix A contains the characteristics required by CRESS for a large number of target elements

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* Section II indicates which data are well documented and which are produced by the best judgement of a few analysts at SRI. The typical values given in the samples for this latter type of data should be questioned by the user and replaced by values derived from other studies or from the user's best judgement, if necessary.

and backgrounds. Appendix B contains detailed flow charts for each of the types of collateral sensors modeled in CRESS-A and CRESS-G. Appendix C presents the propagation equations used in CRESS-S.

II CRESS DESCRIPTION

A. General

CRESS is a manual/computer model designed to simulate the operational use and data output of reconnaissance and surveillance (R & S) systems built around collections of sensors selected from the types listed in Table 1. The computer programs are modular in nature and many of the submodels can be used or bypassed at the option of the user. Use of the entire model requires a large scale digital computer with a random access disk unit and knowledge of intelligence and tactical use of airborne, ground, and SIGINT sensors. While there are three computer programs (aerial, ground, and SIGINT) that direct the computer to do all of the mathematical calculations, most of the bookkeeping, and the printing of the sensor systems output data, users must provide the scenario development, collection plan, weather parameters, target and sensor deployment, the criteria for making reports of sightings, and the intelligence analysis of the reported sensor-generated data.

The sequence of participation by men and the computer is men-computer-men-computer-men. It is anticipated that CRESS will be used in support of studies that require a scenario for other purposes than R & S (e.g., war games, feasibility and tactical concepts studies, ammunition expenditure rate studies, and comparative tactical systems studies). The data requirements of the computer models in CRESS should be understood before the scenario is developed so that the work entailed in developing the scenario will only have to be done and considered once for both CRESS and for whatever other purpose the study is being generated.

Table 1

SENSOR TYPES

Aerial	Ground	SIGINT
Cameras Vertical frame Side oblique Forward oblique Panoramic Infrared line scanners Radars MTI Mapping MTI and mapping Visuals Eye Binoculars Laser line scanners Low light level tele-visions	IR Ground surveillance radars Passive night vision devices Visuals Eye Binoculars Laser line scanners IR binoculars	.1 to 60 MHz Line of sight, near shadow .1 to 60 MHz Transition shadow .1 to 60 MHz Far shadow 3 to 30 MHz Skywave 60 to 40,000 MHz Microwave

Typical R & S efforts undertaken by a Motorized Rifle Division were used as guidelines in determining the size of the problems that can be considered by CRESS. However, this division-size effort serves only as a guideline, and the actual size of the R & S problem to be simulated is limited by the amount of effort that can be put into the problem by men and by the size of the computer and the arrays that have been defined for the computer. The limiting sizes of the arrays are stated in Table 2.

Although the data produced by the sensors reflect the targets as they were at one point in time, it is possible to move the targets as often as the user wishes as long as the total number of targets and movements does not exceed 750. The time interval that a target remains in one position is specified by its beginning and ending clock time. Since the initial and final valid times must be given for each target, each target may be moved at a time specified by the scenario writer, or all the targets can be moved at the same time if desired. The aerial sensors can be flown at any time as specified by the flight planner, and the flight path will be simulated in time as it would be flown in real life. The duty times for each ground observation post (OP) may also be specified for any time interval. Thus, CRESS can simulate the movement of both targets and sensors whenever this movement is scheduled at the outset.

Table 2

MAXIMUM COMPUTER ARRAY SIZES

Descriptor	Upper Limit
Grid areas on map	4 a/
Target groups	40
Targets	750
Target movements	749 b/
Object types	100
Object types in one target	19
Object types capable of anti-aircraft fire	30
Recognition classes	40
Detection classes	10
Weather types	4
Background types	25
Aerial navigation systems	10
Special objects (reports)	10
Aircraft types	15

a/ The map grids used must be contained in a square formed by four contiguous grid areas.

b/ Each time a target moves, it is counted as another target. The total number of targets must be less than or equal to 750.

Table 2 (Continued)

MAXIMUM COMPUTER ARRAY SIZES

Descriptor	Upper Limit
Aerial sensors	40
Sensors of one type (except visual)	10
Visual	5
Sensors aboard one aircraft	4
Targets overflown	4096[c/]
Targets considered by OPs[e/]	4096[d/]
Ground sensors	35
Sensors of one type	5
Sensors in one observation post (OP)	4
OPs[e/]	125
Communication link types	5
SIGINT collection sites	50
Sensors per collection site	1
Emitters	4096

c/ A target is counted each time a reconnaissance aircraft covers it with any of its sensors.

d/ A target is counted again for each OP that covers it.

e/ This includes ground patrols.

In addition to computer programs for the mathematical models of each of the sensor types listed in Table 1, computer submodels are also provided for each of the items in Table 3. Many of these items may be bypassed by the selection of appropriate options if the user is not interested in the effect caused by them.

A good way to explain how CRESS might be used is by an analogy with the game of chess. To play chess, one must learn the six different types of pieces used, the types of moves that each type of piece can make, the constraints placed on the movement by the size and shape of the board, the starting points for each of the pieces, and the object of the game. The interesting situations that can be developed in chess are limited only by the ingenuity of the players in using their resources.

To use CRESS to full advantage, one must learn what each of the resources is that can be used, the rules for using each resource, and the constraints on using each resource. Then, as in chess, any situation that can be developed is allowed if it does not break the rules or go outside the constraints. The resources that one can exploit when using CRESS include the teams of men that deploy the targets, the men who deploy the sensors, the men who do the intelligence analysis based on the simulated reconnaissance systems outputs, and the computer models of the items listed in Tables 1 and 3. (The constraints, or size of the board, are specified in Table 2.)

Table 3

COMPUTER PLAYED ITEMS

• Shadows
• Decision to make report
• Assigning stances to men
• Camouflage
    Nets
    Natural
• Effects of weather
• Position location error
• Failures
    Aircraft
    Navigation systems
    Communication links
    Sensors
• Attrition
    Aircraft
    OP
• Flight path geometry
• Selection of targets covered
• Selection of AA sites within range
	• Amount of imagery taken
	• Timeliness of reports
	• Real time flight
	• Sensors on and off
	• Terrain masking
	• Vegetation masking
	• Cloud masking
	• Misrecognition, misidentification
	• False targets
	• Multisensor enhancement
	• Cumulative looks by ground sensors
	• Grouping of target elements near each other
	• Reconnaissance by firing
	• Output
	    Control copy
	    Time-ordered Intelligence Copy

For two chess players of approximately equal ability to play a fair and interesting game of chess, it is necessary that they have a chessboard and all the pieces and that initially all the pieces start out in their correct (or agreed on) starting positions. Similarly, in using CRESS for any specified use, it is important that all the necessary resources be present and that all the initially needed data be generated and correctly stored according to the appropriate formats. This initialization process* is performed by the scenario developers and the men who deploy the sensors and specify how they are to be used.

The collected and collated data are then fed to the computer. The computer's job is to do all the necessary calculations and printing to display the performance of the sensors against the individual objects in accordance with the options selected.

Next the intelligence team must analyze the computer-simulated reconnaissance/surveillance input data, determine which data are sufficient to answer specific needs, and determine whether more data should be generated to meet other intelligence needs. If more data are needed to meet intelligence needs, the team can elect to search in the desired area with an enhanced probability of detection by deploying its sensors in that area and feeding the information to the computer to be

---

* The detailed instructions for collecting and collating the necessary data are in Section II.E. of this handbook.

processed again with the option selected for enhanced probability of detection. This second play by the computer is fairly simple to set up since only data for the changed deployment of sensors need to be generated. When the results of the directed search are printed out by the computer, the intelligence team again makes its assessment of the situation; this process is continued for as many times as desired. Note that rerunning the sensors in a directed search with an enhanced probability of detection could be equivalent to re-examining the imagery of the first take of the sensors so that it can be a simulation of this re-examination and not an actual redeployment of the sensors.

B. The Aerial Model, CRESS-A

1. Flight Processing

In a typical exercise of CRESS-A, flight planners will schedule a series of flights over areas of interest. Each flight covers one or more reconnaissance and surveillance (RS) areas. Each RS area in turn contains from one to ten parallel and equidistant flight legs (see Fig. 1). Sensors are considered to be turned on only while flying these legs, during which the platform is flying straight and level.

Figure 2 is a simple flow chart showing the order in which the various parts of CRESS-A are processed in the computer phase of the simulation. An overview of the model is given below, followed by a more detailed discussion of each of the major elements except input and output, which are discussed in Section II.F. At the end of each discussion is a list of the computer subroutines that are related to the items discussed. Figure 3 shows how the subroutines are linked together.

The computer calculates the actual flight path, taking into account position errors caused by navigation inaccuracies. Then, on each leg of an RS area, each target in the vicinity is examined to determine if it is within the swath covered by any sensor on board the platform. If a target is covered by a sensor, its image is considered to be taken at the moment of closest approach on that leg.

The flight time to each target is then calculated, and the targets covered are ordered with respect to time, so that they will be processed in the appropriate overflight order. If an aircraft has a side-looking sensor and a vertical sensor aboard, it is possible that the target will be processed twice, once

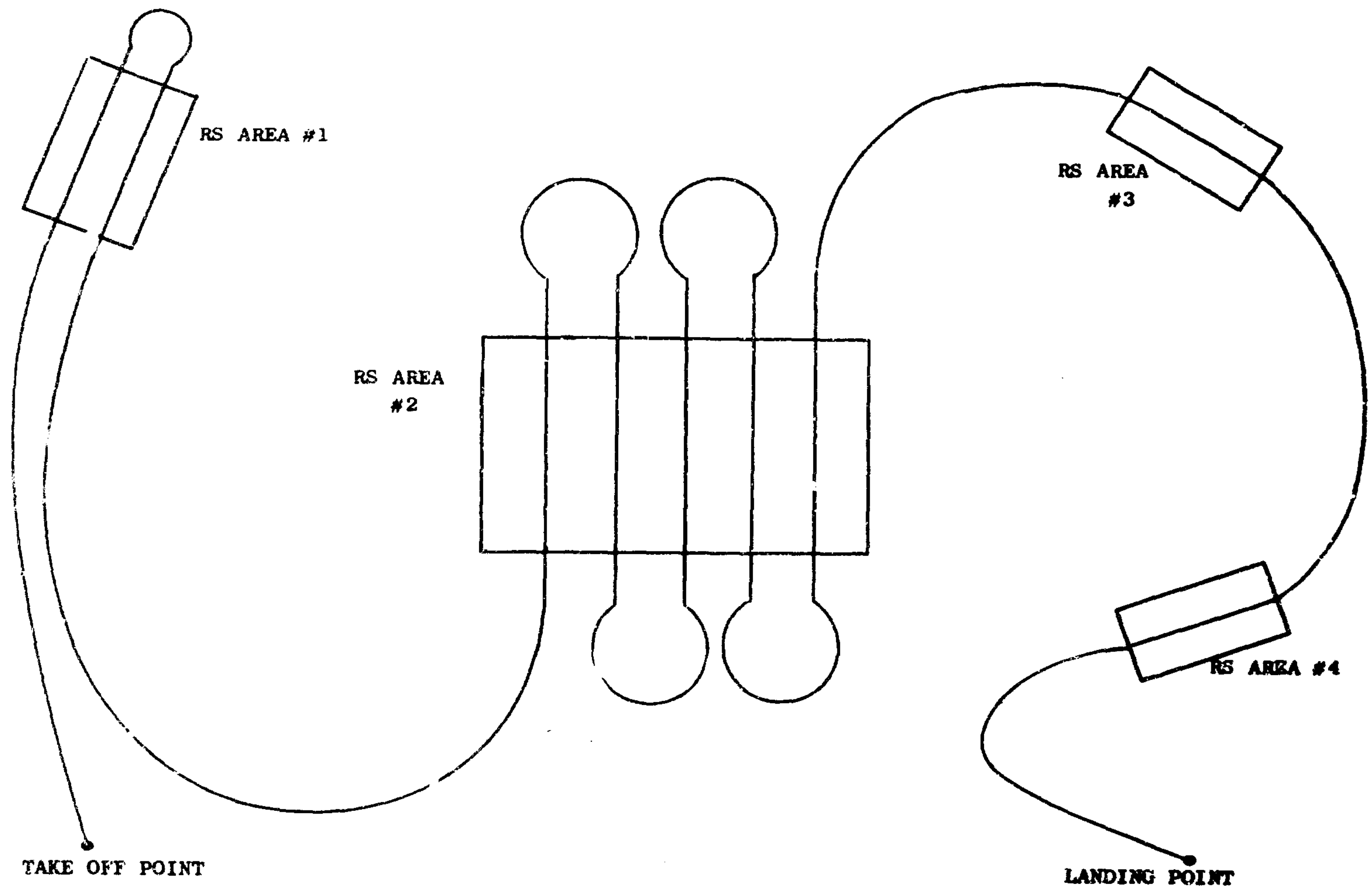


Fig. 1 POSSIBLE FLIGHT PATH

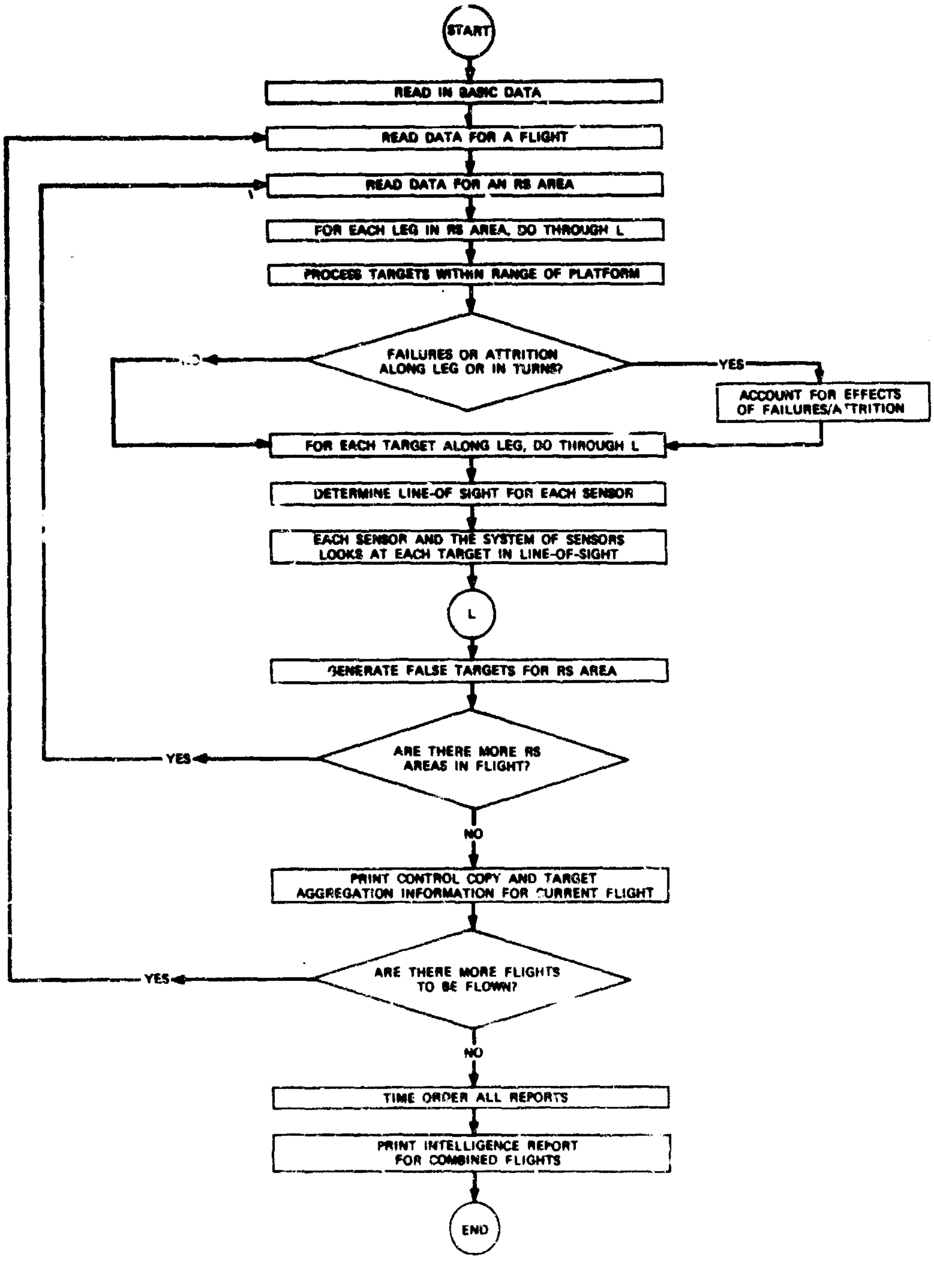


Fig. 2 CRESS-A FLOW CHART

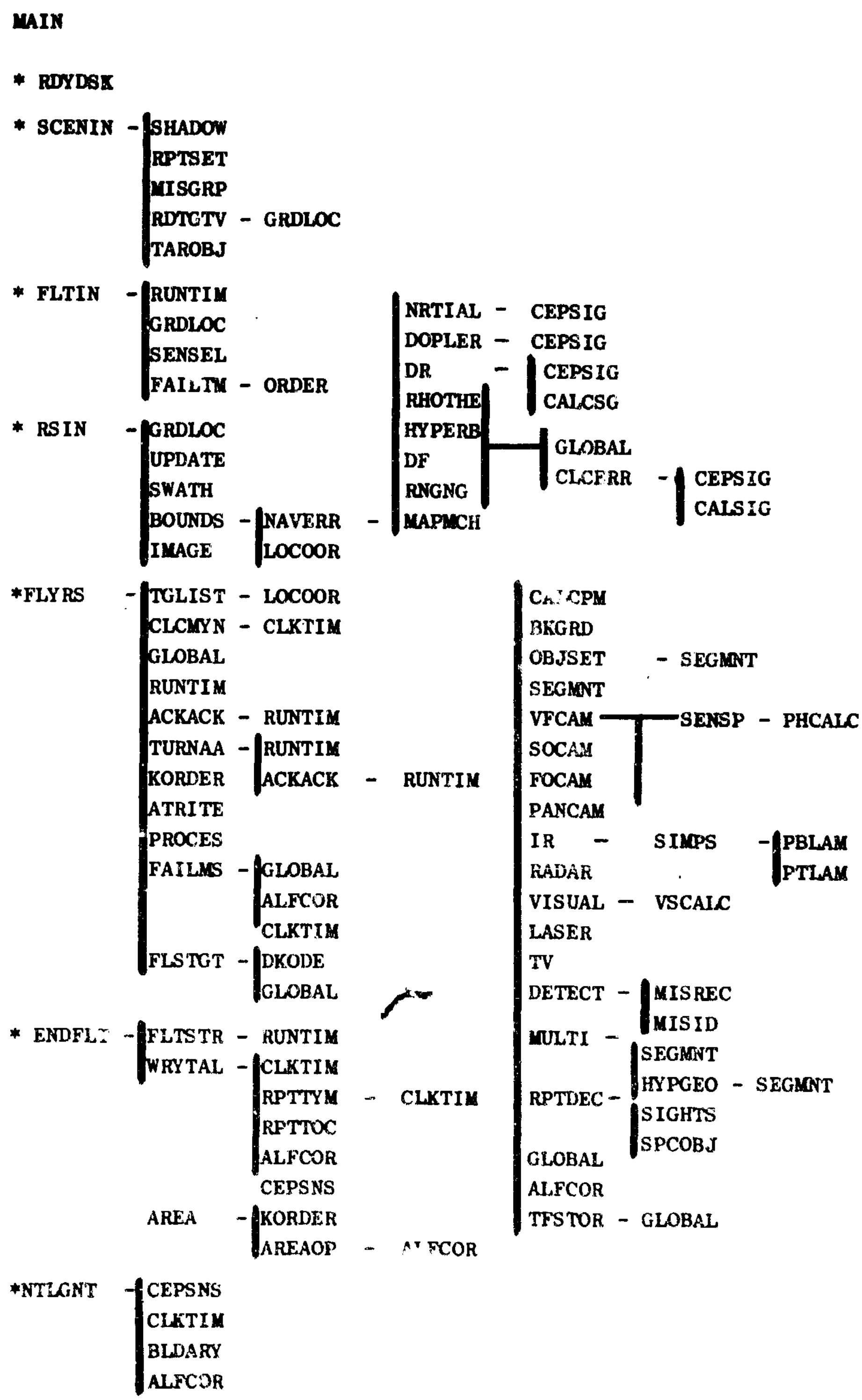


Fig. 3 CRESS-A SUBROUTINE LINKAGE

when the target is overflown by the aircraft for the vertical instrument and once on the next leg, possibly when the side-looking sensor could sense it even though the target is then outside the maximum range of the vertical sensor.

As each target in an RS area is overflown, it is examined for antiaircraft capability. If it has such capability, a simple AA model determines if the platform is destroyed or is allowed to continue its mission. This AA model is also played as the platform makes turns between legs of an RS area.

The time at which each on-board item (platform, navigation system, sensors, and links) will fail is calculated by Monte Carlo processes at the beginning of the program. These times are then ranked and stored in order of occurrence. At the end of each leg, these fail times are compared to see if any failures have occurred. If so, the effect of the failure is considered; a sensor is not permitted to detect targets after it fails, communication links do not transmit data after they fail, and a flight is aborted after the failure of the platform or navigation system. All failures, including those caused by AA, are considered in order of their calculated occurrence.

Each target is processed in the following manner: the target/background characteristics are set and the slant range is calculated. Then, in turn, each object type within the target is considered. The object characteristics are set, and then, in turn, each sensor on board the aircraft is considered. The sensor parameters are set, and using the appropriate sensor model, the probabilities of detection, recognition, and identification are calculated for that particular object. No matter how many objects of that type are present in the target, they will all have the same probabilities of detection, recognition, and identification.

However, each object is considered individually, in that a random number is drawn for each object to determine whether it is detected. If so, another random number is drawn to determine recognition, and if recognition is indicated, a third random number is drawn to determine identification. Additional random numbers are drawn to determine whether recognitions and identifications are made correctly. If there are between 30 and 150 objects of the same type within a target, they are considered five at a time. For between 150 and 300, they are determined 10 at a time, and above 300, they are determined 20 at a time. After the individual sensors have looked at an object, the performance of the system of combined sensors is determined.

A target is considered detected for report purposes if any sensor sights enough objects at a sufficient level of detail to satisfy the report criterion. If the target is detected, the time of delivery of the information to the intelligence center is calculated. After processing the targets contained in each RS area, the number of false targets to be included in that area is determined, and the false targets are generated.

At the end of each flight, the Control Copy for that flight is printed out, as is the target aggregation information for that flight.

At the end of the last flight, all of the target reports are ordered in terms of their arrival times to the intelligence team, and the Intelligence Copy is printed out in that order.

The remainder of Sec. II.B. is devoted to the discussion of the primary topics (except target location accuracy) modeled in CRESS-A. At the conclusion of the discussion for each topic a reference is made to the subroutines listed in Fig. 3 that are germane to that particular topic. The lengthy mathematical presentation of the routines for computing location accuracies is written as Stanford Research Institute's Technical Note CAD-TN 5205-15, "The Covariance of Position Location."

2. Attrition

Not every reconnaissance mission is successfully completed. Sometimes the observation platform is destroyed by enemy action, while on other occasions some critical component may fail, causing partial or complete failure of the mission.

CRESS-A provides for the simulation of failures of four types of items: the platform itself, the navigation system, the sensors, and the data links. The user is required to furnish the mean-time-between-failures (MTBF) for each platform, navigation system, sensor, and data link that is available in the scenario. A time to next failure (TNF) is calculated from each MTBF as follows.

It is assumed that each failure mechanism fits a Poisson distribution. That is, the expected TNF is independent of the point from which time is being measured.

The Poisson distribution is given by $p(\lambda,t) = \lambda e^{-\lambda t}$, where t = time and $\lambda = 1/\mu$, where μ = the MTBF. It is more convenient to work with the cumulative representation where

$$P(\lambda,t) = \int_0^t \lambda e^{-\lambda x} dx = 1 - e^{-\lambda t} \quad .$$

This is the probability that a failure occurs by time t, given λ. Or, given λ and a random number n, $0 \leq n \leq 1$, the TNF, T, is given implicitly by $n = 1 - e^{-\lambda T}$. From which we get,

$$T = \frac{1}{\lambda} \log\left(\frac{1}{1-n}\right)$$

$$T = \mu \log(1/(1-n)) \quad .$$

In considering the possibility of platform loss because of enemy action, each target is assumed to have a certain propensity to fire on any reconnaissance aircraft flying within range. For each target in the scenario, the user must provide the probability that the target will fire at any platform within range, (a) given that the platform first fires upon the target, and (b) given that the platform does not fire on the target.

As each target is encountered, the slant range distance between the platform and the target is compared with the maximum firing range of the target. If the platform is within the range of the target, the response of the target is ascertained (does it fire?) by drawing a random number and comparing it against the appropriate probability of target response. Probability (a) above is used when the reconnaissance mission is employing reconnaissance by fire at the time of target encounter. Probability (b) is used in all other cases.

If the target fires on the platform, each element in the target capable of AA fire gets one single-pass opportunity to destroy the platform. The outcome of that one opportunity is dependent on the firing range of the particular object firing and the probability that that type of weapon will destroy the type of platform being flown.

All failures are noted by messages that appear to have originated at the time of failure. These messages are then printed out on the Intelligence Copy at the appropriate time.

Pertinent subroutines are FAILTM, ACKACK, TURNAA, ATRIT and FAILMS.

3. Reconnaissance by Fire

CRESS-A provides for the utilization of reconnaissance by fire (RBF). In this case, the user specifies that RBF is one of the sensors to be placed on the platform and then indicates for each RS area of the flight whether RBF is to be used in that area.

When used, it is assumed that the platform brings under fire a swath as wide as the firing range of the platform. Each target responds according to its probability of firing at a platform, given that it (the target) is first fired on by the platform. If the random number draw indicates return fire from the target, it is reported as detected.

Pertinent subroutines are ACKACK and TURNAA.

4. Target Masking

Four causes of target masking are considered in CRESS-A: terrain masking, cloud masking, vegetation masking, and camouflage nets. While all sensors are blocked by terrain masking, radar sensors can penetrate clouds, IR sensors can partially penetrate vegetation masking, and both IR and radar sensors can penetrate camouflage nets. The basic masking parameters are determined on a target-by-target basis and IR and radar sensors are allowed to penetrate that masking as appropriate.

Random numbers are drawn before any sensor processing to determine the numbers of objects that will be in line of sight for sensors in each spectrum. Only those objects having line of sight for the particular type of sensor will be processed for that sensor.

If the line of sight probabilities were included in each of the sensor-generated probabilities and then random numbers drawn to determine the number of objects seen by each of the sensors (as many reconnaissance models do), it would be possible for one sensor to sight many objects of a target because of a lucky random number draw while another sensor of about the same capability and on the same aircraft sighted only a few. If this happens when the probability of line of sight is low, an inaccurate simulation of the aircraft reconnaissance system results for that target. This circumstance is avoided in CRESS.

5. Personnel

As each target is processed for possible sighting, it is necessary to know how many of each object type are included in each target. Part of this information is prepared beforehand and is read from data cards. However, data for personnel and camouflage nets need further consideration.

The number of personnel in each target is read from data cards, but there is no indication as to what these men are doing--are they standing, in foxholes, riding in vehicles or other? To allocate personnel correctly to various physical stances, reference is made to a table called MENARY (see Section II.D). This array indicates the percentage of personnel in each of five stances (standing, prone, slit trench, foxholes, or vehicles) for each of 16 postures (e.g., hasty retreat, prepared position, forward march). Each target is identified as to its posture, and the personnel are divided into the appropriate categories.

MENARY also indicates what percentage of the personnel in each stance are under camouflage nets, and an entry in the user prepared target variable array (TARVAR) indicates the same for the equipment in each target. From this information, the number of camouflage nets of various sizes is determined for each target.

The pertinent subroutine is TAROBJ.

6. Shadows

The presence or absence of shadows can affect the probability of detecting an object by sensors that use the visual range (cameras, eyes, and binoculars). CRESS-A recognizes the possibility that it may be an object's shadow, rather than the object itself, that is detected. The length of the shadow may be thought of as having a north-south component and an east-west component.

The north-south component will vary according to the time of year and the latitude of the object. However, it is not a function of the time of day. For example, if one has a wall running in an east-west direction, the shadow line cast by the top of the wall remains the same distance from the wall all day long. That distance will of course be different on different days of the year and at different places on the globe. The program requires the day of the year and the latitude of the center of the scenario to calculate the approximate north-south component of the shadow.

The east-west component of the shadow depends on the time of day or the deviation of the sun from a noon position. The deviation at a given hour will not be the same for every place on earth every day of the year. However, if the number of minutes of daytime for a given place on a given day are known and if the time of day is expressed as the number of minutes before or after noon, the deviation of the sun from a noon position (and thus the east-west component of the shadow) can be calculated. Only the number of minutes of daytime must be given. The computer calculates the number of minutes from noon after it calculates the time of the target sighting.

If the calculated shadow length is over five times the height of the object, the shadow is ignored and detection is calculated on the basis of the object alone. It is felt that if the shadow is over five times the length of the object that shadows of natural objects will make detection of the target object's shadow unlikely.

Permanent subroutines are SHADOW, CLCMYN, and SENSP.

7. Incorrect Target Reports

In discussing the "sensor" performance represented in this model, what is really being discussed is the process of looking at an area by a sensor and interpreting the results of those looks, thus including the role of a human interpreter. The following are possibilities:

a. Sensor-interpreter correctly detects presence of target object; interpreter correctly identifies object.

b. Object correctly detected, but incorrectly identified.

c. Sensor-interpreter fails to detect presence of object.

d. No object present, interpreter assigns object type to false target.

e. No target present, no report made by interpreter.

Cases a, c, and e are those usually covered in a reconnaissance model. This model also includes case b, referred to as the misidentification possibility, and case d, referred to as the false target possibility.

Actually, this model considers two aspects of case b: misidentification and misrecognition. Misdetection was not included on the reasoning that the likelihood of such a gross error would be reduced greatly by the context of the target location and that uncertainty at that low a level of discrimination would often be reflected in the failure of the interpreter to issue any report at all. This was a subjective judgment on the part of the analysis team and one that might be changed by further research on the performance of image interpreters.

Since, for example, it is unlikely that a truck would be misidentified as an airplane, but might be misidentified as an APC, misidentifications are allowed only between objects of the same recognition group. Similarly, misrecognitions are allowed only between objects of the same detection class.

A possible grouping of objects into recognition and detection groups is shown for those objects having their characteristics catalogued in Appendix A.

The probability of misidentifying or misrecognizing an object was obtained as follows. First, an SRI staff member experienced in image interpretation was presented the following problem.

> Suppose that you have correctly detected an object (which is really a T-62 tank). There are three possibilities open to you: (a) you may correctly recognize the object, (b) you may incorrectly recognize the object, or (c) you may say you have only detected it and not assign it to a recognition class. Given "average" conditions and given that there is a .5 probability for possibility (a) (i.e., correct recognition), what probability would you assign to possibility (b) (i.e., misrecognition)? Remember, the probabilities assigned to possibilities (a), (b), and (c) must sum to 1.0.

His answer, say .2, was taken as the average probability of misrecognizing a T-62 tank in all likely background settings. The same type of question was asked for the identification level, where it was now given that the object (really a T-62 tank) was correctly recognized and the probability for correct identification was fixed at .5. His answer, say .3, was taken as the average probability of misidentifying a T-62 tank.

These same two questions were asked for each type of object in the object characteristics list, and the results were entered on data cards and in Appendix A of the User's Handbook.

It would seem reasonable that the number of items misrecognized and misidentified would depend on the viewing conditions, the distance of the object from the sensor, and so forth. Therefore, the average probability of misrecognition is used as the basis for simulating an actual probability of misrecognition that varies from target to target.

The mathematical model for each of the sensors calculates a "performance number" representing the consequences of the physics entailed in considering geometry, environment, and object and sensor characteristics. This performance number is entered into an empirically derived curve representing the interpreter's capability of correctly recognizing the object under the prevailing conditions (see Appendix B). The higher the performance number, the higher the probability of recognition. In considering the misrecognition process, it is argued that a high performance number and a high probability of recognition imply a low probability of incorrect recognition. In the limiting case, the probability of misrecognition should be zero when the probability of correct recognition is one.

Similarly, it is argued that the lower the performance number and probability of correct recognition, the higher will be the ratio of misrecognitions to correct recognitions. However, that ratio remains finite; the probability of misrecognition becomes zero as the probability of correct recognition becomes zero.

Given these arguments, plus the fact that when the probability of recognition is .5 the average probability of misrecognition has been defined, it is possible to construct a simple model of the misrecognition process.

Consider the following relation between the probability of misrecognition (PMR) and the probability of correct recognition (PR).

$$PMR = K \cdot PR(1 - PR)$$

where K is some constant to be determined.

This formula satisfies the above requirements. It is seen that the ratio of misrecognitions to correct recognitions increases as PR decreases, as required by the argument made above.

$$\frac{PMR}{PR} = K(1 - PR) .$$

However, the actual number of misidentifications is zero when PR is either zero or one, also required by the above arguments.

The constant K can be determined as follows.

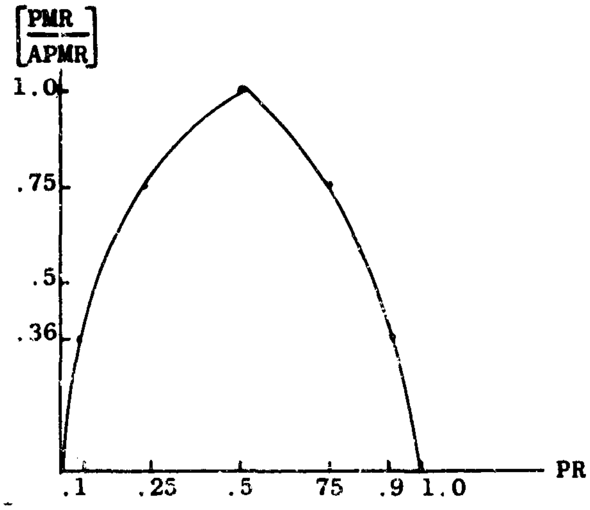
$$\text{The average probability of misrecognition (APMR)} = PMR\Big|_{PR = .5}$$

$$= K(.5)(1.0-.5)$$

$$APMR = .25K$$

$$\text{Therefore,} \quad K = 4(APMR) .$$

The relationship PMR = 4(APMR)(PR)(1 - PR) thus satisfies the arguments made above for the misrecognition process. It is shown graphically below, normalized to 1.0 at PR = .5 by the constant $\frac{1}{APMR}$.



The same arguments applied to the case of misidentifications lead to the following expression for the probability of misidentification:

$$PMI = 4(APMI)(PI)(1 - PI)$$

where PI is the probability of correct identification in a given situation and APMI is the average probability of misidentification analogous to APMR.

Returning to the example of the T-62 tank, suppose that the probability of recognition is .15 in a given situation. The probability of misrecognition in that case would be

$$
\begin{aligned}
PMR &= 4(.2)(.15)(1 - .15) \\
&= .8(.15)(.85) \\
&= .102 \quad .
\end{aligned}
$$

The ratio of misrecognitions to correct recognitions would be

$$
\begin{aligned}
\frac{PMR}{PR} &= \frac{.102}{.15} \\
&= .68 \quad .
\end{aligned}
$$

If instead the probability of correct recognition were .85, then the probability of misrecognition would be

$$
\begin{aligned}
PMR &= 4(.2)(.85)(1 - .85) \\
&= .8(.85)(.15) \\
&= .102 \quad ,
\end{aligned}
$$

the same as above. However, the ratio of misrecognitions to correct recognitions would be only

$$
\begin{aligned}
\frac{PMR}{PR} &= \frac{.102}{.85} \\
&= .12 \quad .
\end{aligned}
$$

As the results of further research become available, the user may be able to provide better estimates of the average probabilities of misrecognition and misidentification for each object.

If the user wants to include the possibility of mistaking decoys for real targets, the decoys must be included in the list of objects and located in the scenario as any other object must be.

For war gaming purposes, it is desirable to have the reports of false targets be indistinguishable from the reports of true targets. Therefore, CRESS-A uses true targets as the basis of any false targets that may be generated. As a true target is detected, an entry is made in a reference table called FLSTYP (FaLSe target TYPes). This table includes the recognition group number of each object that is detected in the true target and the sensor or sensors that detected that object. Thus, FLSTYP becomes a table of representative target types or feasible target compositions for false targets.

Each time a false target is to be generated, reference is made to this table, an entry is selected, objects are selected for reporting, and the sensor or sensors "detecting" each object is/are obtained from the table.

The table FLSTYP is reconstructed for each RS area so that the false targets will be similar to true targets in the same area. While false targets should be similar to true targets, there are also some limitations that must be realistically imposed on any false target. For example, while it is reasonable that one tank or three men will be reported when there was no true object present, it is highly unlikely that 10 tanks or 100 men will be so reported. Therefore, the number of any particular type of object and the total number of false objects in any one target are limited by the numbers determined by the user and input to the program (see Sec. II.E of the User's Handbook for further discussion of these numbers).

The false targets are further restricted in size by allowing a maximum of four types of objects to be included in any one false target.

Another restriction on false targets is that the sighted elements are reported only at the recognition level. This restriction is imposed since it is assumed that (1) an object detected under good enough conditions to cause the image interpreter to try to identify it will be seen in sufficient detail to determine whether it is a bona fide military target element, and (2) an object detected under such poor conditions that only detection is possible cannot be determined to be a military target element, unless other information is available.

Reference 1 indicates that the number of false targets reported for an RS area will depend on (1) the image interpreter's prior expectation of finding a target in the area, and (2) the number of targets he finds in the area. CRESS-A accounts for these two factors by using the following formula to determine the number of false targets to be generated for an RS area:

$$f = n + (n + t) \cdot p$$

where $f \equiv$ number of false targets generated for the RS area,

$t \equiv$ number of real targets detected in the RS area,

$p \equiv$ the expected percentage of false targets for the entire scenario area; supplied by the user.

and

$$n = \begin{cases} 1 & \text{if a random number draw is less than the prior expectation that a target will be detected in the RS area} \\ 0 & \text{otherwise.} \end{cases}$$

Pertinent subroutines are MISGRP, DETECT, MISID, MISREC, PROCES, and FLSTGT.

8. <u>Multisensor Viewing</u>

Research on reconnaissance models has to date focused on the role of individual sensors. However, many potential users of CRESS may be more interested in the information produced by the combination of sensors than in the performance of any sensor in particular. Therefore, SRI is placing greater emphasis on the system of sensors employed on a given mission. Consistent with this, considerable attention has been given to improved methods of determining the probabilities and numbers of objects seen by the multisensor combination.

Since sensors using different parts of the electromagnetic spectrum are sensitive to different characteristics of an object, it is possible that one type of sensor may detect an object while another may not. For the purposes of nomenclature for this section, mapping and MTI radars will be considered as using different parts of the spectrum, since they depend on different characteristics of an object to detect it. It is also possible that neither sensor could detect (or recognize) the object by itself, but by considering the characteristics observed by both sensors, it is possible to detect (recognize) the object. It is also possible that when an object is first detected by one sensor, a second sensor may then be used to add to the information provided by the first sensor. For example, a radar may detect a metal object and a pair of eyes, which had not previously noticed the object, may now be able to tell what type object it is. These are examples of multisensor (or more correctly, multispectral) enhancement.

A possible gain of information may also be attained by using two or more sensors of the same spectrum instead of one. For example, it is possible that two pairs of eyes will detect more objects than either pair viewing an area alone. If a user wishes to place two or more sensors of the same type (e.g., visual) in a reconnaissance airplane, he may do so by repeating the sensor name (VIS) for each observer--up to the maximum number of four.

The effect of doing this would be to allow each sensor an independent look at each object. This effect is calculated by the formula from classical statistics for independent trials,

$$P_i = 1 - \prod_{j=1}^{n} (1 - p_j)$$

which, in the case of multiple sensors of the same type, would be

$$P_i = 1 - (1 - p_0)^n ,$$

P_i being the probability that at least one independent look is successful, P_0 being the probability of sighting by one sensor alone, and n being the number of sensors of the same type employed.

However, in the case of multispectral enhancement, it is presumed that two sensors employing different spectra will together see more than is accounted for by each of them viewing the scene independently. This is an example of the phenomenon of synergy.

This might be represented as the above formula for independent looks, modified by an enhancement factor, Q:

$$P_m = 1 - \prod_{j=1}^{n} (1 - p_j) Q$$

where P_m is the probability of sighting by the multisensor system.

If Q is less than 1.0, P_m will be greater than P_i. It would be desirable to split this enhancement facto into subfactors, $(1 - q_j)$, that are dependent on the particular sensors used. A representation employing q_j in the same manner as the p_j would then be possible as follows:

$$Q = \prod_{j=1}^{n} (1 - p_j)$$

or,

$$P_m = \prod_{j=1}^{n} (1 - p_j) \prod_{j=1}^{n} (1 - q_j)$$

Honeywell, Inc. (Ref. 2), has performed research to quantify these q_j for various sensors. They have found that the following representation gives good results:

$$q_j = \exp(p_j - 1)/K_s)$$

where the K_s depend on the spectrum being used and the type of object being viewed.

Values for the K_s, determined by the Honeywell research, are found in Table 4. An example showing the use of that table follows.

Suppose that a regular camera and an IR line scanner both produce film containing images of the same tank (tracked vehicle). Further suppose that the probabilities of detection for the camera and IR are .2 and .3 respectively. Also assume that the probabilities of recognition and identification for each sensor are zero. Then the combined probability of detection due to independent looks is:

Table 4

MULTI-SENSOR IMAGERY INTERPRETATION WEIGHTING OR ENHANCEMENT COEFFICIENTS[a]

		I	I	I	I	I	I	I	I	I	I	I	I
		6	12	18	24	30	36	42	48	54	60	66	72
	Target-Element Types	Detection Coefficient Ks				Recognition Coefficient Ks				Identification Coefficient Ks			
		Photo	IR	Radar (non/MTI)	MTI	Photo	IR	Radar (non/MTI)	MTI	Photo	IR	Radar (non/MTI)	MTI
1	Personnel	60	40	0	0	80	20	0	0	90	[illegible]	0	0
2	Small Vehicle	30	30	20	20[b]	60	30	10	0	90	10	0	0
3	Wheeled Vehicle	30	30	20	20	60	30	10	0	90	10	0	0
4	Tracked Vehicle	40		10	20	60	30	10	0	90	10	0	0
5	Artillery	40	[illegible]	10	20	80	20	0	0	90	10	0	0
6	Hand Carried Weapons	80	20	0	0	95	05	0	0	95	05	0	0
7	Missile, Rocket, Launcher	40	30	10	20	80	[illegible]	0	0	90	10	0	0
8	Boat	[illegible]	30	30	10	50		25	0	80	20	0	0
9	Helicopter	40	40	20	0	70	30	0	0	90	10	0	0
10	Aircraft	30	40	30	0	70	30	0	0	90	10	0	0
11	Structure	40	40	20	0	60	20	20	0	70	20	10	0
12	Terrain Features	[illegible]	10	60	0	50	10	40	0	50	0	50	0
13	Animal	50	50	0	0	80	20	0	0	90	10	0	0
14	Long Linear Element	30	30	40	0	50	25	25	0	70	15	15	0
15	Surface Opening	35	60	05	0	60	40	0	0	80	20	0	0

a. The coefficients are multiplied by .01 when read into the computer.

b. Non-zero values for MTI apply only when elements are moving at speeds above minimum detectable thresholds.

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$$P_i = 1 - (1 - .2)(1 - .3)$$
$$= .44 \quad .$$

From Table 4, $K_1 = .4$ (detection, photo, tracked vehicle) and $K_2 = .3$ (detection, IR, tracked vehicle). Then

$$q_1 = \exp(2(.2 - 1.0)/.4)$$
$$= .0183$$

and

$$q_2 = \exp(2(.3 - 1.0)/.3) \quad .$$
$$= .0094$$

So,

$$Q = (1 - .0183)(1 - .0094)$$
$$= .9725 \quad .$$

Then, the combined probability of detection due to both independent looks and multispectral enhancement is

$$P_m = 1 - (.56)(.9725)$$
$$= .46 \quad .$$

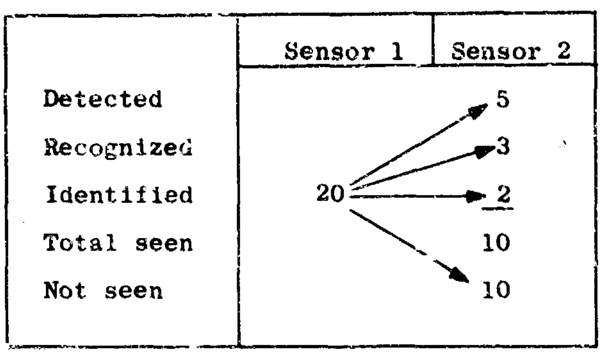
This is .26 better than the camera alone, and .16 better than the IR sensor alone. About 10 percent of this improvement came from the synergistic effect of having two sensors employing different spectra; the rest came from the independent looks aspect of having two sensors view the same object.

In general, the independent look aspect of multisensor viewing is more complicated than in the above example. This is because all three levels of viewing (detection, recognition, and identification) must be considered at the same time. By way of illustration, consider the example of two sensors each looking at the same 100 objects, yielding the results shown below.

	Sensor 1	Sensor 2
Detected	40	25
Recognized	20	15
Identified	20	10
Total seen	80	50
Not seen	20	50

Applying the formula for independent looks, one would expect that a total of 90 of these 100 objects would be seen by at least one of these two sensors and that there would then be 40 objects seen by both sensors. One would now ask how are those 40 common objects allocated among the nine possible common-pairs (e.g., recognized by sensor 1 and also identified by sensor 2)?

Recalling the independent* nature of the two sensors, one would expect the 20 objects identified by sensor 1 to be allocated as follows.



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* This independence assumes that the objects detected by one sensor will be distributed among detections, recognitions, identifications and not seen for the second sensor in the same proportions as the 100 objects were distributed by that second sensor.

Similarly, the allocation of the objects recognized and detected by sensor 1 can be determined. This is summarized in Table 5 below.

Table 5

CORRELATION OF SIGHTINGS

Sensor 2	Sensor 1				
	Detected	Recognized	Identified	Not Seen	Total
Detected	10	5	5	5	25
Recognized	6	3	3	3	15
Identified	4	2	2	2	10
Not seen	20	10	10	10	50
Total	40	20	20	20	100

This indicates that of the 10 objects identified by sensor 2, two were identified by sensor 1, two were recognized by sensor 1, four were detected by sensor 1, and two were not seen by sensor 1. Since only two of the 20 objects identified by sensor 1 were also identified by sensor 2, there were a total of 28 different objects identified by at least one sensor.

In determining the number of objects recognized (but not identified) by at least one sensor, one must be sure to exclude those objects that were identified by either sensor. By doing this, one can count 27 objects whose highest level of sighting is recognition by at least one sensor. Similarly, one can count 35 different objects whose highest level is detection. This accounts for all 90 objects expected to be seen by at least one sensor.

These same values (OMD = 35, OMR = 27, OMI = 28) could have been calculated by applying the formulas:

$$OMI = O1I + O2I - O1I*O2I$$

$$OMR = O1R*(1 - O2I) + O2R*(1 - O1I) - O1R*O2R$$

$$OMD = O1D*(1 - O2R - O2I) + O2D*(1 - O1R - O1I) - O1D*O2D$$

where O refers to object; M refers to the multisensor system; 1 refers to sensor 1; 2 refers to sensor 2; and D, R, and I refer to detection, recrognition, and identification, respectively.

By considering cumulative objects (i.e., objects identified are also considered recognized and detected; objects recognized are also considered detected) and making the following substitutions:

$$O1D' = O1D + O1I$$

$$O1R' = O1R + O1I$$

and similarly for sensor 2, the above formulas reduce to:

$$OMI = 1 - (1 - O1I)(1 - O2I)$$

$$OMR = 1 - (1 - O1R')(1 - O2R') - OMI$$

$$OMD = 1 - (1 - O1D')(1 - O2D') - OMR - OMI \quad .$$

In CRESS-A, these formulas were not used in determining the number of objects seen by the multisensor combination because of the increased realism introduced by allowing stochastic variations in the allocation of objects based on drawings from upper geometric distributions. (Note that the above example was discussed in terms of <u>expected</u> values for purposes of exposition.)

The multisensor probabilities however, were calculated by using the formulas indicated and substituting the probabilities of the individual sensors for the numbers of objects used above, since the probabilities are not modified by stochastic variations.

It is stressed that these formulas apply only to the independent look aspect of multispectral viewing. The additional objects seen because of synergistic effects still need to be determined. It is possible simply to draw random numbers against the combined probabilities, but this is not an optimal procedure because the random number draws of the individual sensors might have been below the mean while the draws of the combined system might have been above the mean. This would simulate a synergistic enhancement larger than appropriate. The situation might also be reversed, in which case, there might be no synergistic enhancement. Therefore, an appropriate differential probability representing the synergistic enhancement is used to determine if any of the objects not yet detected by any sensor might be detected because of that differential probability. That appropriate differential probability, P_s, is, for a given level of sighting:

$$P_s = \frac{P_m - P_i}{1 - P_i} = 1 - Q \quad ,$$

where P_m, P_i, and Q retain their earlier definitions.

Random numbers are drawn and compared with this P_s for those objects not seen by independent looks. Any resulting objects are added to the objects seen by the independent looks to determine the total number of objects seen by a particular system of sensors.

A new way of looking at the set of objects available for viewing by the system of sensors has been developed in CRESS.

Since some sensors can penetrate masking that is opaque to other sensors, a method was devised to divide the objects in a given target into several nonoverlapping groups. The most frequent situation is as follows: one group contains those objects that may be seen by all sensors; another contains those that may be seen only by radar and IR sensors (both types sense through camouflage nets). Yet another contains those objects that may be seen only by IR sensors (IR has some capability through foliage).

After these groups have been formed, they are each reduced in size by line-of-sight considerations for the appropriate group; those objects that are masked and are not considered any further.

Each of these groups is processed for multisensor viewing as appropriate. In the first group, enhancement may come from all sensors; in the second, only from radar and IR; and in the third, no enhancement is possible since only one class of sensor may view those objects. Finally, the objects seen from all three groups by the multisensor combination are added and reported together. Similarly, the multisensor probabilities reported are weighted averages of the probabilities derived for each of these three groups.

Pertinent subroutines are PROCES, BRGRD, OBJSET, and MULTI.

9. Target Aggregation

Once items of military significance have been detected, it might be of interest to identify those items that are part of a larger group of items. For example, it might be helpful to an intelligence team to recognize that several groups of trucks and APCs sighted at different locations are all part of the same battalion. While it would be unrealistic for a simulation to state unequivocally that certain targets are part of the same battalion, a step in that direction can be taken legitimately by indicating which elements are close enough to each other possibly to be in the same battalion.

This model provides for the aggregation of reported target elements within each of five different radii. For any radius selected, the program looks at a reported group of target elements and reports all reported groups of target elements that are within that distance (the radius of interest) of the first group. This group of target elements is called a cluster. It then does the same for another reported target element group, and so on until all reported target element groups have been so treated.* This process is then repeated for each radius of interest.

Only those targets noted in the Intelligence Copy are considered. The basis for deciding whether a pair of targets is within the required distance of each other is their reported position, which may differ from the actual position because of navigation or map errors.

The intelligence team may then take this mechanical grouping of targets and determine--on the basis of target content, knowledge of the enemy, and the state of battle--which groupings have military significance.

Pertinent subroutines are AREA and AREAOP.

10. Timeliness Factors

The target reports included on the Intelligence Copy are sequenced in order of their simulated arrival at an intelligence

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* A target may be reported within more than one cluster. However, if one cluster is completely included within a more populous cluster of the same radius, the smaller cluster is not reported.

center. If the data processing begins after the platform returns to base, the arrival time of the data is calculated as follows:

Arrival time = time of landing + preliminary handling time + time required to process all imagery from flight + hard copy handling time + image interpretation time + report delivery time.

If the data are transmitted in real time from the platform, the arrival time is reduced:

Arrival time = time of target overflight + data transmission time + time required to process imagery taken to that point + hard copy handling time + image interpretation time + report delivery time.

All of the delay times are dependent on the sensor being employed. The image interpretation and report delivery times used are drawn from normal distributions whose means and standard deviations are specified by the user.

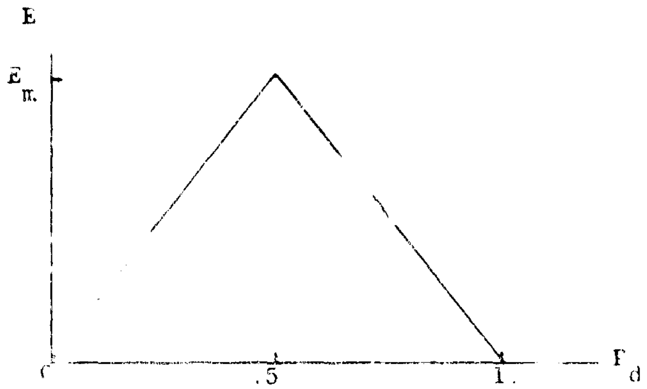
The pertinent subroutine is RPTTYM.

11. Enhancement of the Probability of Detection

Prior information may indicate that a target is in a specified area (e.g., a SIGINT report indicates the position of a surface-to-air missile unit, but with a two km CEP location inaccuracy). If an image interpreter is directed to search the film from a photo reconnaissance mission covering the indicated area, Ref. 1 indicates that his probability of detecting the target will be greater than if he were searching the same imagery without the prior information.

Each of the sensor models includes a curve representing an "average" interpreter's probability of detecting an object being processed under "normal" conditions for processing imagery. If the enhancement option is selected in CRESS-A, an enhancement increment E is added to the probability of detection calculated in the appropriate sensor model.

The rationale used in CRESS-A for the determination of E is similar to that for calculating misrecognition and misidentification. It is assumed that the interpreter's performance will vary most when conditions are such that he would normally have a .5 probability of detection (i.e., is a maximum, E_m, when $P_d = .5$) It is also assumed that no enhancement occurs when P_d is already at its maximum value or when conditions are so poor that $P_d = 0$. It is further assumed that the enhancement increment E varies linearly between $P_d = 0$ and $P_d = .5$, and also between $P_d = .5$ and $P_d = 1$. Hence, E can be depicted as the two line segments illustrated below,



and also expressed as

$$E = \begin{cases} 2\,E_m \cdot P_d \,, & P_d \le .5 \\ 2\,E_m(1 - P_d)\,, & P_d > .5 \end{cases}$$

where E_m is a user supplied value.

If the enhancement option is selected, P_d is replaced by $P_d + E$ and this enhanced probability of detection is used in determining the number of objects detected.

The assumptions were made in the absence of any known experimental determination of the enhancement increment. Experimental research is needed to find the enhancement increment as a function of the probability of detection.

The pertinent subroutine is PROCES.

C. The Ground Model, CRESS-G

1. General

CRESS-G is the portion of CRESS that simulates R & S performed from OPs, fixed elevated platforms, and patrols. This is accomplished by having the computer portion of the model prestore all the information generated by the manual work phase of the simulation and operate on this information to calculate the performance of each sensor in each OP when attempting to sight all the targets within the OP's field of view. It should be emphasized that the model performs this task in such a way that it is a simulation of the set of sensors in an OP versus a target and not a set of independent simulations of the sensors in the OP versus a target. The following discussion is a description of how the computer model simulates R & S activity and provides for equipment failures, attrition, misidentification and misrecognition of target elements, false targets, combined sensors (multisensoring), terrain masking, camouflage, target information received over time, report criteria, and time ordering of reports.

It is helpful to understand the order of processing before examining the various stages of which processing consists. This order is as follows:

a. CRESS-G processes OP by OP

b. Each OP is processed target by target

c. Targets are processed object by object

d. Objects are processed sensor by sensor and then by multisensoring

e. A control copy indicating sighting probabilities and objects sighted is written after each target is processed

f. After processing all targets covered by an OP, false targets are generated, for which a control copy is also written out

g. After all OPs are processed, the reports to the intelligence center are time ordered and printed

The order and stages in processing are given in some detail in the flow chart below.

CRESS-G COMPUTER MODEL FLOW CHART

Set threshold criteria for making reports (number of objects, number of special objects, percent of objects present).

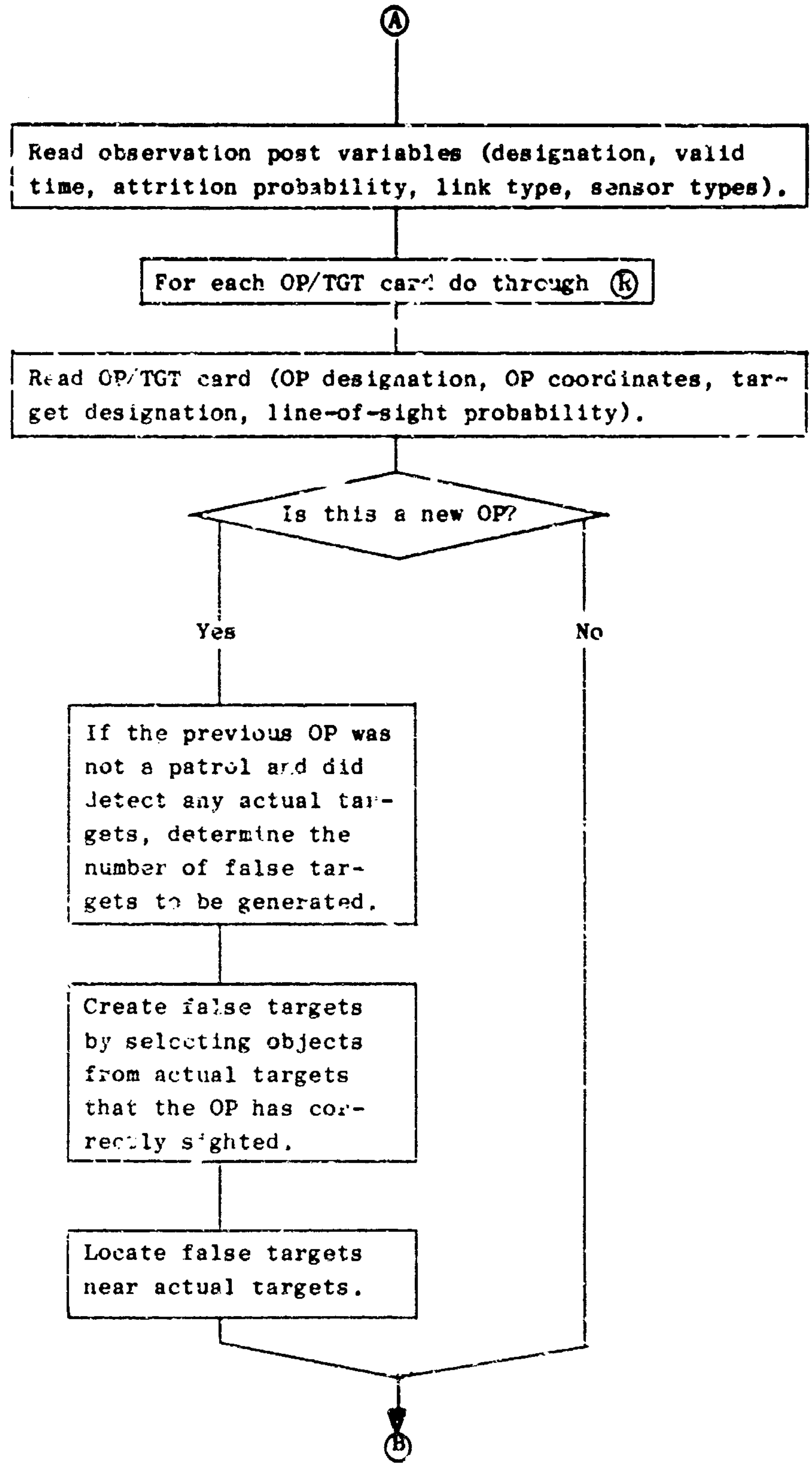
Read weather parameters; background parameters; object parameters; sensor detection, recognition, identification probability curves.

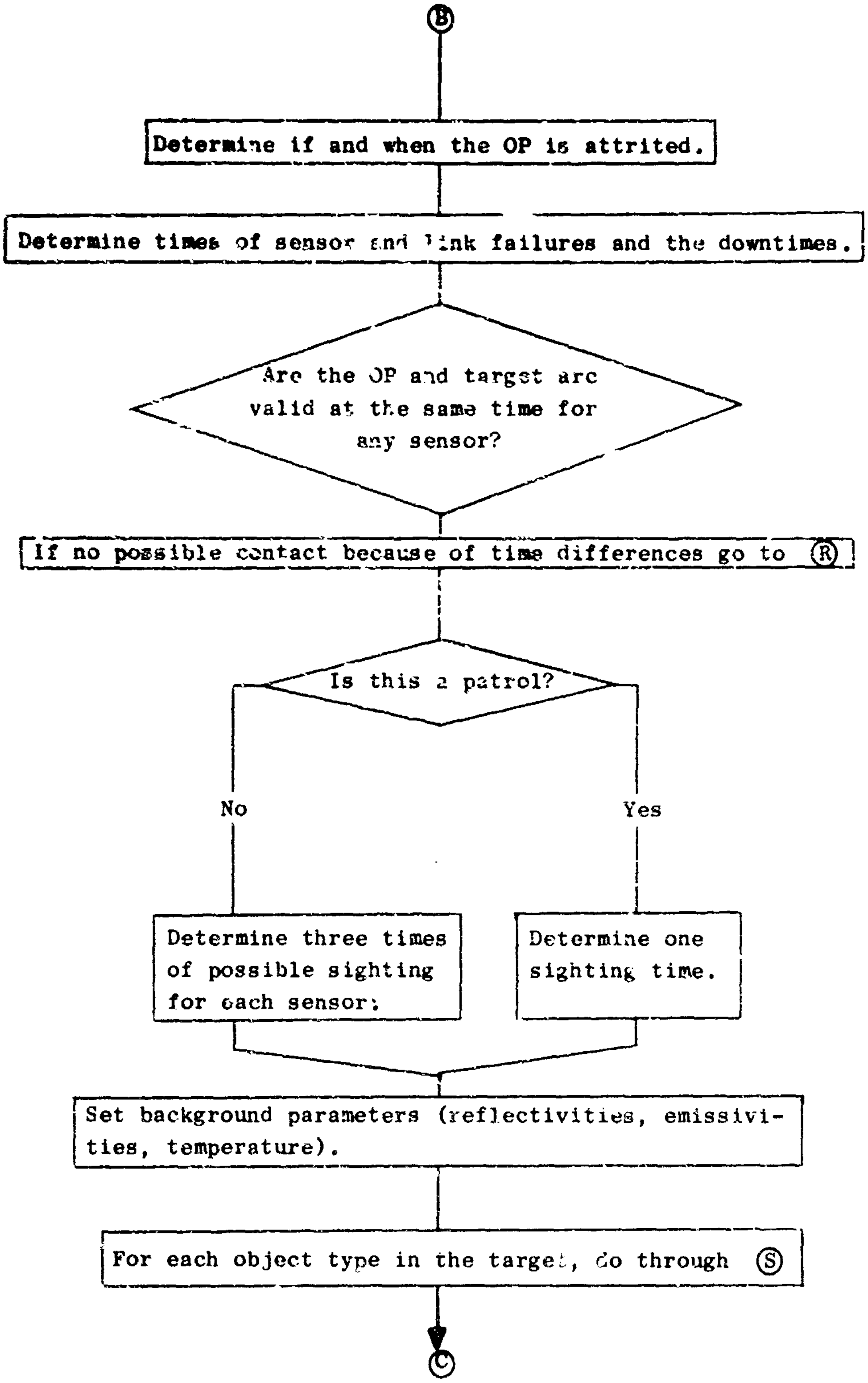
Determine object groupings into which each object may be misrecognized or misidentified.

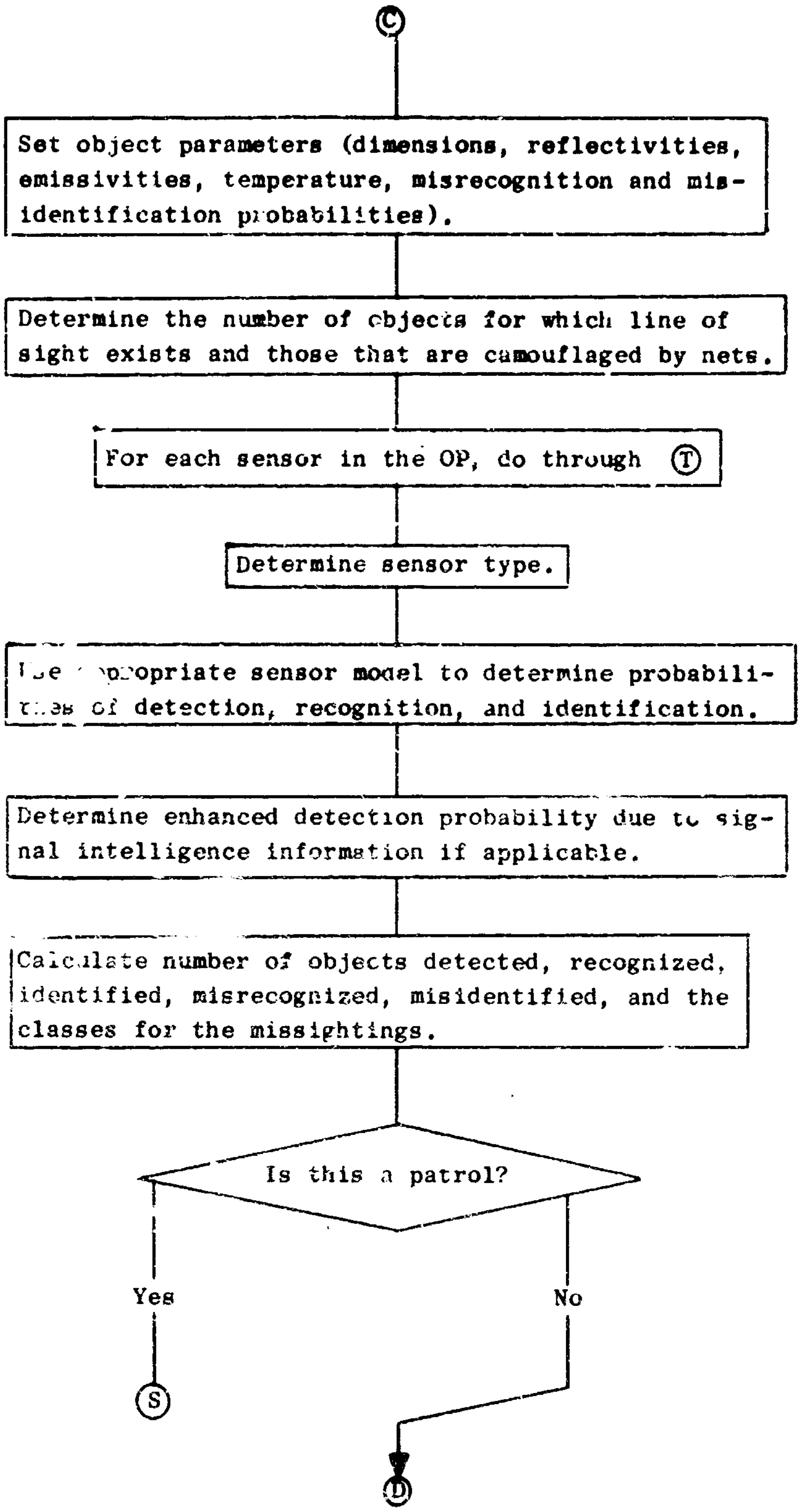
Read target variables (designation, valid time, location, speed, object-camouflage probability, background type).

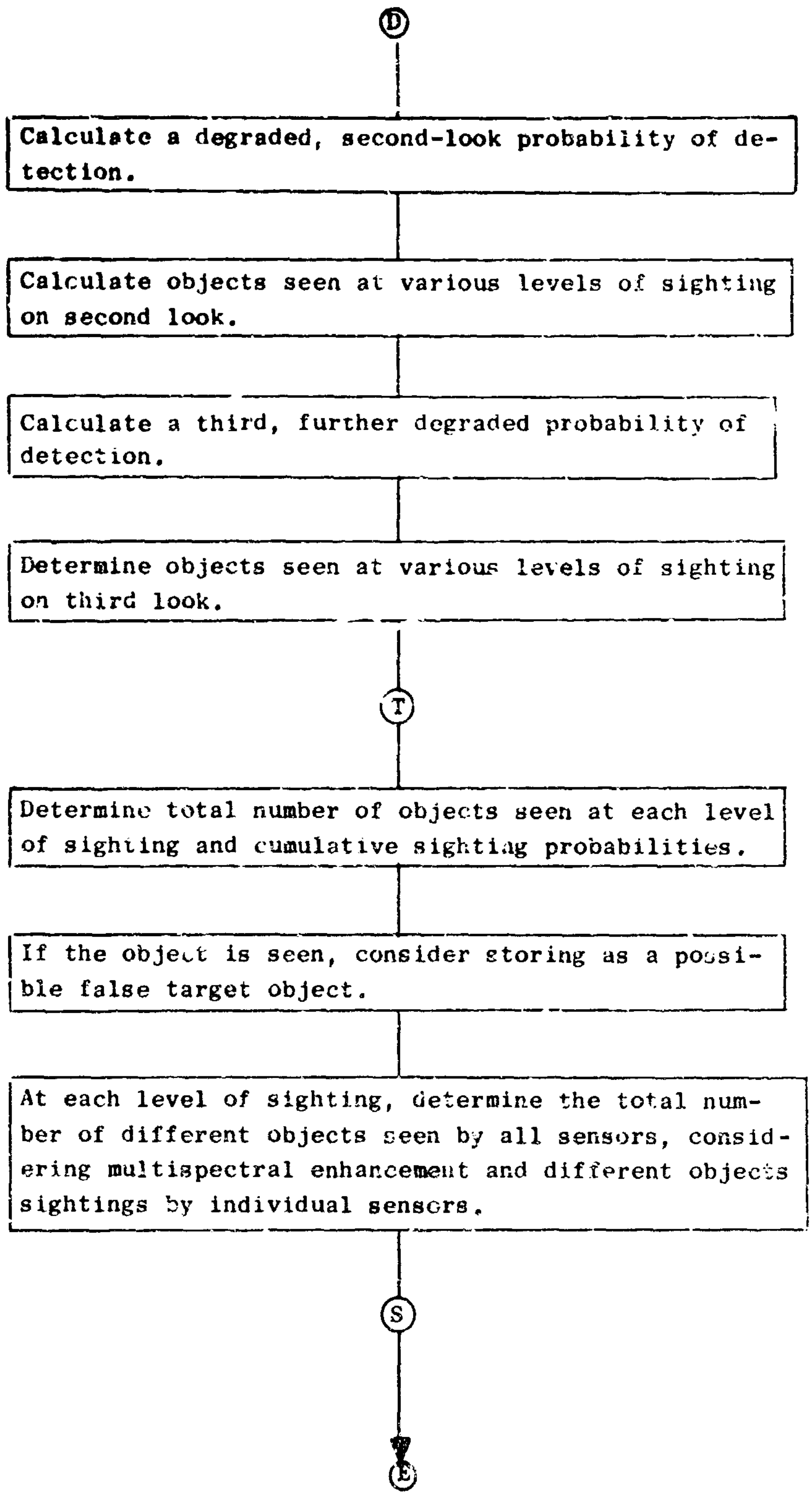
Read target objects (object types and numbers of each type).

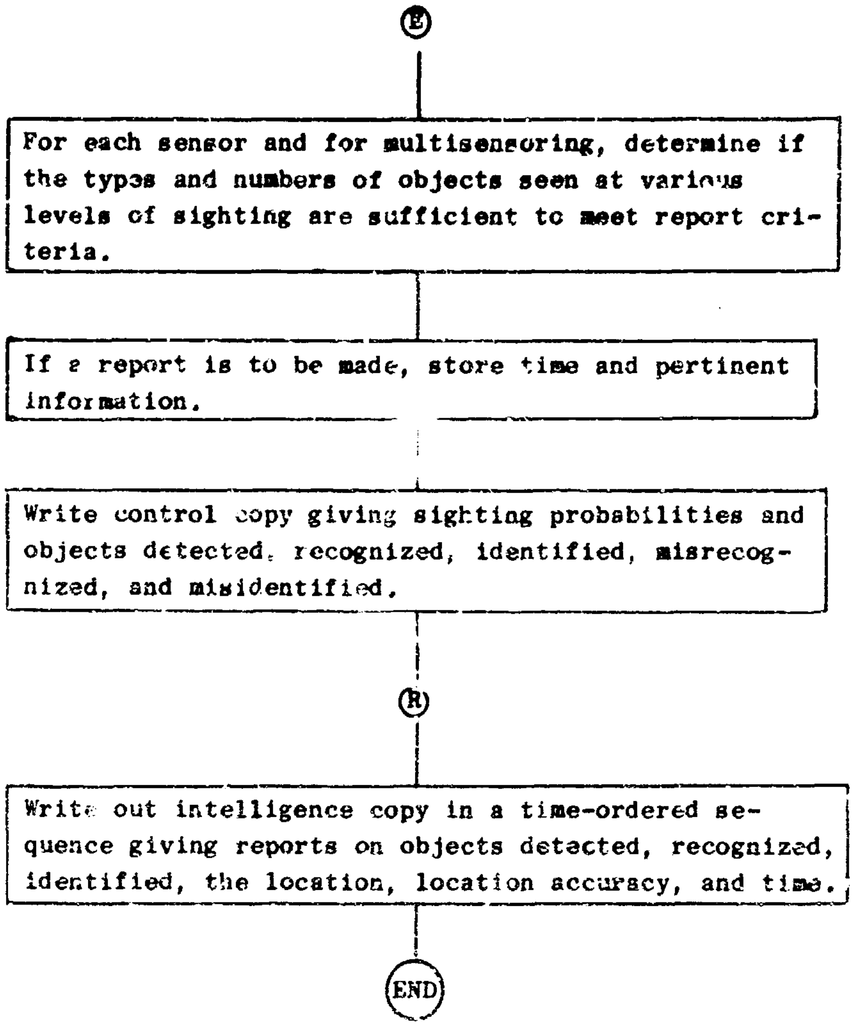
(A)


A
Read observation post variables (designation, valid time, attrition probability, link type, sensor types).
For each OP/TGT card do through K
Read OP/TGT card (OP designation, OP coordinates, target designation, line-of-sight probability).
Is this a new OP?
Yes
No
If the previous OP was not a patrol and did detect any actual targets, determine the number of false targets to be generated.
Create false targets by selecting objects from actual targets that the OP has correctly sighted.
Locate false targets near actual targets.
B


B
Determine if and when the OP is attrited.
Determine times of sensor and link failures and the downtimes.
Are the OP and target are valid at the same time for any sensor?
If no possible contact because of time differences go to R
Is this a patrol?
No
Yes
Determine three times of possible sighting for each sensor.
Determine one sighting time.
Set background parameters (reflectivities, emissivities, temperature).
For each object type in the target, do through S
C


C
Set object parameters (dimensions, reflectivities, emissivities, temperature, misrecognition and misidentification probabilities).
Determine the number of objects for which line of sight exists and those that are camouflaged by nets.
For each sensor in the OP, do through T
Determine sensor type.
Use appropriate sensor model to determine probabilities of detection, recognition, and identification.
Determine enhanced detection probability due to signal intelligence information if applicable.
Calculate number of objects detected, recognized, identified, misrecognized, misidentified, and the classes for the missightings.
Is this a patrol?
Yes
No
S
D


D
Calculate a degraded, second-look probability of detection.
Calculate objects seen at various levels of sighting on second look.
Calculate a third, further degraded probability of detection.
Determine objects seen at various levels of sighting on third look.
T
Determine total number of objects seen at each level of sighting and cumulative sighting probabilities.
If the object is seen, consider storing as a possible false target object.
At each level of sighting, determine the total number of different objects seen by all sensors, considering multispectral enhancement and different objects sightings by individual sensors.
S
E



2. <u>Main Program</u>

The routine CRESSG is the main program and serves to call the three main subroutines, SCENIN, PROCES, NTLGNT, that perform the various operations required for ground reconnaissance simulation.

After readying the disk for storage of information (subroutine RDYDSK), most of the data are read in through calling

SCENIN (SCENario INput data). Then all of the targets that each OP can possibly view are operated on by calling PROCES (PROCESs data), which determines what is sighted and writes out a control copy listing sighting probabilities and objects sighted. When the targets for all OPs have been processed, NTLGNT (Intelligence output data) is called to write out sighting reports from the OPs in a time-ordered sequence.

If it is remembered that PROCES is performed for each OP/TGT combination, the model, although long, is sequential. The following discussion follows this sequential line, with most topics discussed in order of occurence. Many of the operations in the ground model are accomplished in the same manner as in CRESS-A. When this is the case, the Aerial Model is referenced, and very little discussion is included herein. Figure 4 contains a list of all subroutines used and a notation indicating whether the routine is the same as for CRESS-A.

3. <u>Scenario Data Input (SCENIN)</u>

After RDWDSK has opened four files on disk in which to store the results of processing OP/TGT combinations for later printing, SCENIN is called to read in the scenario data. Data input is discussed in detail in Data Preparation, Section IIE, of this handbook.

SCENIN first calls subroutine RPTSET (RePorT switches SET), which sets switches determining the criteria to be used for making decisions on whether groups of sighted elements are to be reported on the Intelligence Copy. The routine is the same

```
MAIN

—RDYDSK*

—SCENIN  -  | RPTSET*
            | MISGRP*
            | RDTGTV*  -  | GROLOC*
            | TAROBJ*     | CONVERT
            | OPVAR

—PROCES  -  | FLSTGT ———————————————| CALTIM
            | CONVERT                | RPTTM  -  RPTTOC*
            | OPATRT  -  RPTTOC*     | OPTSTR
            | GDFAIL  -  RPTTOC*     | WRYTAL  -  | ALFCOR*
            | CALTIM*                             | CEPSNS  -  SEPSIG
            | GRDLOC*                             | CLKTIM
            | OBJSET
            | IR ————————| SIMPS
            | RADAR      | PBLAM
            | PNVD       | PTLAM
            | TV
            | VISUAL
            | LASER
            | IRBNOC
            | DETECT*  -  | MISID*
            | MULTI*      | MISREC*
            | RPTDEC* ——————————————| SIGHTS*
            | RPTTM  -  RPTTOC*     | SPCOBJ*
            | OPTSTR
            | WRYTAL   -   | ALFCOR*
                           | CEPSNS  -  CEPSIG
                           | CLKTIM

—NTLGNT*  - | ALFCOR*
            | CEPSNS  -  CEPSIG
            | CLKTIM
            | RECCEO*  -  BLDARY*
```

* Methodology very nearly the same as in CRESS-A.

Fig. 4 CRESS-G SUBROUTINE LINKAGE

as for CRESS-A. The settings on the report switches indicate whether any of the following criteria are being utilized:

- Threshold number of objects detected, recognized, and identified
- Threshold number of special objects detected, recognized, and identified
- Threshold percent of objects present detected, recognized, and identified.

The creation of groups of objects that delineate the set of objects into which each object may be misrecognized or misidentified is next accomplished by subroutine MISGRP (MISGRouPing) in the same manner as CRESS-A. The objects that each target contains are read in, personnel are divided into personnel in different kinds of stances (standing, prone, foxhole, or slit trench), and the number of camouflage nets of various types is determined. This is accomplished in TAROBJ (TARget OBJects), again the same as for CRESS-A.

SCENIN uses subroutine TGTVAR (TARget VARiables) to read in those target variable parameters needed by the ground model (designation, location, initial and final valid times, speed, percent of objects other than personnel under nets, background type). Subroutine OPVAR (OP VARiables) reads in the OP designation, location, initial and final valid times, link type, sensor types, and probability of attrition by the enemy.

4. Processing of OP/TGT Combinations

Once the scenario data are read in, the model begins to process this information by reading in an OP/TGT card (OP designation, OP coordinates, target designation, probability of line of sight between OP and target, OP height above ground if elevated, and the time that the OP is at this location if the OP is a patrol).

5. OP Attrition (OPATRT)

The first operation performed is to determine stochastically if the OP is attrited by enemy action, based on this OP's probability of attrition. If so, the time of attrition is set equal to some time between the OP initial and final valid times in a random manner, and this time is stored on disk for reporting. Time storage will subsequently be discussed in conjunction with the RPTTM routine.

6. Sensor and Link Failures (GDFAIL)

The times to next failure for the sensors and link are then determined. This is accomplished by using the MTBF, and a Poisson distribution, on the assumption that the expected time to next failure is independent of the point from which time is being measured. A complete discussion of the formulas used is included in CRESS-A (FLTIME).

The time when the sensors and links again become operative are calculated by drawing a random number from a normal distribution with a mean equal to the mean down time added to the failure time and a standard deviation of down time given by the user. This normal distribution draw is accomplished in NORM, which is identical to CRESS-A (NORM). Any of the link and sensor down times and up times that are less than the final valid time of the OP (or less than the attrition time if applicable) are stored away for reporting.

If a link failure occurs during the time that the OP is to be operating, the time at which the link again becomes operative is set equal to the minimum of the calculated link up time or the final valid time of the OP.

7. Timing Calculation (CALTIM)

With the information on attrition and failures now available, the model then determines the earliest time that the sensors are able to see the target (called the "contact" time). This will normally be the initial valid time of the OP or the initial valid time of the target, whichever is the time when both the OP and target become valid. If there is no overlap in the times and the OP and target are valid, again considering attrition times, the OP/TGT card is not processed further, and control is returned to the beginning of PROCES where a new OP/TGT combination is read.

Given the possibility of contact, a lost contact time is determined equal to the last time at which both the OP and target are valid. In the case of patrols, it is assumed that the contact occurs while the patrol is moving, and thus the contact time is the last contact time also. Since the ramifications of a sensor failure are considered, there are a total of four possible sensor report times: contact, lost contact due to sensor failure, regained contact, and lost contact, although the sensor may not make contact at all because of a failure.

In addition to the contact time already calculated, two more report times are determined at increments of time (specified by the user) beyond the first contact time. This second and third look capability will be discussed when the probabilities of detecting at these times are explained.

If a sensor failure occurs before the three looks have taken place, the third or second and third looks are assumed to take place at the specified increments of time beyond the time the sensor operation is restored instead of beyond the first look time. Of course, the computer checks to be sure the sensor has not lost contact permanently before these second and third looks.

5. Distance, Maximum Range, and Background

If contact is made, the model then begins to determine the number of objects seen by setting the distance between the OP and target. This is normally the difference between the two respective coordinate locations, but when the OP is elevated, the sighting distance is increased to account for this elevation. Also, elevated OPs require checking to determine if the maximum range is limited by the field of view of any of the OP (elevated platform) sensors, which would often occur if a sensor is pointed downward. In these cases, the range is set equal to the height divided by the cosine of the view angle of the sensor. If it is desired that an elevated sensor have a slewing capability and be able to see out to the horizon, its view angle should be set equal to 90 degrees when inputting sensor parameters.

Next the reflectivities, emissivity, and temperature of the target background are set, the latter depending on whether it is day or night.

9. Object Processing

The model now begins to process each of the object types within this target by setting the reflectivities, emissivities, temperature, probabilities of misrecognition and misidentification, and object recognition detection classes. The length and width of the object are set if the OP is elevated. Otherwise the vertical dimension and the average horizontal dimension are used.

10. Number of Objects (OBJSET)

The OBJSET routine determines how many objects of the type being processed can possibly be seen. Objects actually present are tested stochastically against the probability of line of sight between the OP and target to obtain the number of objects for which the OP has line of sight. Making the line-of-sight determination before any sensor calculations allows the model to simulate the group of sensors in the OP instead of individual simulations, as is the case in models where line-of-sight calculations are made independently. The OP simulation concept is important in determining multisensor effects. The number of objects having line of sight to the OP is then used to create two groups of objects, those that can be seen by sensors that cannot see through camouflage net and those that can be seen by sensors relatively immune to camouflage nets (radar and IR). This is accomplished by application of the probability of camouflage for nonpersonnel objects or for personnel in different stances (standing, prone, and so forth).

11. Sensor Processing

The object is now processed by the first sensor in the OP. If this sensor has failed, it is skipped and the next sensor is processed. The routine that contains the mathematical model of the type of sensor being used is first called to determine the probabilities of detecting, recognizing and identifying the object. Sensor model descriptions are given in Appendix B.

12. Number of Objects

After determining the probabilities of sighting, the appropriate number of objects is chosen, depending on whether the sensor is IR or radar and sees through nets or is a type of sensor against which nets are effective.

13. Detection Enhancement

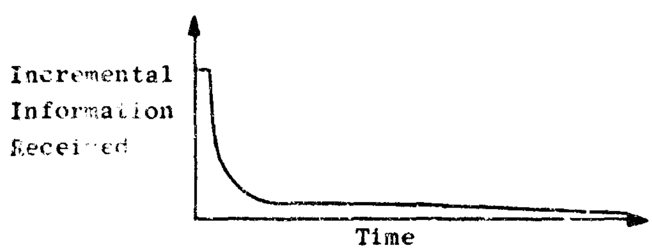
The probability of detection from the sensor routines is upgraded by prior signal intelligence information in an identical manner to CNESS-A.

14. Object Detection (DETECT, MISID, MISREC)

Using the detection, recognition, and identification probabilities and also the average probabilities of misrecognition and misidentification, the number of objects seen by the sensor in these various categories and the types of objects into which the object may be misidentified or misrecognized is determined. This is performed by use of Monte Carlo techniques, and the procedure is described in CRESS-A (DETECT, MISID, MISREC). In the case of patrols, the probability of recognition and identification given detection was set equal to 100 percent on the assumption that the patrol has the ability to temporarily change its course and discover in detail what has been detected.

15. Second and Third Looks

For patrols, no further sightings of this target are allowed. For OPs, however, two more looks are allowed. The hypothesis is that while most of the information on OP reports concerning a target occurs at the earliest time, both the OP and target are valid and other information may still be obtained, albeit in greatly decreasing amounts, after this initial sighting. Thus, the actual new information received from an OP concerning a target might be represented schematically as follows:



where the time axis begins at the time of first possible sighting.

R & S models often use a "snapshot" approach. This consists in allowing a number of independent looks at a target to be taken at various increments in time over which the OP can possibly sight the target. The result of this approach is to enhance greatly the probabilities of detecting, recognizing, and identifying objects in the target. For example, if the independent look probability of detection is .5, four snapshot looks at 15-minute increments result in a cumulative probability of detection of:

$$P_{CD} = 1-(1-.5)^4 = .94$$

CRESS-G makes a rough approximation of the effects of being able to examine an area carefully and "look again" by assuming that the independent look probability of detection calculated by the sensor routines and used to determine objects detected on the first look represents a large fraction (e.g., .9) of what is to be detected of the target by this sensor over an extended time. It is assumed that the amount of additional information acquired during this extended time will be exponentially decreasing. The increment of time between successive looks should be chosen so that one half of the remaining information is likely to be acquired in that time increment (i.e., the increment represents the "half-life" of the information not yet reported).

Degraded probabilities of detection are calculated for the second and third looks as follows:

$$D_2 = . \left|(D_1/F)-D_1\right|$$

if D_1 is less than F, or

$$D_2 = \tfrac{1}{2}(1.0 - D_1)$$

if D_1 is greater, and

$$D_3 = D_2/2$$

where D_1 = first look probability of detection (independent look probability of detection).

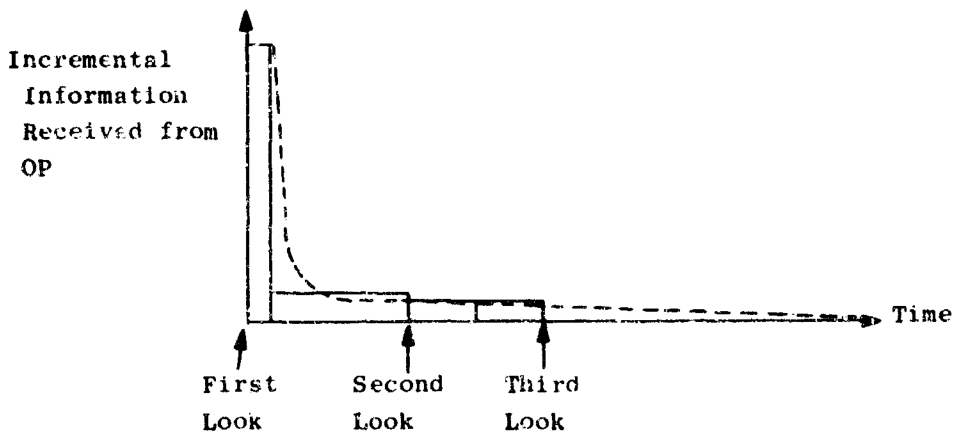
D_2 = second look probability of detection.

D_3 = third look probability of detection.

F = fraction of total detection probability occuring on the first look (user supplied).

Thus, for a D_1 of .5 and a typical F of .9, D_2 would equal .025 and D_3 .0125.

In this manner, the second look accounts for one-half of what remains to be detected after the first look, and the third look accounts for one-half of what remains to be sighted after the second look. Thus, the diagram that the model uses for information received is schematically represented by the three blocks of information below.



Using the reduced probabilities of detection, but the same probabilities of recognition and identification, the DETECT, MISID, and MISREC routines are used twice more to calculate how many of the objects yet to be sighted are detected, recognized, identified, misrecognized, and misidentified.

16. Sensor Looping

The model now repeats all the steps from sensor processing down to this point for each of the remaining sensors in the OP, thus determining the sighting probabilities and objects sighted or missighted of the particular object type being processed.

17. Multisensor Report Time and Probabilities

After all sensors have examined the object being processed, one multisensor report time is chosen, the third look time of the sensor that sights the target earliest.

If no sensors have failed, the third look time would be the same for all sensors. However, sensors that, because of a failure, do not attempt to see the target until a later time or do not have a second or third look before this multisensor time will not be included in multisensoring or will have only a part of their sightings included in multisensoring.

The total number of objects seen by each sensor when the multisensor report time is reached is next determined, and the cumulative probability of detection by each sensor is found by summing the probabilities from the looks occuring on or before the multisensor report time. These quantities are used to determine the effects, cumulative overtime, of using more than one sensor.

18. False Target Objects

If the object is seen by at least one sensor, the object is stored as a possible false target object and the sensors that see this object are noted; up to a maximum of 10 objects are stored. The objects in each target detected by the OP are used to create a corresponding possible false target up to a maximum of 20 false target possibilities for an OP. No false targets are created for patrols, however, since they are assumed to investigate all sightings.

19. Multisensoring (MULTI)

The number of objects detected, recognized, and identified by the cumulative effects of using all sensors (and the corresponding probabilities) is next determined in subroutine MULTI. Two kinds of enhancement occur when more than one sensor is used: (1) enhancement because sensors may sight different objects so that the total sighted is higher than the most seen by any one sensor and (2) enhancement because of the different kinds of information that are received from sensors operating in different spectral regions. A complete discussion of the method by which multisensor enhancement is considered is included in CRESS-A.

20. Object Looping

After completing the multisensor calculations, control is returned to object processing, and each of the target objects is processed in the manner discussed.

21. False Target Location and Times

After determining the performance of all sensors against all target objects, if any objects at all have been sighted, the target location and target initial and final valid times are stored for use in the generation of false targets.

22. Report Decision (RPTDEC)

The information now calculated is sufficient to determine if the numbers and types of objects seen are sufficient to meet the report decision criteria (set previously in RPTSET). Report decisions are made for each individual sensor and for multi-sensoring using methodology that is identical to that of CRESS-A (RPTDEC, SIGHTS, SPCOBJ).

23. Report Number

If any report is to be made on the target, a unique report number is assigned to this target. Subsequently, other OPs that make reports concerning this target will use the same report number, and the problem of collating reports by coordinate matching will be eliminated.

24. Report Times (RPTTM)

All report times are stored on disk except the attrition and failure previously stored. For each sensor, the possible reports are contact, lost contact due to sensor failure, regained contact, and final lost contact; for multisensoring, there is only a contact report.

If a report is to be made, subroutine RPFTM is called. Report times are time-ordered in core in increments of 1000. When the number of reports exceeds 1000, the first 500 are stored on disk and the remaining 500 are time-ordered with subsequent reports until another total of 1000 is reached. This same procedure is repeated as often as is necessary, meaning that report times will actually be time-ordered and stored in groups of 500 but that the groups in total may not be time-ordered. This last step is accomplished in NTLGNT.

If lost contact occurs because the OP reaches its final valid time, this kind of lost contact is not reported. Other reasons (sensor failure, OP attrition, or target movement) are all reported.

Stored along with report time is an index indicating which sensor the report is for, what kind of report it is (e.g., lost contact), and what OP/TGT the report concerns.

25. Information Storage (OPTSTR)

OPTSTR is called to store on disk information concerning the OP and target that will be needed for reporting (designations, coordinates, elevation of OP, distance, and link failure switches). The information on sighting probabilities and objects sighted for each sensor are stored in PROCES using the same index as for the OP/TGT information storage. This index is the one that is stored along with report times to tell which

OP/TGT information a particular report time is to use.

26. Control Copy (WRYTAL)

Subroutine WRYTAL is now called to write out a control copy that contains information not only concerning what has been detected, recognized, identified, misrecognized, and misidentified, but also what the probabilities of correctly detecting, recognizing, and identifying target objects are for each sensor and for multisensoring and of what the actual target consists. The probabilities printed out are conditioned on the next lower level of sighting being given (e.g., probability of recognition given detection). The probabilities listed include the effects of line-of-sight probability but, except for the multisensor, do not include the probability that objects are camouflaged by nets. Sensor probabilities of detection, given line of sight, can be obtained by dividing the detection probability by the probability of line of sight.

The location accuracy for each sensor is determined for the control copy by subroutines CEPSIG and CEPSNS. CEPs are determined by using the standard deviations in range and location accuracy of the sensor to create an error ellipse (if a position location device is used, its accuracies should be prestored in place of the sensor's). This is modified into a circular error, and the inaccuracies caused by the error in locating the OP or patrol and by various map inaccuracies are considered to create a set of cumulative CEPs for the types of maps that can be used.

More information and an example of the control copy is given in the Computer Output Ground section (IIF2) of this handbook.

27. Looping on OP/TGT Combinations

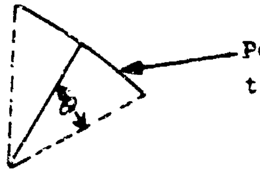
The program now returns to the point where OP/TGT card processing began, reads a new OP/TGT card, and processes the new combination in the manner just discussed. If the OP on the new OP/TGT card is different from the one that has just been processed and if the previous OP saw any objects at all in any target processed, the possibility of false targets is considered before continuing the processing of the new OP/TGT card.

28. False Targets (FLSTGT)

The number of false targets to be generated is determined first. A false-target prior probability is used stochastically to find if at least one false target is to be generated. The number of other false targets to be generated is set equal to a percentage of the total number of targets in which some objects were seen. The user specifies the prior probability and the percentage of targets seen for which false targets are to be created (0 means no false targets will be generated).

Each false target required is created by drawing at random from the list of false target object types that was created while processing real targets for this observation post. Up to four object types out of the false target object type list, the number of each type, and the sensors that can see these objects are selected in the same manner as for CRESS-A (FLSTGT).

Next the location of the false target is generated by selecting at random a target actually seen and by placing the false target somewhere at random along the arc shown below:



where θ = view angle that the OP uses. Locations are selected in the vicinity of targets actually seen in an attempt to avoid placing false targets in locations where terrain masking was present.

The initial and final valid times used are those of the real target near which the false target is placed, rather than random times that might be too conspicuous (many scenario writers use the same initial and final valid times for many targets). The various times of sighting and lost contact are found by calling CALTIM, just as for an actual target.

Then the false target report times and object sightings are stored in the same manner as for real targets. Multisensoring is assumed to generate the same number of an object type that the sensors that sight that object see (i.e., a constant number of objects is sighted by each sighting sensor and by multisensoring).

The output on the Control Copy uses the target designation "FLSE." Since only objects sighted are reported and no probabilities are given, these reports are easily distinguished on the Control Copy, but reports to intelligence are designed to be indistinguishable from real targets.

29. OP/TGT Looping Continued

After generating false targets, the model begins to process the OP/TGT card that relates to the new OP. This procedure of operating on OP/TGT cards and generating false targets when a new OP begins to be processed continues until the last OP/TGT combination has been examined. False targets, if any, are generated for the last OP before writing the Intelligence Copy.

30. Intelligence Reporting (NTLGNT)

Control now is passed to the NTLGNT subroutine, where all reports that have been stored away are written out in a time-ordered manner. A discussion of these reports and typical examples are included in Section IIF2 of this report.

D. <u>The SIGINT Model, CRESS-S</u>

1. <u>Overview of the Logical Flow</u>

Afte six decks of input cards have been prepared, the CRESS-S simulation program is ready for execution. The purpose of this program is to provide the computational functions whose logical information flow is shown in Fig. 5. This flow diagram shows that the data are read in emitter by emitter, target by target, and detectability, location, and identification calculations are made for all appropriate sensors for each emitter in the target. The Control Copy output is printed on line.

The flow diagram summary for the propagation calculations is shown in Fig. 6. In this portion of the simulation, the propagation mode, path classification, terrain clearance height, and emitter detectability are determined.

In Fig. 5, there is a decision block labeled "up ?." In this portion of the routine when a new emitter is input, a random number is selected and compared with the preassigned emitter activity factor. If the emitter is determined to be down, the next emitter is read in. If the emitter is determined to be up, a hearability calculation is made for all appropriate sensor sites. The option card can force all the emitters to be up, thus the program can easily make a hearability calculation on all emitters to all appropriate sensor sites.

2. <u>Detailed Flow and Computations</u>

After deciding on the scenario and deploying the targets and sensors, data cards are punched describing the targets (Figs. 7 and 8), the emitter types (Figs. 9 and 10) and the sensors (Figs. 11 and 12). The target and sensor cards (with the HELP Starter

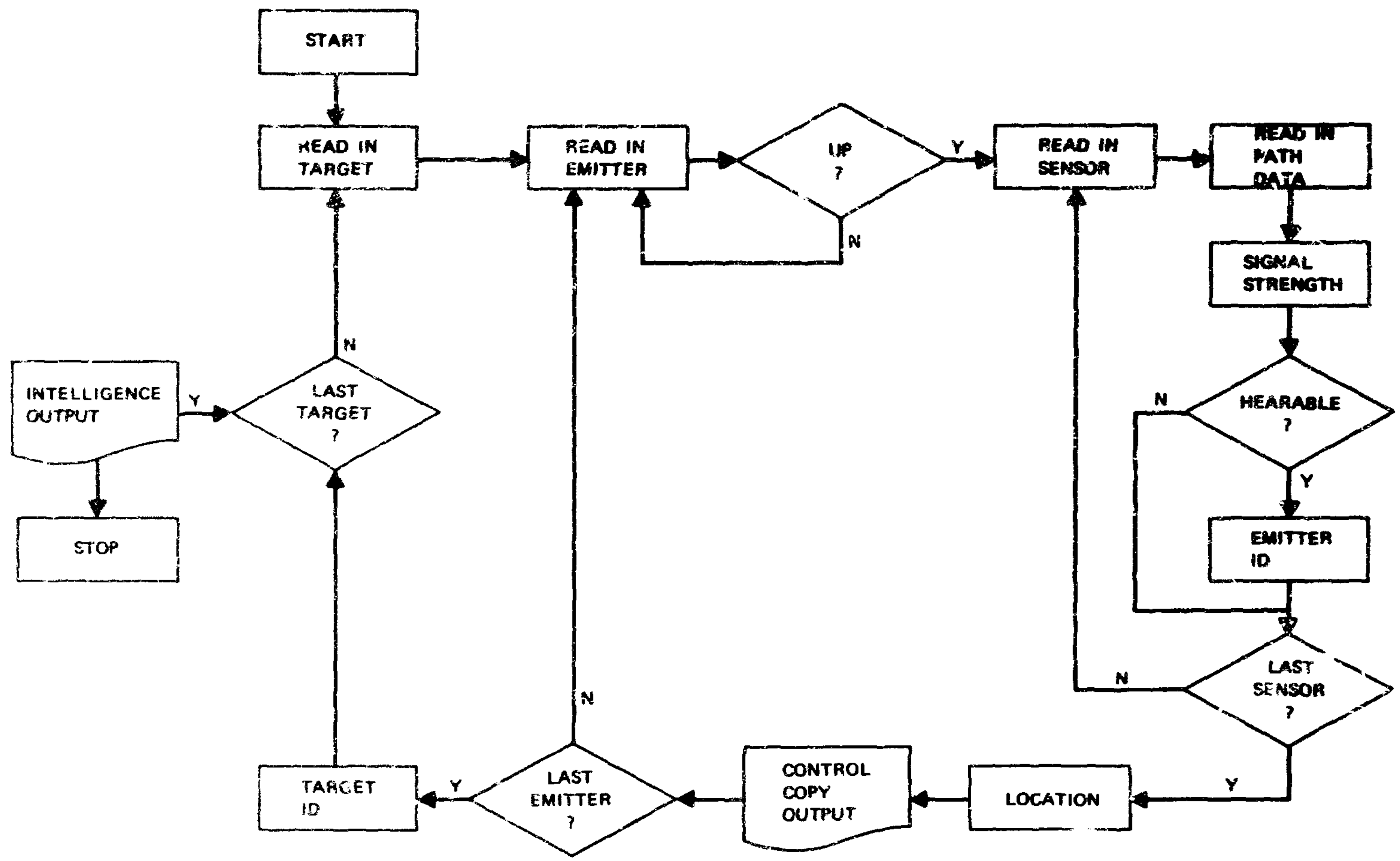


Fig. 5 CRESS-S INFORMATION FLOW CHART

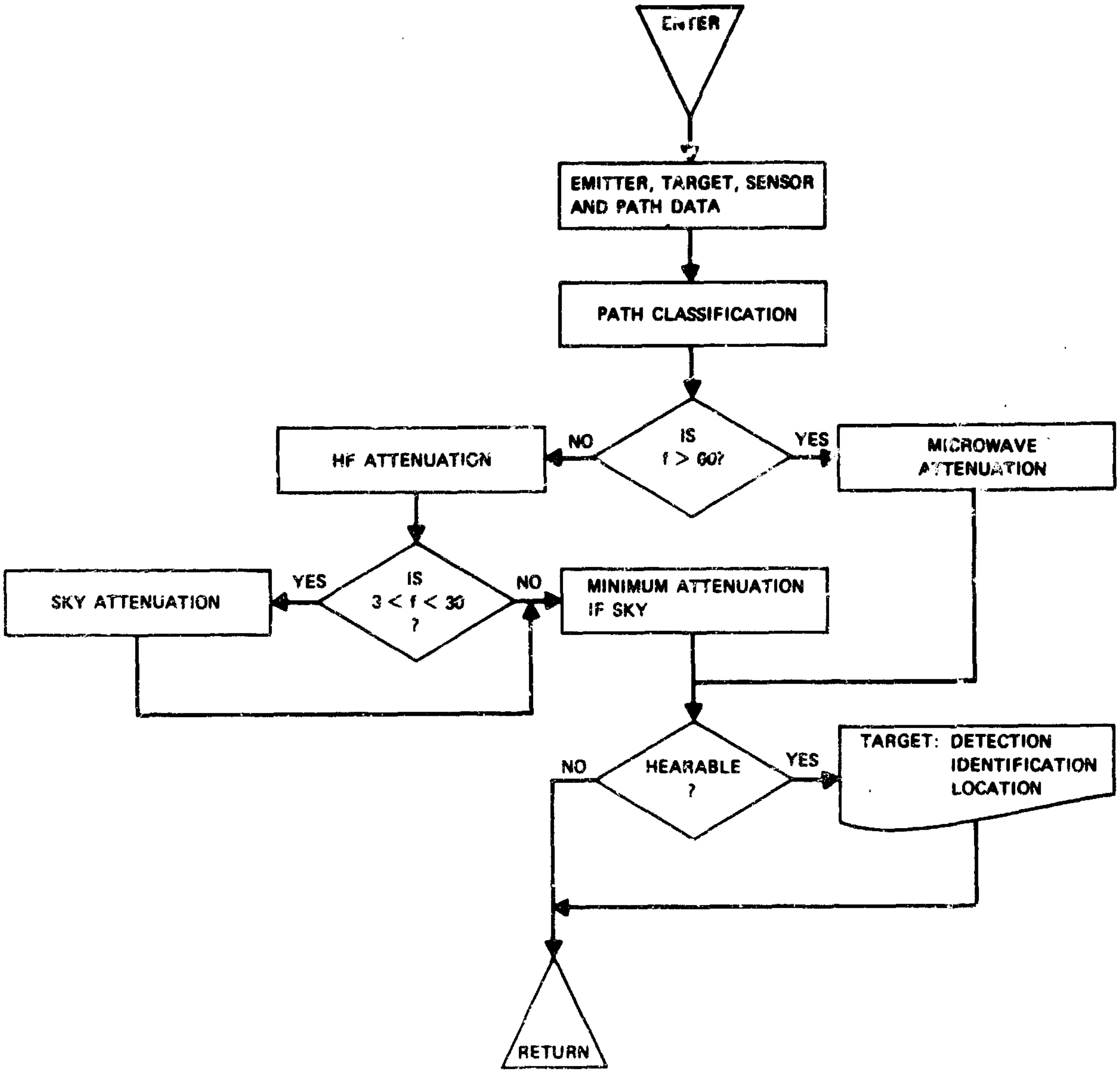


Fig. 6 CRESS-S HEARABILITY FLOW CHART

I	A	A	I	I	I	I
4	6 25	27 28	31	34	40	43
Target ID	Target Description	Target Quadrant Designator	Target Map Coordinate X (100 meters)	Target Map Coordinate Y (100 meters)	Target Elevation (meters)	Number of Emitters at this Target
6	AABY	MA	385	742	100	4
8	TKPL	NB	126	487	42	6

Format (I4, 1X, 2A10, 1X, A2, 2I3, I6, I3)

Fig. 7 SIGINT TARGET CARD FORM A

A	I	R	I	R	R	R
10	12 14	22	28	38	46	54
Emitter Descriptor	Antenna Type	Antenna Azimuth (degrees clockwise from north)	Antenna Height (meters)	Operating Frequency (MHz)	Antenna Scan Angle (degrees)	Uptime Probability
R - XYZ	2	35.0	10	7.1	30.0	0.3
RADAR 1	1	180.0	50	2150.0	180.0	0.95

Format (A10, 1X, I3, F8.0, I6, F10.0, 2F8.0)

Fig. 8 SIGINT TARGET CARD FORM B

A	R	R	R	A	I
10	20	30	40	43 46	50
Emitter Descriptor	Minimum Operating Frequency (MHz)	Maximum Operating Frequency (MHz)	Power (Watts) Output	Modulation Code	Number of Antennas
R - XYZ RADAR 1	1.5 2000.0	10.0 4000.0	30.0 300.0	AMV FC	2 1

Format (A10, 3F10.0, 2X, A4, I4)

Fig. 9 SIGINT EMITTER-ANTENNA CARD FORM A

I	R	R	R	R
5	15	25	35	45
Antenna Type	Horizontal Beam Width (degrees)	Gain of Main Lobe (dB)	Gain of Side Lobe Normalized to Main Lobe (dB)	Gain of Back Lobe Normalized to Main Lobe (dB)
1 6	2.0 10.0	37.0 18.0	-20.0 -12.0	-37.0 -18.0

Format (I5, 4F10.0)

Fig. 10 SIGINT EMITTER-ANTENNA CARD FORM B

I	A	I	I	I	I	R	R	R	R	R
3	6 7	10	13	19	25	35	45	53	61	69
Sensor ID	Sensor Quadrant Designator	Sensor Map Coord. X (100 meters)	Sensor Map Coord. Y (100 meters)	Sensor Altitude (meters)	Sensor Antenna Height (m.)	Minimum Detection Frequency (MHz)	Maximum Detection Frequency (MHz)	Sensor Sensitivity (dBm)	Sensor Azimuth (Degrees from North)	Antenna Scan Angle (deg.)
2	MA	347	820	130	40	2.0	8.0	-50.0	280.0	30.0
4	NB	123	456	101	20	1000.0	2000.0	-41.2	0.0	180.0

FORMAT (I3, 2X, A2, I3, I3, 2I6, 2F10.0, 3F8.0)

Fig. 11 SIGINT SENSOR CARD FORM A

R	R	R	R	R	R
10	20	30	40	48	56
Sensor Antenna Horizontal Beam Width (degrees)	Gain of Main Lobe (dB)	Gain of Side Lobe Normalized to Main Lobe (dB)	Gain of Back Lobe Normalized to Main Lobe (dB)	One Standard Deviation Bearing Inaccuracy (line-of-sight) (degrees)	One Standard Deviation Bearing Inaccuracy (non-line-of-sight) (degrees)
2.0	30.0	-20.0	-30.0	2.0	4.0
8.1	12.0	-10.0	-18.0	1.3	2.1

FORMAT (4F10.0, 2F8.0)

Fig. 12 SIGINT SENSOR CARD FORM B

Card in Fig. 13) are then input to program HELP, which examines all possible emitter-sensor combinations for compatibility in frequency ranges. It prints out a tabulation sheet (as shown in Fig. 18 for use by the data aides) containing the target-sensor paths to be examined. After these sheets are filled in, cards are keypunched (Fig. 16) and merged with the target cards. Program CRESS-S can then be run to produce the on-line generated Control Copy, followed by the intelligence copy which is output from storage on a disk file.

The CRESS-S computer simulation is used to model obstacle calculations, antenna and receiver/emitter characteristics, skywave and groundwave attenuation, detectability, and target locations. The terrain obstruction, detection criteria, antenna pattern characteristics, and propagation equations are delineated in Appendix C. The method of determining the accuracy of target location is presented in SRI Technical Note ORD-TN-5205-15, "The Covariance of Position Location."

The order of data processing is as follows:

a. CRESS-S processes target by target

b. Each target is processed emitter by emitter

c. Each emitter is processed sensor by sensor

d. A report describing the activity, detection, and location by one or more sensors is written on the Control Copy after each emitter is processed.

e. After all of the targets have been processed, the intelligence copy of detected emitter reports is output in a pseudo-random order.

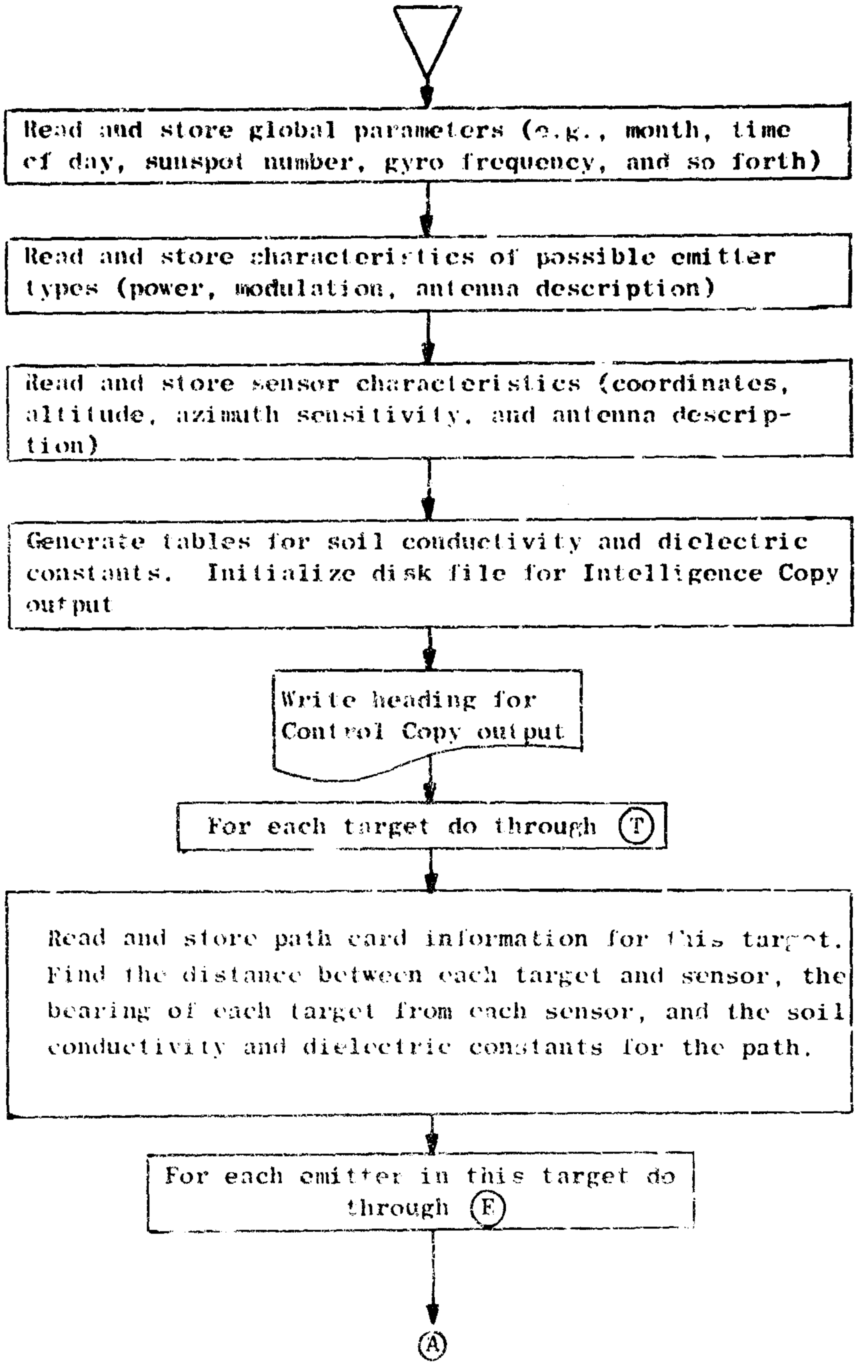
I	I
5	10
Number of Targets	Number of Sensors
100 80	20 8

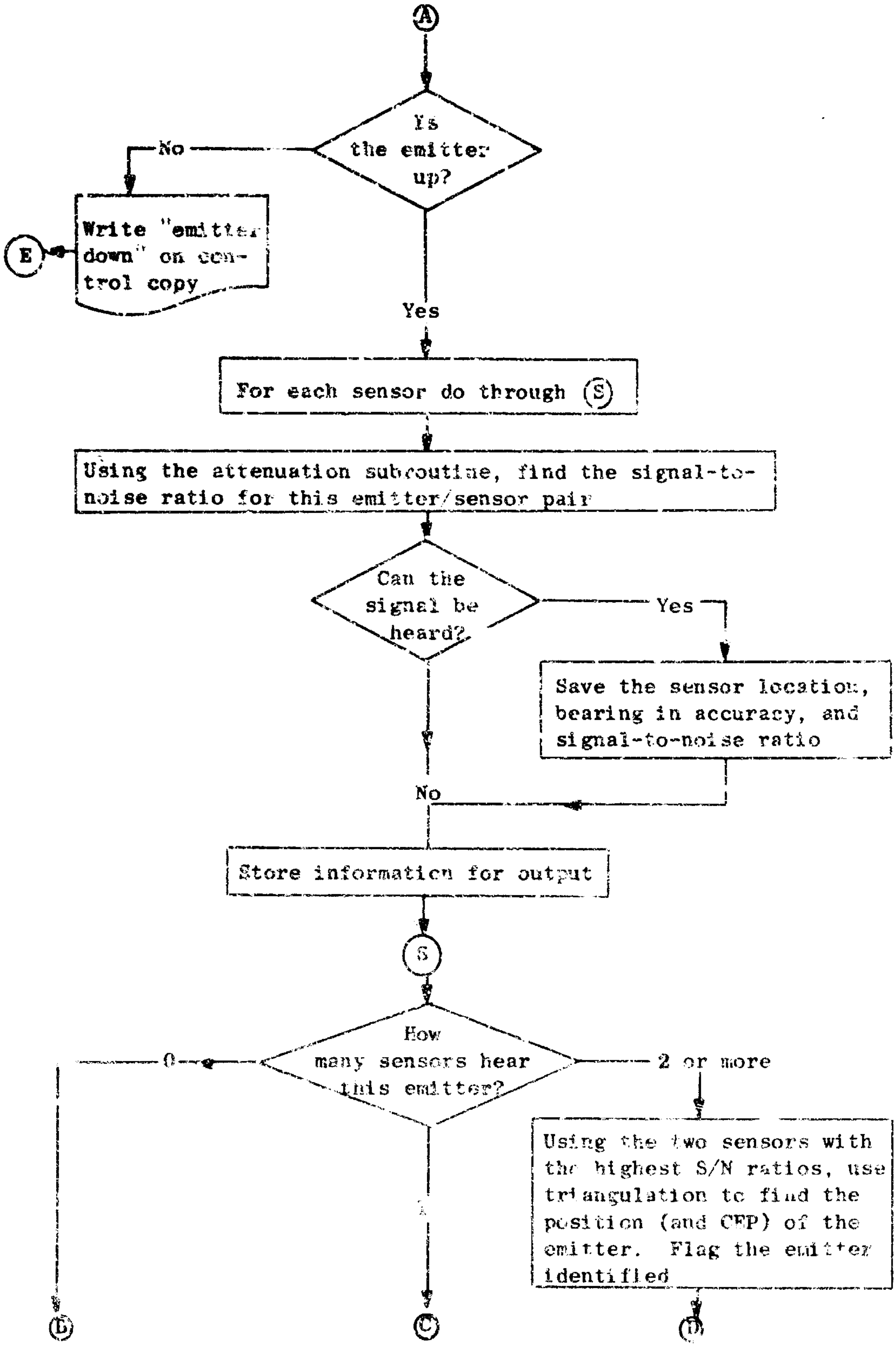
Format (2I5)

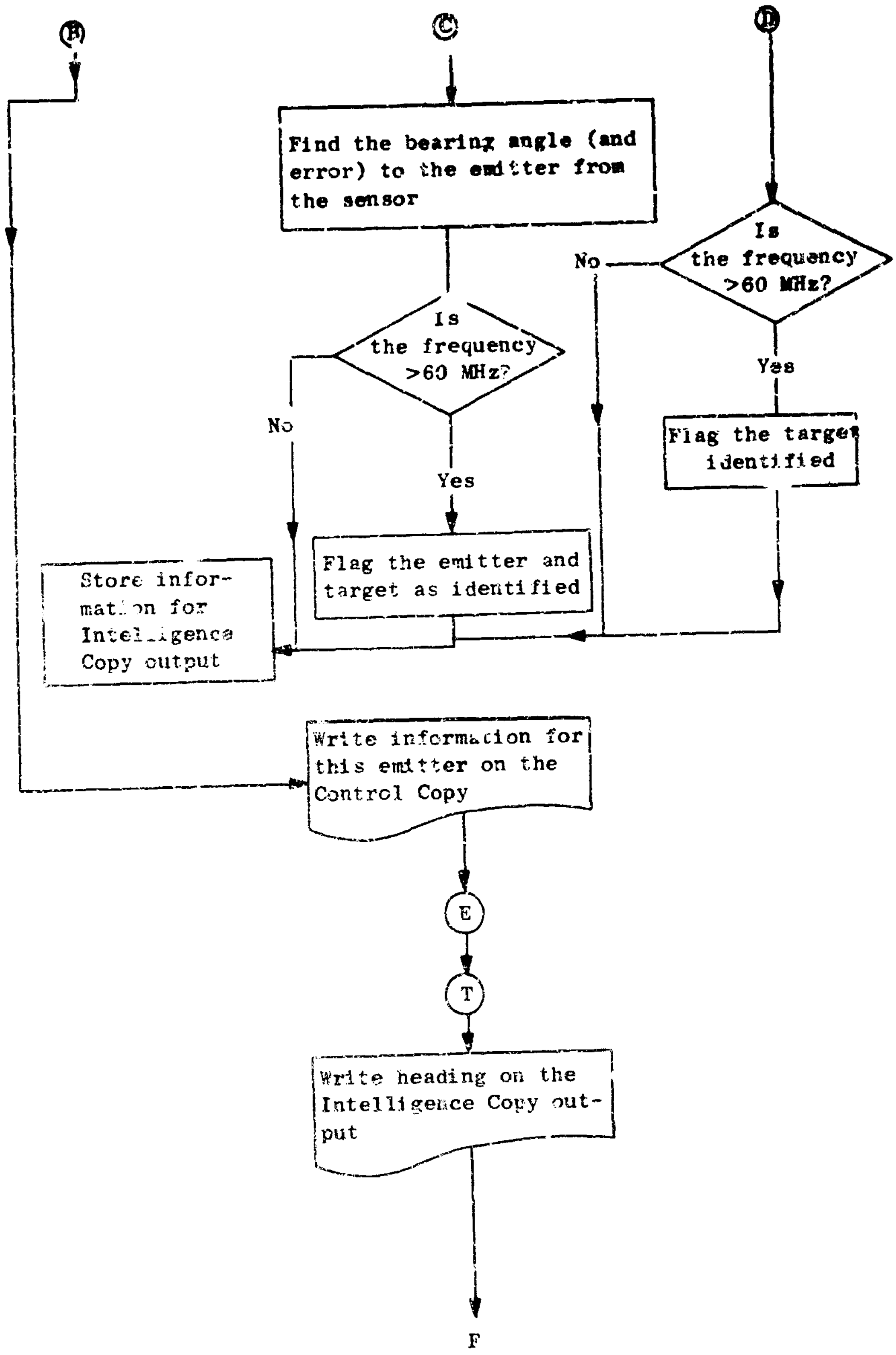
Fig. 13 HELP STARTER CARD

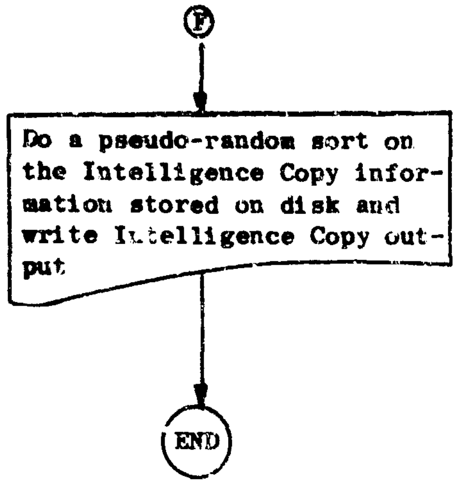
The following flow chart describes the main program flow:

CRESS-S Computer Model Flow Chart




A
Is the emitter up?
No
Write "emitter down" on control copy
E
Yes
For each sensor do through S
Using the attenuation subroutine, find the signal-to-noise ratio for this emitter/sensor pair
Can the signal be heard?
Yes
Save the sensor location, bearing in accuracy, and signal-to-noise ratio
No
Store information for output
S
How many sensors hear this emitter?
0
1
2 or more
Using the two sensors with the highest S/N ratios, use triangulation to find the position (and CEP) of the emitter. Flag the emitter identified
E
C
D


B
C
D
Find the bearing angle (and error) to the emitter from the sensor
Is the frequency >60 MHz?
No
Yes
Is the frequency >60 MHz?
No
Yes
Flag the target identified
Flag the emitter and target as identified
Store information for Intelligence Copy output
Write information for this emitter on the Control Copy
E
T
Write heading on the Intelligence Copy output
F



The main routine CRESS-S controls the program flow as well as handling the data input. In turn, it calls several subroutines that are described in order of program flow.

After reading in a path card, CRESS-S calls two subroutines DISANG, and TERRAFIRM, in order. The purpose of subroutine DISANG is to compute the distance between a target and sensor and the bearing (relative to north) of the emitter from the sensor. The required input consists of the map coordinates of the target and the map coordinates of the sensor. The output consists of the distance between the target and the sensor and the bearing of the emitter from the sensor. The grid coordinate of the target and the sensor are converted to rectangular cartesian coordinates. Then the azimuthal angle is computed by taking the arc-tangent of the slope of a line drawn between the target and the sensor and finding this angle relative to grid north. The distance is computed in the usual way.

Subroutine TERRAFIRM retrieves the soil conductivity and and dielectric constants from prestored tables for later use in the program. The inputs to this subroutine are the terrain area number and the terrain characteristic number. The terrain area number is 1 if the scenario is in Europe or 2 if it is in Southeast Asia. Tables are not currently available for other parts of the world. The terrain characteristics number describes the terrain along the sensor-target path as one of the following:

1 = Fresh water
2 = Cities
3 = Smooth earth; sparse vegetation
4 = Smooth earth; moderate vegetation
5 = Smooth earth; heavy vegetation
6 = Moderately rough earth; sparse vegetation
7 = Moderately rough earth; moderate vegetation
8 = Moderately rough earth; heavy vegetation
9 = Very rough earth; sparse vegetation
10 = Very rough earth; moderate vegetation
11 = Fresh water marsh
12 = Seawater

After reading the path cards for a target and calling the three routines described above, CRESS-S determines whether each emitter at the target is operating. This is done in subroutine UPDOWN. The subroutine first checks whether all emitters are assumed to be up (a flag set on the option card) as shown in Fig. 14. If not, it selects a random number from a uniform 0 - 1 distribution for each emitter. If the random number is less than the probability of up time (read in on Target Card Form B), the emitter is flagged up, otherwise it is flagged down and no sensor-emitter calculations are performed for this emitter. This is repeated for each emitter in the target.

I	I	I	I	R	R	R	I
5	10	15	20	30	40	50	56
Number of Targets	Number of Sensors	Number of Emitter Types	Flag All Emitters Up-1, Otherwise-0	Initial Random Number	Latitude[a] of Geographical Center (degrees)	Longitude[b] of Geographical Center (degrees)	Minimum Terrain Elev. (m)
100	20	11	0	0.12345	15.0	105.5	120
80	8	6	1	0.523	70.9	60.8	90

[a] North or South need not be indicated. It is assumed entire scenario is set in same hemisphere.

[b] East or West need not be indicated. It is assumed entire scenario is set in same hemisphere.

FORMAT (4I5, 3F10.0, I6)

Fig. 14 OPTION CARD

Next, subroutine OBST calculates the effective radio line-of-sight clearance height (H) along an emitter/sensor path, including obstacles. The subroutine requires the distance from the sensor to an obstacle, the height of the obstacle, and the height of the sensors as input. The output from the subroutine consists of three quantities: H, D, and MOBST. H is the maximum value of the clearances for the two recorded obstacles (a maximum of two) processed by the program. D is the distance from the sensor to that obstacle, and MOBST is an index that is determined by whether there is a multiple, single or a no obstacle (line-of-sight)* path.

The main subroutine ATTEN is then called for each emitter-sensor pair. The purpose of subroutine ATTEN is to control the steps of the propagation attenuation calculation. Values of the parameters for the particular emitter and sensor combination are input. The first step of the attenuation calculation is to call the transmitting antenna routine. Subroutine ANTENA models the lobes of the antenna. The losses caused by the gain of the antenna and the aimpoint of the antenna relative to the emitter sensor path are calculated. If it is a nonmicrowave emitter, the calculation proceeds directly to the ground wave calculation (subroutine GRNWV). However, if it is a microwave emitter, the loss caused by diffraction by obstacles is calculated. The HF (nonmicrowave) groundwave propagation calculations include the effects of obstacles, soil conductivity, the dielectric constants of the earth, and foliage, on the propagation of the radio waves. If the frequency is between 3MHz and 30MHz, the sky wave calculation is performed.

If both the groundwave and skywave calculations are performed, the propagation mode with the least attenuation is used as the

* The words "line-of-sight and non line-of-sight" refer to effective Radio LOS. NLOS, which are different than optical LOS due to increased refraction effects at Radio frequencies.

dominant mode. Subroutine ANTENA is called again, this time to model the receiver and the signal-to-noise ratio to be used for the hearability test.

After an emitter has been examined by all sensors, the location of the emitter is determined, if possible. If only one sensor has heard the signal, it is possible to compute the direction of the signal only. If two or more sensors hear a signal, those two with the highest received signal-to-noise ratios are used in the location calculation. Subroutine LOCATE requires as input the location of the sensor(s), the inaccuracy of their direction finders, and the target location. If there is only one sensor, the output will be the reported bearing angle. If there are two sensors, the output is a reported location and the CEP.

After processing each emitter, subroutine CONPUT is called to output the Control Copy data on that emitter. All Intelligence Copy output is stored on a disk file. The Intelligence Copy data is a subset of the Control Copy output data.

After all targets have been processed, a pseudo-random sort is used to select the order in which the data for each detected emitter is recalled from disk storage and printed on the Intelligence Copy output.

3. <u>Input Data and Formats</u>

The preparation and running of the CRESS-S simulation are outlined in Fig. 15. After deciding on the scenario and deploying the targets and the emitters associated with each target, the SIGINT sensors are deployed. The sensor sites are deployed by persons familiar with SIGINT deployment concepts and doctrine. They should also have some detailed knowledge of the target array before them, typical of a tactical deployment situation. On com-

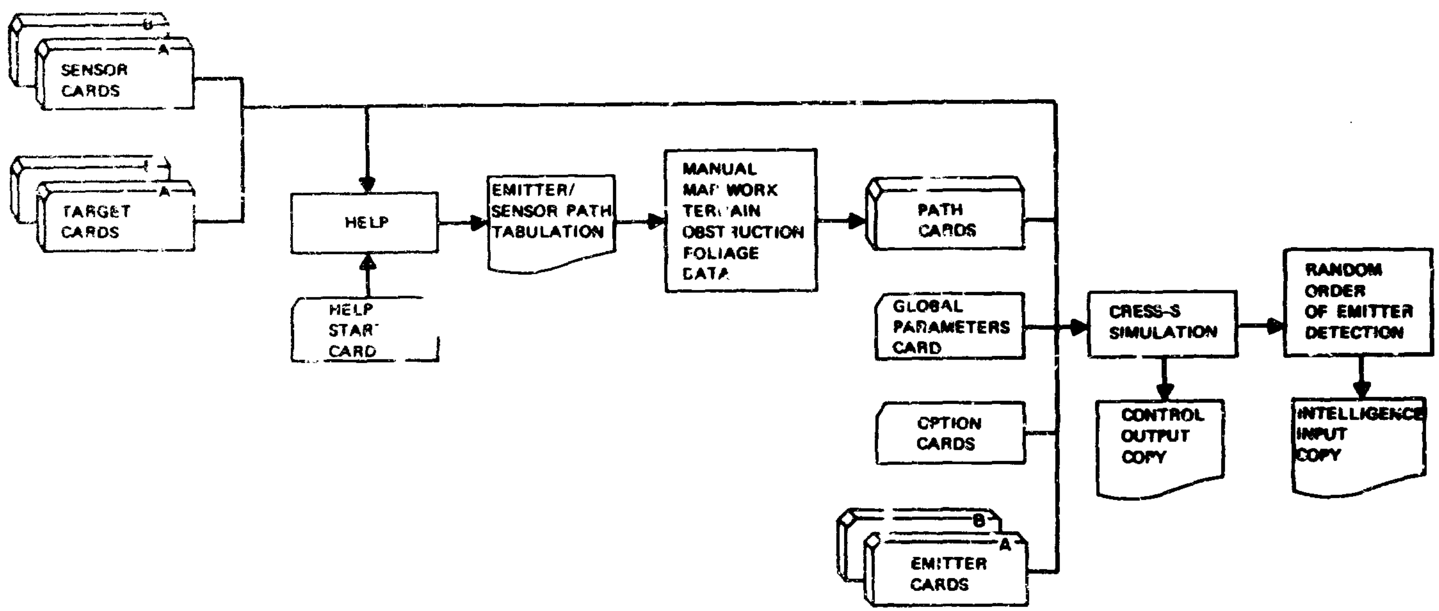


FIG. 15 CRESS-S PROGRAM FLOW OUTLINE

pletion of this deployment effort work, three decks of cards (Emitter A & B, Target A & B, and Sensor A & B) are punched.

Then the Target and Sensor cards are input into program HELP, along with a starter card for program HELP. Program HELP examines all the possible emitter-sensor combinations, printing out a tabulation of all likely emitter-sensor paths that can exist in the array. The printed output sheet (Fig. 18) contains a complete list of all the target sensor paths that must be examined by data aides.

This printout is used as a data sheet by data aides who return to the map and, for each target-sensor path noted, record the required path, foliage, and geological data. The results of the data aides' map work is punched on an additional deck of cards called the path cards. Two additional cards must be punched before each running of the CRESS-S simulation. These are the global parameters card and the option card.

With the preparatory work completed, the six decks of cards (Emitter, Target, Sensor, Path, Global, and Option cards) are appropriately combined and read by the CRESS-S Program, which now runs and produces, on-line, the Control Copy output. When the Control Copy output is completed, the TOCPUT subroutine randomly selects the reported sensor data, which was stored on disk at the time it was printed on the Control Copy, and prints them in the Intelligence Copy in a random ordering.

All of the input to program CRESS-S is in the form of one of the following five card types.

1. Emitter-antenna cards
2. Sensor data cards
3. Target data cards
4. Path data cards
5. Miscellaneous cards

The cards will be discussed in the above order and followed by an explanation of the deck setup for input.

a. Emitter-Antenna Cards (Figs. 9 and 10)

Emitter-Antenna cards are a file of cards describing the characteristics of various emitters that might be deployed. This file is independent of the scenario and may be kept as a library file to be read in at the beginning of each run. The first card (Fig. 9) contains a description of the emitter, the minimum and maximum operating frequency (in MHz) of the emitter, the output power (in watts), and the modulation code. It also contains the number of antenna types that this emitter can have. One card for each of the antenna types follows the emitter card. This type of card contains an antenna type identification, the horizontal beam width (in degrees), the gain (in dB) of the main lobe and the gain (in dB) of the side and back lobes normalized with respect to the main lobe.

b. Sensor Data Cards (Figs. 11 and 12)

The sensor data cards provide information about the sensor site as well as a description of the sensor antenna. Since there is only one SIGINT sensor per site, it is not necessary to separate the site and antenna descriptions. However, in the case of microwave sensors having different sensitivities at each end of their surveillance band, a separate set of cards can be used, locating sensors with differing sensitivities at the same coordinates.

The sensor cards contain the grid coordinate of the sensor. The grid coordinate consists of a quadrant descriptor such as MA, MB, NA, NB, and X and Y coordinates in units of 100 meters. The sensor altitude is the altitude of the sensor site (in meters) above sea level. Sensor sensitivity is measured in dBm and is used in determining signal hearability. The azimuthal angle measurements are all in degrees from north in a clockwise direction. Two standard deviations are given; the first is the bearing measurement accuracy of the antenna when used to detect an emitter along a line-of-sight path and the second is for a nonline-of-sight path. In general, the scan angle will be assumed to be 360° for all sensor antennas.

c. Target Cards (Figs. 7 and 8)

One Form A card is punched for each target. It contains the target ID and a brief description (four FORTRAN characters or less), the grid coordinate of the target, the target elevation (in meters) above sea level, and the number of emitters (not emitter types) at the target. There is then one card (Fig. 8) for each emitter at that target. These cards should be ordered so that all emitters with the same descriptor are together. The emitter descriptor and the antenna type should be identical to one of the emitter descriptors and antenna types on the emitter-antenna file so that the necessary parameters can be pulled from this file.

If the uptime flag on the option card (Fig. 14) is equal to 1, it is not necessary to input a probability for uptime, otherwise the number should be the fraction of time that the emitter is operating.

d. Path Data Cards (Fig. 16)

The tabulated output from Program HELP gives the probable sensor/target propagation paths to be exercised during the CRESS simulation run. From this tabulation, data aides return to the map of the target and sensor deployments to record the following data on the SIGINT path description form (Fig. 16):

The two highest obstacles, the elevation of these obstacles (meters above sea level) and their distances from the sensor (in km). The foliage path length is the approximate span of intervening tree foliage (in km) along the path. The terrain area number is 1 if the scenario is in Europe, 2 for Southeast Asia. This number is used to obtain the dielectric and soil conductivity constants. (The program, at this time, does not have these numbers available for the rest of the world.) The terrain along the path is described by the terrain characteristic number (see Sec. II.D.2 for code).

e. Miscellaneous Cards

The program option card (Fig. 14) gives the number of targets and sensors in the scenario as well as the number of emitter types in the emitter-antenna file. If all emitters are to be up, a 1 is put in the flag word, otherwise a 0. This flag will override the uptime probability number on the target cards. An initial random number between 0 and 1 is input so that a run may be either duplicated or altered as desired.

The global parameter card (Fig. 17) contains numbers that will remain constant throughout a run. The earth's radius correction factor (for refraction) is usually 4/3. All of the numbers on this card are used in the skywave and groundwave calculations in the attenuation subroutine.

f. Deck Setup for CDC 6400 Computer, Program CRESS-S

Order	Type of Cards	Figure Containing Format
1	SCOPE control cards	Computer Center
2	FORTRAN program deck for CRESS-S	
3	A card with 7, 8, and 9 level punches in column 1	
4	SIGINT option card	1

I	I	I	R	I	R	R	I	I
5	10	16	25	31	40	49	52	55
Sensor ID	Target ID	Elevation of Obstacle 1 (meters)	Distance Sensor to Obstacle 1 (km)	Elevation of Obstacle 2 (meters)	Distance Sensor to Obstacle 2 (km)	Foliage Path Length (km)	Terrain Area	Terrain Characteristics
1	6	475	0.4	590	3.5	12.0	1	7
4	8	310	10.0	430	9.8	5.8	2	8

FORMAT (2I5, 2(I6, F9.0), F9.0,2I3)

Fig. 16 SIGINT PATH DESCRIPTION FORM

R	I	R	I	R	R	I	I	I	R
10	13	21	27	35	43	51	59	67	75
Earth's Radius Correction Factor	Number of Month of the Year	Greenwich Mean Time of Day (24 hr.day)	Sunspot Number	Gyro Frequency at 100 km Height (MHz)	Noise Level (dBm)	E-2 Virtual Layer Height (m)	F-2 Layer-3000KM MUF Factor (m)	F-2 Layer-OKM MUF Factor (M)	Maximum Usable Frequency (MHz)
1.333333	2	23.01	50	20.0	-50.0	200000	180000	160000	30.0
1.4	11	10.0	150	25.1	-110.8	250000	235600	218700	9.1

FORMAT (F10.0, I3, F8.0, I6, 2F8.0, 3I8, F8.0)

Fig. 17 SIGINT GLOBAL PARAMETER CARD

Order	Type of Cards	Figure Containing Format
5	SIGINT global parameter card	2
6	All emitter-antenna card forms A and B	3, 4
7	All sensor data card forms A and B	5, 6
8	Target card form A for first target	7
9	Path cards for target 1	9
10	Target card forms B for target 1 (one for each emitter)	8
11	Target card form A for second target	7
	.	
	.	
	.	
	.	
	A card with 7, 8, and 9 level punches in column 1	
	A card with 6, 7, 8, and 9 level punches in column 1	

g. Deck Setup for CDC 6400 Computer, Program HELP

Order	Type of Cards	Figure Containing Format
1	SCOPE control cards	Computer Center
2	FORTRAN program deck for HELP	
3	A card with 7, 8, and 9 level punches in column 1	
4	HELP starter card	10
5	All emitter-antenna card forms A and B	3, 4
6	All sensor data card forms A and B	5, 6
7	All target card forms A and B	7, 8
8	A card with 7, 8, and 9 level punches in column 1	
9	A card with 6, 7, 8, and 9 level punches in column 1	

4. Computer Output

There are three types of output provided from the SIGINT model. The first (Fig. 18) is from Program HELP. It is to be used by the data aides while obtaining path obstruction data from the map. The second type of output (Fig. 19) is the Control Copy. This output records all sensor-emitter interactions. The third type (Fig. 20) is the Intelligence Copy and contains the collected data operationally available from an array of SIGINT collection sites.

a. Program HELP Output (Fig. 18)

The output from HELP contains a tabulation of the target/sensor paths that must be examined on the map. The items that must be added by data aides to this output (and then key punched as path cards) are identical to those described for the Path description form (Fig. 16).

b. Control Copy Output (Fig. 19)

The Control Copy output is ordered target by target. The first line contains the target ID number, the target description, and the actual target location in map coordinates. Next, each emitter at that target is described. ACT is the activity factor of the emitter and is the same as the assigned uptime probability number on the input. ID is either YES or NO, depending on whether the emitter was identified. RPT LOC is the reported location of the emitter. This is the location that also appears on the Intelligence Copy. The CEP implies the inaccuracy of this location in meters for the geometry of the two sensors used in LOCATE. For each sensor there are three pieces of information given. First, a 1 or a 0; 1 means that the sensor heard the signal, 0 means it did not. Next there is either an L or an N;

SENSOR SITE	TARGET	ELEV1 (METERS)	DIST1 (KM.)	ELEV2 (METERS)	DIST2 (KM.)	FOLL (KM)	IA	IC
1	1	310	3.2	220	1.2	3.0	0	7
1	2	310	3.2	220	1.2	3.0	0	7
1	3	310	3.2	220	1.2	3.0	0	7
1	4	310	3.2	220	1.2	3.0	0	7
SENSOR SITE	TARGET	ELEV1 (METERS)	DIST1 (KM.)	ELEV2 (METERS)	DIST2 (KM.)	FOLL (KM)	IA	IC
2	1	190	2.2	—	—	0	0	6
2	2	190	2.2	—	—	0	0	6
2	3	190	2.2	—	—	0	0	6
2	4	190	2.2	—	—	0	0	7
SENSOR SITE	TARGET	ELEV1 (METERS)	DIST1 (KM.)	ELEV2 (METERS)	DIST2 (KM.)	FOLL (KM)	IA	IC
3	1	—	—	—	—	—	0	2
3	2	—	—	—	—	—	0	2
3	3	—	—	—	—	—	0	2
3	4	—	—	—	—	—	0	2
SENSOR SITE	TARGET	ELEV1 (METERS)	DIST1 (KM.)	ELEV2 (METERS)	DIST2 (KM.)	FOLL (KM)	IA	IC
4	1	400	1.2	310	7.0	6.0	0	7
4	2	400	1.2	310	7.0	6.0	0	7
4	3	400	1.2	310	7.0	6.0	0	7
4	4	400	1.2	310	7.0	6.0	0	7

Fig. 18 PROGRAM HELP OUTPUT

```
                                        CONTROL COPY

          INITIAL RANDOM NUMBER= .156700  RADIUS FACTOR=1.333333  MONTH= 7  TIME=2300.0  SSN= 50  AMPLTDE= -80.00

          GYRO=  1.40  F-2 VINT=275000  F-2 3000= 18.00  F-2 0=  6.00  MAX UP=  6.30  LAT= 58.00  LONG=  9.00

     TARGET   2 TEST TARGET 1            ACTUAL LOCATION MA755832

EQUIPMENT    FREQ    ACT  MOD   ID  RPT. LOC   CEP  SENSOR 1   2   3   4   5   6   7   8   9   10  11
H1           49.37   .13 F3    YES  MA755832   396         1L  1L* 1L* 0N  1N
H1           49.37   .13 F3    YES  MA752844   396         1L  1L* 1L* 0N  1N
H2           21.80   .05 F3    YES  MA752831   396         1L  1L* 1L* 0N  1N                  0N  0N
H2           21.80   .05 F3    YES  MA752830   396         1L  1L* 1L* 0N  1N                  0N  0N
H3           40.80   .08 F3    YES  MA751827   396         1L  1L* 1L* 0N  1N
H4           21.80   .05 F3    YES  MA752844   396         1L  1L* 1L* 0N  1N                  0N  0N

     TARGET 166 TEST TARGET 2            ACTUAL LOCATION MB755  1

EQUIPMENT    FREQ    ACT  MOD   ID  RPY. LOC   CEP  SENSOR 1   2   3   4   5   6   7   8   9   10  11
H5           28.45   .12 F3     NO                         0L  0L  0L  0L  0L                  0L  0L
H6            2.00   .08 A1A3   NO                         0L  0L  0L  0L  0L                  0L  0L
H7            3.70   .08 A1F1   NO                         0L  0L  0L  0L  0L                  0L  0L
A1        11190.00  1.00        NC                                             0L      0L
A2          880.00  1.00        NO                         0L  0L  0L  0L  0L  0L      0L
A3         4950.00  1.00        NO                                             0L      0L
A4           81.00  1.00        NO                         0L  0L  0L  0L  0L  0L      0L

     TARGET 174 TEST TARGET 3            ACTUAL LOCATION MA793875

EQUIPMENT    FREQ    ACT  MOD   ID  RPT. LOC   CEP  SENSOR 1   2   3   4   5   6   7   8   9   10  11
H6            3.12   .03 A1A3  YES  MA829854  2905         1L  1L  1L  1N  1N*                 0N  1N*
H5           40.20   .04 F3    YES  MA792859   516         0L  1L* 1L* 0N  0N
H2           22.25   .04 F3    YES  MA793873   516         0L  1L* 1L* 0N  0N                  0N  0N
H8            3.12   .03 A1A3  YES  MA793884   884         1L  1L* 1L  1N  1N*                 1N  1N
A5        16390.00  1.00        NO                                             0L      0L
A6        36950.00  1.00        NO                                             0L      0L
```

Fig. 19 CONTROL COPY OUTPUT

L means that the propagation path was radio line-of-sight, and N means it was nonline-of-sight (due to obstruction or skywave). The two sensors flagged with an * were the ones used to calculate the reported emitter location. If only one sensor heard the signal, the RPT LOC column will contain the reported bearing of the signal (degrees clockwise from north), and the CEP column will contain the 1σ error of this measurement; the σ corresponding to LOS or NLOS inaccuracies. If a target is identified, this will be noted (YES).

c. Intelligence Copy (Fig. 20)

The Intelligence Copy output is a subset of the Control Copy output. The emitters are listed in a pseudo-random order. If the emitter has been identified (only microwave emitters are identified), the emitter ID will contain the emitter description, otherwise it will be blank. The location is the reported location shown on the Control Copy. The information given for each sensor is the same as the Control Copy except that it is not noted whether the signal was a line-of-sight path.

5. Computer System Considerations

CRESS-S was written to run on the CDC 6400 computer. It is written in FORTRAN IV and could be run on the CDC 3300 or other large-scale computers with minor modifications. The input is all punched cards and no tapes are required; however, random access disk storage is needed.

The program is currently limited to 50 sensor sites and 100 emitter-antenna types. There is no limit on the number of targets. The program is designed to run on a computer with only 32K words of core storage; however, at this time it has only been exercised on a CDC 6400 with 131K words of core storages.

INTELLIGENCE INPUT

EMITTER ID	FREQUENCY	MODULATION	LOCATION	SENSOR 1	2	3	4	5	6	7	8	9	10	11
R4	21.80	F3	MA752844	1	1*	1*		1						
R5	40.20	F3	MA 92859		1*	1*								
R2	21.80	F3	MA752931	1	1*	1*		1						
R6	3.12	A1A3	MA829854	1	1	1	1	1*						1*
R8	3.12	A1A3	MA793884	1	1›	1	1	1*					1	1
R1	49.38	F3	MA755842	1	1*	1*		1						
R2	21.80	F3	MA752830	1	1*	1*		1						
R1	49.38	F3	MA752844	1	1*	1*		1						
R2	22.25	F3	MA793873		1*	1*								
R3	40.80	F3	MA751827	1	1*	1*		1						

LAST RANDOM NUMBER= .483941

Fig. 20 INTELLIGENCE COPY OUTPUT

The sample scenario being used to evaluate the program consists of 186 targets. Approximately 100 man-hours of data aide map work generated the data required for the path cards, and approximately 16 man-hours were used in punching and checking the 1300 path cards. The omitter cards required approximately 12 man-hours to punch and check. The target cards required approximately 8 man-hours to punch and check. This case ran on the CDC 6400 in approximately two minutes of processor time, plus printer time.

6. Discussion

To conclude this description of the SIGINT model, CRESS-S, some discussion of the development, use, and limitations of the model is presented together with some ideas for future additions and extensions.

Past SIGINT simulations developed at SRI have been essentially manual, with the computer used only for elementary data sorting and tabulation functions. The present model is an extension of this earlier work. The propagation computations have been programmed for the computer, using for the most part the propagation model of the ACCESS simulation. While a number of minor programming errors in the ACCESS model have been corrected, a good number of the propagation equations used have not been checked against original sources by SRI, but rather have been assumed to be correct if the ACCESS program listing agreed with the written equations in the ACCESS program manuals and flow charts. The accuracy of the propagation model used has been verified in a number of the test cases by comparing the computer program output with the results of hand calculations.

CRESS-S relies on interaction between the analyst and the computer and requires a considerable amount of detailed preparation in generating target area data, deploying the SIGINT sensors,

providing technical characteristics of emitters and sensors, deriving terrain profile data from maps, and providing ionospheric and terrain characteristics data. These manual operations are a strength of this model in that they force the analyst to consider in detail the validity of the input data he is providing; they are also a limitation of the model in the sense that the people providing these inputs must be familiar with the technical aspects of electromagnetic propagation and SIGINT deployment and operations. Once the appropriate input data for a particular scenario have been provided, the model can be exercised easily and reliably by people who are familiar with the computer operations but who may not have the technical skills required to provide the inputs. If any changes are required in the type of output or the way in which the output data are presented to satisfy particular user requirements, (e.g., bookkeeping and data tabulation functions) these can be made by an experienced programmer with only a minimum knowledge of the technical aspects of SIGINT. However, if, for some reason, changes in the technical or computational parts of the program are called for, it is suggested that the SRI personnel who developed this model be consulted.

There are a number of relatively straight forward additions and extensions to the program that should be made to provide increased capabilities or greater accuracy and convenience:

1. The SIGINT model is in need of an extension to include moving airborne sensor platforms. The present airborne platforms are modeled by assigning the sensor altitude. While the addition of moving sensor platforms is straightforward in concept, it will increase the complexity and running time of the program considerably.

2. The alternative of using available digital-type terrain models with the SIGINT and perhaps other sensors should be provided the user to increase the options at his disposal. This alternative would reduce the amount of data aide assistance needed for map work, but would increase the program complexity, running time, and computer storage requirements.

3. The propagation equations used in the model should be revised to include the results of recent research on jungle propagation effects which exhibit considerable differences in attenuation, particularly in the HF range. Furthermore, the propagation equations should be extended to include the case of horizontally polarized signals.

4. The present SIGINT model uses a simplified antenna model that assumes the vertical antenna beamwidth is 90° for all antennas. This model limitation will need to be realistically updated when SIGINT sensors are used in highly elevated modes, such as moving airborne platforms.

There is an additional group of program modifications that differ from those in the preceding paragraph in that their implementation is not a straightforward matter of programming available information, but rather requires additional research efforts to derive the necessary input information. Program modifications fitting into this category are the following:

1. The present SIGINT model uses a simiplified approach to the question of emitter and target identification. Additional study in this area is called for to make this part of the model more realistic. This extension will be of increasing importance when CRESS is used to provide inputs to a model of the intelligence processing functions that take place at the TOC

2. Another serious deficiency in the present SIGINT model as well as in the collateral sensor models is a lack of provision for electronic warfare activities. The models should be modified to include the effects of passive and active ECM and consequent degradation in sensor performance. Such an extension would also permit the inclusion of radio frequency interference from friendly or ambient emitters.

3. The SIGINT model should be extended to provide realistic patterns of emitter activity. These patterns can be used to provide a sense of the time at which intercepts occur and to give a basis for modeling delays incurred in on-site data processing and data dissemination.

In using this model it must be remembered that the propagation equations are based on long-term average effects without consideration for fading. Additional sophistication of the model to determine the effects of fading on detection probability would increase the accuracy and reliability of the output.

It will be apparent that the present model treats the interaction between the SIGINT and collateral sensors in a very simple manner. While extensions would probably be of major significance, it must be emphasized that any such improvements will require a great deal of prior research effort to generate and evaluate potential ways in which this interaction can take place before their inclusion in a model can be meaningful.

E. Data Preparation

There are three general types of data that must be collected and put into the correct formats: (1) data derived from maps and the scenario description; (2) technical data describing the sensors, position location systems, platforms, and communication links, and (3) sensor deployment data. Collection and preparation of the data of the first two types should proceed concurrently. After the targets are deployed, the sensor systems selected and their characteristics ascertained, the sensors can be deployed.

1. Map and Scenario Data

a. Master Form

The first form that should be completed is a working "master" form, which is to be filled out and used by the scenario writer while he is deploying the targets. Several of the forms for tabulating data for the keypunchers will be filled out from this master form. Figure 21 is a sample of the master form. Additional fields of information may be added to this form at the descretion of the scenario writer, and fields 2, 3, 13, and 16 may be deleted if desired, but fields 1, 4, 5-12, 14, and 15 must be included since data in these fields will be used as input data for CRESS.

When the data in the master form are transcribed to other forms for keypunching, extreme care must be taken to ensure that the transcribed data adhere to the applicable format restrictions. Thus, it is preferable, but not mandatory, that the data entered into the master form also be in the required format (see Table 6 for the required format).

Tgt ID	Target Description	Unit Designation	Location	Weapons	Vehicles	Personnel	Radios Radars	Other Objects	Posture of Unit	Camouflage: % ob under nets	Camouflage: natural	Target Radius (m)	Terrain Type	Speed (kph)	Activity Remarks
1	Rifle Co. (-)	4/1/21MRR	MA762[illegible]		[illegible] Trk (2 ton)	4	[illegible]-1[illegible]5D IR-114 IR-213	Bldg, 2-story	6	0	0	50	1	0	
1A	[illegible]le Pit [illegible]h tk pl[illegible] [illegible]d.	1/A/1/21MRR	MA760832	3 Gun, tk (11[illegible])	2 APC-60P 3 Tk-T62	44	IR-126 3R-113	Primary rd jct	11	0	0	250	1	3	

Fig. 21 MASTER FORM

Table 6

FORMATS FOR MASTER FORM DATA

Field	Designation	Type[a]	Explanation and Restrictions
1	Target identification	A	4 FORTRAN characters or less, left justified
2	Target description	--	Descriptive material, no restrictions
3	Unit designation	--	Descriptive material, no restrictions
4	Location	A,I	Grid coordinates, 2 letters followed by 6 digits
5	Weapons	I,A	Numbers and types of weapons--weapon names limited to 18 characters
6	Vehicles	I,A	Numbers and types of weapons--weapon names limited to 18 characters
7	Personnel	I	Number of personnel attached
8	Radios, radars	I,A	Number and types of radios, radars--names limited to 18 characters
9	Other objects	I,A	Number and types of objects--names limited to 18 characters
10	Posture of men	I	Refers to row number in posture array[b] for different types of tactical targets

Table 6 (concluded)

Field	Designation	Type	Explanation and Restrictions
11	Percent of objects under nets	I	Percent of nonpersonnel objects camouflaged by nets, between 0, 100
12	Natural camouflage	I	0 indicates none, 1 indicates effort to blend into background
13	Target radius	I	Indication of area target occupies, meters
14	Terrain type	I	1 indicates smooth, 2-rolling, 3-rough[c]
15	Speed	I	Speed of target in kph, maximum of 999
16	Activities remarks	--	Space for notes

a/ A indicates left-justified alphanumeric entries. I indicates right-justified integer entries.

b/ For each type of tactical target, the posture array (see Figure 22) breaks the number of personnel attached into the numbers of personnel standing, prone, in trenches, in foxholes, and covered in equipment or buildings; it also indicates the percent of men in each of these classes that are covered by nets.

c/ The definitions of the three allowable terrain types are in Table 7.

Table 7

DESCRIPTIONS OF TERRAIN TYPES[a]

Per 12,000-foot square Section	Terrain Type: 1. Fairly Smooth	2. Rolling	3. Rough
Average slope, degrees	2	8	12
Number of slope direction changes	1	6	9
Average distance to first hill or mountain, feet	7500	6750	3500

a/ From Erickson (1961, Ref. 3). This reference should be read prior to classifying the terrain for each target.

In both the CRESS-A and CRESS-G, probabilities of detection, recognition, and identification are calculated for each type of object in a target covered by the sensor. Thus, objects that are of the same general type but differ significantly in size should be grouped separately when the target composition is being specified on the master form. This is necessary if, for example, it is desired that the simulation produce a probability of detecting a 20-ton truck that is different from the probability for detecting a 3/4-ton truck by the same sensor under the same conditions.

The limitations caused by array sizes in CRESS must be recognized when the composition of a target is being prescribed. Each tactical target can contain not more than 19 object types, exclusive of radios;* there can be up to 999 of each object type. If more than 999 are required for a given target, it is permissible to count each group of 999 (or fraction thereof) of the object type as another object type.

Two objects are of different types if any characteristic important to sensor performance is different for the two (e.g., a prone man is a different object type than a standing man since the heights are considerably different). There is an option available that makes it possible to have the computer assign a stance to each of the personnel attached to a tactical unit (target) according to a posture array (see Fig. 22) that indicates the percentage of personnel in each stance for any given posture of the target. If this option is used and personnel is one of the object

---

* Radios are usually contained in vehicles or buildings, so that they are listed for SIGINT model use only.

Percent Men Attached in Various Stances

Target Category Number b/	Target Posture Identification	I	I	I		I	I	I	I
		a/ 4 36	8 40	12 44	16 48	20 52	24 56	28 60	32 64
		Standing		Prone		Slit Trench Equivalency		Foxhole	
		Open	Under Nets	Open	Under Nets	Open	Under Nets	Open	Under Nets
1	Dismounted personnel in attack - up to assault	60		40					
2	Dismounted personnel in assault	90		10					
3	Hasty position. Dismounted personnel in assembly area.	50		30				20	10
4	Hasty position. SSM, SAM, CP's indirect fire weapons.	50	20	30				2[illegible]	20

a/ Two lines are put onto 1 card.

b/ FORMAT (16I4). Maximum of 16 categories.

Fig. 22. POSTURE-MEN ARRAY

types in a target, 14 is the maximum number of object types allowed. This is usually enough; however, if more object types are required for one target the target can be processed by splitting it into two targets and giving both targets the same location.

b. Object Characteristics Form (Fig. 23)

The next form that should be filled out is the "object characteristics" form as shown in Fig. 23. The steps in filling out this form are:

(1) Make a list containing each object type that occurs in the master form.

(2) Rearrange this list of object types into groups of object types that belong to the same recognition class and assign a name (≤ 18 characters) to each recognition class.

(3) Rearrange the resulting recognition classes into groups of recognition classes that belong to the same detection class and assign a name (≤ 18 characters) to each detection class.

(4) Assign consecutive numbers to the resulting list of object types, starting with the number 1.

(5) Assign consecutive numbers to the resulting list of recognition classes, starting with the number 1.

(6) Assign consecutive numbers to the resulting list of detection classes, starting with the number 1.

(7) Assign the appropriate characteristics to each object type.

The primary reason for grouping object types into recognition classes, and those classes into detection groups, is

I	A	I	I	R	R	R	R	R	R	R	R	R	R	R	I
3	5 24	27	30	39	47	55	63	71	11	19	27	35	43	51	59
Obj. No.	Object Name	Det. Class	Rec. Class	Dimensions (Meters) Length	Width	Height	Visual Reflect.	IR Reflect.	Radar Reflect.	IR Emissivity	Temp (°F) Day	Night	Ave. Prob. Mis. ID	Ave. Prob Mis. Rec.	Multi-Sensor Classific.
1	Bridge Laying Tank	5	16	12.	3.5	2.5	.14	.13	.3	.87	65.	53.	.08	.10	4
2	100MM Aslt Gun, SP	5	16	11.1	3.3	2.4	.12	.10	.3	.90	68.	69.	.25	.10	4

FORMAT (I3, 1X, 5A4, 1X, I2, 1X, I2, 1X, 5F8.0/3X, 6F8.0, I8)

Fig. 23 OBJECT CHARACTERISTICS FORM

to provide a method for reporting sighted target elements on the Intelligence Copy at a level of detail consistent with the performance of the sensor (e.g., if a T-62 tank is recognized then it should be reported as a tracked vehicle, not as a T-62 tank). Another reason for having recognition and detection classes is to allow the simulation of misidentification and misrecognition of objects. A recognition class is a group of object types, any one of which is likely to be misidentified by an image interpreter as another object type in that same recognition class. Similarly, a detection class is a group of recognition classes that are similar enough to each other that the image interpreter may mistake any one of them for any other recognition class in the same detection class. The user may group the object types to form the recognition classes (maximum of 40) and the detection classes (maximum of 10) in any manner he chooses. However, he should be aware that if a recognition (detection) class contains only one object type (recognition class), that object type cannot be misidentified or misrecognized. Appendix A provides an example of an extensive list of object types that are divided into recognition classes and the resulting recognition classes divided into detection classes.

Most of the object types occurring in a target are given in Appendix A. If they are found there, the characteristics can be transcribed onto the object characteristics form. If an object type to be used does not appear in Appendix A, the user must supply the characteristics. He can do this simply by supplying the dimensions of the object type and by using a similar object type that does occur in Appendix A for the remaining characteristics.

The entries for average probability of misidentification and misrecognition for each of the objects in Appendix A were assigned by Mr. Christopher Nosworthy of Stanford Research Institute, a systems analyst and experienced image interpreter. Although these numbers reflect his best subjective judgment, Mr. Nosworthy feels that experimental work with image interpreters is needed to fix these values more accurately.

The column labeled multisensor classification refers to the row number for the object in the classification system (see Table 4) that Honeywell (Ref. 1) used in developing the multisensor enhancement model that is being used in CRESS.

c. Detection and Recognition Classes Form (Fig. 24)

The detection and recognition classes form shown in Fig. 24 is filled out for keypunching by listing the detection classes in order and then listing the recognition classes in order. It is important that each of these lists be numbered consecutively, starting with the number 1. The maximum number of characters permitted in a descriptor is 18.

d. Posture-Men Array (Fig. 22)

To generate the posture-men array (Fig. 22), make a list of the types and postures of the targets in the scenario. Number the entries in this list sequentially starting with the number 1. A maximum of 16 different target postures are allowed. For each target type and posture in the list, prescribe the persentages of men attached that are in each of the following stances: standing, prone, in slit trenches (or presenting equivalent viewing area), and in foxholes. These percentages do not need to sum to 100 since some men may be in equipment or buildings (and thus they will be undetectable by the sensors). In addition, for each

I	A	
4	6	23
Class No.	Class Descriptor	
1	Long, narrow target	
2	Large land object	
⋮	⋮	
8	Aircraft	
1	Road	
2	Bridge	
3	Large building	

FORMAT (I4, 1X, 5A4)

Note: List all detection classes then all recognition classes

Fig. 24 DETECTION AND RECOGNITION CLASSES FORM indicated stance of the men, assign the percent of the total number of men attached that are under nets.

The first two columns of information are for identification purposes only. The percentages are the only entries punched on cards. Thus, it is important that the target category numbers be assigned in sequential order starting with the number 1.

e. Target Object Form (Fig. 25)

After all the different object types in the scenario targets have been assigned numbers as described above, the target object form shown in Fig.25 can be filled in for keypunching. This task, with the exception of filling of column 2 (target posture) is simply a matter of transcribing the target identification, and for each object type contained in the target, writing down the object type number and the corresponding number of elements of that type in the target. Column 2 is filled in for each target by assigning the identifying number of the posture in the posture-men array that most nearly describes the posture of the target.

If the option of having the machine assign stances to the personnel is not desired for a particular target, that target should be assigned the posture that assigns 100 percent of the personnel to the standing stance. In this case, it is permissible to have men in any other stance (e.g., prone) as a separate object type, since the computer apportions standing personnel only according to the percentages listed in the posture-men array.

f. Target Variable Form (Fig. 26)

The information for the target variable form shown in Fig. 26 is derived from: (1) personnel writing the scenario and deploying the targets, and (2) map features. As the scenario is

(T = Object Type; N = Number of Objects of Type T)

A	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I		I
1 4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72		80
Target	Post-	1		2		3		4		5		6		7		8		19	
ID No.	ure	T	N	T	N	T	N	T	N	T	N	T	N	T	N	T	N	T	N
1	1	30	1	61	4	11	1												
1A	1	20	3	18	2	61	44	2	1										
1B	1	18	2	61	32	[illegible]	4												
1C	1	18	2	61	32														
2	1	30	1	61	4														
2A	1	18	2	61	32														
2B	1	18	2	20	3	61	44												
2C	1	18	2	61	32														
3	11	30	1	20	1	61	[illegible]												
3A	11	18	2	20	1	61	36												
3B	11	18	2	20	[illegible]	61	36												
3C	11	18	2	20	1	61	36												
4	4	60	3	19	3	61	17	11	1	12	1	13	1						
5	4	22	2	61	16														
6	11	18	3	30	8	61	44												

Fig. 25 TARGET-OBJECTS FORM

I	A	A	I	I	I	I	I	I	I	I	I	I	R	R
2	4	9	16	22	28	34	40	42	46	54	56	59	63	67
Tgt. Grp. No.	Tgt. ID.	Grid	Location	Elev. (m)	Initial Time	Final Time	Speed (kph)	Terrain Type	Veg. Cov.	Camouflage		Bkgrd. Type	Propensity to fire given, fired upon	Propensity to fire given, not fired upon
										Nets[a]	Natural			
14	501	MB	718362	350	11200	11800		3	99	80	1	14	1.0	1.0
14	502	MB	740398	320	11200	11800		3	95	70	1	9	1.0	1.0
16	503	MB	739539	300	11200	11230	10	3	50	0	0	14	1.0	1.0

a/ Nets for objects other than men.

FORMAT (I2, 1X, A4, 1X, A2, I6, 6X, 3I6, I2, I4, 5X, I3, I2, I3, 2F4.0)

Fig. 26 TARGET VARIABLE FORM

developed, an overlay depicting the targets on the map should be produced, and the targets should be assigned identifications for the computer (a maximum of four characters per target ID). It is suggested that similar designations be used for related targets. For example, 24, 24A, 24B, and 24C could be used as designations for a rifle company and its three platoons. Similarly, if a tactical target move and occupies three different positions during the period of time being simulated, it must be treated as three targets in the computer. Assigning similar designations to these three targets (for example, 57P, 57Q, and 57R) will aid the analysts.

The person deploying the targets must specify:

(1) The time that the target is at the location given

(2) The speed of moving targets

(3) The percentage of objects (other than personnel) covered by camouflage nets

(4) Whether natural camouflage (e.g., shrubbery, dirt) is being used (0--not used; 1--used)

(5) The probability that the target would fire back at an aircraft firing in the target's general direction (this is needed only if reconnaissance-by-fire is being played)

(6) The probability that the target would fire on a reconnaissance aircraft (this is needed only if the option for playing attrition is being used).

The remaining fields of information are filled in from the map. The target group number is read from an overlay that preferably is drawn after the initial flight plans have been developed. Assigning targets near each other to the same group is necessary to keep the computer from processing every target when the sensors are turned on in an RS area in one small part of the entire region being considered in the scenario. The dividing lines can be drawn in such a way that the areas of the resulting groups are similar to political boundaries in the United States (i.e., gerrymandering is allowed) if desired. The guiding principal in drawing the dividing lines is that the computer should have to process as few targets as possible on each flight. The maximum number of groups permissible is 40. There must be at least one group. Groups containing 20 to 30 targets (although any number ≤ 750 is allowed) oriented so that most of the RS areas will reference only a few of these groups is a good trade-off between maproom work and computer time. After the boundaries for the groups are drawn, the groups may be numbered in any order on the map; however, it is mandatory that the numbers start with 1 and be consecutive. After the target variable cards are punched they must be ordered by ascending values of the group numbers.

The elevation above mean sea level (in meters) should be written onto the form for each target. The terrain in the vicinity of the target must be classified as smooth (code 1), rolling (code 2) or rough (code 3). Definitions of smooth, rolling, and rough terrain are stated in Table 5.

The vegetation coverage for the target represents the percentage (no decimal point) of the target masked to an aerial observer by vegetation. This is determined by ascertaining (from the map) the percentage of the target area covered by vegetation and considering the posture of the target. A subjective judgment to determine the percentage of the target taking available cover from a reconnaissance aircraft is then made. This vegetation coverage figure is used only in the aerial sensors model.

The background type number is assigned as follows:

(1) Assign consecutive numbers (starting at 1) to each background type found in the legend of the map (1:50,000 maps are essential, 1:25,000 or larger are desired). It is sometimes desirable to assign numbers to background types that do not occur in the legend (e.g., concrete for aircraft on runways).

(2) Where the target area contains more than one type of background, assign the number of the predominant background type to each target.

g. Background Characteristics Form (Fig. 27)

The contrast between objects and background is computed from the characteristics given the background characteristics form shown in Fig. 27 and the object characteristics form. Characteristics must be supplied for each of the background types used by the deployed targets. Appendix A contains a list of commonly occurring background types and the corresponding characteristics. If a background type is encountered that does not occur in Appendix A, the materials forming the background should be ascertained and the required characteristics looked up in the references for Appendix A. If this fails, the numbers will have to be approximated, based on those of similar materials with known characteristics.

The background types must occur in consecutive order, starting with type number 1.

Appendix A contains the definitions of the reflectances used on this form.

I	A	R	R	R	R	R	R
3	5 42	45	49	54	58	64	70
Back-ground No.	Background Description	VIS	IR	RADAR	Emiss.	Day Temp. (°F)	Night Temp. (°F)
1	Asphalt road	.05	.09	.06	.91	62.	50.
2	Gravel road	.22	.24	.02	.76	58.	43.
3	Pasture	.05	.10	.09	.90	52.	40.

FORMAT (42X, F3.0, 1X, F3.0, 1X, F4.0, 1X, F3.0, 2(1X, F5.0))

Fig. 27. BACKGROUND CHARACTERISTICS FORM.

2. Technical Data

a. Sensors

Each type of equipment that can be simulated in CRESS is described parametrically in the models. The appropriate characteristics of the sensors to be simulated must be determined and keypunched. With the exception of the SIGINT sensor models that are new, the sensor models in CRESS are essentially the same as those in the models from which CRESS has evolved. Appendix I contains the characteristics of most of the sensors that have been simulated by CRESS and its predecessor models. These characteristics are listed in the correct format for keypunching. The definitions of each of the parameters are found in the sensor model descriptions contained in Appendix B.

When a sensor to be simulated is not listed in Appendix I, it is necessary for the user to determine the required characteristics. If the sensor is in use or being developed, the engineers of the manufacturing company can easily supply the necessary data. If it is a sensor that is forecast for future use, engineers in companies engaged in research and development of that type of sensor should be able to supply the required parameters.

Whenever two or more sensors cover the same target, there is a potential for producing more information than could be collected from the independent use of the sensors. The table of enhancement coefficients for the multisensor enhancement submodel is in Table 4. The enhancement submodel is explained in Section II.B.8.

b. Aircraft

The only parameters needed for each type of reconnaissance aircraft are speed, altitude, mean time between failures

(MTBF), and vulnerability to fire from AA weapons. The flight planners will supply the speed and altitude for each flight. The MTBF for a reconnaissance aircraft is defined here to be the mean time between failures that would cause the mission to be aborted. These failure data are needed only if the option to play noncombat failures is selected. Sources for MTBFs for Air Force reconnaissance aircraft and their subsystems are Refs. 4 and 5. Figure 28 depicts the form for aircraft MTBF data. The aircraft types should be numbered consecutively starting with number 1

	A	R
	6 17	21
	Aircraft Designation	MTBF (hours)
1	OV-1D	70.
2	UH-1B	80.
3	RF-4C	50.

FORMAT (5X, 3A4, F4.0)

Fig. 28 AIRCRAFT MTBF FORM

c. Air Attrition

If attrition caused by enemy ground based AA weapons is to be played, the attrition probability form shown in Fig. 29 must be filled in. The attrition submodel used in the aerial model, is a simple stochastic model based on the average capability of a given type weapon to shoot down a given type of aircraft. These average values can be obtained from more sophisticated attrition models, or from field data if the situation being simulated is similar to real battles for which attrition data exist.

I	A	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
3		8	13	18	23	28	33	38	43	48	53	58	63	68	73	78
Obj. Typ.	Object	1[a/]	2	3	4	5	6	7	8	9	10	11	12	13	14	15
17	Tracked Amphib K61	.03	.081	.004												
38	SAM Lnchr, SP	0.	0.	.5												
9	Boat	.02	.049	.0025												

a/ Numbers 1, 2, ..., 15 refer to aircraft numbers in Fig. 12
FORMAT (I3, 15F5.0)

Fig. 29 ATTRITION CAPABILITY FORM

The probabilities used in checking CRESS were derived from Project PACE (Ref 6).

It should be noted that in developing the scenario, it is not always desirable to list all of the objects in a target. For example, if the target is an airfield, it will contain a large number of object types and probably a considerable number of AA weapons. Instead of listing each weapon type, attrition can be played in CRESS by assigning an appropriately large attrition capability to object type "airfield" in the attrition capability form. A maximum of 30 different object types can be assigned attrition capabilities. The columns labeled 1, 2, 3, ..., 15 refers to the correspondingly numbered aircraft in Fig. 28.

d. Aerial Data Links

The required information for each type of data link used for transmitting sensor imagery or reports is a number to designate each type data link and the MTBF for each type data link. Figure 30 depicts the form for aeriel sensors' data links and Fig. 31 shows the form for ground sensors' links.

e. Ground Communication Link Failure Form (Fig.31)

It is assumed that ground based equipment that fails can be repaired or replaced and put back in service. If the option to play equipment failures is used: (1) the MTBFs for the communication links to OPs and patrols, (2) mean downtime, and (3) standard deviation of the downtimes must all be specified. Each link is failed according to a sample from a Poisson distribution with the specified MTBF as parameter. The amount of time the link remains out of service is simulated by drawing a normal deviate from the normal distribution described by the specified mean down time and standard deviation.

I	A	R
2	3 20	24
No.	Data Link	MTBF (hours)
1	ARC 52	50.
2	ARC 27	50.

FORMAT (20X, F4.0)

Fig. 30 DATA LINK MTBF FORM

	R	R	R
	27	35	43
Link Number	MTBF	Mean down time (hours)	Standard deviation of down time (hours)
1	50.	2.	1.
2	50.	2.	1.

FORMAT (20X, 3(F7.0,1X))

Fig. 31 GROUND COMMUNICATIONS LINK FAILURE FORM

f. Time Delay Factors Form (Fig. 32)

It is assumed that operators for all ground sensors will have a communication link directly to the intelligence team, so no time delay is simulated for ground based sensors.

The aerial model provides for simulating the amount of time from overflight of a target to the delivery of interpreted data (about that target) to the intelligence team. If a data link is not available for a sensor, the remaining flight time and imagery unloading time are calculated in place of the data link transmission time. Time for imagery handling and preliminary processing is added in. However, the largest amounts of time added in are usually for the image interpreter and the subsequent report to the appropriate intelligence units. These two times are simulated by sampling normal distributions that are specified by means and standard deviations prescribed by the user for each airborne sensor.

The image interpreter times given for cameras in Fig. 31 were derived from an experiment that Mr. Harold Martinek arranged at the U.S. Army Behavioral Science Research Laboratory, Washington, D.C. A class graduating from the Image Interpreter's Course at Fort Holabird interpreted tactical photo imagery of North Vietnam. The mean time per frame was 9.213 minutes for the class; the standard deviation was 6.698 minutes.

The other times given in Fig. 31 are best estimates. Although Fig. 31 lists only one sensor of each sensor type, there must be a row of information for each aerial sensor simulated.

g. Aerial Navigation Systems Form (Fig. 33)

Models are provided for the types of navigation systems listed in Table 8. The parameters for each navigation system to

A	R	R	R	R	R	R	R	R
7	14	21	28	35	42	49	56	63
Sensor	Trans-mission	Film Handling	Prelim. Process (per frame or ft)	Copy Handling	Mean, Interpret (per frame or ft)	1 σ for Interpret.	Mean, Message Delivery	1 σ, Message Delivery
K56A	.25	5.	.117	1.5	9.213	6.698	12.	4.
IR1	.05	5.	.234	1.5	13.7	10.0	12.	4.
R94	.05	5.	.351	1.5	13.7	10.0	12.	4.
VIS	.5	0.	0.	0.	1.	.9	1.	.5
LASR	.05	5.	.234	1.5	13.7	10.0	12.	4.
TVI	.05	0.	0.	0.	3.	1.	5.	2.
RBF	.5	0.	0.	0.	.25	.1	1.	.5

Note: All times are in minutes.
FORMAT (3X, A4, 8F7.0)

Fig. 32 TIME DELAY FACTORS FORM

A		R	R	R	R	R	R	R	R	R	R	R
1	12	14	16	23	30	37	44	51	58	65	72	79
Nav. Name		Type[a/] No.	No.[b/] of Type	1[c/]	2	3	4	5	6	7	8	9
ASN-56		1	1	1.	5.	.05	5.					
Doppler		2	1	5.	.05	.00278	.00408	.00225	.00445	.00225		
Radar		4	1	2.	.00673	30.	20.	65000.	25000.			

[a/] Table 6 lists the types that can be simulated, together with the associated type number for use here.

[b/] The number of different navigation systems of the same generic type being simulated.

[c/] See Tables 7 through 15 for the definition of these numbered fields. (Dependent on type.)

FORMAT (3A4, 2F2.0, 9E7.0)

Fig. 33 AIR NAVIGATION SYSTEM FORM

be simulated must be entered into the form depicted in Fig. 33. The parameters required for each type of navigation system are listed in Tables 9 through 17. The necessary parameters can be obtained from manufacturers of the type of navigation systems being simulated.

Table 8

NAVIGATION SYSTEMS MODELED[a/]

Type of Number	Type of Navigation System
1	Inertial
2	Doppler
3	Dead Reckoning (DR)
4	Rho-Theta
5	Hyperbolic
6	Direction Finding (DF)
7	Ranging
8	Mapmatching

a/ See Ref. 7 for description of models.

h. Navigation Systems MTBF Form (Fig. 34)

A MTBF must be specified for each navigation system being simulated if the option for playing equipment failures is selected. MTBF information for navigation systems in U.S. Air Force reconnaissance aircraft can be found in Refs. 4 and 5.

Table 9

SIMPLE INERTIAL NAVIGATOR PARAMETERS

Field[a/]	Definition	Typical Value
1	Type of inertial system (1~ simple, 2~ sophisticated)	1.
2	1 σ error in setting inertial system at airport (meters)	5.
3	Altitude coefficient for 1 σ error of inflight updating (percent/100)	.05
4	Drift rate of system (meters/min.)	5.

[a/] Corresponds to field numbers in Fig. 33.

Table 10

INERTIAL NAVIGATOR PARAMETERS

Field[a]	Definition	Typical Value
1	Type of inertial system	2
2	$Gyro_1$ drift rate (radians/sec)	$1. \times 10^{-6}$
3	$Gyro_2$ drift rate (radians/sec)	$5. \times 10^{-4}$
4	$Accelerometer_1$ drift rate ($meters/sec^2$)	$2. \times 10^{-6}$
5	1 σ error in initial leveling of platform along longitudinal axis (radians)	$5. \times 10^{-5}$
6	1 σ error in initial leveling of platform along transverse axis (radians)	$5. \times 10^{-5}$
7	1 σ error (longitudinal axis) in setting inertial system at airport (meters)	5
8	1 σ error (transverse axis) in setting inertial system at airport (meters)	5
9	Altitude coefficient for 1 σ error of inflight updating (percent/100)	.05

[a] Corresponds to field number in Fig. 33

Table 11

DOPPLER NAVIGATOR PARAMETERS

Field[a]	Definition	Typical Value
1	1 σ error in setting Doppler system at airport (meters)	5.
2	Altitude coefficient for 1 σ error of inflight updating (percent/100)	.05
3	β - bandwidth of noise (sec^{-1})	1/360
4	Doppler sensor 1 σ error along track	.00408
5	Computer 1 σ error along track	.00225
6	Doppler sensor 1 σ error across track	.00445
7	Computer 1 σ error across track	.00225

[a] Corresponds to field number in Fig. 33

Table 12

DR NAVIGATION PARAMETERS

Field[a]	Definition	Typical Value
1	Altitude coefficient for 1 σ error of inflight updating (percent/100)	.05
2	1 σ error in direction resolution (radians)	.035
3	1 σ error in velocity (meters/min.)	90.

[a] Corresponds to field numbers in Fig. 33

Table 13

RHO-THETA NAVIGATION PARAMETERS

Field[a]	Definition	Typical[b] Value
1	1 σ error in station location (meters)	5.
2	1 σ error in direction resolution (radians)	.035
3	1 σ error in range resolution (meters)	30.
4	1 σ error in altitude resolution (meters)	20.
5	x coordinate of station with respect to origin at lower left grid corner (meters)	--
6	y coordinate of station with respect to origin at lower left grid corner (meters)	--

a/ Corresponds to field numbers in Fig. 33.

b/ Typical values for ground control radar.

Table 14

HYPERBOLIC NAVIGATION PARAMETERS

Field[a/]	Definition	Typical Value
1	1 σ error in station location (meters)	5.
2	1 σ error in time difference measurement, slave station 1 (microseconds)	.5
3	1 σ error in time difference measurement, slave station 2 (microseconds)	.5
4	x coordinate[b/] of slave station 1 (meters)	--
5	y coordinate[b/] of slave station 1 (meters)	--
6	x coordinate[b/] of slave station 2 (meters)	--
7	y coordinate[b/] of slave station 2 (meters)	--
8	x coordinate[b/] of master station (meters)	--
9	y coordinate[b/] of master station (meters)	--

[a/] Corresponds to field numbers in Fig. 33.

[b/] Coordinates are given with respect to origin at lower left grid corner  (meters).

Table 15

DF NAVIGATION PARAMETERS

Field[a]	Definition	Typical Value
1	1 σ error in locating stations (meters)	5.
2	1 σ error in direction resolution (radians)	.035
3	x coordinate[b] of station 1	--
4	y coordinate[b] of station 1	--
5	x coordinate[b] of station 2	--
6	y coordinate[b] of station 2	--

[a] Corresponds to field numbers in Fig. 33.

[b] Coordinates are given with respect to origin at lower left grid corner (meters).

Table 16

RANGING NAVIGATION PARAMETERS

Field[a]	Definition	Typical Value
1	1 σ error in locating station (meters)	5.
2	1 σ error in height resolution (meters)	20.
3	1 σ error in range resolution (meters)	30.
4	x coordinate of station 1	--
5	y coordinate of station 1	--
6	x coordinate of station 2	--
7	y coordinate of station 2	--

[a] Corresponds to field numbers in Fig. 33

[b] Coordinates are given with respect to origin at lower left grid corner (meters).

Table 17

MAPMATCH NAVIGATION PARAMETER

Field[a]	Definition	Typical Value
1	1 σ error of map (meters)	14

a/ Corresponds to field number in Fig. 33.

A		R
1	12	16
Navigation System		MTBF (hours)
A SN-56		94
DOPPLER		110
RADAR		120

FORMAT (3A4, F4.0)

Fig. 34 NAVIGATION SYSTEMS MTBF FORM

i. Position Location

The models of the navigation systems compute the error associated with locating the reconnaissance aircraft in terms of error ellipses. The reported position and location accuracy for a sighted target incorporates this error with the errors inherent to Class A, B, and C maps. The resulting errors are stated in terms of circular errors probable (CEPs). Table 18 is the digital form of a curve used in converting from an error ellipse to a CEP, with the format for keypunching. Table 19 lists the Class A, B, and C map CEPs.

Table 18

ELLIPSE TO CEP CONVERSION CURVE

R	R	R	R	R	R	R	R	R	R	R	R
6	12	18	24	30	36	42	48	54	60	66	72
CR1	CR2	CR3	CR4	CR5	CR6	CP1	CP2	CP3	CP4	CP5	CP6
0	.1	.15	.2	.25	.3	.675	.680	.690	.71	.725	.75

FORMAT (12F6.0)

Table 19

MAP CEPs
(Meters)

R	R	R
5	10	15
Class A	Class B	Class C
7.0	14.0	28.0

FORMAT (3F5.0)

The computer model will accept positions of targets, ground OPs, and flight path checkpoints in grid coordinates composed of two letters followed by six digits. Before calculating distances between targets and sensors, the computer converts the grid coordinates into rectangular Cartesian coordinates with the origin at the lower left-hand corner of the lower left-hand lettered grid. One, two, three, or four lettered grids can be accommodated if they will all fit into a square 200 kilometers on a side. Figure 35 depicts the numbering system for these grids. The order given the lettered grids is important. If, for example, only grids MA and MB are used then MA and MB must occur in columns 1 and 3 of the Grid Form (see Fig. 36).

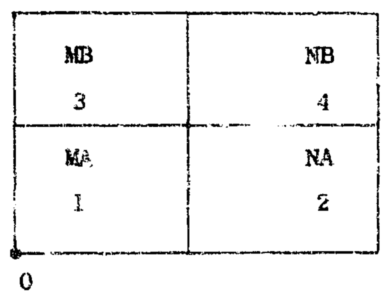


Fig. 35 PERMISSIBLE GRIDS

A	A	A	A
1	5	9	13
Grid 1	Grid 2	Grid 3	Grid 4
MA	NA	MB	NB

FORMAT (4(A2, 2X))

Fig. 36 GRID FORM

Occasionally, it is necessary to use maps that are distorted along a longitudinal line because of the type of projection used to produce the map. These maps cannot be used directly by CRESS since distances calculated between points on opposite sides of this "seam" would be in error. Thus, if it is necessary to use such a map, it will also be necessary to make a grid overlay for the map and to record all positions with reference to the square grid overlay.

j. Atmospheric Parameters Form (Fig. 37)

Each type of sensor is affected by some of the characteristics of the atmosphere. Since the weather varies from place to place on the earth and from one time of year to another, it is necessary to describe the atmosphere at the place and time the scenario prescribes. The cloud coverage, cloud base, visibility range, relative humidity, air temperature near the ground, and horizontal plane illuminance can be obtained from a meteorologist familiar with the area. There are also historical weather data for many parts of the world that give monthly averages for these parameters. The remaining parameters in Fig. 37 depend on the physics of the atmosphere and water droplets and do not usually vary for different scenarios. The values given in Fig. 37 are representative values for these parameters.

A	I	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R
1 12	13	17	23	28	33	39	46	53	61	69	7	15	23	31	39	47
ADI*	DAY	CCC	BASE	VR	RH	TG	AA	AR	NJ	RJ	ISI	TAUA	FR	EJS	EJA	DEGF
Description	Day(0) or night(1)	Cloud coverage (fraction)	Cloud base (feet)	Vis. range (km)	Rel. humidity	Air temp. near ground (OF)	Radar: Atm. absorpt. loss (db/km)	Radar: Rain absorpt. loss (db/km)	Laser: No. of water droplets (per cm^3)	Laser: Radius of water droplet (cm)	Horizontal plane illuminance (ft-candle)	Atm. trans. coef.	Radar: Rain reflect. factor (m^3)	Laser: Scatter area ratio of particles	Laser: Absorpt. area ratio of particle	GSR: Degrad. factor
Clear Day	0	0.	99000.	20.	.85	50.	.000015	0.0	0.0	0.0	8000.	1.	0.0	.45	.82	1.
Clear Night	1	0.	99000.	20.	.90	42.	.000015	0.0	0.0	0.0	.002	1.	0.0	.45	.82	1.
Degraded Day	0	.80	3000.	3.0	.98	46.	0.0	.028	10.0	.0005	1000.	.9	6.6×10^{-18}	.45	.82	.75
Degraded Night	1	.80	3000	3.0	.98	40.	0.0	.028	10.0	.0005	.001	.9	6.6×10^{-18}	.45	.82	.75

*FORTRAN names of parameters.

FORMAT (12X, I1, F4.2, F6.0, 2F5.0, F6.0, 2E7.0, 2F8.0/5(F7.0, 1X))

Fig. 37 ATMOSPHERIC PARAMETERS FORM

3. **Miscellaneous Data**

a. **False Target Maximum Form (Fig. 38)**

When false targets are generated (see Section II.B.7 for a description of the false target submodel), their elements are always reported as being recognized. It is necessary for the **user to prescribe the maximum** number of elements of each recognition class that can occur in a false target report. (No more than four recognition classes can be represented in a false target.) This will allow the possibility of having several small objects (e.g., men, small weapons) of a recognition class represented in a false target report, but limiting the number of large objects (e.g., bridges, boats) of a recog .tion class. These numbers will be a product of the user's ubjective judgement concerning the numbers of different elemen s that might be reported together as a target. The numbers sh ald not represent the extreme case, but should reflect the user's judgment of what the composition of the "average" false target might be. In generating these numbers, it should be kept in mind that CRESS plays the interaction of sensors and target elements, not targets. Therefore, the maximum numbers should reflect the numbers of objects likely to be reported, and not necessarily the TOE of the enemy.

b. Report Criteria

The aerial and ground models both produce two computer outputs: the Control Copy and the Intelligence Copy. The Control Copy displays essentially all the information about the interaction of the sensors and the targets that the computer processes. The Intelligence Copy displays only data that units deploying the sensors would be able to acquire from their sensors. Thus, for example, targets that are covered by a sensor but not detected will not be reported on the Intelligence Copy.

I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
Maximum number of elements in each recognition class.																			
1	2	3	4	5	6	[illegible]	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	1	1	1	10	3	4	1	1	4	4	4	10	10	1	1		

Note 1. When more than 20 recognition classes are used the maximum numbers should be given on a second card (same format) for classes 21–40.

FORMAT (2013)

Fig. 38 FALSE TARGET MAXIMUM FORM

Exactly what should be reported on the Intelligence Copy depends on the user's reasons for using CRESS. If CRESS is being used to examine the effect of using reconnaissance systems in various combinations, perhaps the Intelligence Copy is not needed. If CRESS is being used as an input to the teams playing a closed war game, the Intelligence Copy should reflect the type of detail expected. For example, if the game is being played at the company level, anything that is detected should probably be reported. However, if the Intelligence Copy is meant for the intelligence team at the division or corps level, perhaps only sizable targets and/or targets containing important equipment (e.g., rocket launchers) should be reported.

To provide flexibility in the use of the Intelligence Copy, the user can specify his own criteria for reports within the limits of the options listed in Table 20. The user can choose none, any one, any two, or all three of the criteria. If he chooses none (all zeros or blanks) entered in the report criteria form (Fig. 39), no Intelligence Copy will be printed. Otherwise, a report will be generated for a sensor-target interaction if any one of the criteria that the user selects is met.

Table 20

REPORT CRITERIA

Criteria Numbers	Criteria
1	Threshold number of objects identified, recognized or detected.
2	Threshold number of special objects identified, recognized, or detected.
3	Percent of objects present identified, recognized, or detected.

I	I	I	I	I	I	I	I	I
4	8	12	24	28	32	44	48	52
Criterion 1			Criterion 2			Criterion 3		
Criterion[a] selected?	Sighting[b] Detail	Threshold[c] number	Criterion[a] selected?	Sighting[b] Detail	Threshold[c] number	Criterion[a] selected?	Sighting[b] Detail	Percent[d]
1	3	1						

[a]Leave blank if not selected, otherwise enter the criterion number.
[b]Enter 1 for identification, or 2 for recognition, or 3 for detection.
[c]The threshold number must be an integer greater than or equal to 1.
[d]The percent must be an integer greater than or equal to 1.

FORMAT (3(3I4,8X))

Fig. 39 REPORT CRITERIA FORM

For each criterion selected, the user must specify the threshold number, or percent, and which one of identification, recognition, and detection is to be used. He does this by filling out the report criteria form. When criterion 2 is selected, he must also provide a list of the numbers (a maximum of 10, of the special objects chosen (see Fig. 40 for format). The example shown in Fig. 39 is the weakest possible condition for generating a report; if any object is detected, a report will be generated.

c. Area Target Radii Form (Fig. 41)

If the user wants a list of all reported groups of target elements that are within a prescribed radius of each other, he must put the radii (in meters) he desires in ascending order into the form in Fig. 41. The computer will then group the reported groups of target elements for each of the radii listed. This may be beneficial in ascertaining which elements belong to a tactical unit type that is assumed to occupy an area of the given radius.

d. Situation Heading Card Form (Fig. 42)

The information printed in columns 2 through 49 of the situation heading card will be printed as a label at the top of each output form. Any acceptable FORTRAN characters are allowed.

e. MEN/NET Designation Form (Fig. 43)

If the option to have the computer assign the prescribed percentages of personnel to the various stances and provide for camouflage nets in the simulation is used, the object numbers and recognition class numbers for standing personnel and large nets must be entered in the MEN/NET designation form (Fig. 43).

I	I	I	I	I	I	I	I	I	I	I
4	8	12	16	20	24	28	32	36	40	44
Number of special objects	Special object numbers[a/]									
3	19	27	2							

a/ These numbers must correspond to the object numbers used in the object characteristics form

FORMAT(11I4)

b/ A card is punched in this format and used only if report criterion 2 is selected.

Fig. 40 SPECIAL OBJECTS FORM[b/]

R	R	R	R	R
10	20	30	40	50
Radii of Tactical Targets of Interest				
1000.	1500.			

FORMAT (5F10.0)

Fig. 41 AREA TARGETS RADII FORM

A	
2	49
Situation Heading	
Ammunition Expenditure Rates, Clear Day	

FORMAT (1X, 12A4)

Fig. 42 SITUATION HEADING CARD FORM

I	I	I	I
4	8	12	16
Object Number, Standing Men	Object Number, Large Net	Recognition Class Number, Nets	Recognition Class Number, Men
61	14	7	15

a/ For ground model only.

FORMAT (4I4)

Fig. 43 MEN/NET DESIGNATION FORM[a/]

f. Random Number Initialization Form (Fig. 44)

The pseudo-random number generator generates a sequence of pseudo-random numbers by performing precisely prescribed operations. Thus, if the initial conditions are the same each time a list of numbers is to be generated, the same list will be generated each time. It is sometimes desirable to repeat part of a simulation with exactly the same results. This can be done if the user ensures that he uses the same number to initialize the pseudo-random number generator for each desired repetition. The user can choose any number between 0 and 1 as the initializing number. If the simulating is stopped and is to be resumed where it was stopped, the user may continue with the same sequence of pseudo-random numbers that was originally being generated if he restarts the simulation using the final value of the pseudo-random number that the computer prints on a normal stop.

R	
	15
Initial Random Number	
.73496521	

FORMAT (F15.0)

Fig. 44 RANDOM NUMBER INITIALIZATION FORM

4. Aerial and Ground Sensor Deployment Data

The purposes for using CRESS will influence the manner in which the sensors are deployed. If CRESS is being used for a closed war game, the team members deploying the sensors should not be given any more information about the enemy forces than they would have from the general scenario development and previous intelligence reports. However, if CRESS is being used to evaluate different reconnaissance systems, using the knowledge of exactly where all the targets are located while deploying the sensors may make the comparison more valid.

For any purpose, sensor deployment is a key task that significantly affects the amount and quality of data generated by sensor systems. Thus, an understanding of the capabilities of the sensor systems being simulated is essential. If it is important to simulate tactical operations realistically, a team of personnel experienced in reconnaissance flight planning (for both low and high performance aircraft) and ground sensor deployment should perform this important task.

a. Flight Parameters Form (Fig. 45)

There are four forms that must be filled out for the computer to process a flight. The first of these gives the general flight information that is listed in the headings of the form in Fig. 45. The Flight ID is used only for printing and card identification purposes and can consist of up to 20 FORTRAN characters. The platform designation, however, must be exactly the same as one of the platform designators listed in the Aircraft-MTBF form (OV-1D and OV1D are not the same).

One line on this form represents one flight.

b. Flight Instrumentation Form (Fig. 46)

One line of information must be entered on the flight instrumentation form shown in Fig. 46 for each flight.

The Flight ID is only for card identification; however, the designations entered on this form for the navigation system and for each of the sensors must be exactly the same as corresponding designations in the air navigation systems form and the sensor parameters form, respectively. (The computer matches designations to find the appropriate parameters to use for the equipment being simulated on the particular flight.) The communication link number must be 0 (for no air-to-ground link) or a number corresponding to the appropriate link in the data link MTBF form. A maximum of four sensors per aircraft is allowed.

c. RS Area Description Card 1 Form (Fig. 47)

Two cards are required to describe an RS area. This section discusses the first card. One line must be entered on the RS area description card 1 form shown in Fig. 47 and on the target groups overflown form for each RS area of the flight. An RS area is a rectangular area that is covered by the operating sensors aboard the aircraft. The simulation model requires that

FLIGHT PARAMETERS FORM

A	A	R	A	I	A	I	I	R	I
1 20	22 33	39	41	48	50	57	63	69	72
Flight ID	Platform[a] Designator	Speed Between RS Areas (knots)	Takeoff Point		Landing Point		Takeoff[b] Time (Day and hour)	Flight time to starting point of 1st RS area (Minutes)	Weather[c] Condition Code
A-17PV	OV-ID	180	MA	700440	MA	700440	11549	15	1
A-18PV	OV-ID	180	MA	700440	MA	700440	11751	18	1

[a]This entry must correspond to an entry in the aircraft-MTBF form.
[b]Day 1 starts at 0000 hours of the day containing the starting time of the simulation.
[c]This entry must correspond to the desired row number of the Atmospheric Parameters form.

FORMAT (5A4,IX,3A4,F6.0,2(IX,A2,I6), I6, F6.0, I3)

Fig. 45 FLIGHT PARAMETERS FORM

A	A	A	I	A	I	A	I	A	I
1 20	22 33	35 38	41	43 46	49	51 54	57	59 62	65
		1		2		3		4	
Flight ID	Navigation System	Sensor	Comm. Link	Sensor	Comm. Link	Sensor	Comm. Link	Sensor	Comm. Link
A-17PV	DOPPLER	K61A	0	VIS	1				
A-18PV	DOPPLER	K61A	0	VIS	1				

FORMAT (21X, 3A4, 4 (1X, A4, 13))

Fig. 46 FLIGHT INSTRUMENTATION FORM

A	R	R	I	A	I	A	I	I	A	I	R	I	I
1 20	27	33	36	38	45	47	54	59	61	68	74	76	80
Flight ID	Altitude above ground in RS area (feet)	Speed in RS area (knots)	No. of legs in RS area	Starting Point of leg 1		Ending Point of leg 1		Distance between legs (meters)	Direction[a] of 1st turn	Turn Distance (meters)	Altitude during turn (feet)	RBF[b] indicator	False Target Prior
A-17PV	20[illegible]	180	1	MA	846811	MA	854814					0	0.5
A-18PV	2000	180	2	MA	785799	MA	798800	1500[c]	L	1500	200	0	0.2
A-18PV[d]	2000	180	1	MA	785810	MA	778799					[illegible]	0.6

[a]R-Right, L-Left

[b]1-Reconnaisance-by-fire being used in RS Area, 0-RBF not being used in RS Area.

[c]If only one leg is flown turn information need not be given.

[d]A separate set of RS Area cards is needed for each RS Area flown.

FORMAT (21X, 2F6.0, I3, 2(1X, A2, I6), I5, 1X, A1, I7, F6.0, I2, 3X, I1

Fig. 47 RS AREA DESCRIPTION, CARD 1 FORM the aircraft be in straight and level flight while its sensors are operating. Thus a route-recce mission would consist of a number of straight line segments, each of which defines an RS area. If a wide area is to be covered and the aircraft is flown along paths parallel to each other with the sensors being turned on and off opposite the endpoints of the preceding leg, the RS area can be described by giving the starting and ending points of the first leg, the distance between legs, the direction of the first turn, and the total number of legs (see Fig. 1). A maximum of 10 legs is allowed. It is noted that the route-recce RS area is a special case of the area surveillance RS area, with the number of legs being 1. A maximum of 20 RS areas are allowed on any one flight.

The capability of simulating avoidance of AA fire when the sensors are not being used is provided by allowing a change in altitude while the aircraft is turning for the next leg or proceeding to the next RS area. The aircraft is considered to stay on the flight leg extensions of the RS area to the turn distance specified while turning and lining up for the next leg. Three minutes is allowed for turning and coming back over the starting point of the next leg. The altitude during the turn is used in computing the possible attrition during the turn maneuver. No attrition is played when the aircraft is not in an RS area or the turn area.

Reconnaissance by fire is considered to be used for the entire RS area according to the code entered in the RBF indicator column (0--No RBF, 1--RBF).

The option to synthesize and report false targets is available to CRESS users. The false target submodel is based on the concept that the number of false targets reported in an area is dependent on: (1) the instructions that the image interpreters or sensor operators receive, and (2) the amount of targets that are found in the area. Reference 1 indicates that if an interpreter: (1) expects to find targets (receives instructions to that effect), or (2) finds several targets, he probably will report false targets. The false-target prior for an RS area is a number between 0 and 1 that the flight planner must assign to the RS area to indicate the extra effort that should be exerted in processing the imagery of the area. The discussion of the false target submodel (Sec II.B.7), indicates the relation between the false target prior and the number of false targets generated for the RS area.

d. RS Area Description Card 2 Form (Fig. 48)

When the sensor operator or image interpreter has prior information indicating that targets are in the general area covered by an RS area, he is more likely to detect a target if it is there than he would without that information. (As indicated above, he is more likely to report false targets also.) If, for example, SIGINT collection means indicate that there is an emitter in an area and the flight planners send a photographic mission to cover that area specifically, the photo interpreter would be more likely to detect the target than he would if he were viewing imagery that was taken of the same area on a general reconnaissance flight. CRFSS simulates this enhanced probability of detection* for a given RS area if the enhancement entry on the card is not zero (i.e., set to 1).

The numbers of the target groups overflown in an RS area must be supplied by someone who is allowed to know where all

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* See Section II.B.11 for a description of the method for enhancement.

	I	I	I	I	I	I	I	I	I	I	I
1 20	21	25	29	33	37	41	45	49	53	57	61
Flight ID	Enhance a/	Target groups overflown b/									
		1	2	3	4	5	6	7	8	9	10
A-17PV	0	4									
A-18PV	1	3									
A-18PV	0	6	9	10							

a/ 0--No directed search enhancement for RS area.
1--Enhancement for RS area.

b/ The entries are the ID numbers of each of the target groups overflown.

FORMAT (20X,I1,10I4)

Fig. 48 RS AREA DESCRIPTION CARD 2 FORM

the targets are (the Control team in a closed war game). This can be done by: (1) putting an overlay of the flight path over the overlays which contain the targets and the target group areas; (2) drawing (perhaps mentally only) the boundaries of the area covered by the sensor aboard the aircraft that has the widest coverage; and (3) writing the numbers of any target group area that is partly covered by the sensors on the RS area description card 2 form. Up to 10 target groups are allowed for one RS area.

Not all the targets contained in the listed target groups will be processed. Only targets that fall inside the area covered by the sensor having the widest coverage will be put into arrays in the computer for further processing. The maximum allowed in the array for an RS area is 150 targets. The maximum allowed in the array for one leg of an RS area is 100 targets. After the arrays are filled with the maximum numbers of targets, the remaining targets in the target groups listed will be ignored even though they fall inside the area covered by a sensor. Thus, occasionally it may be necessary to artificially break a long RS area provided by the flight planner who presumably does not know where all the targets are into several smaller RS areas. If the maximum number of targets for the RS area is exceeded because there are too many high density legs, the RS area can be subdivided into two (or more) RS areas by reducing the number of legs for the first RS area and starting the next RS area on the next leg of the given RS area. If the maximum number of targets for one leg is exceeded, the RS area should be subdivided by shortening the length of the leg for the first replacement RS area and starting the second replacement RS area at the point where the first one ends.

A set of the two RS area description cards must be punched for each RS area of the flight.

e. Navigation Update Form (Fig. 49)

It is possible to simulate updating the navigation system before reaching any RS area by inserting a navigation update card immediately before the first card for the RS area. This card, which contains the coordinates of the point where the navigation system is to be updated, signals the computer to reset the accrued navigational error to the inflight update accuracy capability for the system. The navigation error then accrues from this update point.

I	A	I
Update Code[a]	Update Point Coordinates	
33	MA	788 821

a/ 33 is the code for an update point.

b/ This card will be read by the same instruction that causes the RS area description card 1 to be read.

FORMAT (21X, 2F6.0, I3, 2(1X,A2,I6),I5,1X,A1,I7,F6.0,I2,3X,I1)

Fig. 49 NAVIGATION UPDATE FORM[b]

f. Observation Post Parameters Form (Fig. 50)

There are two forms that must be filled out for ground sensor deployment. The first of these gives the OP identification, the time of operation of the OP, the probability of the OP being attrited during that time, the number of the type of communication link being used by the OP, and the sensors employed. A

A	I	I	R	I	A	A	A	A
1 4	10	16	20	23	28	33	38	43
OP	Initial[a] Time (day-hour)	Final[a] Time (day-hour)	Probability of Attrition[b]	Comm. Link	Sensors			
					1	2	3	4
1	11200	11800	.02	1	PPS9	EYE	BNC7	
101	11200	11800	.01	2	PPS5	EYE	BNC7	BN20
201	11200	11330	.005	3	PPS9	BNC7	BN20	

[a]Day 1 starts at 0000 hours of the day containing the starting time of the simulation.
[b]The probability that the OP will be attrited during the stated operating time.

FORMAT (A4, 2I6, F40, I3, 1X, 4(A4, 1X))

Fig. 50 OBSERVATION POST PARAMETERS FORM moving patrol should be assigned a single identification in the OP column, as should each fixed OP. In the remaining discussion of this form, a patrol should be considered as an OP.

The OP identification must consist of four or fewer FORTRAN characters. Each OP identification may occur only once on this form. It is helpful to assign similar designations to related OPs. For example, it is possible to simulate an OP using its sensors intermittently. This can be done by giving the OP being simulated several different names (e.g., R26A, R26B, R26C) with the times entered on the form for each successive OP identification corresponding to the successive on and off times for the sensors. However, the restriction that no more than 125 OP identifications can be used must be observed.

The probability that the OP will be attrited during the stated operating time must be supplied by someone knowing the disposition and intent of the enemy (e.g., the scenario writer or the control team).

The number of the communication link used by the OP must correspond to the number used in the failure array for that type of communication link.

Each sensor name used on this form must exactly match one of the sensor names entered in the ground sensors card 1 form. If it is desired to simulate more than four sensors at one OP location, it will be necessary to put two OPs at the same location, operating at the same time.

g. OP/Target Data Form (Fig. 51)

The deployment of the OPs is simulated by positioning them on a map overlay. This should be done without knowledge of all the targets' positions when CRESS is being used in a closed war game or in a simulation where the person deploying the sensors

A	A	I	A	I	R	R
1 4	6	13	15	23	30	37
OP	OP Coordinates		Target	Probability of line-of-sight	Patrol sighting time[a/] (day-hour)	OP height[b/] (feet)
3	MA	867847	50	20		
6	MA	859830	163	70		
6	MA	859830	104C	80		
6	MA	859830	103C	100		
P1	MA	853828	104	60	11325	
EL1	MA	860829	152	100		500

a/ This must be blank for fixed OPs. Day 1 starts at 0000 hours of the day containing the starting time of the simulation.

b/ For elevated platforms height is stated as feet above ground.

FORMAT (A4,1X,A2,I6,1X,A4,I5,2F7.0)

Fig. 51 OP/TARGET DATA FORM

should not know the enemy positions (i.e., the players fill in the columns labeled "OP," "OP coordinates," and "OP height"). Control fills in the remaining columns. The centerline and the entire angle of the sector that each fixed OP is to observe should be indicated on the overlay.

Coverage and detection by each of the ground based systems deployed in the field is critically affected by line-of-sight restrictions caused by terrain and vegetation. For this reason, the probability of line of sight between an OP and each of the targets within range of any of the OP's sensors is determined manually from the map, rather than using a simple probabilistic model in the computer. This manual map chore is tedious and time consuming. The following suggestions have been found helpful in performing the task of line-of-sight determination.

A template of the sector to be scanned should be drawn on a small piece of acetate for each OP. This consists of drawing the angle of the sector to be scanned and then drawing an arc across this angle. The distance from the vertex of the angle to the arc should correspond to the maximum range of the sensors in the OP (see Fig. 52). (Note: Since the computer processes a target listed for an OP by every sensor in the OP, every sensor scans the same angular sector in the simulation.) The same template will probably suffice for most of the OPs that are using the same types of sensors.

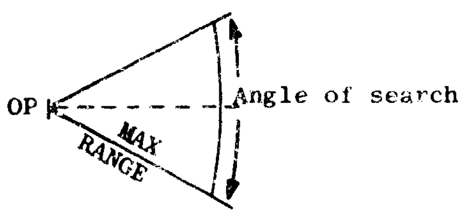

Fig. 52 OP SECTOR TEMPLATE

When the overlay of OPs and their associated template are completed, the overlay should be placed on the map over the overlay containing the targets (by someone allowed to see the target deployment; i.e., the control team).

To determine the entries for the OP/target data form for an OP, tack the vertex of the template for the OP to the OP and orient the template with the center of its sector along the indicated center of the OP search sector. Each of the targets inside the sector on the template are to be processed in any order desired. They are entered on the form only if the probability of line of sight between the OP and the target is determined to be greater than 0.

The determination of line of sight is done by first deciding if terrain blocks the line of sight. This is done by noting the elevations of the OP, target and intervening terrain; i.e., observing the contour lines and deciding if there are any ridges or hills between the OP and target. Holding a string tacked to the OP position along the path to the target will aid the eye in finding the contours of interest. Targets near each other should be processed at nearly the same time in the map room since the same contour lines will often be under consideration for each of the targets. If terrain does mask the target from the OP, that target can be ignored. Otherwise a subjective determination of the probability of line of sight must be made.

The persons ascribing the probabilities of line of sight should become familiar with the general area of the scenario before actually starting on the individual targets. They can do this by studying the legend on the map (the larger the scale the better) and noting the various types of vegetation markings, studying photographs of the area, and talking to people who have been in that particular part of the world. For individual OP target pairs, they should consider factors such as where an OP is likely to be located (looking across valleys or depressions or looking up or down a slope or along level ground, roads, or fire trails that a moving target would cross); the density of the foliage, the height of the foliage, the posture of the particular target, and how likely it is that the target will take advantage of vegetation cover available. Some of the elements of a target may be masked, while others are in the open. In this case, the persons ascribing probability of line of sight should estimate the percentage of the target elements that would be in the clear. If it is determined that a probability of line of sight greater than 0 exists, it should be entered, with the target number, on the OP/target data form for the OP.

Patrol sightings are treated the same as OPs, except that the template depicting the patrol's coverage can be a swath along its planned path instead of an angular sector. The coordinates of the patrol's position at the time that line of sight exists must be entered. Also, it is necessary to enter the time that the patrol would be at that position. (The time entry must be left blank for fixed OPs since this entry indicates to the computer whether a patrol is being processed; the computer will determine the simulated time of sighting for fixed OPs.)

An elevated sensor platform can also be considered as an OP. The only additional input needed is the height of the platform above the ground. The area of coverage of an elevated platform at a given position is determined by the range of the sensor and/or the maximum angle from the vertical that the sensor can scan. This maximum angle is usually dependent upon how the sensor is mechanically attached to the platform.

5. Miscellaneous Cards for the Aerial Model

There are many miscellaneous items of information that must be read into the computer before the simulation can be run. These data are to be punched on the seven cards described in this section.

A logical unit number must be assigned for each file opened on the random access disk. The aerial model requires five files on the disk unit. Any five positive integers less than 15, except 5 and 6, may be used. (The card reader uses 5, and the line printer uses 6 in this program.) Figure 53 illustrates the necessary format for the card that fixes these logical unit numbers.

I	I	I	I	I
2	5	8	11	14
Logical unit numbers for disk files				
TP3	TF2	FLT2	TYMS	NDXS
7	8	9	10	11

FORMAT (5(I2,1X))

Fig. 53 LOGICAL UNIT NUMBERS FORM

An "SR" card must be punched with the letter S in column 1 and the letter R in column 2.

The sizes of various arrays are prescribed by the integers read in from two "size" cards (Fig. 54). The entries on these forms must state the exact number of the corresponding items occurring in the simulation.

SIZE CARD 1 FORM[a]

I	I	I	I	I	I	I	I	I	I
5	10	15	20	25	30	35	40	45	50
Vertical[b] frame cameras	Side[b] oblique cameras	Forward[b] oblique cameras	Panoramic[b] cameras	IR's	Radars	Visuals	Lasers	TV's	RBF
10	10	10	10	10	10	5	10	10	1

SIZE CARD 2 FORM

I	I	I	I	I	I	I	I	I	I
5	10	15	20	25	30	35	40	45	50
Background types	Sets of Atmospheric Parameters	Platform types	Navigation systems	Total sensors	Comm. links	Object types	Detection classes	Recognition classes	AA weapon types
25	4	15	10	40	10	100	10	40	30

[a]For each field of information the sample entries are the maximum number of items allowed.

[b]There is a maximum of 10 allowed for all types of cameras combined.

FORMAT (10I5)

Fig. 54 SIZE CARDS FORM

Figure 55 illustrates the card form required for a variety of items. The first three items are used when the computer assigns stances to personnel. The fourth item is used to limit the size of any false target that might be generated. The last item states the number of different sized circles to be used in determining which target elements are within a prescribed distance of each other (see Sec. II.F for a discussion of the printout of groups of target elements that are within a specified distance of each other).

I	I	I	I	I
5	10	15	20	25
Recognition class of nets	Recognition class of personnel	Object type number of standing personnel	Total number[a/] of elements allowed in false target	Number of radii for grouping of elements
7	15	61	10	5[b/]

a/ This number is exclusive of personnel.

b/ 5 is the maximum allowed.

FORMAT (10I5)

Fig. 55 MISCELLANEOUS INFORMATION (AERIAL) FORM

Figure 56 illustrates the form for more required items. The maximum probability for detection, recognition, and identification by photographic systems can be set arbitrarily; usually it should be given the value 1.0 (see Sec. II.B.11 for a discussion of the enhancement in detection expected as a result of directed search; see Sec. II.B.7 for a discussion of false target generation).

R	R	R	R	R	R	R	A
7	14	21	28	35	42	49	51
Number of minutes between sunrise and sunset	Maximum value of photo probabilities of Det., Rec., ID.	Amount of forward overlap of photography (fraction)	Enhancement factor for directed search detection	Expected ratio of false target elements to detected target elements	Day of the[a] year (Numerical)	Latitude[b] of target area	
720	1.0	0.10	0.2	0.15	275	47.5	N

[a]January 1 is day 1, December 31 is day 365.
[b]S-South N-North.

FORMAT (7F7.0, 1X, A1)

Fig. 56 MISCELLANEOUS INFO (AERIAL) FORM 2

Table 21 lists the topics that are bypassed by the computer when a 1 is entered in the corresponding column on the option card (Fig. 57). All the entries in Table 21 must be keypunched; the tenth card must be blank in columns 2-49.

Table 21

SUPPRESSION OPTIONS

	A	
	2	49
1.	Navigation error of aircraft	
2.	Attrition caused by enemy ground fire	
3.	Failure of aircraft, sensors, links, or navigation systems	
4.	Misidentification of target objects	
5.	Multisensor enhancement	
6.	Generation of false targets	
7.	Aggregation into possible area targets	
8.	Timeliness caused by data handling	
9.	Vegetation coverage	

I	I	I	I	I	I	I	I	I
5	10	15	20	25	30	35	40	45
Options to be suppressed[a/]								
1	2	3	4	5	6	7	8	9
1	1	1					1	1

a/ The column headings refer to the corresponding options listed in Table 20. 1--suppress, blank--play.

Fig. 57 SELECTED OPTIONS FOR SUPPRESSION FORM

6. Miscellaneous Cards for the Ground Model

The ground model requires four files on the disk unit. Any four positive integers less than 15, except 5 and 6, may be used. The card reader is assigned the number 5, and the line printer uses the number 6 in this program. Figure 58 illustrates the format for the necessary card.

I	I	I	I
2	5	8	11
Logical unit numbers for disk files			
TP3[a/]	OT2	TYMS	NDXS
7	8	9	10

a/ These are the names of storage files (or arrays) on disk.

FORMAT (4(I2,1X))

Fig. 58 LOGICAL UNIT NUMBERS (GROUND) FORM

The integers entered into the ground size card form (Fig. 59) prescribe the sizes of arrays to be used in the simulation.

Figure 60 illustrates the required formats for the remaining cards needed by the ground model. The probabilities of detection are cumulative over a period of time in the ground model (see Sec. II.C. for discussion). In the simulation model, approximately 90 percent of what is going to be seen by a sensor will be reported at the time that the sensor and target are both valid, approximately another 5 percent will be reported delta t minutes later, and another 2.5 percent will be reported another delta t later. The delta t can be fixed by the user of CRESS. Twenty

I	I	I	I	I	I	I	I	I	I	I	I	I	I	I
5	10	15	20	25	30	35	40	45	50	55	60	65	70	75
Sensors	OP's	IR's	Lasers	PNVDs	TV's	Visuals	Radars	IR Binocs.	Object types	Detection Classes	Recognition Classes	Back-ground types	Comm. links	Weather codes
35	125	5	5	5	5	5	5	5	100	10	40	25	5	5

Note: The example entries are the maximum values allowed.

FORMAT (15I5)

Fig. 59 GROUND SIZE CARD FORM

minutes were used for delta t while testing CRESS. The average accuracies (CEPs) of locating the fixed OPs and patrols are to be supplied in accordance with the methods used for fixing locations. The other items in Fig. 60 are either self-explanatory or discussed in the aerial model miscellaneous forms paragraphs.

R	
1	5
Expected ratio of false target elements to detected target elements	
.15	

FORMAT (F5.0)

R	R
1 7	14
Average CEP (meters)	
Fixed OP	Patrol
10.	50.

FORMAT (2F7.0)

I	
1	2
Atmospheric parameters index for simulation run	
1	

FORMAT (I2)

I	R	R	R
3	7	11	15
Total number[a] of elements allowed in a false target	Half-angle of the field-of-view the OP searches (degrees)	Time between successive reports for cumulative detections (minutes)	Enhancement factor for directed search detection
10	55	20	.2

a/ Exclusive of personnel

FORMAT (I3,3(1X,F3.0))

Fig. 60 GROUND MISCELLANEOUS INFORMATION CARDS FORMS

F. Computer Output

The Aerial and Ground computer models both provide two different copies of the sensor systems' performance: the Control Copy and the Intelligence Copy. In addition, the Aerial Model provides a checklist of the options selected for the run and a listing of all groups of sighted elements that are within specified radii of each other.

The Control Copy displays essentially all the information about the interaction of the sensor systems and the targets that the computer processes. This copy, meant for the control team in closed war games, could also be used as the sole output for (1) sensitivity analyses; (2) producing tables of probabilities of detection, recognition, and identification; (3) sensor systems comparison studies; and (4) any other types of studies that do not require an output copy that displays only the information normally available to a sensor system user (i.e., the Intelligence Copy).

1. Aerial Model

The first output to be printed is a list of the options (Fig. 61) that were selected during the run. An X indicates that the feature described was not simulated.

THE FOLLOWING OPTIONS ARE SUPPRESSED

X NAVIGATION ERROR OF PLATFORM
X ATTRITION DUE TO ENEMY GROUND FIRE
X FAILURE OF PLATFORM, SENSORS, LINKS, OR NAV SYS
  MISIDENTIFICATION OF TGT OBJECTS
  MULTISPECTRAL ENHANCEMENT
  GENERATION OF FALSE TARGETS
  AGGREGATION INTO POSSIBLE AREA TGTS
  TIMELINESS DUE TO HANDLING OF DATA
X VEGETATION COVERAGE

Fig. 61 OPTIONS, CRESS-A

Figure 62 is an illustration of the Control Copy format for the Aerial Model. The computer prints the results of each simulated reconnaissance flight by printing out flight and equipment information and, for each RS area in order of overflight, the performance of the sensors aboard the aircraft against each of the targets that was covered by (i.e., within range of) any sensor aboard the aircraft. The time of overflight, target designator, report number assigned, and distance (in meters) from the ground track of the aircraft are printed for the target. The number of moving target elements detected is reported, if any, and targets detected by reconnaissance by fire are reported. The performance of each sensor aboard the aircraft against each object in the target is then printed, including misidentification and misrecognition of objects. If more than one sensor (not counting reconnaissance by fire) is being used, the performance of the sensors used as a single composite system is printed under the columns labeled MULTI.

```
FLIGHT          AF-2                          SITUATION       MODEL TEST AMMO EXPENDITURE RATE SCENARIO CDC
PLATFORM        RF4C                          NAVIGATION      ASN-56                     ALTITUDE  15000   SPEED    900
SENSORS         K72A  VIS    K56A
TAKEOFF TIME    11158                         FLIGHT TIME      33                        NBR TGTS     95

RECONNAISSANCE/SURVEILLANCE AREA  1      ALTITUDE  15000     SPEED   600

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

TIME   11215       TARGET     32      TRUE LOCATION      MA 701833      REPORT GROUP       0      DISTANCE     2489

                                 K72A  PLOS=  0     VIS    PLOS=  0     K56A  PLOS=  0     MULTI
 NBR OBJECT                 R.D  PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI

   1 2-TON TRUCK            9.5  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0
   1 T-32 TANK              8.5  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0
   1 PLASTER BLDG           6.4  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

TIME   11215       TARGET    398      TRUE LOCATION      MA 703835      REPORT GROUP       0      DISTANCE     2771

                                 K72A  PLOS=  0     VIS    PLOS=  0     K56A  PLOS=  0     MULTI
 NBR OBJECT                 R.D  PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI

   2 APC-60P                8.5  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0
  21 STANDING PERSONNEL    15.7  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0
  10 PRONE PERSONNEL       15.7  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

TIME   11215       TARGET     42      TRUE LOCATION      MA 688822      REPORT GROUP       0      DISTANCE      786

                                 K72A  PLOS=  0     VIS    PLOS=  0     K56A  PLOS=  0     MULTI
 NBR OBJECT                 R.D  PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI

   1 2-TON TRUCK            9.5  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0
   3 2-STORY WOOD BLDG      6.4  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0
   2 STANDING PERSONNEL    15.7  -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0 -1  0  0  0  0  0

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -

TIME   11215       TARGET    43C      TRUE LOCATION      MA 684821      REPORT GROUP      94      DISTANCE      420

                                 K72A  PLOS= 10     VIS    PLOS= 10     K56A  PLOS= 10     MULTI
 NBR OBJECT                 R.D  PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI

   2 APC-60P                8.5  10 93 90  0  0  1  0  0  0  0  0  0  4  0  0  1  0  0  9 97 90  0  0  1
  26 STANDING PERSONNEL    15.7   9  0  0  5  0  0  0  0  0  0  0  0  0  0  0  0  0  0 -1  0  0  5  0  0
   5 PRONE PERSONNEL       15.7  10  0  0  2  0  0  0  0  0  0  0  0  0  0  0  0  0  0 -1  0  0  2  0  0
REPORT TIME                      11464             0                    11393              11404
REPORTED POSITION                MA 684819            0                 MA 684819          NA      0
CEP - , A , B , C                100 100 100 103    0  0  0  0           100 100 100 103    100 100 100 103

- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

Fig. 62 CONTROL COPY--CRESS-A

The probability of line of sight printed beside each sensor name is:

P(LOS) = (1-probability of terrain masking) x (1-probability of cloud masking) x (1-probability of vegetation masking)

The probability of terrain masking depends on the aircraft's altitude and horizontal distance to the target. The probabilities of cloud masking and vegetation masking are both dependent on the sensor since radar is the only sensor type that can sense target elements through clouds and IR is the only sensor type modeled that can sense target elements through foliage.

For each object type in the target, a line of output containing the number present, type, recognition class number, and detection class number is printed. On this same line, for each sensor aboard the aircraft, the following is printed:

a. Probability of detection (given no terrain masking and no cloud masking; but including a factor for vegetation masking)

b. Probability of recognition given detection

c. Probability of identification given recognition

d. Number of objects detected (includes recognized and identified objects)

e. Number of objects recognized (includes identified objects)

f. Number of objects identified

-1 is printed under Pd (probability of detection) for each sensor that does not cover the target.

If an object is misidentified (or misrecognized), lines of print will occur immediately after the object line of print described above giving the name of the object (or recognition class name) that the bonafied object is mistakenly thought to be and the numbers of these identified (or recognized).

The report time is the time that a report about the target reaches the intelligence center. This time reflects the time necessary for imagery handling, processing, and interpreting, but not the intelligence processing time.

In order, the four CEPs given are those for no map error incorporated, and Class A, B, and C map errors incorporated.

When the data for all the targets in the RS area have been printed, the false targets generated for that RS area (if any) are printed in the same format as for the bonafide targets. However, no probabilities are recorded, and objects are recognized only (see Section II.B.7 for a discussion of false target generation).

This type of data is repeated for each RS area on the flight. If a piece of equipment fails during the flight, a message specifying the failure will be printed out at the simulated time of failure.

When the above data for the flight have been printed, the groupings of reported targets that are within each specified radius are printed. The intelligence team can use this area output (Fig. 63) as an aid in determining which reported target elements might be combined to form part of larger enemy unit.

THE ELEMENTS DENOTED BY THE FOLLOWING REPORT NUMBERS ARE RE-
PORTED WITHIN 500 METERS OF EACH OTHER

6	MA 667808
8	MA 665812
9	MA 664809

THE ELEMENTS DENOTED BY THE FOLLOWING REPORT NUMBERS ARE RE-
PORTED WITHIN 500 METERS OF EACH OTHER

2	MA 671815
3	MA 670818
4	MA 670814
5	MA 670821
7	MA 666819

Fig. 63 TARGET ELEMENT CLUSTERS

After the data for all flights have been processed and printed, the Intelligence Copy (Fig. 64) is printed. The reports coming to the intelligence team from all aerial sensor systems are covered chronologically in this output. These reports include the equipment failure and attrition messages and the sensor reports of target elements.

All reports in the Intelligence Copy concerned with sighting of target elements contain the time that the report reached the intelligence team; the report number assigned to the group of target elements reported (every sensor aboard an aircraft uses the same report number for the same target elements sighted on any one leg); the time that the imagery was taken; the flight number; the type of aircraft; the navigation system used; the horizontal distance from the flight path to the target elements;

```
RPT TIME 11356  RPT GRP  12?  IMG TIME  11228  FLT AF-2                   AC RF4C           NAV ASN-56        DIST  4388
POSIT MA 811921  CEPS  248 248 248 2??  RS   3  ALT 15000  SPEED  600  MD   0  RBF 0  SENSOR K56A
         IDENTIFIED                           RECOGNIZED                          DETECTED
            0                                    4 WHEELED VEHICLE                   1 ?? ?00)+00,100#000
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RPT TIME 11357  RPT GRP  12?  IMG TIME  11228  FLT AF-2                   AC RF4C           NAV ASN-56        DIST  3378
POSIT MA 842920  CEPS  248 248 248 249  RS   3  ALT 15000  SPEED  600  MD   0  RBF 0  SENSOR K56A
         IDENTIFIED                           RECOGNIZED                          DETECTED
            0                                    3 TOWED VEHICLE                     0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RPT TIME 11400  RPT GRP  121  IMG TIME  11229  FLT AF-2                   AC RF4C           NAV ASN-56        DIST    66
POSIT MA 807966  CEPS  248 248 248 249  RS   3  ALT 15000  SPEED  600  MD   0  RBF 0  SENSOR K72A
         IDENTIFIED                           RECOGNIZED                          DETECTED
            1 TRACTOR, AT-S                      1 LARGE BUILDING                    3 LGE LAND OBJECT
            1 122MM GUN/HOW                      0                                   5 VERY SM LAND OBJ
            4 130MM FIELD GUN                    0                                   0
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RPT TIME 11400  RPT GRP  121  IMG TIME  11228  FLT AF-2                   AC RF4C           NAV ASN-56        DIST    66
POSIT MA 807966  CEPS  248 248 248 249  RS   3  ALT 15000  SPEED  600  MD   0  RBF 0  SENSOR MULT K72A VIS  K56A
         IDENTIFIED                           RECOGNIZED                          DETECTED
            1 TRACTOR, AT-S                      1 LARGE BUILDING                    3 LGE LAND OBJECT
            1 122MM GUN/HOW                      0                                   1 SM LAND OBJECT
            4 130MM FIELD GUN                    0                                   5 VERY SM LAND OBJ
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RPT TIME 11400  RPT GRP  376  IMG TIME  11205  FLT AF-15P                 AC RF4C           NAV ASN-56        DIST  5346
POSIT MB 789478  CEPS   88  88  89  92  RS   1  ALT 10000  SPEED  600  MD   0  RBF 0  SENSOR K56A
         IDENTIFIED                           RECOGNIZED                          DETECTED
            0                                    0                                  11 LGE LAND OBJECT
            0                                    0                                   2 SM LAND OBJECT
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
RPT TIME 11404  RPT GRP   94  IMG TIME  11215  FLT AF-2                   AC RF4C           NAV ASN-56        DIST   428
POSIT MA 684819  CEPS  100 100 100 103  RS   1  ALT 15000  SPEED  600  MD   0  RBF 0  SENSOR K73A
         IDENTIFIED                           RECOGNIZED                          DETECTED
            1 APC-50P                            0                                   7 VERY SM LAND OBJ
- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
```

Fig. 64 INTELLIGENCE COPY--CRUSS-A

the target elements' reported position (this may be different than their actual position); location accuracies (no map error, and Class A, B, and C errors included); RS area of flight; aircraft altitude and speed; the number of moving objects detected (this can be nonzero only if an MTI radar is being used); the results of reconnaissance by fire (0-not used, 1-no detection, 2-return fire detected); the sensor system generating the report; and the number of elements identified, recognized, and detected. On the Intelligence Copy, the elements identified are not included in the count of elements recognized, and similarly the elements recognized are not included in the count of elements detected; i.e., the target elements are exclusively reported at the highest level of detail attained. (This is different from the Control Copy in which the elements were reported inclusively; the reported detections contain the reported recognitions, which in turn contain the reported identifications.) For example, if one T-62 Tank is reported as identified, two TRACKED VEH are reported as recognized, and three MED LAND OBJECT are reported as detected on the Intelligence Copy, a total of six different objects have been reported.

The misidentified and misrecognized objects have been combined with the bonafide identifications and recognitions, respectively. The elements of a generated false target are reported in the same way as for a bonafide target. Thus, any group of elements reported on the Intelligence Copy may contain any possible combination of bonafide, incorrectly identified or recognized, and false target elements. (The true identity of the reported elements can be found by referring to the corresponding flight and report group on the Control Copy.)

After all the reports have been printed, the computer prints the final value of the pseudo-random number and is finished with the aerial simulation until the human intelligence analysts assess the output, schedule more flights, and submit another run.

2. Ground Model

The Ground Control Copy (Fig. 65) is essentially the same as the Aerial Control Copy, with two differences. First, the reports are OP by OP instead of flight by flight. Second, the output manifests the idea of cumulative searching over time (versus the "snapshot" look used in the Aerial Model) by presenting a first contact report at the time of the first possible sighting, succeeded by two more reports spaced by an interval of time prescribed by the user.

The first contact report probabilities of detection represent 90 percent of the sensors' capabilities for detection. The second report represents an additional 5 percent of the sensors' capabilities, and the third report represents another 2.5 percent of the sensors' capabilities. (The times of the reports are given at the bottom of each report.) Thus, the probabilities of detection are always less on the second and third reports, but the probabilities of recognition and identification remain the same since these probabilities are conditional on having detection and recognition, respectively.

```
42W 46
O.P.  46  LOCATION=MA685012

        TARGET   42W      REPORT GROUP    230     DISTANCE     447     PLOS    89

                                PPS9                   EYE                    BNC7
 NOR OBJECT             R,D     PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI CD OR OI

  26 STANDING PERSONNEL15,7     83100  0 25 25  0 29100100  8  8  8 80100100 22 22 22
      PRONE PERSONNEL                           0                   5                 0
      MAN-FOXHOLE                               0                   0                 3
   2 APC-GUP              6,5   83100  0  1  1  0 60100100  1  1  1 87100100  1  1  1
   5 PHONE PERSONNEL     15,7   83100  0  5  5  0 22100100  3  3  3 75108100  4  4  4
CONTACT TIME                    11400             11500             11400
LOST CONTACT                    11800             11800             11800
REPORTED POSITION               MA 687816         MA 687816         MA 687816
CE  - , A , B , C                 43  43  45  51    30  30  33  41    30  30  33  41

                                PPS9                   EYE                    BNC7
 NOR OBJECT             R,D     PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI

  26 STANDING PERSONNEL15,7      3100  0 25 25  0  1100100  9  9  9  4100100 22 22 22
      PRONE PERSONNEL                           0                   5                 0
      MAN-FOXHOLE                               0                   0                 3
   2 APC-GUP              6,5    2100  0  1  1  0  3100100  1  1  1  1100100  1  1  1
   5 PHONE PERSONNEL     15,7    2100  0  5  5  0  1100100  3  3  3  4100100  4  4  4
CONTACT TIME                    11420             11420             11420
LOST CONTACT                    11800             11800             11800
REPORTED POSITION               MA 687816         MA 687816         MA 687816
CEP - , A , B , C                 43  43  45  51    30  30  33  41    30  30  33  41

                                PPS9                   EYE                    BNC7                  MULTI
 NOR OBJECT             R,D     PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI PD PR PI OD OR OI

  26 STANDING PERSONNEL15,7      1100  0 25 25  0  0100100  9  9  9  2100100 22 22 22 90100 97 25 25 25
      PRONE PERSONNEL                           0                   5                 0                 1
      MAN-FOXHOLE                               0                   0                 3                 0
   2 APC-GUP              6,5    1100  0  1  1  0  1100100  1  1  1  0100100  1  1  1 90100100  1  1  3
   5 PHONE PERSONNEL     15,7    1100  0  5  5  0  0100100  3  3  3  2100100  4  4  4 90100 33  5  5  3
CONTACT TIME                    11440             11440             11440             11440
LOST CONTACT                    11800             11800             11800                 0
REPORTED POSITION               MA 687816         MA 687816         MA 687816         MA 687816
CEP - , A , B , C                 43  43  45  51    30  30  33  41    30  30  33  41     0   0   0   0
```

Fig. 65 CONTROL COPY--CRESS-G

Note, however, that the numbers of objects printed on a report represent all the objects that have been detected, recognized, and identified up to the time of the report. For example, a probability of detection of .02 may be given on the third report for each of 128 objects of one type in the target, yet 65 objects of that type may be reported. The reason for this can be seen by checking the probability of detection for the same sensor-object type combination on the initial contact report: the probability there may be .55.

After all the bonafide targets covered by the OP have been processed, false target information is generated and printed (see Section II.B for discussion).

Whenever any equipment fails, a failure message is printed. When the equipment is repaired or replaced (simulated by the computer), reports of further contacts are printed. Similarly, when a target moves away or the OP ceases to operate, a lost contact message is printed for those target elements that have been reported, unless the time corresponds with the end of the time period for the simulation.

The Ground Model Intelligence Copy (Fig. 66) is similar in almost every respect to the Aerial Model Intelligence Copy. In particular, the remarks pertaining to the numbers of objects reported are still applicable. The reports are ordered by time of report. The time printed is the time of the report from the OP. Normally, if there is more than one sensor in an OP, the lists of target elements sighted by each sensor in the OP

```
11200
  O.P. 14  MADE CONTACT RPT GRP     16  DIST  1529  CEPS   30  31  33  41
  MA828810            MA825825         SENSOR  EYE
        IDENTIFIED                        RECOGNIZED                         DETECTED
            1 APC-60P                         0                                 0
            1 STANDING PERSONNEL              0                                 0
            4 MAN-FOXHOLE                     0                                 0

11200
  O.P. 14  MADE CONTACT RPT GRP     16  DIST  1529  CEPS   30  31  33  41
  MA828810            MA825825         SENSOR  BNC7
        IDENTIFIED                        RECOGNIZED                         DETECTED
            2 APC-60P                         0                                 0
           20 STANDING PERSONNEL              0                                 0
            7 PRONE PERSONNEL                 0                                 0
            1 MAN-FOXHOLE                     0                                 0

11200
  O.P. 14  MADE CONTACT RPT GRP     17  DIST  1802  CEPS   77  77  78  82
  MA828810            MA829828         SENSOR  PPS9
        IDENTIFIED                        RECOGNIZED                         DETECTED
            0                               1 TRACKED VEHICLE                   0
            0                               1 RADAR                             0
            0                               3 MEDIUM ARMS                       0
            0                              20 PERSONNEL                         0

11200
  O.P. 14  MADE CONTACT RPT GRP     17  DIST  1802  CEPS   30  31  33  41
  MA828810            MA829828         SENSOR  EYE
        IDENTIFIED                        RECOGNIZED                         DETECTED
            1 APC-60P                         0                                 0
            1 STANDING PERSONNEL              0                                 0
            1 PRONE PERSONNEL                 0                                 0
            2 MAN-SLIT TRENCH                 0                                 0

11200
  O.P. 14  MADE CONTACT RPT GRP     17  DIST  1802  CEPS   30  31  33  41
  MA828810            MA829828         SENSOR  BNC7
        IDENTIFIED                        RECOGNIZED                         DETECTED
            2 APC-60P                         0                                 0
           13 STANDING PERSONNEL              0                                 0
            6 PRONE PERSONNEL                 0                                 0
            1 MAN-SLIT TRENCH                 0                                 0
            7 MAN-FOXHOLE                     0                                 0
```

Fig. 66 INTELLIGENCE COPY--CRESS-G

will occur consecutively on the Intelligence Copy. If equipment failure occurs this grouping of reports on a target from sensors in the same OP may be disrupted. The coordinates of the OP are printed directly below the OP designator, and the coordinates of the sighted target elements appear directly below the report group label.

III DIRECTIONS FOR COMPUTER PROCESSING AND ANALYSIS

A. General

1. Possible Program Changes Required

The Aerial, Ground, and SIGINT models are run separately on the computer. They are all programmed in FORTRAN IV for the CDC 6400 computer, 131K core storage, and random disk auxiliary storage. With the exception of the input/output (I/O) statements for the random disk, the programs conform to ASA standards. A maximum of four alphanumeric characters are stored in an[illegible] storage location. Thus, if the I/O statements for disk are changed to conform with the computer installation chosen, the programs should run on any other machine that has at least a 24-bit word length and the corresponding core and disk storage.

The large computer programs and the large arrays used combine to make the use of a 32K core storage machine unacceptable for either the Aerial or Ground models. The Ground Model can be modified to run on a 65K machine (1 word per real number capability) with a random access disk by

(a) reading the two large arrays TGTVAR(9,750) and TGTOBJ(43,750) onto disk instead of into core when they are initially read in subroutines RDTGTV and TAROBJ, respectively;

(b) after reading in the OP/TGT card in subroutine PROCES, reading the columns of TGTVAR and TGTOBJ, corresponding to the target to be processed from disk into the one dimensional arrays TGTVR(9) and TGTOB(43), respectively; and

(c) replacing the two dimensional array names TGTVAR and TGTOBJ by the one dimensional array names TGTVR and TGTOB, respectively, wherever the former occur in the current CRESS-G program.

Since these changes require only two calls for information filed on disk per target processed, approximately .3 of a second of extra computer time per target processed would be required on a 65K core storage computer (processing time on the 131K-CDC 6400 is approximately .3 seconds per target).

The Aerial Model can also be adapted to run on a 65K core storage computer (1 word per real number capability) with a random access disk. After the target variable data have been read into TGTVAR(14,750) in subroutine ROTGTV, TGTVAR should be read into an array TGTVR(14,750) on disk. To save core storage, the array CLUSTR(100,102) in subroutine AREA should be set in EQUIVALENCE with TGTVAR. This EQUIVALENCE statement will cause the contents of TGTVAR to be altered whenever CLUSTR is used in subroutine AREA near the end of the processing for a flight, after the array TGTVAR is no longer needed for the flight. Thus, TGTVAR must be reset at the beginning of the processing for each flight. To do this, all that is required is that the instructions necessary to read TGTVR from the disk into TGTVAR be inserted as the first executable statements in subroutine FLTIN.

The array TGTOBJ(43,750) will also have to be stored on disk instead of in core storage when it is initially read in subroutine TAROBJ. Each column of this array contains the object composition of a target. Whenever objects of a particular target enter into the processing, it will be necessary to have the column of TGTOBJ corresponding to that target in core storage. This can be done by replacing TGTOBJ by a one-dimensional array TGTOB(43) everywhere that TGTOBJ occurs in the current program and making sure that the column for the correct target has been read in from disk before TGTOB is used. This can be done by reading from TGTOBJ on disk into TGTOB in core storage at the places in the program indicated in Table 22.

Table 22

POSITIONS OF REPLACEMENT OF TGTOBJ BY TGTOB

Subroutine	Line	Column of TGTOBJ
FLYRS	1st statement after statement 40	K
TURNAA	1st statement after statement 80	K
PROCES	6 statements before statement 50	TWO

The additional cost in time caused by accessing the disk will be approximately .15 seconds per flight to read in TGTVAR and approximately .45 seconds for each target processed by the sensors on the flight to read in the TGTOB data (processing time on the 131K-CDC 6400 is approximately .5 seconds per target). The SIGINT model can be run on a 32K word core storage machine as it is, with the possible exception of the disk I/O statements.

The subprogram to generate pseudo-random numbers in each of the models is also dependent on the machine and will require a change to use a uniform pseudo-random number generator compatible with the machine to be used. Most computer centers maintain a library of commonly used subprograms. One of their uniform random number generators, on the interval from 0 to 1, should be used in the subprogram RANDOM(Z) to fix the value of Z.

When the above programming changes have been incorporated (if they are necessary) the programs will be ready to be run. The programs can be compiled and run directly from the FORTRAN source deck, or a binary deck can be punched by the computer and used on subsequent runs. It will be more efficient to use a binary deck of the program, if the program is to be run several times. The user should consult with a systems analyst at the computer center for the simple procedures for obtaining and running a binary deck.

B. Data Collation and Computer Processing

Each of the three programs require a large amount of input data. Extreme care should be used in preparing these data for computer use since the computer will tolerate few, if any, errors. Extreme care will result in few errors, but it is still likely that errors in the data will occur. The general suggestions below should be helpful in finding errors before the computer runs.

After all the cards are punched from one form (i.e., the same format), they should be listed before they are mixed with cards punched from another form. Visual examination of the listing should quickly reveal any deviation from the format, since all the entries for one field of information will occur in a column. Without checking the individual lines of the listing against their sources, a quick check can be made to ensure that every entry in a column is reasonable (i.e., within bounds for that field of information).

Since most of the alphanumeric information is used in a computer search to identify the particular item, execution will stop if the alphanumeric information cannot be identified. For this reason, it is particularly important that all alphanumeric fields of information be checked for consistency and correct alignment (e.g., OV-1D is not the same as OV1D).

After the keypunched data from each form have been double-checked in the above manner, the cards should be collated into a deck structured according to the instructions in this handbook for the program being run (the instructions for CRESS-A and CRESS-G appear below; CRESS-S instructions are listed in Sec. II.D). The data should be listed again. The order of the different types of cards should then be checked against the order of the read statements in the FORTRAN computer program. This should ensure that no cards are missing or out of place.

This may appear to be lot of checking; however, it is not time consuming and it is important. If a mistake occurs in the data, an execution stoppage is likely to occur. If it does not, there is a good chance that large amounts of the output will be erroneous. Thus, the time and care for checking the data thoroughly are mandatory.

1. Aerial Model Deck Structure

The input data must be punched in the formats specified in Section II.E. The cards must be collated in the order of the entries in Table 23 for the computer run. The entries in Table 23 are for a card deck prepared for the CDC 6400 computer. If the program is run on another computer, the control cards and the cards between the program and data may be different and should be checked with a systems analyst at the computer center.

When the data are collated in the order indicated in Table 23, they are ready to be submitted to the computer for processing. The first run on the computer should include only one or two flights. If the data read incorrectly, the output should appear in the correct format and have reasonable values. When this happens, the entire set of flights should be submitted for the production run for Aerial sensors.

If an error is present in the data, it is likely that an execution stoppage will occur at or just after the read statement that attempts to read the erroneous datum. The position in the program where the abnormal stop occurred will usually indicate where the error is in the data. If many errors are encountered in the data, it is recommended that write statements

Table 23

AERIAL PROGRAM CARD DECK ORDER

Order	Type of Cards	Figure or Table Containing Format
1.	SCOPE control cards	Computer Center
2.	FORTRAN program deck for Aerial Model	--
3.	A card with 7 8, 9 level punches in Column 1	--
4.	Logical unit numbers card	53
5.	Initial value of random number card	44
6.	Situation heading card	42
7.	SR (Columns 1 and 2) card	--
8.	Size cards 1 and 2	54
9.	Miscellaneous information card 1	55
10.	False target maximum card(s)	38
11.	Miscellaneous information card 2	56
12.	Map errors card	Table 19
13.	Map grids card	36
14.	Error ellipse to CEP conversion card	Table 18
15.	Report criteria card	39
16.	Special object list card (if required)	40
17.	Area targets radii card	41
18.	Probability curves, digital form--NNP, PPPDS, PPPI, PPPR, YY, [illegible], PMO, PMR, PMS, SSN, IIPDS, NNI, IIPR, IIPI, SSNR, PPDRS, NNRE, PPRR, PPIR, SSNMTI, PPDMS, PPA, RRI	Appendix A

Table 23 (continued)

AERIAL PROGRAM CARD DECK ORDER

Order	Type of Cards	Figure or Table Containing Format
19.	Attrition capability cards (if played)	29
20.	Atmospheric parameters cards	37
21.	Background characteristics cards	27
22.	Object characteristics cards	23
23.	Detection classes cards	24
24.	Recognition classes cards	24
25.	Target variables cards (ordered by target group)	26
26.	Men/net designation card	43
27.	Posture-men array cards	22
28.	Target objects cards	25
29.	Multisensor enhancement coefficients cards	Table 4
30.	Aircraft MTBF cards	28
31.	Air navigation systems cards	33
32.	Navigation systems MTBF cards	34
33.	Camera systems parameters cards (if played)	Appendix I
34.	IR sensors parameters cards (if played)	Appendix I
35.	Radar systems parameters cards (if played)	Appendix I
36.	Visual sensors parameters cards (if played)	Appendix I

Table 23 (continued)

AERIAL PROGRAM CARD DECK ORDER

Order	Type of Cards	Figure or Table Containing Format
37.	Laser sensors parameters cards (if played)	Appendix I
38.	TV parameters cards (if played)	Appendix I
39.	Reconnaissance-by-fire sensor parameters (if played)	Appendix I
40.	Data link MTBF cards	30
41.	Timeliness factors car	32
	Each flight must have the remaining set of data cards in the order listed.	
42.	Flight parameters card	45
43.	Flight instrumentation card	46
	Each RS area must have the remaining set of data cards in the order listed.	
44.	Navigation update card (present only if updated since last RS area or take off)	49
45.	RS area description card 1	47
46.	RS area description card 2	48
	Repeat card types 42 through 45 for all flights. End the card deck with the following two cards.	
47.	A card with 7, 8, and 9 level punches in Column 1	--
48.	A card with 6, 7, 8, and 9 level punches in Column 1	--

be inserted after the read statements in the subroutines SCENIN, RDTGTV, and TAROBJ to ensure that the data are being stored correctly.

When all the data errors have been found and corrected, the program and data deck, with all the flights to be simulated, should be submitted to the computer for the production run.

2. Ground Model Deck Structure

The input data must be punched in the formats specified in Section II.E. The cards must be collated in the order of the entries in Table 24 for the computer run. The remarks concerning the initial run of the Aerial Model also apply to the first run of the Ground Model; only a few OP/TGT cards should be used until the data read in are checked. After the data have been read in successfully, all the OP/TGT cards for the desired atmospheric condition should be used for a production run.

C. Analysis

CRESS is designed to be a tool for use in a variety of R & S-related studies. As such, it should always be viewed in the setting it occupies within the framework of the study using it. Accordingly, the results of the computer simulations performed by CRESS should be examined within the constraints and context of the parent study.

However, it should be recognized that the computer output is not the only thing gained in using CRESS. Performing the

Table 24

GROUND PROGRAM CARD DECK ORDER

Order	Type of Cards	Figure or Table Containing Format
1.	SCOPE control cards	Computer Center
2.	FORTRAN program deck for Ground Model	--
3.	A card with 7, 8, and 9 level punches in Column 1	--
4.	Logical unit numbers (Ground) card	58
5.	Situation heading card	42
6.	Report criteria card	39
7.	Special object list card (if required)	40
8.	Expected ratio of false target elements to detected elements card	60
9.	Ground size card	59
10.	Map errors card	Table 19
11.	Map grids card	36
12.	Error ellipse to CEP conversion card	Table 18
13.	Average CEPs for OPs and patrols card	60
14.	Probability curves, digital form--NNP, PPPDS, PPPI, PPPR, SSN, IIPDS, NNT, IIPR, IIPI.	Appendix A
15.	Atmospheric parameters cards	37
16.	Atmospheric parameters index card	60
17.	Background characteristics cards	27
18.	Object characteristics cards	23
19.	Detection classes cards	24

Table 24 (continued)

GROUND PROGRAM CARD DECK ORDER

Order	Type of Cards	Figure or Table Containing Format
20.	Recognition classes cards	24
21.	Target variables cards	26
22.	Men/net designation card	43
23.	Posture-men array cards	22
24.	Target objects cards	25
25.	Multisensor enhancement coefficients cards	Table 4
26.	Ground communication link failure cards	31
27.	IR sensors (Ground) cards (if played)	Appendix I
28.	Laser sensors (Ground) cards (if played)	Appendix I
29.	PNVD sensors (Ground) cards (if played)	Appendix I
30.	TV sensors (Ground) cards (if played)	Appendix I
31.	Visual sensors (Ground) cards (if played)	Appendix I
32.	Radar sensor (Ground) cards (if played)	Appendix I
33.	IR binocular sensor (Ground) cards (if played)	Appendix I
34.	Observation post parameters form	50
35.	Miscellaneous data card	60 (Card 4)
36.	Messages cards	--

Table 24 (continued)

GROUND PROGRAM CARD DECK ORDER

Order	Type of Cards	Figure or Table Containing Format
37.	Initial value of random number card	44
38.	OP/TGT data cards (ordered by OP)	51
39.	Card with -99 in columns 1, 2, and 3	--
40.	A card with 7, 8, and 9 level punches in Column 1	--
41.	A card with 6, 7, 8, and 9 level punches in Column 1	--

required manual tasks will impart a detailed appreciation of the problem and help generate an important subjective awareness of what the results should be and what they may imply. In some instances, the knowledge gained in this manner may be even more important than the knowledge gained directly from the numerical data generated by the computer.

CRESS generates large amounts of computer outputs from all three of the major models (Aerial, Ground, and SIGINT). Since these major programs are run independently of each other on the computer, three separate sets of output data can be generated. The corresponding outputs (Control Copies and Intelligence Copies) of the Aerial and Ground models are very similar to each other in both format and content. The SIGINT model processes quite different types of information and its outputs, both Control Copy and Intelligence Copy, are quite different from the corresponding copies of the Aerial and Ground Models.

For studies that are directly concerned with sensor performance (e.g., making tables of probabilities of detection versus sensor-to-target distances for a given weather condition), the Control Copies of the pertinent major models can be examined separately. Summary tables for the sensors' performance can be built directly from one Control Copy.

For studies that require the analysis of many aspects of tactical reconnaissance (e.g., providing target lists, updating a war game intelligence map), it will be necessary to examine the data from each of the major models being used concurrently.

This will allow the intelligence analyst to make his estimates on the basis of all the simulated reconnaissance that the computer has produced.

To perform this concurrent examination, it is suggested that the analyst lay out the Aerial, Ground, and SIGINT output copies side by side and physically near his situation map. The Intelligence Copy reports are ordered by the time of receipt of the reports so that the situation map can be updated in the same sequence that it would be in actual practice. It is suggested that a form similar to the one in Fig. 67 be used to collate the information about possible individual tactical targets. The user should definitely design his own form to ensure the inclusion of all pertinent data that can be garnered from the computer output and other sources.

The information from the computer printout for each group of target elements should be entered into that part of the intelligence analysis form already containing information on targets in the same geographic area (and time span) as the group of objects being reported. If the report supplements (a already attained, the analysis of sighting section should be updated. In particular, extensive use of the remarks subsection should be made to provide documentation of the analyst's ability to combine the computer-produced information with his prior knowledge of the terrain (possibly gained from the map in a simulation), weather, and enemy (e.g., TOE, capability, vulnerability, intentions).

Reports Numbers	Times of Reports	Location	Group Numbers	Reports' Origins	Times of Sightings	Location Accuracies	Objects Identified	Things Recognized	Things Detected	Target Composition	Analysis of sighting			
											Type of Target	Confi-dence	Target Designation	Remarks
33G	11200	MA7'2836	12G	OP-GSR	11200	35	1 T-62 Tanks	1 Mov. Veh.	5 small obj.	2 Tanks	Tank Platoon	0.8	T1	Moving tank platoon near forest for cover.
10	11305	MA762835	4	A-11VR, Visual	11200	105		1 TR VEH						
25	11 32	Same	4	A-11VR Radar	11201	105		2 Mov. Veh.						

Fig. 67 INTELLIGENCE ANALYSIS FORM

It is impossible to anticipate the explicit needs of all potential CRESS users. The analysis required for any one user will probably be quite different from that for any other user. Thus, forms for analysis of the data generated by CRESS in a simulation must be generated by the user to fit his individual needs. It is encumbent on the user to learn exactly what CRESS can and cannot accomplish for him and to design his analysis methodology in a manner that will fully exploit the capabilities of CRESS in the most efficient way.

REFERENCES

1. J. Zeidner, et al; "Human Factors Studies in Image Interpretation; The Impact of Intelligence Information Furnished Interpreters" (U), Technical Research Note 117; Human Factors Research Branch, TAG Research and Development Command, U.S. Army; August 1961 (UNCLASSIFIED)

2. "Advanced Surveillance Systems Investigation through Simulation on TARS (ASSIST)" (U), Volume II; Systems and Research Center, Honeywell, Inc., Minneapolis, Minnesota; 5 October 1967 (CONFIDENTIAL)

3. R. A. Erickson; "Empirically Determined Effects of Gross Terrain Features Upon Ground Visibility from Low-Flying Aircraft"; Naval Ordnance Test Station, China Lake, California; September 1961 (NOTS Tech. Pub. 2760)

4. "Air Force/Industry Sensor Reliability Team Report" (U), 6700 NF-490; Air Material Area, Hill Air Force Base, Ogden, Utah; November 1967 (SECRET)

5. "Air Force Reports 66-1, Maintenance-Logistics Statistics"; Wright Patterson Air Force Base, Dayton, Ohio; (Continually Updated)

6. "Probable Attrition of Army Air Vehicles in Varying Combat Environments (U), (Project PACE)"; Cornell Aeronautical Laboratory, Inc., Buffalo, New York; 28 March 1965 (SECRET)

7. H. A. Mailiot; "The Covariance of Position Location," Stanford Research Institute, ORD Technical Note 5205-15; Menlo Park, California; December 1968

Appendix A

TARGET OBJECT AND BACKGROUND CHARACTERISTICS

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Appendix A - TARGET OBJECT AND BACKGROUND CHARACTERISTICS

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Appendix A

TARGET OBJECT AND BACKGROUND CHARACTERISTICS

A. Introduction

The characteristics of 241 target objects (Table A2) and 53 background types (Table A3) are included as possible inputs to the R & S computer model. The characteristics specified for each target object and background are reflectivity values for the visual, IR, and radar (microwave) portions of the electromagnetic spectrum, and IR emissivity values. Dimensional data (length, width, and height in meters) are also given for each target object. Daytime and nighttime temperature, in degrees Kelvin, are additional parameters that should be included for each entry; however, since temperatures vary widely depending on geographical location and season of year, they were included only for those targets whose temperatures are stable, i.e., personnel and animals. A procedure that can be used to provide a rough estimate of target and background temperature is described in Section E.

B. Dimensional Data

Length, width, and height for most types of enemy equipment were taken from Ref. 1. Dimensional data for many of the smaller weapons were not available and estimates were made from photographs. The height for mortars, field artillery, and AA artillery assumes the gun tube at a 45° elevation angle; the length specified for equipment with a gun tube includes the length of the tube. Dimensions for aircraft types were taken from "Jane's All The World's Aircraft," and those for the remaining targets were estimated.

C. Visual and IR Reflectivity, and IR Emissivity

Visual reflectivity values given in the listings were averaged over the .4 to .7 micron region; IR reflectivity and emissivity values over the 8 to 15 micron region. Emissivity will, of course, fluctuate widely because the operational state of the vehicle or weapon. The reflectivity and emissivity specified can be considered average midday values

References 2 and 3 were the major sources of visual and IR reflectivities. These documents, prepared by the University of Michigan's Infrared and Optical Sensor Laboratory, contain an extensive catalog of target and background signature data, reduced to a standard format of presentation. The catalog was compiled from experimental studies conducted during the last three decades; as new data become available, supplements to the compilation will be published. The Michigan reflectivity curves are grouped according to the subject code (e.g., bridges, trucks, canvas, sand, rice) that best describes the object or sample measured.

The preponderance of Michigan reflectivity curves are for background materials (leaves, crops, soils, etc.). Unfortunately, however, wavelength coverage for these background features is largely limited to the .4 to 2.7 micron region. There are only a few curves which extend out as far as 15 microns. Thus, while visual reflectivity values for many backgrounds can be readily obtained, IR values for the 8 to 15 micron region must, in many cases, be estimated. In general, the IR reflectivity value for this region closely approximates the visual reflectivity.

In addition to reflectivity curves for natural terrain materials, the Michigan compilation includes considerable data for paints, metals. and fabrics. Curves for paints and metals often extend from .3 to 15 microns; those for fabrics from .3 to 2.7 microns. Among other categories which include a few curves each are roads, building materials (e.g., concrete, brick, asphalt), wood, paper, and plastic.

Unfortunately, there are as yet very few reflectance curves specifically for military-type targets such as aircraft, tanks, and guns; what is available consists largely of the spectral reflectance of various metals and military paints. Since military field equipment is normally protected by paint for durability, the reflectance characteristics of olive drab paint, which is commonly used on field vehicles, can be used when data for the actual vehicle or weapon is not available. Similarly, the reflectivities of small guns can roughly be determined by considering, for example, the reflectance curves for unpainted metal; for military and civilian personnel, the curves for fabrics (khaki shirt, olive drab fabric, etc.) can be used.

Reference 4 was a secondary source of visual reflectivity data. This report contains about 40 spectral reflectivity curves of target objects and backgrounds characteristic of S.E. Asia, including, for example, straw hats, Thai skin, sampans, and rice stubble. Wavelength coverage is from .4 to .9 microns only.

In the visible and infrared portions of the spectrum, the data presented in the Michigan reports are chiefly for reflectance, with only a very small amount of emittance information given. The emissivity of any target or background depends on the amount of energy its surface can absorb. A surface that absorbs most of the infrared radiation striking it will emit a relatively high amount and thus the emissivity will be comparatively large. The following guidelines can be used in approximating the emissivity of targets and backgrounds:

(1) In general, a rough and dark surface has a high emissivity and low reflectance; the reverse is true for a bright and shiny surface.

(2) For an opaque material (and most targets and backgrounds are opaque or nearly opaque), the emissivity is roughly equal to 1 minus the IR reflectivity value.

(3) Emissivities of targets and backgrounds are generally high, and correspondingly, their IR reflectances are low. For example, in the 8 to 15 micron region the emissivities of surfaces exposed in normal terrain (e.g., soils, rock, water, vegetation) usually range between .85 to .99. And since the sum of the reflectivity and emissivity of an opaque surface is roughly one, the reflectance of such terrain features must range between zero and .15 in the 8 to 15 micron region.

D. Radar Reflectivity

The radar reflectivity value for a particular target (or background) is computed by dividing the target's radar cross section by the projected area. When an object is illuminated by a radar, some energy is absorbed and the remainder is scattered.

The radar cross section is a measure of the echo return at the radar produced by the backscattered energy and is usually expressed in square meters. Projected area is the surface area of the target illuminated by the radar, also in square meters.

Radar cross sections for scatterers with simple shapes (e.g., sphere, cone, circular plate) have been tabulated. However, the radar cross section of complex targets (aircraft, terrain, buildings, etc.) are much more difficult to determine since such targets are composed of many individual scatterers each with different scattering properties. Moreover, interactions may occur among the scatterers which affect the cross section.

In addition, there are three significant parameters which affect the radar cross section of complex targets: viewing aspect angle, radar's operating frequency, and polarization. The radar reflectivities given in the listings can be considered rough values for a K_a band radar (frequency = 26.5 to 40 GHz) and for a 45^o aspect angle; polarization (vertical or horizontal) was variable.

The chief sources of cross section values used in computing radar reflectivities were the Michigan reports. In these reports, active microwave data, in the form of radar cross section (in decibels) as a function of angle measured from the normal (aspect angle), occurs for many background materials such as various types of vegetation, soils, water, industrial areas, concrete, and asphalt but not as yet for military-type targets. Significant parameter information appears in the curve header of each

Michigan cross section graph, including radar frequency band, polarization, and total sampling area per average point (projected area). However, parametric information is sometimes not complete, especially in the case of projected area.

Some radar cross section information for military-type targets can be found scattered throughout the literature, e.g., Refs. 5, 6, and 7, and these data were utilized when applicable. In many cases, however, radar reflectivities for targets and backgrounds were extrapolated or estimated.

E. Target and Background Temperature

Determination of target and background temperature is a complex matter that is usually not amenable to quantitative treatment except for computing rough approximations. The following procedure can be used to provide a rough estimate of target temperature. For the country of interest, consider the average ambient daytime and nighttime temperatures for the appropriate season of the year. Target temperature data are generated around these day and night temperatures, and a judgment is made as to whether a specific target would be hotter or cooler (or the same as) ambient temperature. In making this judgment, several factors are considered: target color, emissivity, and heat conductivity; size, shape, and material of the target; target movement; target background. This list is not exhaustive but most likely includes the most important parameters.

Background temperature will generally be ± 10 percent of average daytime or nighttime Fahrenheit temperature.

Mean temperatures for January, April, July, and October are given in Table A1 for selected countries. For some countries, temperatures were available for only one city, which is named in the table; the temperatures for other countries represent the average of several cities.

Table A1

MEAN TEMPERATURES FOR SELECTED COUNTRIES[a]

Country	Mean Temperature (°F)			
	January	April	July	October
Argentina (north of 35° S latitude)	74	62	50	63
(south of 35° S latitude)	70	56	43	56
Austria (Vienna)	32	49	66	49
Brazil (north of 15° S latitude)	79	79	76	79
(south of 15° S latitude)	77	74	67	73
Bulgaria (Sofia)	28	50	69	53
China (NW, Sinkiang)	23	59	80	57
(SW, Tibet)	24	42	58	46
(Central Interior)	34	60	79	58
(NE, Peiping area)	25	57	81	58
(E Central, Shanghai area)	40	58	82	65
(SE, Hong Kong area)	60	71	83	77
Congo, Republic of the	73	72	67	75
Cuba (Havana)	70	74	79	77
Czechoslovakia (Prague)	30	48	[illegible]	49
England (London)	39	48	64	50
Finland (north of 64° N latitude)	10	28	56	32
(south of 64° N latitude)	21	37	64	41
France	41	52	69	55
Germany, East	29	44	64	48
Germany, West	31	46	64	48
Greece	48	59	79	66
Hungary (Budapest)	32	52	70	52

Table A1 (Continued)

Country	Mean Temperature (°F)			
	January	April	July	October
India (N, Delhi area)	59	85	88	80
(S, Madras area)	76	85	87	82
(E, Bombay area)	76	83	81	82
(W, Calcutta area)	67	86	84	81
Ireland (Dublin)	40	45	58	48
Italy (north of 42° N latitude)	34	54	74	55
(south of 42° N latitude)	48	58	76	65
Jordan and Israel (Jerusalem)	45	60	76	70
Laos (Luang Prabang)	69	83	83	80
Lebanon (Beirut)	55	65	80	73
Nepal (Katmandu)	50	68	76	68
Netherlands (Amsterdam)	38	47	63	51
Norway (north of 64° N latitude)	24	30	50	35
(south of 64° N latitude)	28	39	60	43
Poland	25	46	66	48
Rumania	26	50	72	52
Scotland (Glasgow)	39	45	58	47
South Africa, Republic of	70	63	54	63
Spain (north of 40° N latitude)	42	51	68	56
(south of 40° N latitude)	50	59	78	66
Sweden (north of 64° N latitude)	10	28	56	32
(south of 64° N latitude)	27	38	63	43
Thailand (Bangkok)	79	87	74	83
Turkey (Istanbul)	42	53	75	63
United Arab Republic (Cairo)	55	70	83	74
USSR (NW, Archangel area)	8	30	60	34
(W Central, Moscow area)	13	38	64	39
(SW, Rostov area)	21	48	75	50
(N Central area)	-20	4	54	13
(S Central area)	-5	31	67	33
(NE area)	-25	4	52	16
(SE, Vladivostok area)	7	40	65	49
Venezuela	73	76	76	74
Vietnam, North (Hanoi)	63	75	85	79
Vietnam, South (Saigon)	79	86	81	81
Yugoslavia (Belgrade)	33	53	72	54

Table A2

Note: The numbers for each object type are in order; 1st row: length, width, height, visual spectrum reflectance, IR spectrum reflectance; 2nd row: radar reflectivity, emissivity in IR spectrum, average probability of misidentification, average probability of misrecognition, and category for multisensor processing.

```
C        LISTING OF OBJECTS BY DETECTION AND RECOGNITION CLASS
C
         DETECTION GROUP 1  -  AREA TARGET
C
1        RECOGNITION GROUP 1  -  LARGE AREA TARGET
C                                     LENGTH WIDTH HEIGHT  (METERS)
    AIRFIELD, CONCRETE               1450.    950.    .01     .28     .30
  .03      .70                               .07     .01     11
    RUNWAY, ASPHALT                  2750.     50.    .01     .03     .09
  .03      .91                               .09     .01     14
    AIRFIELD, EARTH                   300.    175.    .01     .09     .09
  .03      .91                               .15     .09     12
    TAXIWAY, ASPHALT                 2000.     25.    .01     .03     .09
  .03      .91                               .05     .01     14
C
1        RECOGNITION GROUP 2  -  MEDIUM AREA TARGET
C
    HANGAR, STEEL                     150.     50.  40.       .18     .19
  .02      .81                               .20     .35     11
    POND                               75.     75.    .01     .06     .02
  .03      .98                               .20     .30     12
    METAL DOME                         60.     60.  55.       .40     .41
  .03      .59                               .30     .45     11
C
         DETECTION GROUP 2  -  LINEAR TARGET
C
2        RECOGNITION GROUP 3  -  ROAD
C                                     LENGTH WIDTH HEIGHT  (METERS)
    ASPHLT RD JUNCTION                25.     25.    .01      .05     .09
  .4       .91                               .00     .00     12
    MASONARY WALL                     100.       .5  2.       .28     .28
  .03      .72                               .28     .35     11
    BAMBOO FENCE                       10.       .1  1.5      .22     .24
  .00006   .78                               .30     .35     11
C
2        RECOGNITION GROUP 4  -  BRIDGE
C
    WOODEN RR BRIDGE                  100.      5.  2.        .27     .20
  .3       .80                               .01     .01     11
    STEEL BRIDGE                       75.     4.8  1.        .10     .13
  .02      .87                               .01     .01     11
    CONCRETE BRIDGE                    50.      6.  10.       .30     .31
```

```
  .03        .69                                   .01       .01        11
   STEEL BRIDGE                        60.       4.8  1.        .10        .13
  .02        .87                                   .01       .01        11
   STEEL BRIDGE                        50.       4.8  1.        .10        .13
  .02        .87                                   .01       .01        11
   WOODEN RR BRIDGE                    50.       4.   10.       .28        .25
  .03        .75                                   .01       .01        11
   1-LANE WOOD BRIDGE                   25.      2.0       1.3      .27        .20
    .03        .80                                 .01       .01        11
   FOOTBRIDGE                          10.       1.0       1.0      .27        .20
    .03        .80                                 .01       .01        11
C
2       RECOGNITION GROUP 5  -  RAILROAD TRACK
C                                       LENGTH WIDTH HEIGHT (METERS)
   RR, MULTIPLE TRACKS                 250.      4.5  .1        .20        .20
  .02        .80                                   .00       .00        14
   RR, SINGLE TRACK                    250.      1.5  .1        .20        .20
  .02        .80                                   .03       .02        14
   RR SIDING                           250.      1.5  .1        .17        .18
  .03        .82                                   .00       .00        14
   RR SWITCH TRACK                     250.      1.5  .1        .17        .18
  .03        .83                                   .20       .10        14
   RR SPUR                             200.      1.5  .1        .20        .20
  .02        .80                                   .09       .03        14
   RAILROAD JUNCTION                    250.     4.5       .1       .20        .20
    .02        .80                                 .00       .00        14
C
2       RECOGNITION GROUP 6  -  RAILROAD CAR
C
   RAILROAD ENGINE                     11.       2.5  3.1       .10        .10
  .3         .90                                   .20       .10        3
   RAILROAD GONDOLA                    11.       2.5  2.3       .10        .13
  .3         .87                                   .10       .20        3
   RAILROAD PSNGRCAR                   11.       2.5  3.1       .10        .13
  .3         .87                                   .10       .10        3
   RAILROAD KITCHEN                    11.       2.5  3.1       .10        .11
  .3         .89                                   .10       .40        3
   RAILROAD COACH                      11.       2.5  3.1       .10        .13
  .3         .87                                   .10       .10        3
   RAILROAD BOXCAR                     11.       2.5  3.1       .10        .13
  .3         .87                                   .10       .10        3
   RAILROAD TANKCAR                    11.       2.5  3.1       .10        .11
```

```
 .3          .89                                     .10       .20         3
  RAILROAD CABOOSE                            8.2         2.5  3.1         .10       .13
 .3          .87                                     .10       .10         3
  RAILROAD TENDER                             6.7         2.5  2.5         .10       .12
 .3          .88                                     .10       .10         3
C
          DETECTION GROUP 3  -  OBJECT ON WATER
C
3         RECOGNITION GROUP 7  -  BOAT
C                                             LENGTH WIDTH HEIGHT (METERS)
  POWER BOAT                                  8.        2.4  1.2           .09       .13
 .3          .87                                     .10       .40         8
  SAMPAN                                      6.        2.      .5         .12       .16
 .3          .84                                     .08       .20         8
  18-FOOT WOOD BOAT                           5.5       2.   1.            .12       .16
 .3          .84                                     .08       .20         8
  PONTON                                      7.2       2.4       2.5        .09       .13
   .3            .87                                 .0[illegible]      .20         8
C
          DETECTION GROUP  4  -  LARGE LAND OBJECT
C
4         RECOGNITION GROUP 8  -  SMALL AREA TARGET
C
  CULTIVATED FIELD                            30.       30.     .01        .08       .12
 .03         .88                                     .10      .00        12
  BAMBOO ENCLOSURE                            30.       30.     .1         .22       .22
 .00006      .78                                     .20      .30        11
  GAME COURT, EARTH                           30.       15.     .01        .10       .10
 .02         .90                                     .25      .40        12
  CLEARED AREA                                30.       10.     .01        .18       .19
 .02         .8[illegible]                                      .20      .35        12
  RESERVOIR                                   17.       17.     .01        .06       .02
 .03         .98                                     .10      .00        12
  CORRAL                                      10.       10.     1.5        .18       .19
 .02         .91                                     .25      .30        11
C
4         RECOGNITION GROUP 9  -  LARGE BUILDING
C                                             LENGTH WIDTH HEIGHT (METERS)
  CONCRETE BLDG                               40.       20.     9.         .25       .25
 .03         .75                                     .15      .15        11
  TARGET BUTTS, EARTH                         50.       10.     .01        .12       .12
 .00006      .88                                     .25      .30        11
```

```
  PLASTER ADMIN BLDG              20.      9.5  7.5     .28     .28
 .03      .72                         .15      .15    11
  WOOD BLDG, 2 STORY               9.      20.  7.5     .21     .20
 .3       .80                         .15      .15    11
  FIRE DIRECT CENTER              15.      10.  3.      .14     .19
 .3       .81                         .30      .30    11
  PLASTER HOUSE                   15.3     9.5  4.5     .28     .28
 .03      .72                         .15      .15    11
  HOUSE, TILE ROOF                15.3     9.5  4.5     .20     .21
 .02      .79                         .15      .15    11
  SHED, WAREHOUSE                 18.2     7.6  4.      .18     .19
 .02      .81                         .15      .15    11
  WOODEN ADMIN BLDG               15.3     8.5  5.5     .18     .19
 .03      .81                         .15      .15    11
C
4       RECOGNITION GROUP 10  -  CAMOUFLAGE NET
C
  WPN CAMOUFLAGE NET               9.      9.    .01    .10     .15
 .00006   .85                         .35      .30    12
  CAMOUFLAGE NET                   8.8     8.8   .01    .10     .15
 .00006   .85                         .39      .30    12
  CAMOUFLAGE NET                   4.5     4.5   .01    .10     .15
 .00006   .85                         .45      .30    12
C
        DETECTION GROUP 5  -  MEDIUM LAND OBJECT
C
5       RECOGNITION GROUP 11  -  MEDIUM BUILDING
C                                 LENGTH WIDTH HEIGHT (METERS)
  HUT, THATCHED ROOF              15.2     5.5  4.      .18     .19
 .02      .81                         .15      .30    11
  SHED, THATCHED ROOF             15.2     5.5  4.      .18     .19
 .02      .81                         .15      .30    11
  PLASTER BLDG                    12.2     6.1  4.5     .28     .28
 .03      .72                         .15      .15    11
  WOOD SERVICE BLDG               12.2     6.1  4.      .18     .19
 .02      .81                         .15      .15    11
  HUT, THATCHED ROOF              15.2     4.6  4.      .18     .19
 .02      .81                         .15      .30    11
  KITCHEN, THTCH ROOF              8.      8.   4.      .18     .12
 .02      .68                         .15      .35    11
  SHED, THATCHED ROOF             12.2     4.6  4.      .18     .19
 .02      .81                         .15      .30    11
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   HUT, THATCHED ROOF                  12.2      4.6  4.        .18      .19
 .02       .81                              .15       .30      11
   HOUSE, TIN ROOF                      7.6      6.1  4.        .14      .15
 .02       .85                              .10       .15      11
   WOOD HOUSE                           7.6      6.1  4.        .18      .19
 .02       .81                              .15       .15      11
   LARGE MUD HUT                        7.6      4.6  3.5       .18      .19
 .02       .81                              .15       .15      11
   WOODEN BLDG                          6.       4.5  3.1       .18      .19
 .02       .81                              .15       .15      11
   FUEL STORAGE TANK                    5.       5.   2.        .07      .07
 .07       .93                              .15       .10      11
C
5       RECOGNITION GROUP 12  -   MEDIUM BUILDING
C
   ELECT SUBSTATION                    10.       5.   4.        .15      .15
 .03       .85                              .15       .10      11
C
5       RECOGNITION GROUP 13  -  MEDIUM BUILDING
C                                 LENGTH WIDTH HEIGHT (METERS)
   WOOD RR STATION                      6.       6.   3.1       .18      .19
 .02       .81                              .00       .00      11
C
5       RECOGNITION GROUP 14  -  LARGE TOWER
C
   STEEL RADIO TOWER                    8.       8.  75.        .18      .19
 .02       .81                              .10       .00      11
   STEEL CONTRL TOWER                   6.       6.  15.        .18      .19
 .02       .81                              .10       .10      11
   POWER LINE PYLON                     5.       5.  18.5       .22      .22
 .02       .78                              .10       .00      11
C
5       RECOGNITION GROUP  15  -  LARGE SELF-PROPELLED WEAPON
C                                 LENGTH WIDTH HEIGHT (METERS)
   400MM TRAC MORT SP                  20.       3.6  3.8       .12      .10
 .3        .90                              .15       .10       5
   310MM TRAC GUN, SP                  16.       3.6  3.8       .12      .10
 .3        .90                              .15       .10       5
C
5       RECOGNITION GROUP  16  -  TRACKED VECHICLE
C
   BRIDGE LAYING TANK                  12.       3.5  2.5       .14      .13
```

.3	.87		.10		.08	4	
100MM ASLT GUN, SP		11.1		3.3	2.4	.12	.10
.3	.90		.10		.25	4	
122MM ASLT GUN, SP		11.6		3.1	2.5	.12	.10
.3	.90		.10		.25	4	
HEAVY TANK		10.		3.6	2.6	.12	.10
.3	.90		.10		.08	4	
MINE CLEARING TANK		8.5		4.	2.4	.12	.10
.3	.90		.10		.08	4	
152MM ASLT GUN, SP		10.8		3.1	2.5	.12	.10
.3	.90		.10		.25	4	
ROCKET/TNK CHASSIS		10.5		3.1	3.2	.12	.10
.3	.90		.10		.10	4	
AMPHIBIOUS TRACTOR		9.2		3.1	2.7	.12	.12
.3	.88		.10		.10	4	
MEDIUM TANK		7.9		3.3	2.4	.12	.10
.3	.90		.12		.30	4	
HVY ARTY TRACTOR		7.		3.1	2.9	.12	.12
.3	.88		.15		.35	4	
TRAC DITCHING MACH		7.		3.1	4.2	.12	.12
.3	.88		.25		.30	4	
TRACKED DOZER		6.6		3.2	2.1	.17	.14
.3	.86		.25		.30	4	
AMPHIBIOUS TANK		7.0		3.1	2.2	.12	.10
.3	.90		.18		.20	4	
TRACKED APC		6.7		3.1	1.9	.12	.10
.3	.90		.10		.20	4	
TRACKED APC		7.2		2.8	2.2	.12	.10
.3	.90		.10		.20	4	
TANK RECOVERY VEH		6.1		3.	2.	.12	.10
.3	.90		.10		.15	4	
MED ARTY TRACTOR		5.9		2.6	2.6	.12	.12
.3	.88		.19		.25	4	
57MM ASLT GUN, SP		7.		2.1	1.7	.12	.10
.1	.90		.20		.30	4	
ARMORED ARTY TRCTR		4.5		2.5	1.8	.12	.12
.3	.88		.20		.30	4	
LIGHT ARTY TRACTOR		5.1		2.2	2.1	.12	.12
.3	.88		.20		.30	4	
T-62 TANK		6.0		3.3	2.4	.12	.10
.3	.90		.12		.30		
PT-85 TANK		6.7		3.1	2.2	.12	.10

.3 .90 8. .12 .30 4
TRACTOR, AT-P 4.5 2.5 1.8 .12 .12
.3 .88 .20 .30 4
TRACTOR, AT-S 5.9 2.6 2.6 .12 .12
.3 .88 .19 .25 4
ATGM LNCHR, SP 5.6 2.1 1.6 .12 .13
.3 .87 .10 .10 7
FROG LNCHR, SP 10.2 3.1 3.6 .12 .13
.3 .87 .10 .10 7
C
5 RECOGNITION GROUP 17 - WHEELED VECHICLES
C LENGTH WIDTH HEIGHT (METERS)
40-TON DUMP TRUCK 10.6 3.4 3.7 .12 .14
.3 .86 .12 .15 3
LOW BOY TRAILER 12.6 2.7 1.7 .12 .14
.3 .86 .12 .20 3
MISSILE TRAILER 10. 3.2 3. .12 .14
.3 .86 .19 .25 3
TRCTR TRK, SEMITRLR 11.4 2.7 3.6 .12 .14
.3 .86 .12 .20 3
25-TON DUMP TRUCK 8.3 3.2 3.7 .12 .14
.3 .86 .12 .19 3
12-TON TRUCK 9.7 2.7 2.6 .12 .14
.3 .86 .12 .15 3
280MM RKT/LNCHR SP 9. 2.7 4. .12 .12
.3 .88 .10 .10 3
2 1/2-T AMPHIB TRK 9.5 2.5 2.7 .12 .14
.3 .86 .12 .20 3
7-TON TRUCK 8.5 2.7 2.9 .12 .14
.3 .86 .12 .15 3
10-TON DUMP TRUCK 8.2 2.7 2.8 .12 .14
.3 .86 .12 .15 3
TRCTR TRK, SEMITRLR 8.8 2.3 3.4 .12 .14
.3 .86 .12 .15 3
7 1/2-TON TRUCK 7.2 2.6 2.6 .12 .14
.3 .86 .12 .15 3
GRADER 7.5 2.3 2.9 .17 .14
.3 .86 .15 .25 3
SHWR DECON TRUCK 6.8 2.5 2.5 .12 .14
.3 .86 .20 .35 3
BUS 7. 2.4 3. .28 .11
.3 .89 .12 .19 3

	4-TON TRUCK	6.7		2.5	2.3	.12	.14
.3	.86		.12		.15	3	
	CEMENT TRUCK	6.7		2.4	2.5	.13	.14
.3	.86		.15		.20	3	
	OIL/WATER TANK TRK	7.		2.3	2.7	.13	.14
.3	.86		.10		.15	3	
	FUEL TANK TRUCK	6.7		2.4	2.5	.13	.14
.3	.86		.10		.15	3	
	5-TON TRUCK	6.4		2.5	2.3	.12	.14
.3	.86		.12		.15	3	
	WHEELED APC	6.9		2.3	2.1	.12	.10
.3	.90		.18		.25	3	
	240MM RKT/LNCHR SP	5.9		2.6	3.5	.12	.12
.3	.88		.10		.10	3	
	7-TON DUMP TRUCK	5.7		2.6	2.6	.12	.14
.3	.86		.12		.15	3	
	TRK, COMMUNICA VAN	6.1		2.3	2.8	.12	.14
.3	.86		.12		.15	3	
	3 1/2-TON DUMP TRK	6.		2.3	2.2	.12	.14
.3	.86		.12		.15	3	
	2 1/2-TON TRUCK	5.7		2.3	2.1	.12	.14
.3	.86		.12		.15	3	
	TRACTOR TRUCK	5.5		2.[illegible]	2.4	.12	.14
.3	.86		.12		.15	3	
	30MM AA GUN, SP	5.8		2.1	2.9	.12	.12
.1	.88		.15		.25	3	
	MILITARY AMBULANCE	5.5		2.2	2.1	.12	.14
.3	.86		.12		.12	3	
	140MM RKT/LNCHR SP	5.5		2.2	2.2	.12	.12
.3	.88		.10		.10	3	
	57MM AT GUN, SP	7.8		1.5	1.7	.11	.11
.1	.89		.20		.30	3	
	TRACTOR TRUCK	5.		2.2	2.2	.12	.14
.3	.86		.12		.15	3	
	2 1/2-TON DUMP TRK	5.2		[illegible].1	2.1	.12	.14
.3	.86		.12		.20	3	
	GEN-PURPOSE TRAILR	4.3		2.2	2.	.12	.14
.3	.86		.12		.15	3	
	WATER TRAILER	4.2		2.1	1.4	.12	.14
.3	.86		.12		.15	3	
	BRDM-RECON VEH	5.6		2.2	1.9	.12	.10
.3	.90		.12		.15	3	

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   SAM LNCHR, SP                       11.3      3.1      3.7      .12      .13
    .3           .87                         .10      .10      7
   WEAPON CARRIAGE                      4.3      2.2      2.0      .12      .14
    .3           .86                         .12      .15      3
   MISSILE TRANSP, SP                   6.7      3.1      2.8      .15      .14
    .3           .86                         .12      .15      3
   MISSILE TRAILER                     10.       3.2      3.       .12      .14
    .3           .86                         .19      .25      3
C
5     RECOGNITION GROUP  18  -  MISSILE
C
   SS GUIDED MISSILE                  21.        1.8  1.8       .12      .14
 .3          .86                             .10      .35      7
   SURFACE-TO-AIR MSL                 11.3        .5   .5       .12      .14
 .3          .86                             .10      .35      7
C
5     RECOGNITION GROUP 19  -  CRANE
C                                     LENGTH WIDTH HEIGHT (METERS)
   10-TON CRANE TRUCK                  9.6       2.7  3.4       .12      .12
 .3          .88                             .15      .28      3
   3-TON CRANE TRUCK                   6.9       2.3  4.7       .12      .12
 .3          .88                             .14      .25      3
C
5     RECOGNITION GROUP 20  -  LARGE RADAR
C
   LARGE RADAR                         7.6       2.4  7.6       .12      .11
 .3          .89                             .10      .30     11
   MEDIUM RADAR                        4.5       2.4  3.5       .12      .11
 .3          .89                             .10      .35     11
C
      DETECTION GROUP 6  -  SMALL LAND OBJECT
C
6     RECOGNITION GROUP 21  -  TOWED VECHICLE
C                                     LENGTH WIDTH HEIGHT (METERS)
   203MM GUN/HOW TOWD                 11.7       2.5  7.6       .12      .12
 .3          .88                             .18      .40      5
   130MM AA GUN TOWED                 11.        2.6  7.        .12      .12
 .3          .88                             .18      .40      5
   100MM AA GUN TOWED                  8.1       2.1  5.2       .12      .12
 .3          .88                             .18      .40      5
   85MM AT GUN, SP                     9.8       1.7  3.        .12      .11
 .1          .89                             .18      .35      5
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  130MM FLD GUN TOWD          9.2     1.8  5.6     .12    .11
.1      .89                       .18      .40     5
  57MM AA GUN, TOWED          7.      2.1  4.8     .12    .12
.3      .88                       .18      .40     5
  100MM FLD GUN TOWD          8.      1.8  4.3     .12    .11
.1      .89                       .18      .40     5
  122MM FLD GUN TOWD          8.      1.8  4.9     .12    .11
.1      .89                       .18      .40     5
  152MM GUN/HOW TOWD          7.4     1.8  4.5     .12    .11
.1      .89                       .18      .40     5
  240MM MORTAR, TOWED         5.3     2.5  3.8     .11    .11
.3      .89                       .25      .45     5
  122MM HOWIT, TOWED          5.8     1.7  2.      .12    .11
.1      .89                       .18      .40     5
  160MM MORTAR, TOWED         4.      2.   3.      .11    .11
.1      .89                       .25      .45     5
  14.5MM AA HMG, QUAD         3.6     1.8  2.8     .11    .10
.1      .90                       .30      .40     5
  107MM RECOILSS GUN          2.7     1.3  1.4     .10    .10
.00006  .90                       .30      .35     5
  120MM MORTAR, TOWED         2.      1.   1.4     .10    .10
.00006  .90                       .25      .45     5
C
6      RECOGNITION GROUP  22  -  SMALL VECHICLE
C
  CIVILIAN SEDAN              5.3     1.9  1.6     .20    .11
.3      .89                       .19      .30     2
  WRECKED SEDAN               5.      1.9  1.      .22    .20
.3      .80                       .19      .20     2
  3/4-TON TRUCK               4.4     2.1  2.1     .12    .14
.3      .86                       .19      .35     2
  1-TON TRUCK                 4.4     2.1  2.      .12    .14
.3      .86                       .18      .35     2
  1/2-TON TRUCK               4.5     1.9  2.      .12    .14
.3      .86                       .18      .35     2
  1/2T CANVS-TOP TRK          3.9     1.9  2.      .09    .13
.3      .87                       .18      .35     2
  1/4 TON TRUCK               3.4     1.7  1.7     .09    .13
.3      .87                       .18      .35     2
C
6      RECOGNITION GROUP 23  -  SMALL SHELTER
C                                LENGTH WIDTH HEIGHT (METERS)
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   HUT, THATCHED ROOF                 4.6      3.5  3.      .18     .19
 .02      .81                             .20       .35     11
   LRG CANVAS SHELTER                 4.6      3.5  3.      .10     .14
 .02      .86                             .20       .35     11
   SMALL MUD HUT                      4.6      3.1  3.5     .18     .19
 .02      .81                             .20       .35     11
   HUT, THATCHED ROOF                 3.       3.   2.      .18     .19
 .02      .81                             .20       .35     11
   METAL STORAGE BINS                 3.       3.   3.      .27     .27
 .3       .73                             .25       .30     11
   SANDBAG REVETMENT                  3.       3.   1.8     .19     .19
 .03      .81                             .30       .40     11
   MEDIUM TENT                        3.       2.8  2.      .10     .14
 .02      .86                             .20       .30     11
   ADOBE HUT                          2.5      2.5  2.8     .18     .18
 .02      .82                             .25       .35     11
   BOXES ON PALLETS                   3.7      1.2  1.      .15     .19
 .05      .81                             .30       .40     11
   PUP TENT                           2.1      1.5  1.      .10     .14
 .02      .86                             .35       .40     11
   WOODEN OUTHOUSE                    1.5      1.5  2.      .18     .19
 .02      .81                             .35       .45     11
C
6      RECOGNITION GROUP 24   -   SMALL TOWER
C
   SPIRE TOWER                        3.       3.   45.     .15     .25
 .03      .75                             .20       .15     11
   WIND PUMP                          2.       2.   4.5     .18     .19
 .02      .81                             .15       .10     11
   WOOD OBS TOWER                     1.8      1.8 10.      .18     .19
 .02      .81                             .15       .15     11
   WOODEN TOWER                       1.5      1.5  3.      .21     .20
 .02      .80                             .20       .15     11
C
6      RECOGNITION GROUP 25   -   WEAPON EMPLACEMENT
C                                   LENGTH WIDTH HEIGHT (METERS)
   CIRCULAR EMPLACEME                 5.       5.   .01     .15     .15
 .03      .85                             .10       .25     5
   AAMG EMPLACEMENT                   3.       3.   .6      .14     .14
 .03      .86                             .10       .30     5
   81MM MORT EMPLAC                   2.4      2.4  .7      .14     .14
 .03      .86                             .15       .35     5
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  60MM MORT EMPLACEM                  1.8      1.8   .6       .14      .14
.03      .86                                .15      .35      5
C
     DETECTION GROUP  7  -  VERY SMALL LAND OBJECT
C
7    RECOGNITION GROUP 26  -  EXCAVATION
C
  TRENCH                             20.       1.    .8       .14      .14
.03      .86                                .25      .15      15
  TRENCH                              5.       1.5   .3       .14      .14
.03      .86                                .30      .35      15
  LOG/EARTH BUNKER                    2.5      2.    .7       .18      .19
.02      .81                                .35      .30      15
  TRENCH                              2.       2.    1.2      .18      .19
.02      .81                                .35      .35      15
  FOXHOLE                             1.5      1.5   .01      .14      .14
.03      .86                                .45      .20      15
  TUNNEL ENTRANCE                     1.5      1.5   .01      .03      .03
.03      .97                                .45      .20      15
  FOXHOLE                              .9       .9   .01      .14      .14
.03      .86                                .45      .25      15
C
7    RECOGNITION GROUP 27  -  MEDIUM ARMS
C                                     LENGTH WIDTH HEIGHT (METERS)
  14.5MM AA HMG, THIN                 2.1      1.    2.       .10      .10
.00006   .90                                .30      .20      5
  82MM RECOILSS GUN                   2.        .5   .5       .10      .10
.00003   .90                                .30      .25      5
  57MM RECLSS RIFLE                   2.        .5   .5       .10      .10
.00003   .90                                .30      .25      5
  12.7MM AAMG                         2.        .5   1.       .10      .10
.00006   .90                                .40      .45      5
  82MM MORTAR                         1.3       .8   .5       .10      .10
.00003   .90                                .30      .40      5
  7.62MM HVY MG                       1.        .5   .5       .10      .10
.00006   .90                                .40      .45      5
  60MM MORTAR                         1.        .5   .5       .10      .10
.00003   .90                                .30      .40      5
C
7    RECOGNITION GROUP 28  -  SMALL ARMS
C
  7.62MM LIGHT MG                     1.        .4   .3       .10      .10
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 .00006   .90                                .40      .46       6
   RECOILSS AT LNCHR                 1.2         .13   .13      .10        .10
 .00003   .90                                .35      .30       6
   7.62MM RIFLE                      1.           06   .1       .10        .10
 .00006   .90                                .48      .50       6
C
7        RECOGNITION GROUP  29  -  LARGE ANIMAL
C                                     LENGTH WIDTH HEIGHT (METERS)
   CAMEL                             3.         1.    2.2       .08        .13
 .3          .87                             .10      .40      13
   CATTLE                            2.5        1.    1.5       .15        .15
 .3          .85                             .10      .20      13
   WATER BUFFALO                     2.5        1.    1.5       .22        .22
 .3          .78                             .15      .20      13
   HORSE                             2.3          .9  2.        .15        .15
 .3          .85                             .10      .40      13
C
7        RECOGNITION GROUP 30   -  PERSONNEL
C
   DONKEY                            2.           .8  1.7       .10        .10
 .3          .90                             .15      .18      13
   PRONE MAN, EUROPE                1.76       .53   .16       .14        .11
 .5          .89                             .20      .10       1
   PRONE MAN, SE ASIA               1.66       .44   .15       .14        .11
 .5          .89                             .20      .10       1
   GOAT                              1.2          .6  1.        .15        .15
 .5          .85                             .30      .25      13
   KNEELNG MAN, EUROPE                .95       .53   .88       .14        .11
 .5          .89                             .25      .15       1
   KNEELNG MAN, SEASIA                .88       .44   .83       .14        .11
 .5          .89                             25       .15       1
   SHEEP                              .9         .4    .6       .15        .15
 .5          .85                             30       .25      13
   MIL PRSNL, EUROPE                  .33       .53  1.76       .14        .11
 .5          .89                             .35      .30       1
   CIV PRSNL, EUROPE                  .32       .46  1.61       .16        .11
 .5          .89                             .35      .30       1
   CHOGI BEARER                       .3         .5  1.6        .16        .11
 .5          .89                             .40      .25       1
   MIL PRSNL, SE ASIA                 .32       .44  1.66       .14        .11
 .5          .89                             .40      .25       1
   DOG                                .7         .2   .4        .20        .20
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  .5        .80                                 .30      .30        13
    CIV PRSNL, SE ASIA                     .31       .40  1.55       .16       .11
  .3        .89                                 .40      .25        1
C
7        RECOGNITION GROUP 31   -  MISCELLANEOUS OBJECTS
C                                          LENGTH WIDTH HEIGHT (METERS)
    WIND TEE                               3.        2.   1.         .16       .16
  .00003    .84                                 .25      .20        11
    CART                                   4.        1.5  1.5        .09       .11
  .3        .89                                 .20      .10        2
    DYEING VATS                            2.        2.   1.         .07       .07
  .05       .93                                 [illegible]      .05        11
    DUMMY TARGET                           1.8       1.8  2.5        .09       .20
  .02       .86                                 .25      .30        11
    ROAD BARRICADE                         4.         .5  1.8        .13       .13
  .1        .87                                 .10      .05        11
    BICYCLE                                1.8       1.1   .46       .09       .11
  .00006    .89                                 .15      .10        2
    TARGET BACKSTOP                        3.         .5  2.         .09       .09
  .00006    .91                                 .18      .15        11
    GRAVESTONE                             1.        1.   2.         .28       .25
  .00006    .75                                 .20      .05        11
    FURNACE AND FORGE                      1.        1.    .3        .03       .03
  .3        .97                                 .20      .10        11
C
7        RECOGNITION GROUP 32   -  SMALL MISCELLANEOUS OBJECTS
C

    PUNJI TRAP                             1.        1.    .01       .22       .07
  .00006    .93                                 .35      .25        12
    SMALL RADAR                             .6       1.   1.5        .08       .07
  .3        .93                                 .30      .20        11
    STEEL DRUM                              .6        .6   .9        .10       .13
  .3        .87                                 .30      .10        11
    PLOTTING BOARD                          .6        .6  1.5        .20       .20
  .00006    .80                                 .45      .45        11
    SPIDER HOLE                             .6        .6   .01       .14       .14
  .03       .86                                 .40      .25        12
    SUPPLY CASE                             .7        .5   .5        .15       .19
  .3        .81                                 .30      .20        11
    COOKING FIRE                            .5        .5   .01       .03       .03
  .03       .97                                 .15      .05        12
    FIELD RADIO                             .06       .3  1.         .05       .10
```

```
 .000v5   .90                                   .30       .20        11
   WOODEN BOX                                .6       .3   .3          .14      .19
 .05       .81                                  .30       .20        11
   METAL BOX                                 .5       .3   .6          .07      .10
 .3        .90                                  .30       .20        11
   FIELD RADIO                               .68      .2   .74         .05      .10
 .00003   .90                                   .30       .20        11
   FIELD RADIO                               .34      .17  .37         .05      .10
 .00003   .90                                   .30       .20        11
   FIELD TELEPHONE                           .3       .1   .1          .03      .05
 .00006   .95                                   .40       .30        11
   DEMOLITION CHARGE                         .2       .06  .06         .08      .10
 .00006   .90                                   .45       .45        11
C
7        RECOGNITION GROUP 33  -  POLES
C                                        LENGTH WIDTH HEIGHT  (METERS)
   ANTI-HELO STAKES                          .1       .1  1.7          .22      .24
 .00006   .78                                   .25       .05        12
   DRYING POLES                              .1       .1  1.2          .22      .22
 .00006   .78                                   .25       .05        12
         DETECTION GROUP 8  -  AIRCRAFT
C
8        RECOGNITION GROUP 34  -  HELICOPTER
C
   TRANSPORT HELO                        16.8     21.   5.2           .12      .14
 .02       .86                                  .10       .05         9
C
8        RECOGNITION GROUP 35  -  FIXED WING AIRCRAFT
C                                        LENGTH WIDTH HEIGHT  (METERS)
   JET MEDIUM BOMBER                     36.5     33.5 10.8           .18      .19
 .02       .81                                  .03       .01        10
   TRANSPORT A/C                         31.      28.  10.            .18      .19
 .02       .81                                  .03       .01        10
   JET LIGHT BOMBER                      18.9     20.8  6.7           .18      .19
 .02       .81                                  .03       .01        10
   JET FIGHTER                           31.      28.  10.            .18      .19
 .02       .81                                  .03       .01        10
```

Table A3

BACKGROUND CHARACTERISTICS

Background	Reflectivities			Emissivity
	Visual	IR	Radar	
Trees				
dense forest or jungle	.08	.05	.06	.95
galleried forest	.08	.02	.06	.98
timbered savanna	.10	.12	.06	.88
clear forest	.10	.02	.06	.98
coniferous winter forest (no snow)	.03	.03	.09	.97
coniferous winter forest (snow)	.55	.56	.06	.44
coniferous summer forest and dry meadows	.09	.09	.09	.91
deciduous summer forest and lush grass	.10	.12	.09	.88
deciduous autumn forest and ripe field crops	.19	.19	.09	.81
evergreens	.06	.03	.09	.97
rubber trees	.09	.09	.07	.91
palms	.10	.10	.07	.90
brushwood	.07	.14	.10	.86
pine	.08	.02	.10	.98
nipa; mangrove	.09	.07	.07	.93
orchard	.08	.18	.03	.82
Grass and Shrubs				
grassy clearing in jungle	.09	.11	.08	.89
bamboo	.08	.12	.06	.88
grass savanna	.09	.13	.03	.87
shrub and grass savanna	.08	.13	.03	.87

Table A3 (Continued)

Background	Reflectivities			Emissivity
	Visual	IR	Radar	
Grass and Shrubs (continued)				
dry meadow	08	.15	.04	.85
green meadow	.05	.10	.09	.90
Plants and Crops				
plantation	.10	.15	.02	.85
tea	.02	.02	.06	.98
coffee	.02	.02	.06	.98
rice	.04	.04	.05	.96
cultivated field	.08	.12	.03	.88
garden	.06	.03	.03	.97
alfalfa	.04	.04	.04	.96
wheat	.04	.04	.04	.96
Water				
canal or ditch	.06	.02	.03	.98
lake or pond	.06	.02	.03	.98
swamp	.14	.02	.05	.98
rice paddy	.14	.02	.05	.98
river	.10	.04	.03	.96
Snow				
snow, fresh fallen	.77	.80	.003	.20
snow covered with ice film	.74	.75	.003	.25
Rock				
gravel	.22	.24	.02	.76
granite	.18	.21	.02	.79
bare rock	.20	.22	.03	.78

Table A3 (Concluded)

Background	Reflectivities Visual	IR	Radar	Emissivity
Sand				
sand	.24	.20	.01	.80
sand dunes	.25	.27	.03	.73
Built-up Area				
built-up area, city	.15	.16	.02	.84
village	.15	.13	.02	.87
Road, Trail				
concrete road	.25	.28	.01	.72
asphalt road	.05	.09	.06	.91
cobblestone street	.24	.26	.03	.74
dirt road	.10	.10	.04	.90
trail	.12	.12	.10	.88
Miscellaneous				
railroad tracks	.15	.10	.03	.90
salt evaporator	.74	.74	.01	.26
clear area	.18	.19	.03	.81
hard packed dirt	.10	.10	.03	.90

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Appendix B

SENSOR MODELS

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Appendix B

SENSOR MODELS

This appendix presents a description and data flow diagram for each of the sensors in the CRESS-A and CRESS-B computer programs. These models were developed in conjunction with Honeywell, Inc., Minneapolis during the SRI participation in the U.S. Army study "TAPS-75," in 1966, and in the SRI study "Systems Analysis of Advanced Target Acquisition Systems (U)," done for the U.S. Marine Corps in 1967.

The models developed in these studies were designed for independent simulation of the performance of the sensors in an aircraft, or observation [illegible]. CRESS is designed to simulate the combined performance of the group of sensors in an airplane, or observation post. However, the capability to simulate the sensors independently also remains in CRESS. The calculations to simulate the numbers of objects sighted are in a single subroutine in CRESS instead of each sensor subroutine.

I PHOTOGRAPHIC SENSOR MODEL

The analytical model developed for photographic sensors includes as inputs mission variables (altitude, distance from flight path), atmospheric conditions, sensor parameters, and target element characteristics. Model outputs include probabilities of target element detection, recognition, and identification.

The photographic sensor model is shown in block diagram form in Figs. B-1 through B-3, and is based on an approximation to the MTF (modulation transfer function) approach to computing system resolution. Results obtained from the simplified approach should be sufficiently accurate to simulate tactical photo-reconnaissance missions. Simulations of very-high-resolution strategic reconnaissance systems, however, might require that MTF techniques be used in the computer model.

High-contrast resolution (R_{max}) is obtained from an optimum balance of lens, film, and image motion, as shown in Fig. B-1, for postulated systems. To simulate photographic systems for which actual operational data are available, only the operational value of high-contrast resolution (R_{max}) is necessary.

Figure B-2 illustrates the computation of system operational resolution. Operational resolution (R) is related to high-contrast resolution (R_{max}) as a function of apparent target-contrast modulation (M_a). As shown in Fig. B-2, intrinsic target contrast is first determined as the ratio of highlight to lowlight reflectance. If the target reflectance is greater than the background reflectance, target reflectance will be used for the highlight. Should the background have a higher reflectance than the target, its value is entered for highlight reflectance and the target reflectance is taken as the lowlight value. Intrinsic contrast is reduced by the effects of haze, smoke, or rain. Contrast reduction is assumed to vary exponentially with the ratio of slant range (S_r) to visibility range (V_r). The visibility range (or meteorological range) is defined as that range at which target contrast is reduced to 2 percent of its initial value (Ref. 1).

The geometry of the photographic model is shown in Fig. B-3. Targets are assumed to have sufficient height so that they subtend the same angle when viewed obliquely as when viewed vertically. Thus, ground-resolved distance (D_g) varies only as a function of scale (S) and system operational resolution (R). Photographic scale is computed for four camera types:

1. Vertical frame
2. Forward oblique
3. Side oblique
4. Panoramic (vertical or forward oblique).

A conditional probability of detection is next determined as a function of the ratio of target area to ground-resolved distance, ($D_{tx} \cdot D_{ty}/D_g^2 = N_p$). The detection probability obtained (P_d) is conditional on the event that line-of-sight and the decisions on whether it exists or not are made external to

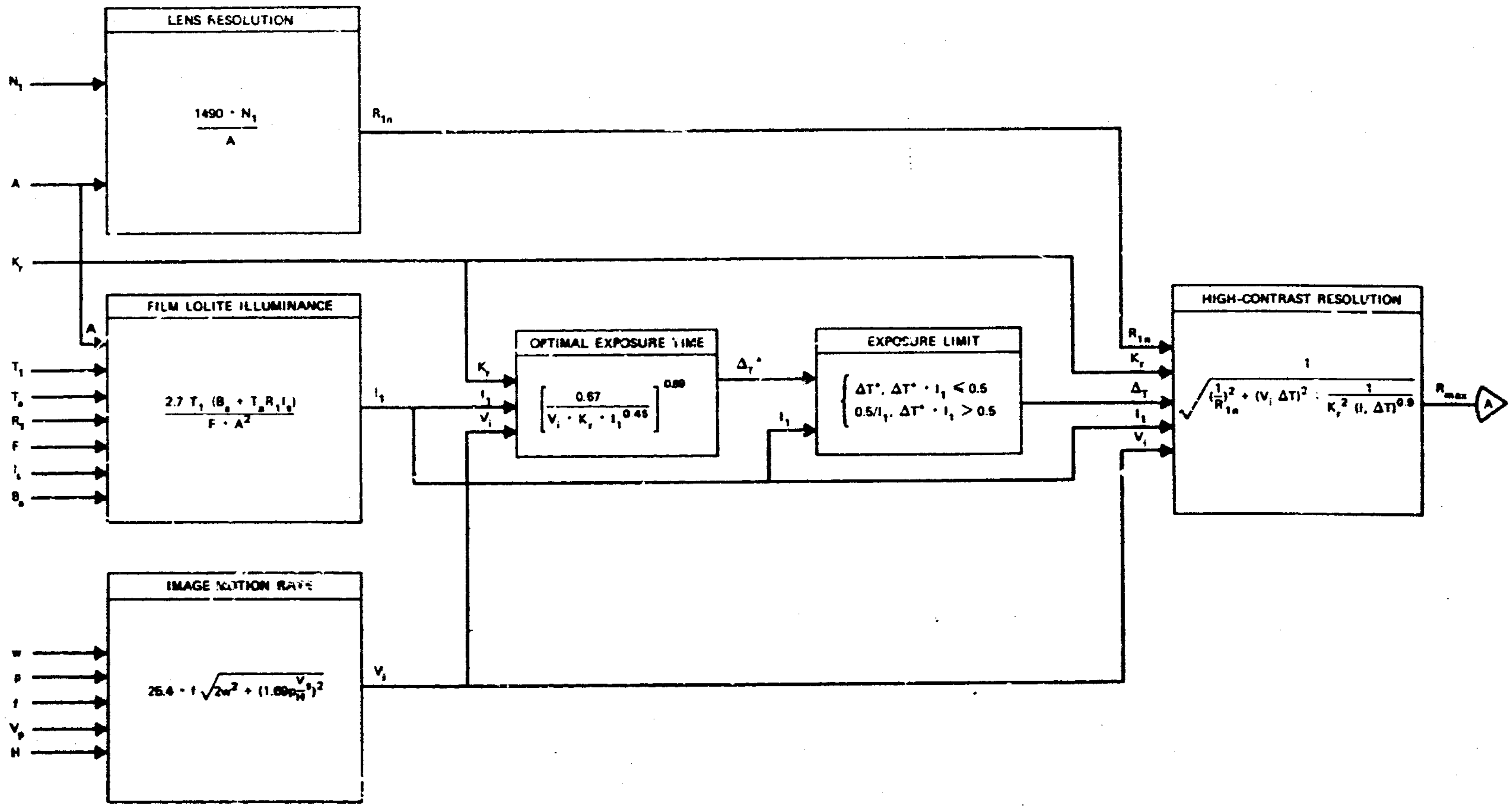


FIG. B-1 PHOTOGRAPHIC SENSOR MODEL – HIGH CONTRAST RESOLUTION

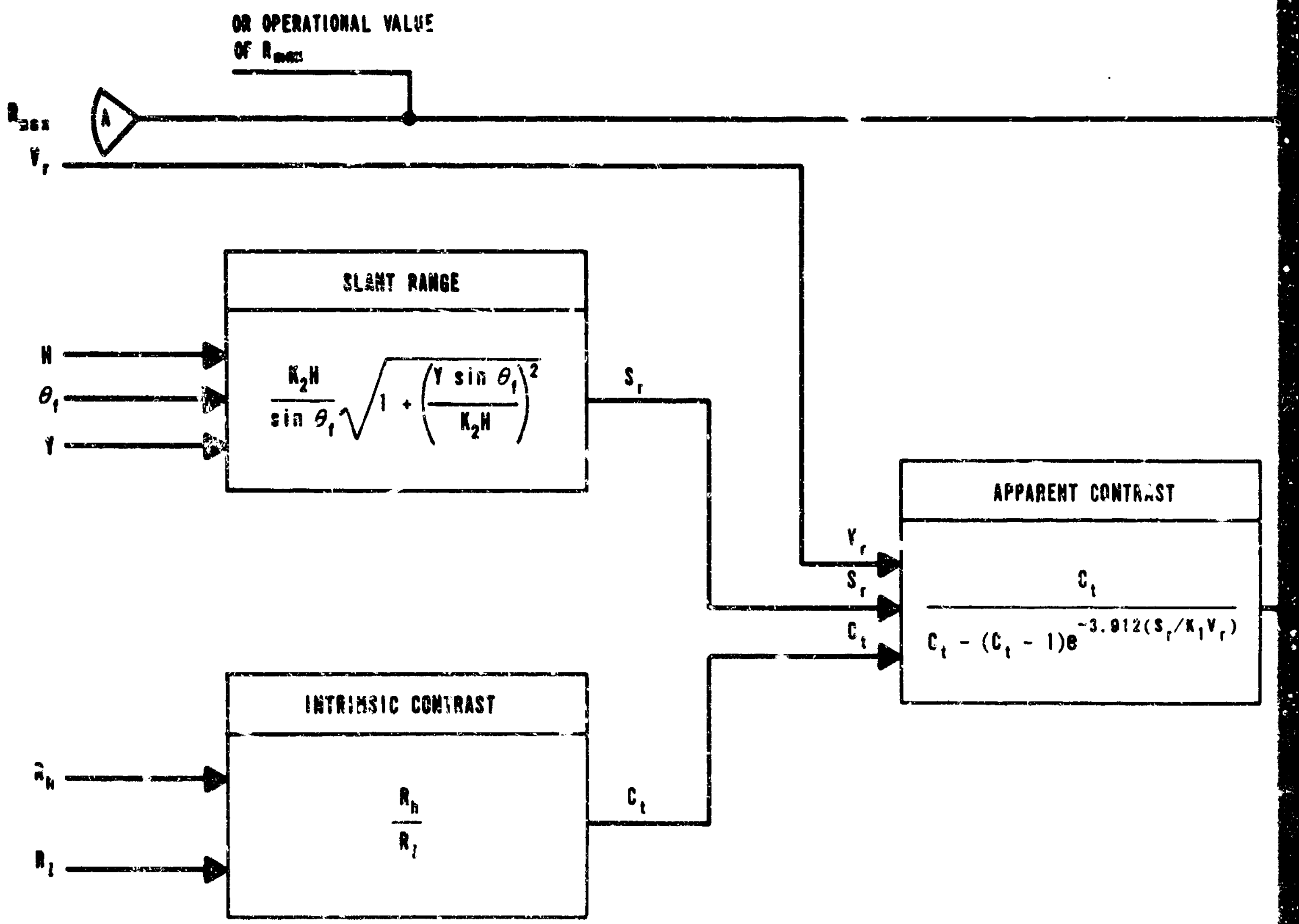
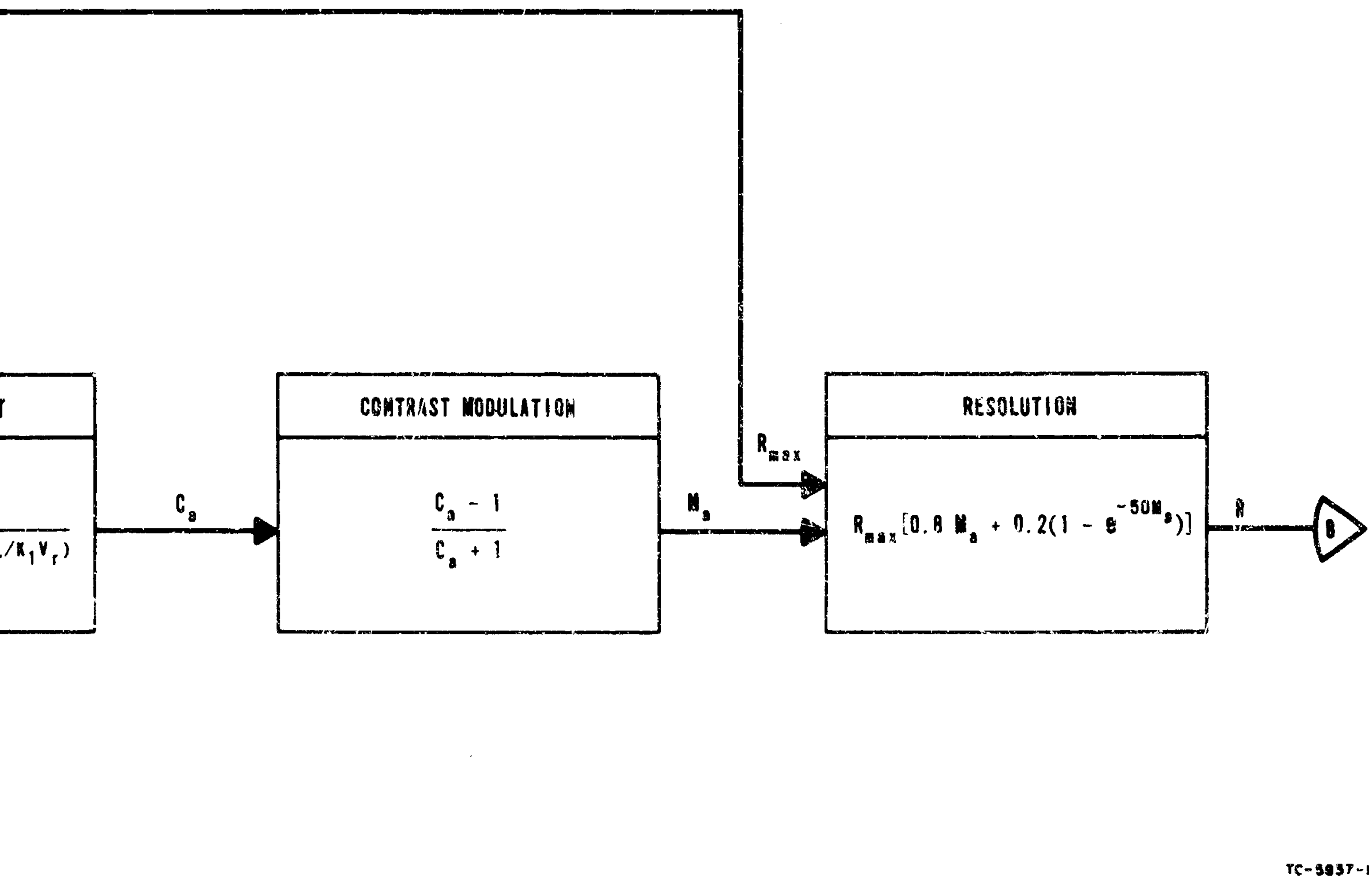


FIG. B-2 PHOTOGRAPHIC SENSO



HIC SENSOR MODEL -- RESOLUTION

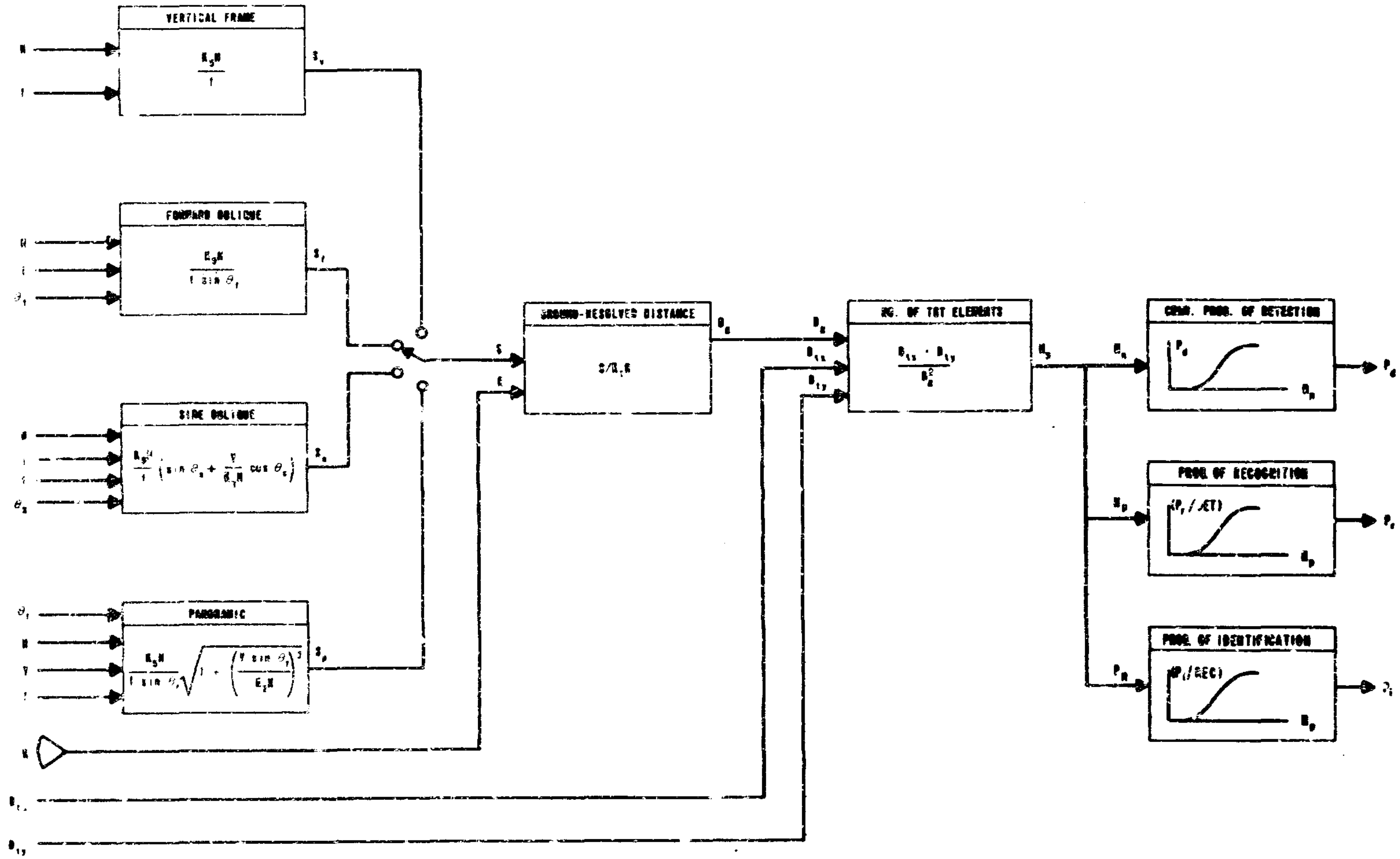


FIG. B-3 PHOTOGRAPHIC SENSOR MODEL – GEOMETRICAL EFFECTS the photographic model. However, the probability of detection printed on the Control Copy incorporates the line-of-sight probability.

The detection, recognition, and identification probability curves (Table B-I) included in the photo model were estimated from the limited data available in Refs. 2, 3, and 4; therefore, initial results of the simulations were reviewed by SRI and military personnel experienced in reconnaissance missions to ensure that the probability curves yielded realistic target detections, recognitions, and identifications.

The effect of photo-interpreter performance is approximated by having the probability curves approach some value less than unity for $N_p \gg 1$. For example, if the photo-interpreters are assumed to detect 50 percent of the unmasked targets, then P_d will approach 0.5 as N_p grows larger.

The model is called on twice for each target element, once to obtain the probability of detecting the element, P_{de}, and once to calculate the probability of detecting the element's shadow, P_{ds}. The probability of detecting that type of target element is then calculated as $P_d = 1-(1-P_{de})(1-P_{ds})$ in the calling program.

Table I

PHOTOGRAPHIC SENSOR MODEL--VARIABLES AND DIMENSIONS

A. **Mission Variables**

- H - Aircraft altitude, feet
- Y - Lateral distance of target from flight path, meters
- I_s - Horizontal plane illuminance, foot-candles
- V_g - Platform ground-track velocity, knots

B. **Atmospheric Variables**

- B_a - Atmospheric luminance, foot-lamberts
- C_c - Percent cloud coverage/100
- T_a - Atmospheric transmission
- V_r Visibility range, kilometers

C. **Camera Parameters**

- A - Relative aperture (f-number)
- F - Filter factor
- f - Focal length, inches
- K_r - Film-resolution coefficient, mm^{-1}-(meter-candle-seconds)$^{-.45}$
- N_l - Lens efficiency, percent diffraction-limited/100
- p - Percent IMC error/100
- T_l - Lens transmission
- R_{max} High-contrast operational resolution (if applicable), lp/mm
- w - Residual platform rate, radians/second
- θ_f - Forward oblique depression angle, degrees
- θ_s - Side oblique depression angle, degrees
- Camera type - Forward oblique, side oblique, vertical frame, panoramic

Table B-I (Continued)

PHOTOGRAPHIC SENSOR MODEL--VARIABLES AND DIMENSIONS

D. Target Characteristics

D_{ty} - Target dimension in crosstrack direction, meters

D_{tx} - Target dimension in flight direction, meters

R_h - Highlight reflectance (target or background, whichever is larger)

R_l - Lowlight reflectance (target or background, whichever is smaller)

E. Constants

K_1 - 1000 mm/meter, meter/kilometer

K_2 - 0.3048 meter/foot

K_5 - 12 inches/foot

F. Variables Internal to the Model Only

C_a - Apparent target contrast (with atmospheric loss)

C_t - Intrinsic target contrast (no atmospheric loss)

D_g - Ground-resolved distance, meters

I_l - Film lowlight illuminance, meter-candles

M_a - Apparent contrast modulation

N_p - Ratio of target area to resolved distance-squared

P_d - Probability of Detection

P_i - Probability of identification

P_r - Probability of recognition

R - Effective operational resolution, lp/mm

R_{ln} - Lens-only resolution (high-contrast), lp/mm

R_{max} - High-contrast resolution, lp/mm

S_f - Forward-oblique scale factor

S_p - Panoramic scale factor

Table B-I (Continued)

PHOTOGRAPHIC SENSOR MODEL--VARIABLES AND DIMENSIONS

S_r - Slant range, meters

S_s - Side-oblique scale factor

S_v - Vertical-frame scale factor

T - Optimized exposure time, seconds

V_i - Image velocity, mm/second

II INFRARED SENSOR MODEL

The infrared sensor model simulates scanning-type infrared systems whose imagery is recorded line-by-line on photographic film in a manner somewhat analogous to the photographic strip camera. SRI's infrared sensor model operates according to the block diagram presented in Figs. B-' through B-6.

The geometric characteristics of the infrared scanner are shown in Fig. B-4 The sensor angular resolutions in the flight (α_x) and crosstrack (α_y) directions are combined with slant range (S_r) to yield a resolution cell on the ground (A_g). The target area included within the resolution cell (A_{te}) is calculated along with any background area (A_{be}) within the cell. The number of target elements resolved (N_t) is also determined as shown in Fig. B-4.

The infrared energy radiated from the actual resolution cell as well as the energy radiated from a reference cell assumed to contain only background is attenuated by atmospheric absorption and scattering. The absorption coefficient (r_a) and scattering coefficient (r_s) are computed for one of eight infrared "windows" as outlined in Fig. B-5. The particular window for which the absorption coefficient is calculated is that window whose wavelength interval of maximum transmission corresponds to the wavelength interval of peak IR detector response. The quantitative values for determining scattering and absorption are taken directly from Ref. 5. The altitude correction term, $\Delta(H)$, was obtained by fitting a third-order polynomial to an altitude correction curve also given in Ref. 5. Atmospheric losses, lens effective area, and range-squared loss are combined for convenience of notation as R_o in Fig. B-5.

The power received at the infrared detector is found (Fig. B-6) by integrating Planck's equation over the wavelength interval of detector response for both the actual resolution cell containing target and surrounding background (P'_t) as well as the reference cell containing only background (P'_b). Both P'_b and P'_t are then compared with the noise-equivalent-power (NEP) of the detector. If either of these power components is less than the NEP, the actual power value is replaced with NEP for calculating the signal-to-noise ratio (S/N). To illustrate, assume that $P'_t > NEP$ but $P'_b < NEP$. The effective target power will then be set equal to the actual target power received ($P_t = P'_t$), but the background power will be clamped to its minimum effective level, $P_b = NEP$, thus yielding a smaller (and more realistic) value of signal-to-noise ratio.

The conditional probability of detection (P_d) is calculated as a function of signal-to-noise ratio. As is the case with photo and radar models, the probability of detection is conditioned on the existence of line-of-sight between the sensor and target. The effect of IR vegetation cover (C_{vi}) is combined with the conditional probability of detection to yield the probability of detection (P_d) printed on the Control Copy.

Interpreter performance is included on a percentage performance basis by having the probability curves approach a value less than unity as N_t becomes very large.

Table B I lists the infrared model variables and their dimensions.

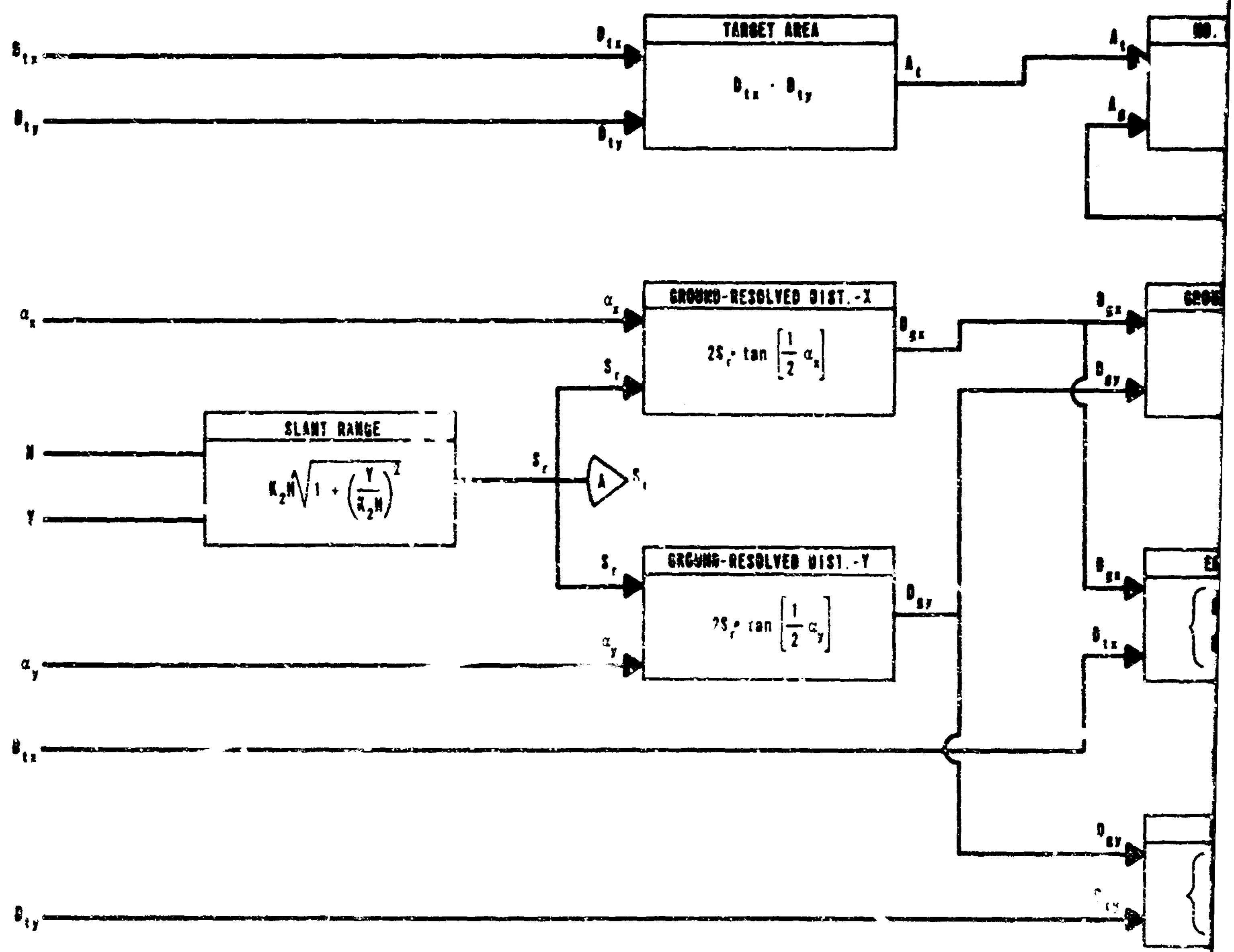
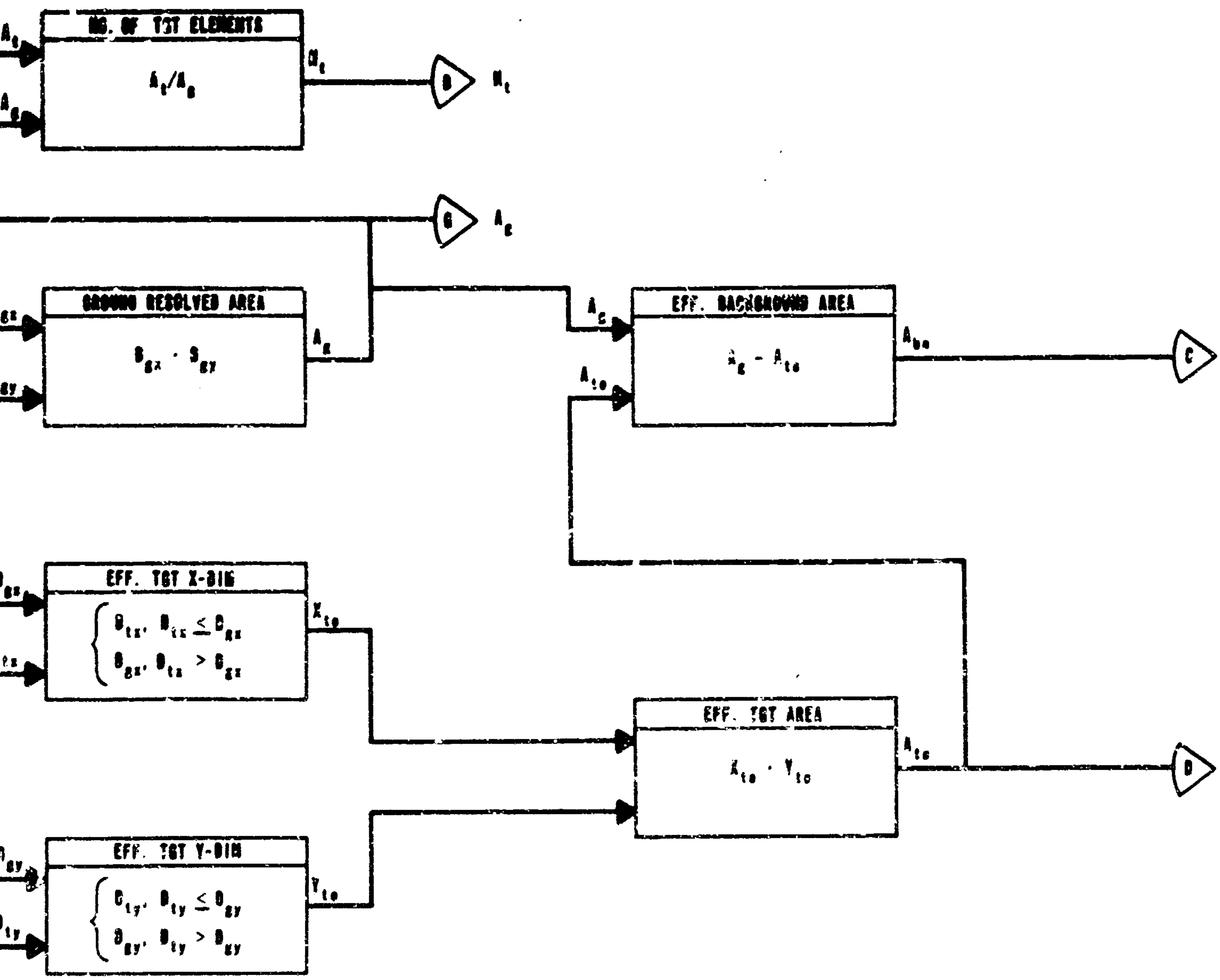


FIG. B-4 INFRARED SENSOR MODEL



SOR MODEL – GEOMETRICAL EFFECTS

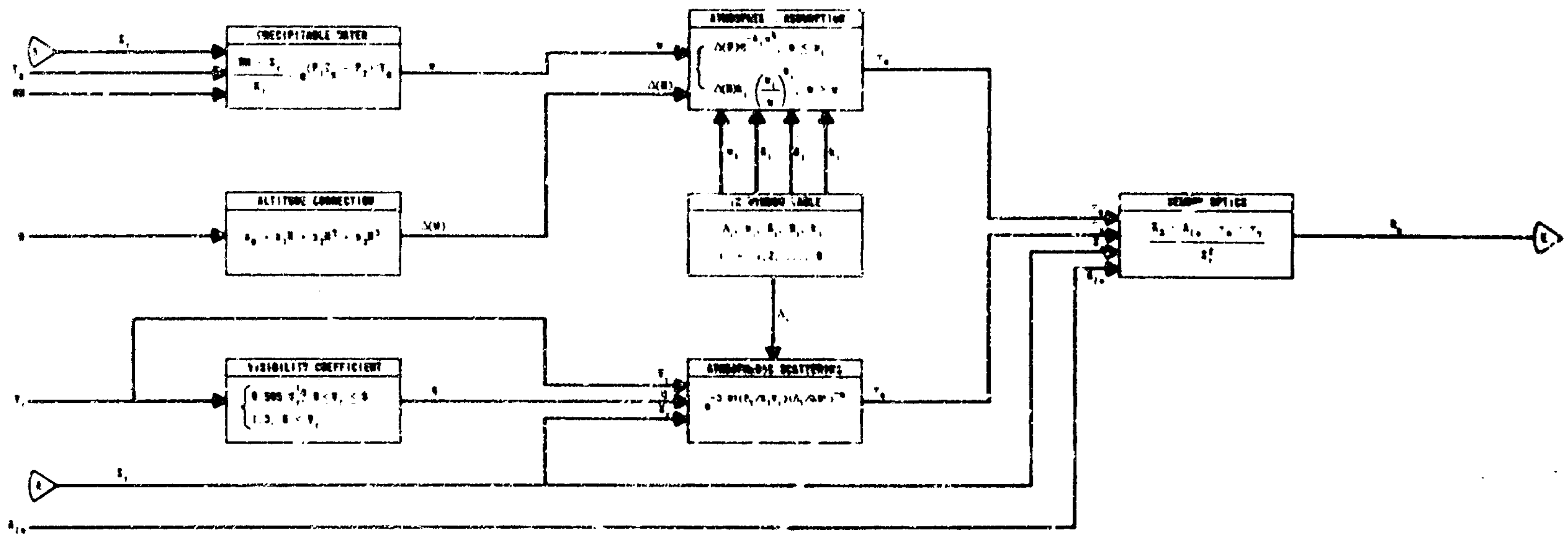


FIG. B-5 INFRARED SENSOR MODEL — ATMOSPHERIC EFFECTS

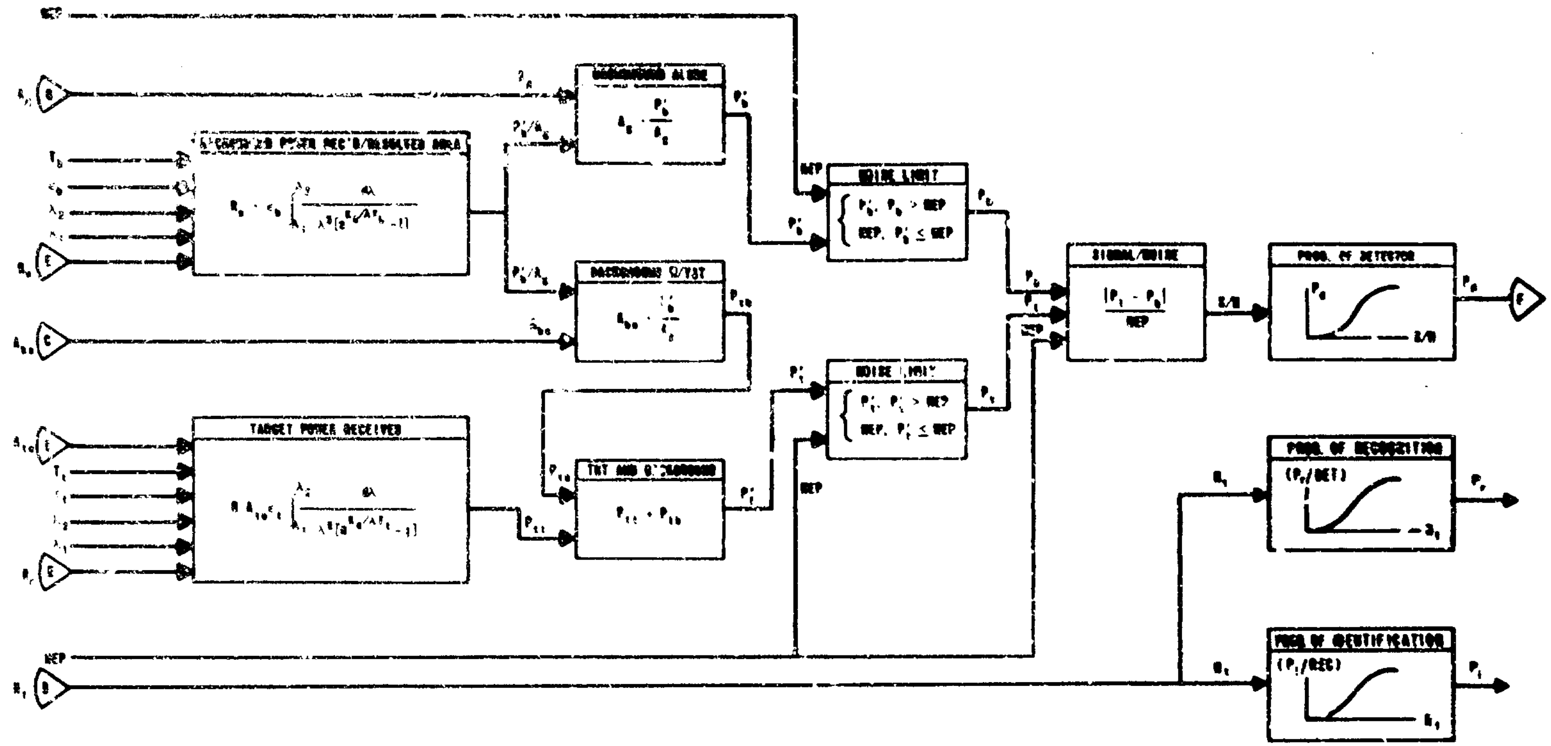


FIG. B-6 INFRARED SENSOR MODEL – PROBABILITY OF DETECTION

Table B-II

INFRARED SENSOR MODEL--VARIABLES AND DIMENSIONS

A. Mission Variables

C_{vi} - Percent effective IR vegetation coverage/100

H - Aircraft altitude, feet

Y - Lateral distance of target from flight path, meters

Terrain type - Smooth, rolling, or rough

B. Atmospheric Variables

C_c - Percent cloud coverage/100

RH - Percent relative humidity/100

T_g - Absolute ground air temperature, $^{o}C + 273.2 = {}^{o}K$

V_r - Visibility range, kilometers

C. Infrared Sensor Parameters

A_{le} - Effective* lens aperture, meter^2

NEP - Noise equivalent power of detector, watts

α_x - Net angular resolution in flight direction, radians

α_y - Net angular resolution in crosstrack direction, radians

λ_1 - Lower wavelength limit of detector, microns

λ_2 - Upper wavelength limit of detector, microns

---

* Effective aperture = (physical aperture) x (system transmission)

Table B-II (Continued)

INFRARED SENSOR MODEL--VARIABLES AND DIMENSIONS

D. <u>Target Characteristics</u>

D_{tx} - Target dimension in flight direction, meters

D_{ty} - Target dimension in crosstrack direction, meters

T_b - Absolute background temperature, $^oC + 273.2 = {}^oK$

T_t - Absolute target temperature, $^oC + 273.2 = {}^oK$

ϵ_b - Background emissivity

ϵ_t - Target emissivity

E. Constants

K_1 - 1000

K_2 - 0.3048 meter/foot

K_3 - 1.19076×10^8 micron^4-watts/meter^2

K_4 - 1.43870×10^4 micron-^oK

P_1 - 19.83

P_2 - 4969 ^oK

a_0 - 1.0000

a_1 - 4.245×10^{-6} (feet)$^{-1}$

a_2 - 3.62×10^{-11} (feet)$^{-2}$

a_3 - 5×10^{-17} (feet)$^{-3}$

λ_i - Mid-wavelength of i^{th} window, microns (i = 1 to 8)

w_i - Precipitable water constant of i^{th} window, mm

A_i - Absorption constant of i^{th} window, $mm^{-1/2}$

B_i - Absorption constant of i^{th} window

k_i - Absorption constant of i^{th} window

Table B-II (Continued)

INFRARED SENSOR MODEL--VARIABLES AND DIMENSIONS

F. Variables Internal to the Model

A_{be} - Effective background area, meters^2

A_g - Ground-resolved area, meters^2

A_t - Target area, meters^2

A_{te} - Effective target area, meters^2

D_{gx} - Ground-resolved distance in flight direction, meters

D_{gy} - Ground-resolved distance in crosstrack direction, meters

N_t - Number of target elements resolved

P_b - Effective power received from reference resolution cell, watts

P'_b - Power received from reference resolution cell containing background only, watts

P_d - Probability of detection

P_i - Probability of identification

P_r - Probability of recognition

P_t - Effective power received from actual resolution cell, watts

P'_t - Total power received from resolution cell containing target and surrounding background, watts

P_{tb} - Power received from background surrounding target within resolution cell, watts

P_{tt} - Power received from target within resolution cell, watts

q - Visibility coefficient

Table B-II (Continued)

INFRARED SENSOR MODEL--VARIABLES AND DIMENSIONS

F. <u>Variables Internal to the Model (Contd.)</u>

R_o - Intermediate variable for convenience only, micron^4-watts/meter^2

S_r - Slant range, meters

S/N - Signal-to-noise ratio

w - Precipitable water, mm

X_{te} - X dimension of target lying within resolution cell, meters

Y_{te} - Y dimension of target lying within resolution cell, meters

$\Delta\varepsilon$ - Altitude correction term for absorption

r_a - Attenuation coefficient due to atmospheric absorption

r_s - Attenuation coefficient due to atmospheric scattering

III RADAR SENSOR MODEL

The side-looking-airborne-radar (SLAR) sensor model employed by SRI is taken directly from the Minneapolis-Honeywell radar model (Refs. 5 and 7). The description of the radar model that follows deals principally with the minor modifications made to the Honeywell model to simplify it.

The modified Honeywell radar model employed by SRI is outlined in the block diagrams shown in Figs. B-7 through B-12. Figure B-7 describes the computation of antenna gain, target and background radar cross-section, and the radar cross-section of a reference cell assumed to contain only background. The methods shown in Fig. B-7 are identical to the Honeywell approach, with the exception that target lateral distance from the aircraft ground track is fed into the model rather than being computed as a part of the model.

The radar noise power resulting from rain backscatter (P_{nc}) is obtained as shown in Fig. B-8 along with the attenuation coefficient (γ_{ra}) caused by atmospheric and rain absorption. Honeywell's model uses a layered atmosphere for several purposes, including the computation of rain backscatter; SRI's model assumes an average rain and/or atmospheric density between the sensor and ground. The SRI model also assumes that all radar systems employed have a "cosecant-squared" antenna gain pattern receiving uniform power from the ground scene independent of target depression angle. This characteristic of "cosecant-squared" antennas makes possible a simplified calculation of **average** power density on the rain cell (Fig. B-8) without having to compute the specific variation in antenna gain along the rain cell by slicing the cell into layers.

Figure B-9 shows the steps required for computing the power received from the target (P_{tt}) and background (P_{tb}) within the resolution cell as well as the power from the reference cell (P_{rb}) containing only background. The procedure shown in Fig. B-9 is identical to that of Honeywell for coherent radars. Noncoherent and scanning radar signal enhancement (pulse integration) is computed as shown in Fig. B-12. The effective number of pulses integrated is assumed to equal the square-root of the number of pulses received, as suggested by Ref. 8 for post-detection pulse integration and an operator monitoring a display scope.

The procedures for calculating mapping and MTI signal-to-noise ratios presented in Fig. B-10 are also identical to the Honeywell approach. At this point, the SRI and Honeywell models diverge, with the Honeywell model using the signal-to-noise ratios at the receiver plus a radar display-scope model to arrive at a binary (yes or no) decision on detection. SRI's model assumes that the display scope is included in the pulse-integration effectiveness and that the recording film places an upper limit on resolution. The SRI model then calculates a detection probability based on the MTI or mapping signal-to-noise ratios.

The decision processes for MTI detection and for detection, recognition, and identification in the mapping mode are shown in Fig. B-11.

Table B-III presents the radar model variables and their dimensions.

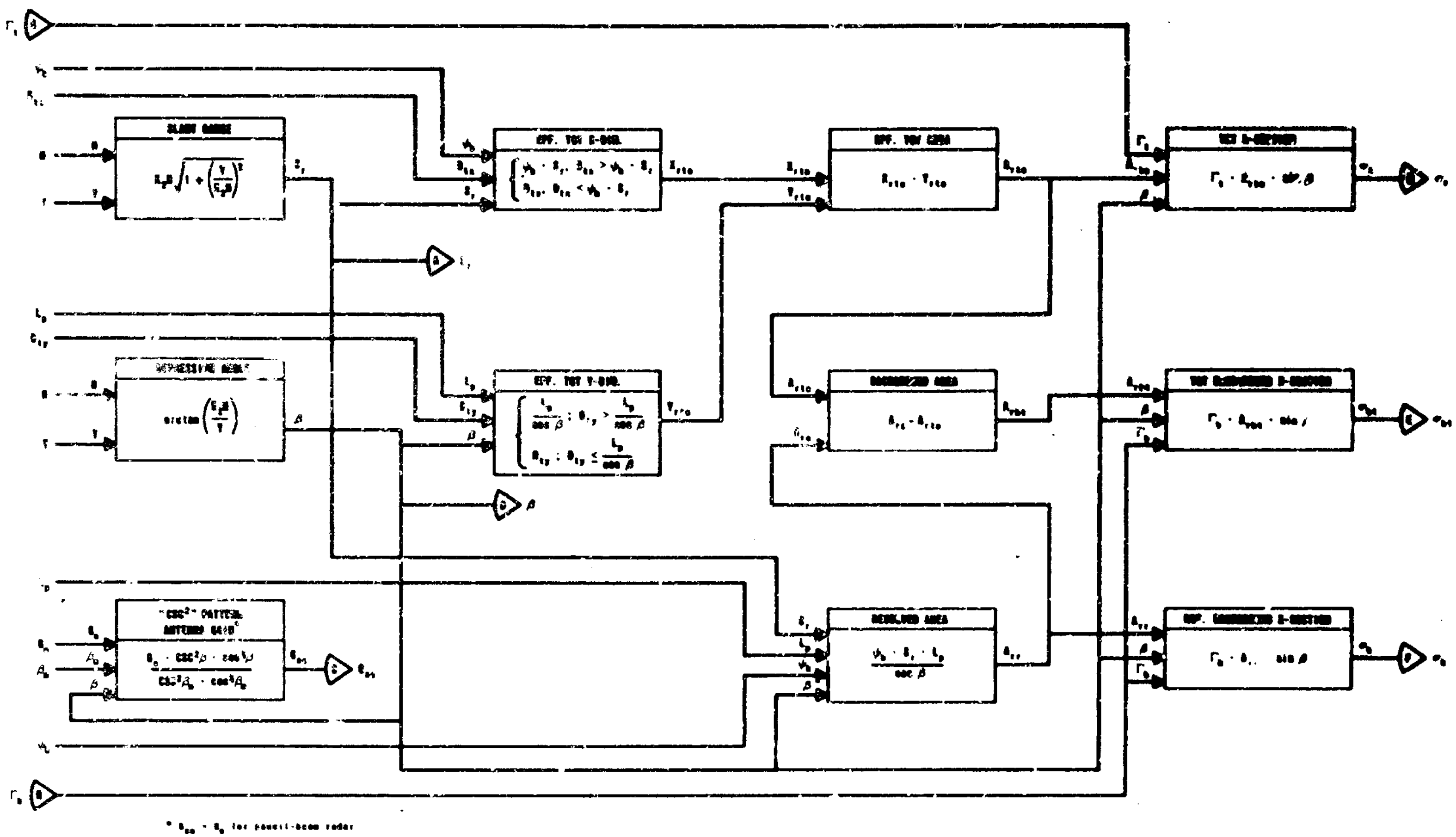


FIG. B-7 SLAR SENSOR MODEL – GEOMETRICAL EFFECTS

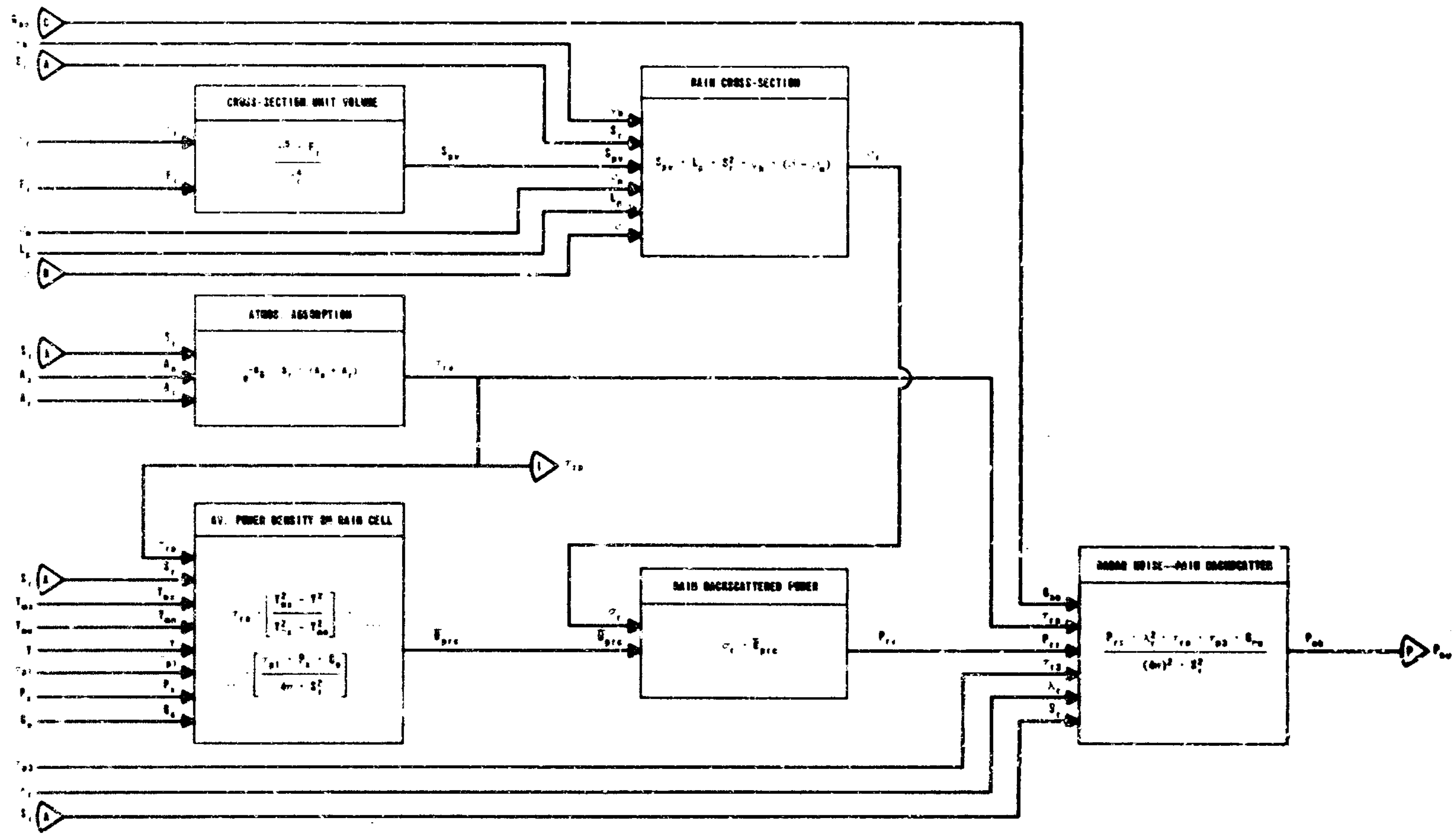


FIG. B-8 SLAR SENSOR MODEL – ATMOSPHERIC EFFECTS

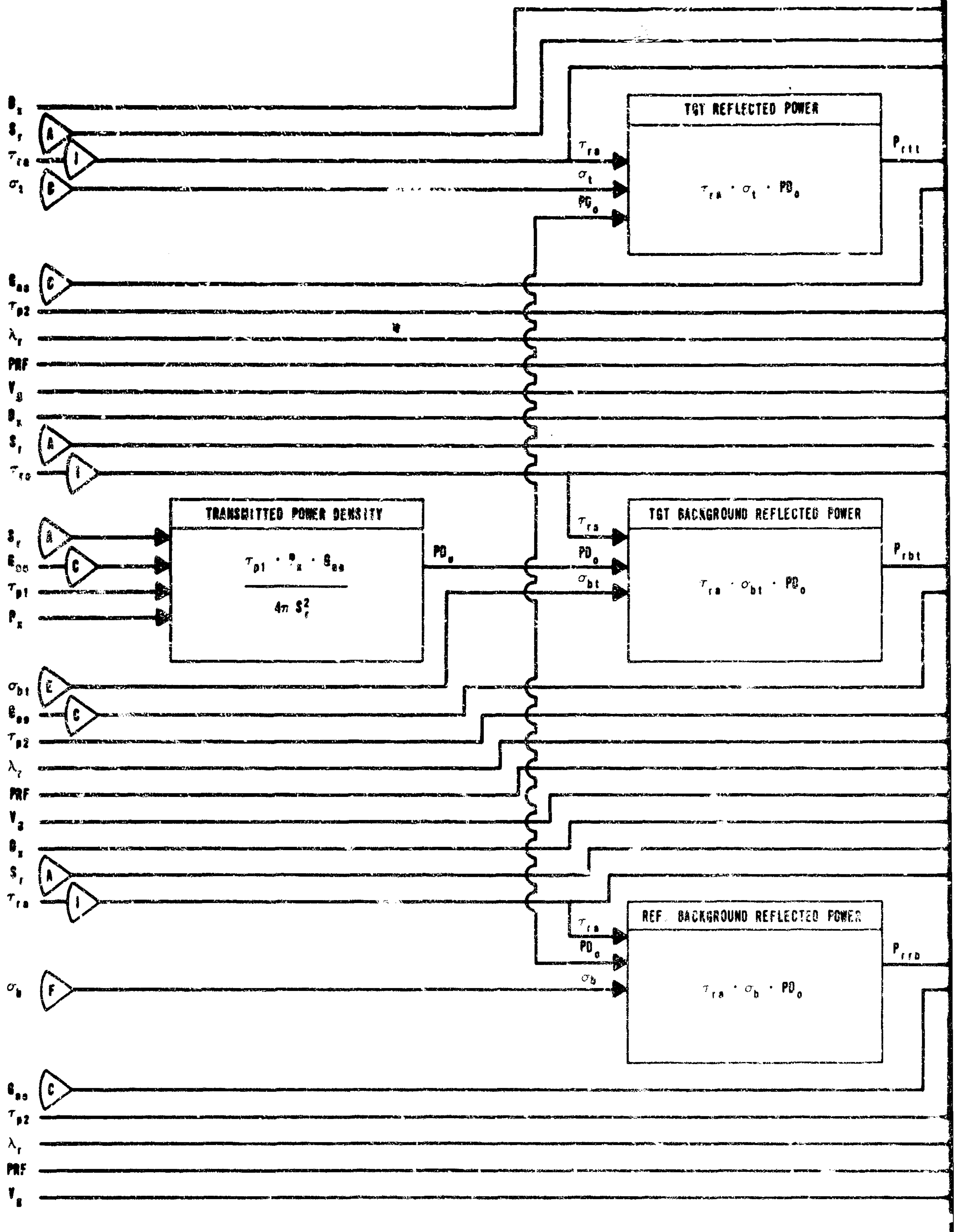
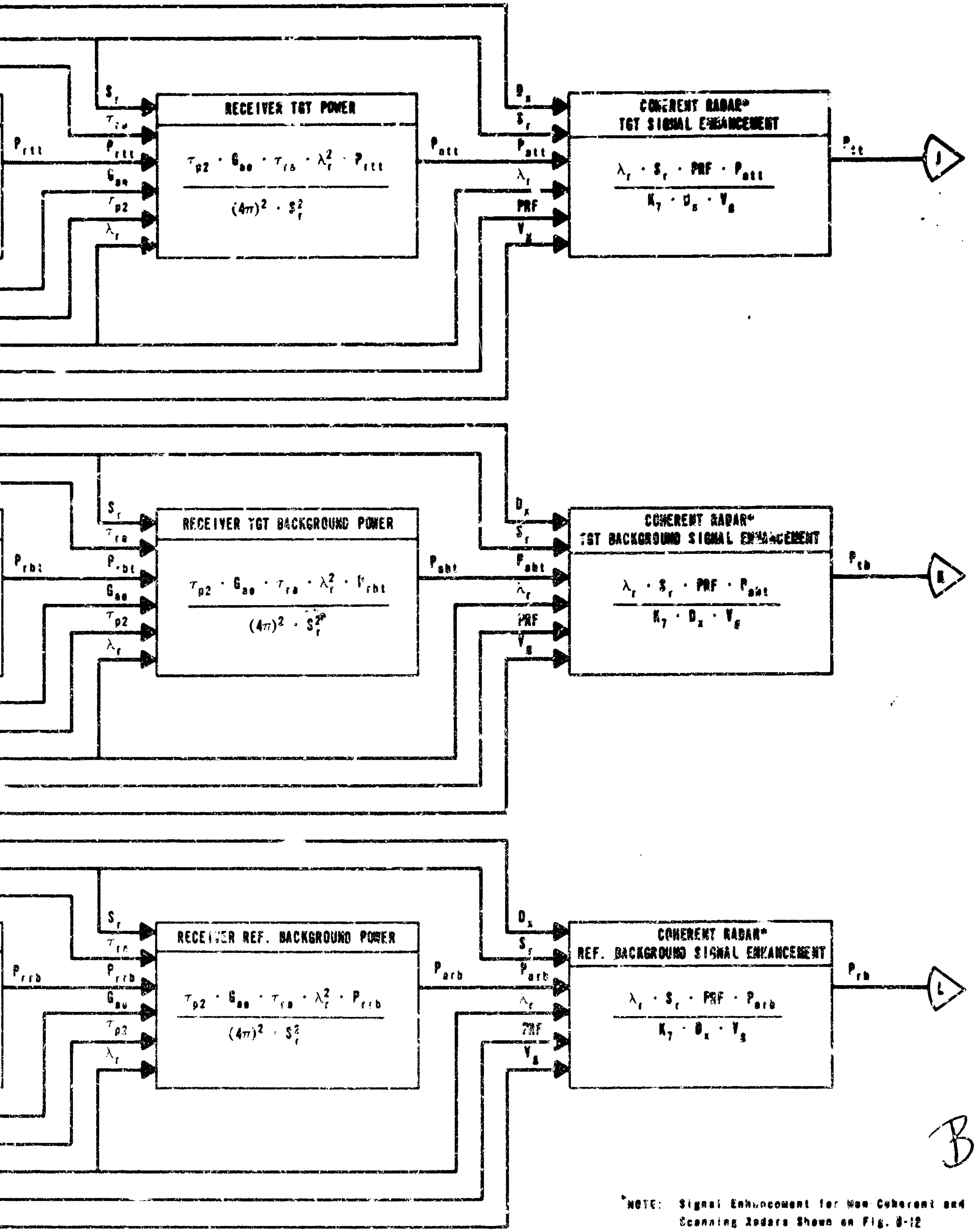


FIG. B-9 SLAR SENSOR MOD



*NOTE: Signal Enhancement for Non Coherent and Scanning Radars Shown on Fig. B-12

SOR MODEL – SIGNAL POWER

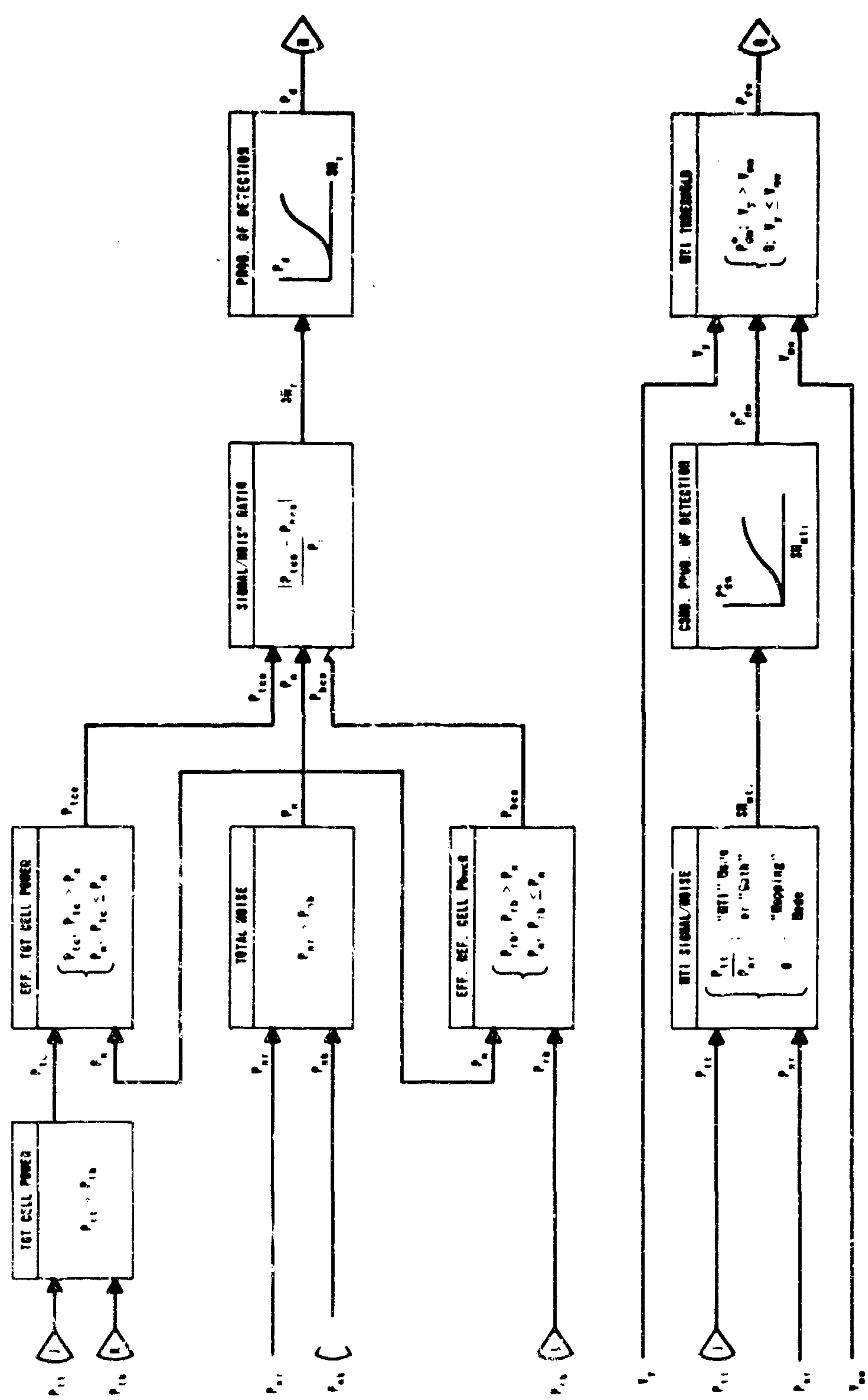
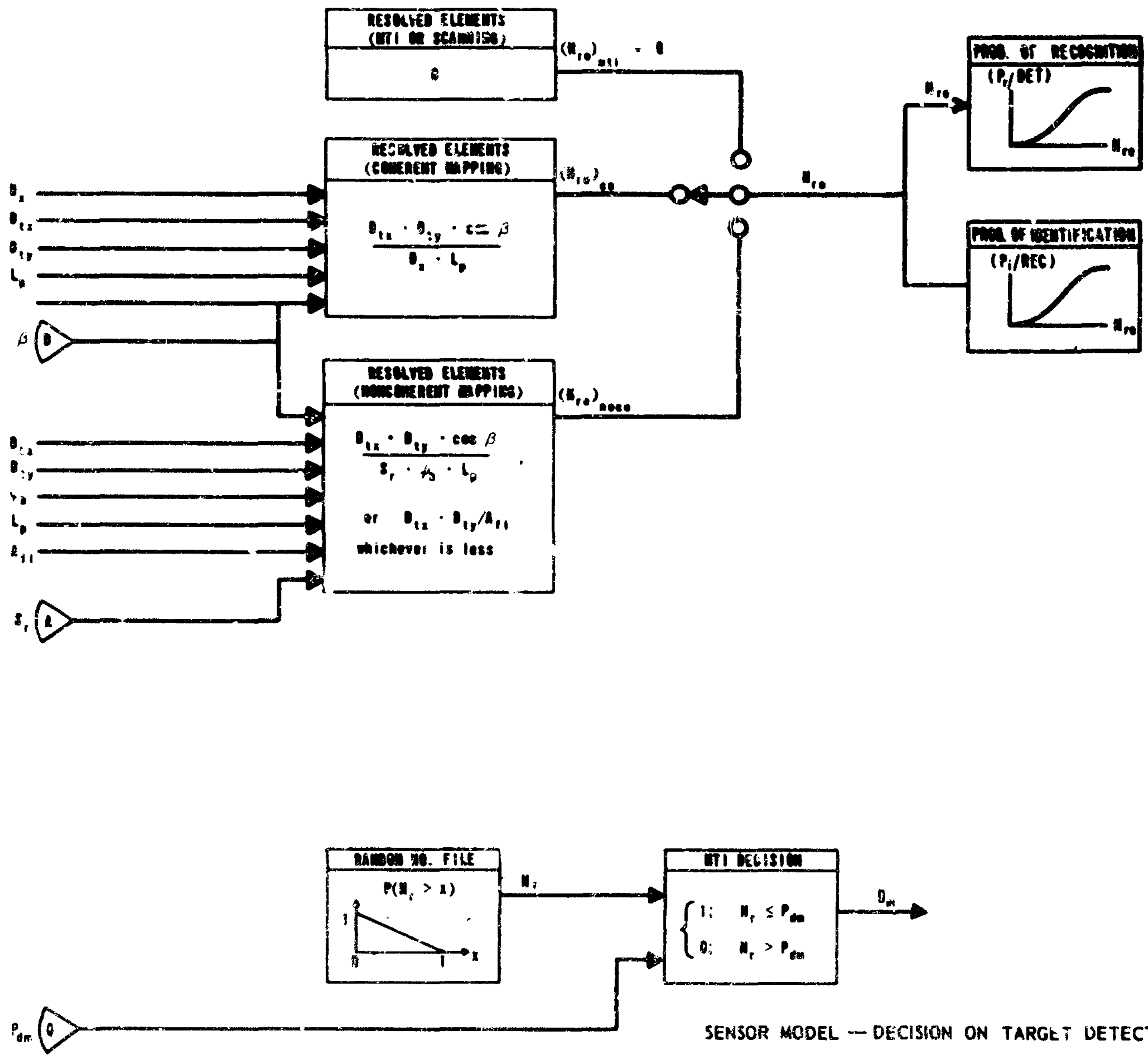


FIG. B-10 SLAR SENSOR MODEL -- DETECTION PROBABILITY



SENSOR MODEL — DECISION ON TARGET DETECTION, RECOGNITION, AND IDENTIFICATION

FIG. B-11 SLAR SENSOR MODEL – DECISION ON TARGET DETECTION, RECOGNITION, AND IDENTIFICATION

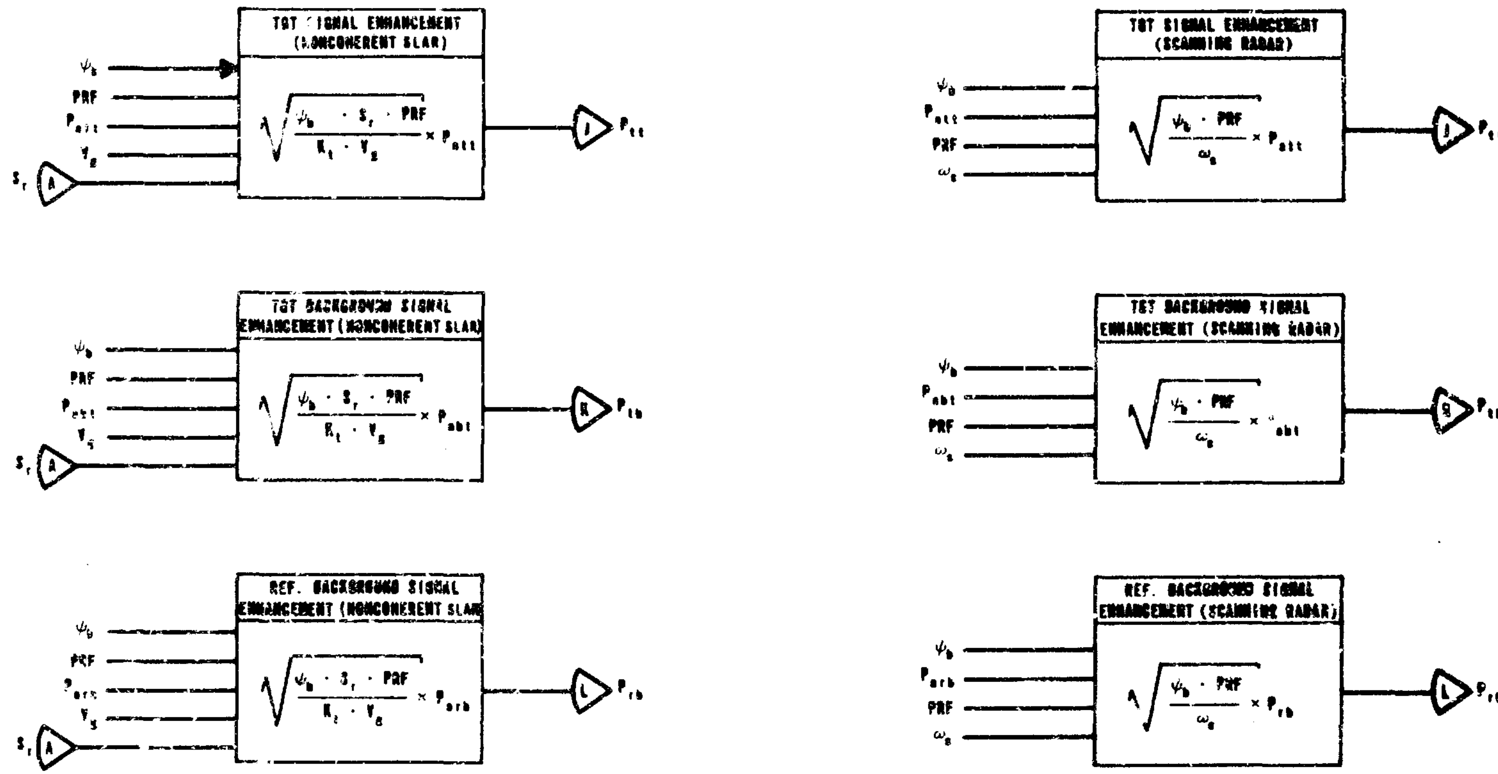


FIG. B-12 RADAR SENSOR MODEL – SIGNAL ENHANCEMENT FOR NONCOHERENT AND SCANNING SLARS

Table B-III

SLAR SENSOR MODEL--VARIABLES AND DIMENSIONS

A. Mission Variables

- C_{vr} - Percent effective radar vegetation coverage/100
- H - Aircraft altitude, feet
- V_g - Aircraft velocity, knots
- Y_{mn} - Minimum lateral radar range, meters
- Y_{mx} - Maximum lateral radar range, meters
- Terrain type - Smooth, rolling, rough

B. Atmospheric Variables

- A_a - Atmospheric absorption loss, dB/kilometer
- A_r - Rain absorption loss, dB/kilometer
- F_r - Rain reflectivity factor, $meters^3$

C. SLAR Sensor Parameters

- A_{1f} - Film-limited resolved area, $meters^2$
- D_x - Effective linear azimuthal resolution of synthetic antenna, meters
- G_o - Maximum antenna gain, watts/watt
- L_p - Range resolution = ½ CT/chirp-ratio, meters
- V_{mn} - Minimum detectable velocity (MTI), knots
- PRF - Pulse repetition frequency, $seconds^{-1}$
- P_{nr} - Radar electronic noise power, watts
- P_x - Transmitted pulse power, watts

Table B-III (Continued)

SLAR SENSOR MODEL--VARIABLES AND DIMENSIONS

C. SLAR Sensor Parameters (Contd.)

β_m - Minimum depression angle, radians

δ - Percent MTI blind speed tolerance/100

λ_r - Radar wavelength, meters

τ_{p1} - Attenuation coefficient due to transmitter plumbing loss

τ_{p2} - Attenuation coefficient due to receiver plumbing loss and signal filtering

τ_{p3} - Attenuation coefficient due to receiver plumbing loss and rain-clutter filtering

ψ_b - Horizontal beamwidth, radians

ω_s - Scan rate of scanning radar radians/second

D. Target Characteristics

D_{tx} - Target dimension in flight direction, meters

D_{ty} - Target dimension in crosstrack direction, meters

V_y - Target velocity component normal to flight track, knots

Y - Target lateral distance from flight track, meters

Γ_b - Background radar reflectance

Γ_t - Target radar reflectance

E. Constants

K_2 - 0.3048 meters/foot

K_6 - $2.30259 \times 10^{-4} = (0.1 \log_e 10) \times 10^{-3}$

K_7 - 0.5144 (meter/second)/knot

Table B-III (Continued)

SIAR SENSOR MODEL--VARIABLES AND DIMENSIONS

F. **Variables Internal to the Model**

A_{rbt} - Effective background area, meters^2

A_{rr} - Resolved area, meters^2

A_{rs} - Ground-resolved area, meters^2

A_{rt} - Target area, meters^2

A_{rte} - Effective target area, meters^2

D_m - MTI detection decision, yes = 1, no = 0

$\bar{D}_{prc}$ - Average power density on rain cell, watts/meter^2

G_{ae} - Antenna gain, watts/watt

N_r - Uniformly distributed random variable $(0 \leq N_r \leq 1)$

N_{re} - Number of resolved elements

P_i - Probability of identification

P_n - Total noise power, watts

P_{nb} - Radar noise power due to rain backscatter, watts

P_{dm} - Probability of detection (MTI)

P^*_{dm} - Conditional probability of detection (MTI)

P_r - Probability of recognition

P_{rb} - Reference background signal power, watts

P_{rr} - Rain backscattered power, watts

P_{tb} - Background signal power, watts

P_{tt} - Target signal power, watts

P_{abt} - Receiver background power, watts

P_{arb} - Receiver reference background power, watts

Table B-III (Continued)

SLAR SENSOR MODEL--VARIABLES AND DIMENSIONS

F. **Variables Internal to the Model (Contd.)**

P_{att} - Receiver target power, watts

P_{bce} - Effective reference cell power, watts

P_{mti} - MTI signal power, watts

P_{rrb} - Reference background reflected power, watts

P_{rtt} - Target reflected power, watts

P_{tc} - Total power from target cell, watts

P_{tce} - Effective target cell power, watts

PD_o - Transmitted power density, watts/meter^2

R_d - Recognition decision, yes = 1, no = 0

S_r - Slant range, meters

S_{pv} - Rain radar cross-section per unit volume, meters^2/meter^3

SN_r - Signal-to-noise ratio (mapping)

SN_{mti} - Signal-to-noise ratio (MTI)

V_b - MTI blind velocity, knots

X_{rte} - Target X - dimension within resolution cell, meters

Y_{rte} - Target Y - dimension within resolution cell, meters

β - Depression angle, degrees

σ_b - Reference background radar cross-section, meters^2

σ_r - Rain radar cross-section, meters^2

σ_t - Target radar cross-section, meters^2

Table B-III (Continued)

SLAR SENSOR MODEL--VARIABLES AND DIMENSIONS

F. Variables Internal to the Model (Contd.)

σ_{bt} - Background radar cross-section, meters^2

Γ_{ra} - Radar attenuation coefficient due to absorption

IV VISUAL SENSOR MODELS

The aerial visual sensor model is a direct adaptation of the Franklin Whittenburg visual model. Reference 9 presents a detailed description of the model. Figure B-13 is a flow chart of the model. A modification to allow the simulation of binoculars was made by multiplying the apparent size of the target element (SA) by the magnification. The model is called on twice for each target element type, once to obtain the probability of detecting the element, P_e, and once to calculate the probability of detecting the element's shadow, P_s. The probability of detecting that type of element is then calculated as $P_d = 1 - (1 - P_e)(1 - P_s)$ in the calling program.

The ground visual sensor model is a direct adaptation of the aerial model depicted in Fig. B-13. The altitude, H, is taken as 0 and the effective time, T_E, is set to 1.

Table B-IV presents the visual model variables and their dimensions.

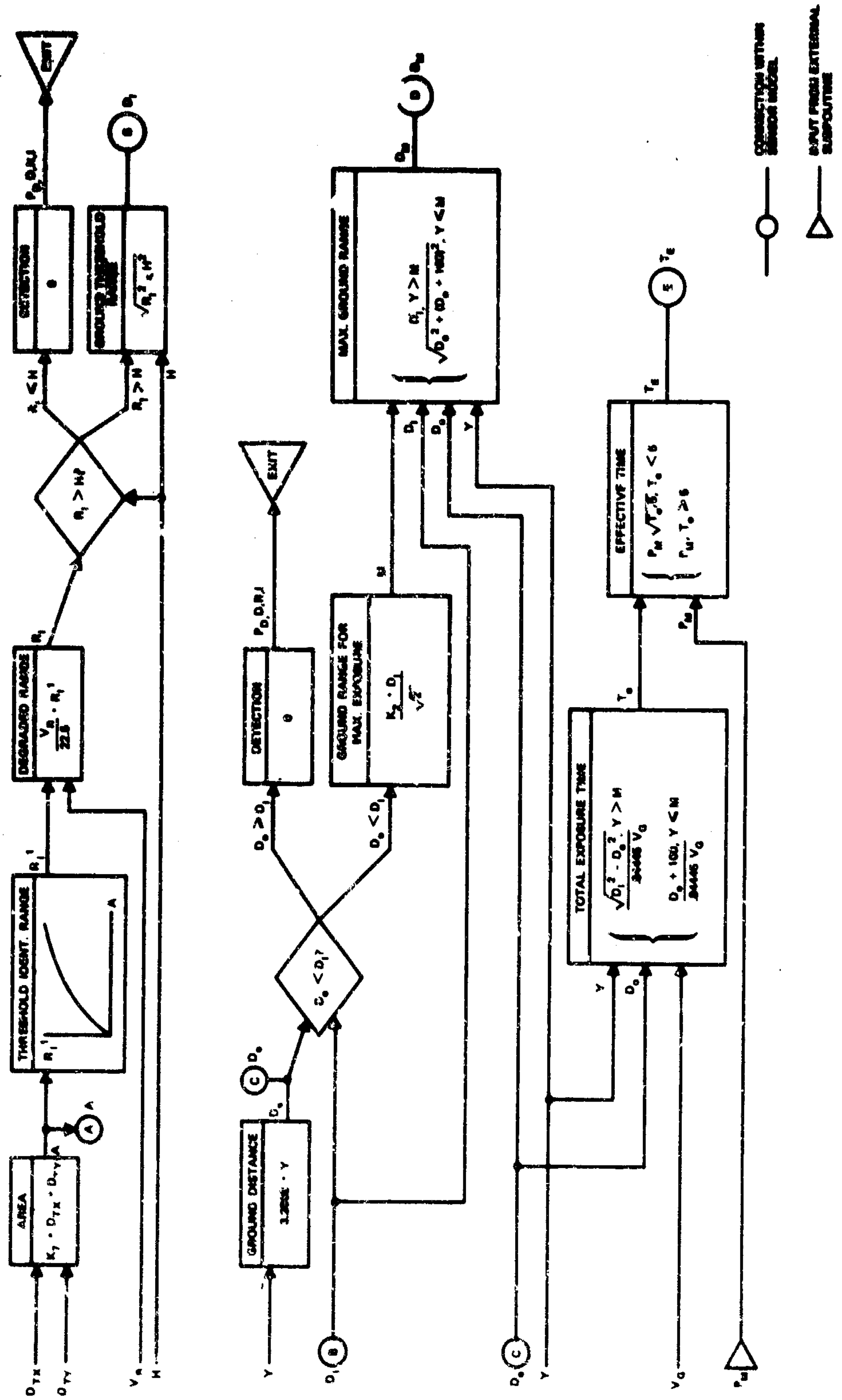


FIG. B-13 VISUAL SENSOR MODEL — GEOMETRY AND TIME

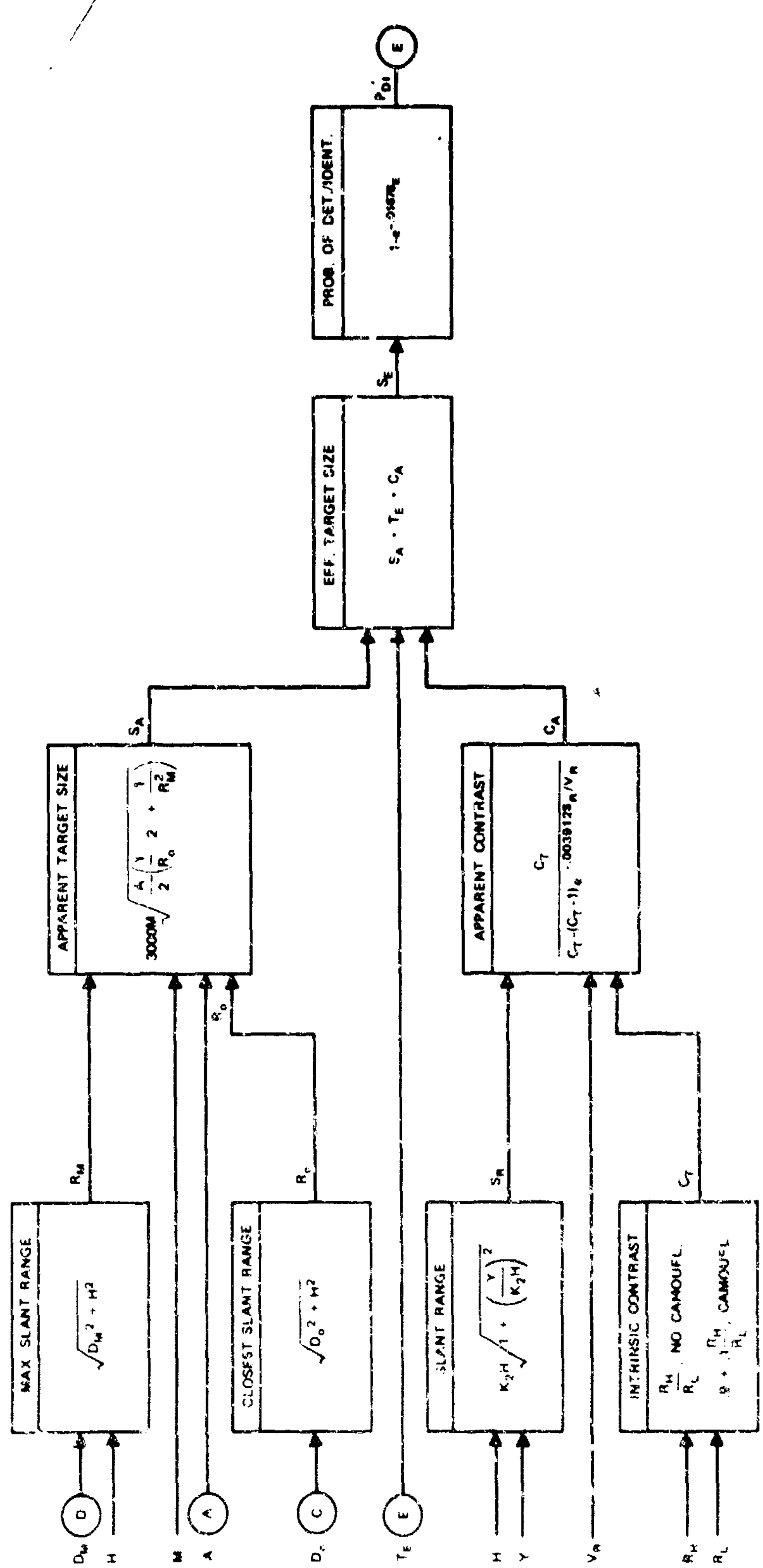


FIG. B-14 VISUAL SENSOR MODEL — CONTRAST

Table B-IV

VISUAL MODEL--VARIABLES AND DIMENSIONS

A. Mission Variables

H - Aircraft altitude, feet

V_g - Aircraft ground speed, knots

Y - Lateral distance from target to flight path, meters

B. Atmospheric Variables

HZ - Haze factor

H_o - 95 percent haze altitude, feet

V_r - Visual range, kilometers

C. Target Characteristics

D_{tx} - Target dimension, meters

D_{ty} - Target dimension, meters

R_h - Highlight reflectance (TGT or BKGND, whichever is higher)

R_l - Lowlight reflectance (TGT or BKGND, whichever is lower)

D. Sensor Characteristics

M - Magnification

E. Constants

K_2 - .3048 meter/feet

K_7 - 1.0936 yards/meter

V LASER SENSOR MODEL

The laser model was developed at SRI during the Advanced Target Acquisition Study for the U.S. Marine Corps (Ref. 10). This model (see Figs. B-15, B-16, and B-17) assumes that a laser operating in the IR spectrum, probably at 10.6 microns, will be used to illuminate the target area and that a receiver similar to the IR line scanners will be used to process the reflected energy.

Table B-V presents the laser model variables and their dimensions.

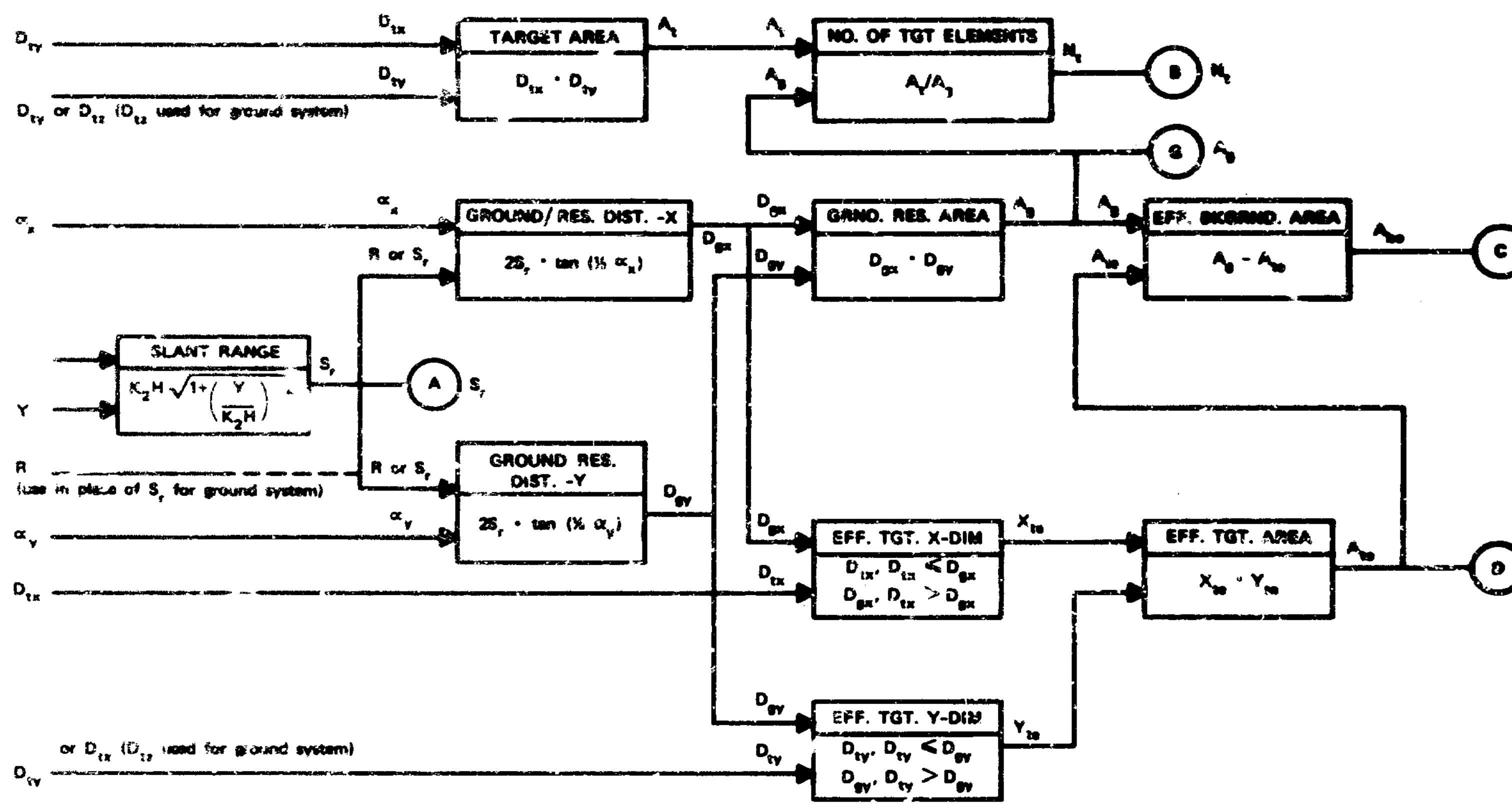


FIG. B-15 LASER SENSOR MODEL – GEOMETRICAL EFFECTS

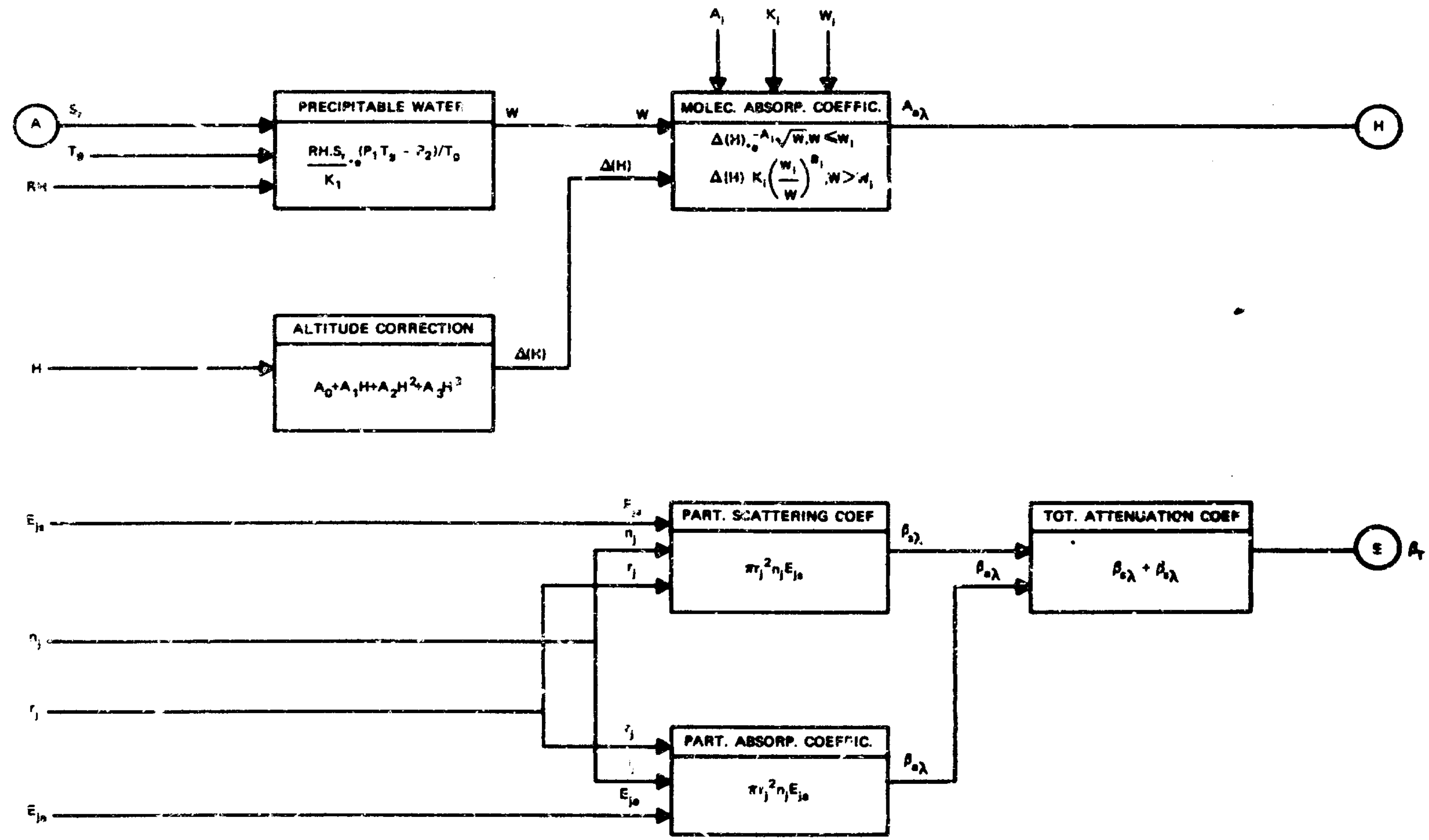


FIG. B-16   LASER SENSOR MODEL – ATMOSRHERIC EFFECTS

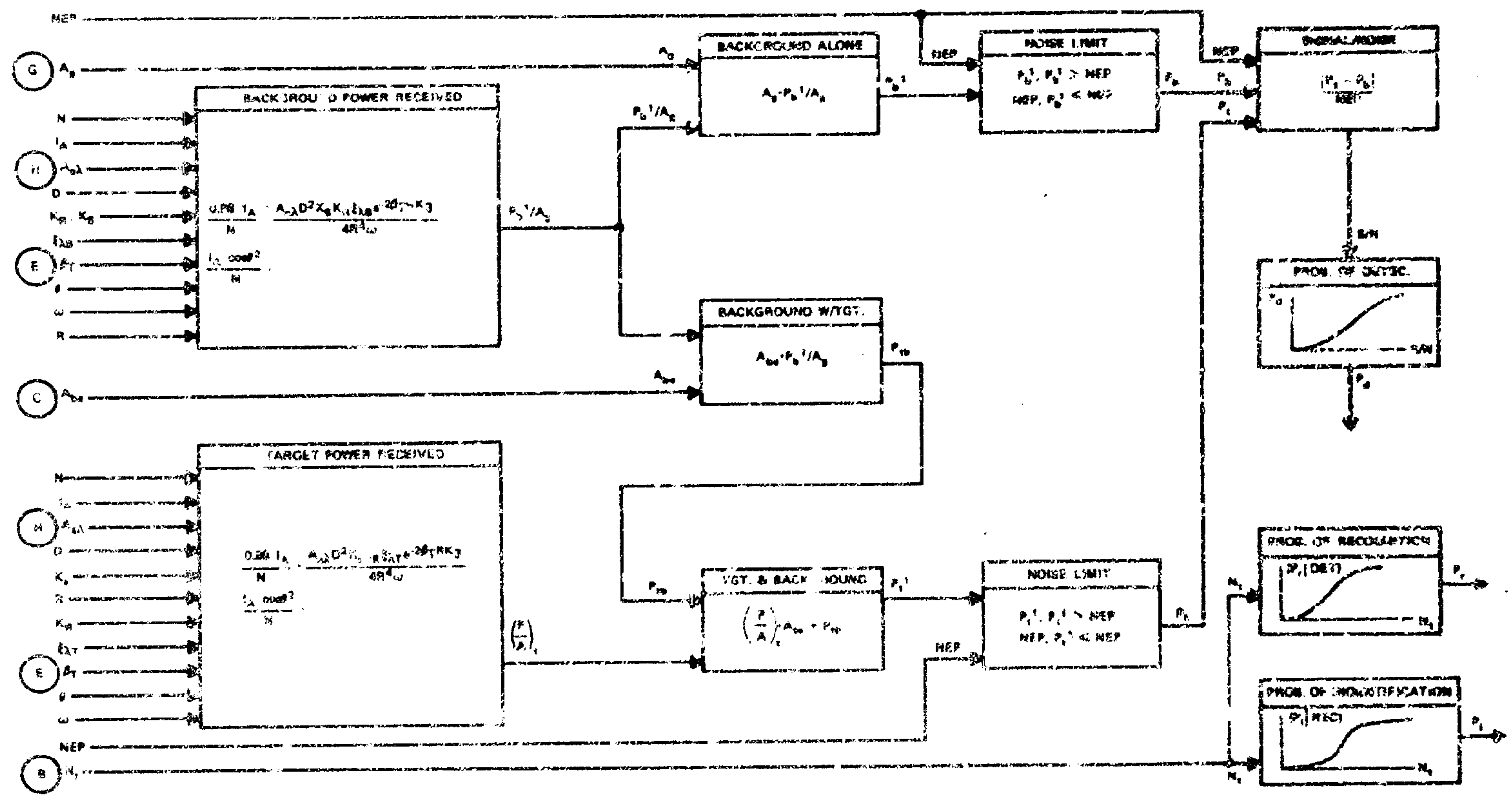


FIG. B-17 LASER SENSOR MODEL — PROBABILITY OF DETECTION

Table B-V

LASER SENSOR MODEL--VARIABLES AND DIMENSIONS

A. Mission Variables

C_{vi} - Percent effective vegetation coverage/100

H - Aircraft altitude, feet

Y - Lateral distance of target from flight path, meters

Terrain type - Smooth, rolling or rough

B. Atmospheric Variables

RH - Percent relative humidity/100

E_{sj} - Scattering area ratio of particle

T_g - Absolute ground air temperature, ^oK

E_{aj} - Absorption area ratio of particle

h_j - Number of water droplets in the atmosphere, particles/cm^3

r_j - Radius of water droplets in the atmosphere, cm

C. Laser Sensor Parameters

NEP - Noise equivalent power of detector, watts

α_x - Net angular scan resolution in flight direction, radians

α_y - Net angular scan resolution in crosstrack direction, radians

I_A - Average power from CW laser, watts

D - Diameter of receiving optics, meters

K_3 - Optical efficiency of transmitter optics including scanner

Table B-V (Continued)

LASER SENSOR MODEL--VARIABLES AND DIMENSIONS

C. Laser Sensor Parameters (Contd.)

K_R - Optical efficiency of receiving aperture including filter

$\xi_{T\lambda}$ - Target reflectivity

$\xi_{B\lambda}$ - Background reflectivity

ω - Transmitter beamwidth, steradians

N - Number of receiver resolution cells

ϑ - Angle between nadir and target for air system

W_i - Precipitable water constant of i^{th} window, mm

A_i - Absorption constant of i^{th} window, $mm^{-\frac{1}{2}}$

B_i - Absorption constant of i^{th} window

K_i - Absorption constant of i^{th} window

D. Target Characteristics

D_{ta} - Target dimension in vertical direction, meters

D_{tx} - Target dimension in flight direction, meters

D_{ty} - Target dimension in crosstrack direction, meters

$\xi_{\lambda T}$ - Target reflectivity

$\xi_{\lambda B}$ - Background reflectivity

E. Constants

K_1 - 1000

K_2 - 0.3048 meter/foot

K_3 - 100

Table B-V (Continued)

LASER SENSOR MODEL--VARIABLES AND DIMENSIONS

E. Constants (Contd.)

P_1 - 19.83

P_2 - 4969° K

a_0 - 1.000

a_1 - 4.245×10^{-6} $(feet)^{-1}$

a_2 - 3.62×10^{-11} $(feet)^{-2}$

a_3 - 5×10^{-17} $(feet)^{-3}$

F. Variables Internal to the Model

A_{be} - Effective background area, $meters^2$

A_g - Ground-resolved area, $meters^2$

A_t - Target area, $meters^2$

A_{te} - Effective target area, $meters^2$

D_{gx} - Ground-resolved distance in flight direction, meters

D_{gy} - Ground-resolved distance in X-track direction, meters

D_{gz} - Ground-resolved distance in vertical direction, meters

N_t - Number of target elements resolved

P_b - Effective power received from reference resolution cell, watts

P'_b - Power received from reference resolution cell containing background only, watts

P_d - Probability of detection

Table B-V (Continued)

LASER SENSOR MODEL--VARIABLES AND DIMENSIONS

F. Variables Internal to the Model (Contd.)

P_r - Probability of recognition

P_t - Effective power received from actual resolution cell, watts

P'_t - Total power received from resolution cell containing target and surrounding background, watts

P_{tb} - Power received from background surrounding target within resolution cell, watts

P_H - Power received from target within resolution cell, watts

R - Measured sensor to target range for ground system use, meters

S_r - Slant range, meters

S/N - Signal-to-noise ratio

W - Precipitable water, mm

X_{te} - X dimension of target lying within resolution cell, meters

Y_{te} - Y dimension of target lying within resolution cell, meters

Z_{te} - Z dimension of target lying within resolution cell, meters

$\Delta(H)$ - Altitude correction term for absorption

$A_{a\lambda}$ - Molecular absorption coefficient

$\beta_{s\lambda}$ - Particle scattering coefficient (cm^{-1})

$\beta_{a\lambda}$ - Particle absorption coefficient (cm^{-1})

β_T - Total particle attenuation coefficient (cm^{-1})

VI LLLTV SENSOR MODEL

The LLLTV sensor model is shown schematically in Fig. B-18 and represents the general performance characteristics of an image intensifier-SEC vidicon tube. Resolution (in TV lines) is assumed to be a function of photocathode illuminance (I_{pc}) and apparent contrast modulation at the photocathode (M_a). The functions approximating tube resolution were determined heuristically for photocathode illuminance in the range $10^{-7} \leq I_{pc} \leq 1$ as

$$\frac{N}{N_{max}} = M_a^{\left[\frac{1}{73\left(I_{pc}^{0.234}\right)}\right]}$$

and

$$N_{max} = N'_{max} \sum_{j=0}^{5} a_j \left(\log I_{pc}\right)^j$$

where

$a_o = 0.999736$ $\quad$ $a_3 = 0.0311491$

$a_1 = 0.0198410$ $\quad$ $a_4 = 0.00524140$

$a_2 = 0.0725046$ $\quad$ $a_5 = 0.000277677$

Photocathode illuminance is determined by scene illuminance (I_s), target reflectance (R_t), atmospheric transmission coefficient (τ_a), lens transmission coefficient (τ_1), and the relative aperture, or f-number, of the lens. Contrast ratio of the target against its background (C_t) is calculated and then attenuated by the atmosphere to obtain the apparent contrast modulation at the photocathode (M_a). The modulation transfer function of the objective lens is assumed to be unity for the relatively low spatial frequencies (<50 line-pairs/mm) resolvable by TV systems. Apparent contrast modulation and photocathode illuminance are then used to compute the effective operational resolution of the TV system (N) according to the equations listed above.

The number of target area elements resolved (N_t) is then calculated by dividing the target cross-sectional area, $W_t \times H_t$ (or width times length for an airborne TV system), by the target resolved distance (D_t). D_t is obtained from lens focal length (f), operational resolution (N), target slant range (S_r), and a constant (K_9), as shown in Fig. B-18.

The detection probability (P_d) depends on the number of target elements resolved (N_t) and viewer efficiency (P_v). Recognition cannot occur unless the target is first detected, and identification cannot occur unless the target has been both detected and recognized. Note, however, that the printed probabilities of recognition and identification can have higher numerical values than the probability of detection. This can occur because detection probability is conditional upon line of sight and viewer efficiency. Once a target is detected, it is assumed that the viewer will also recognize and identify it if sufficient resolution exists to make recognition or identifi-

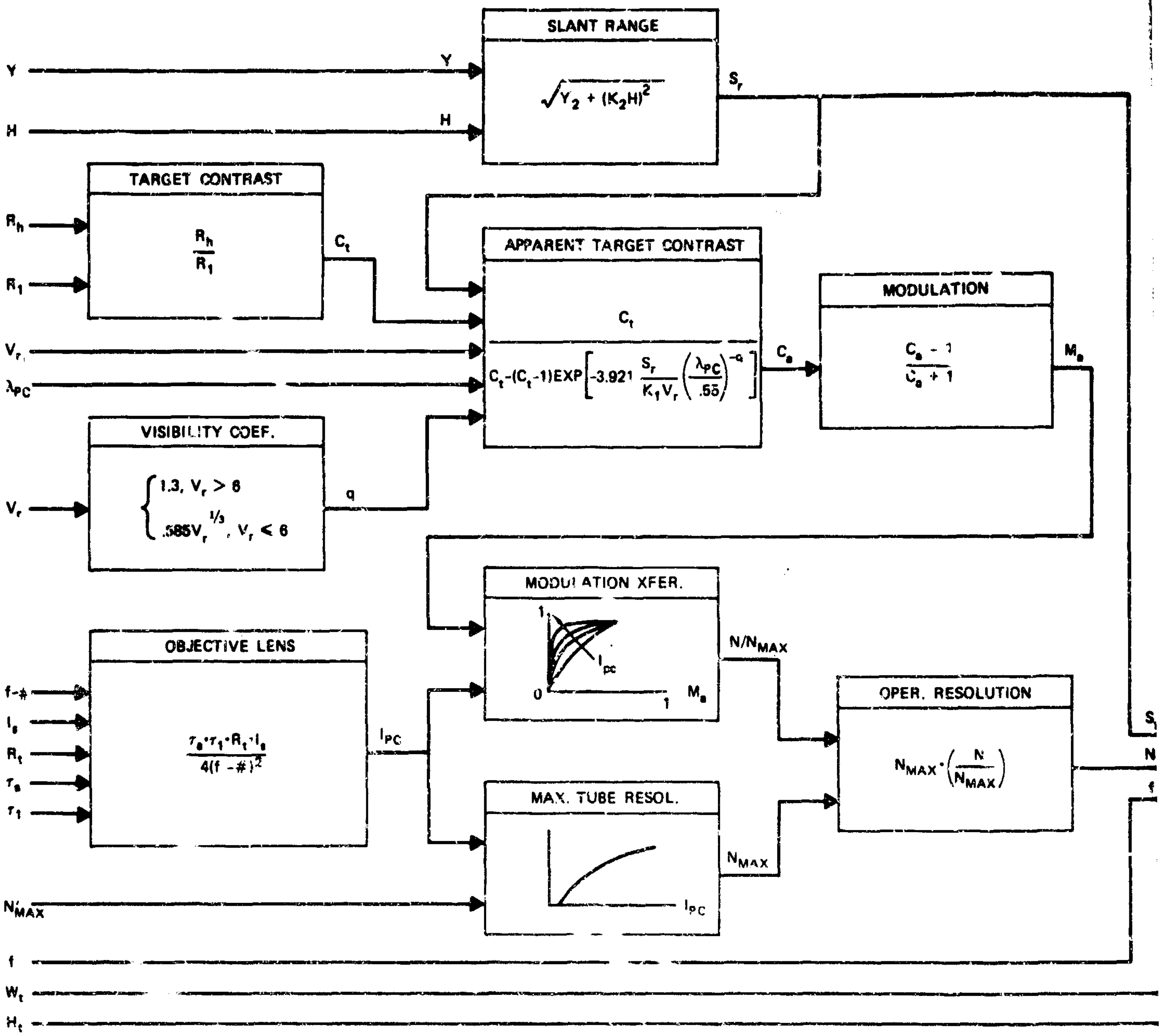
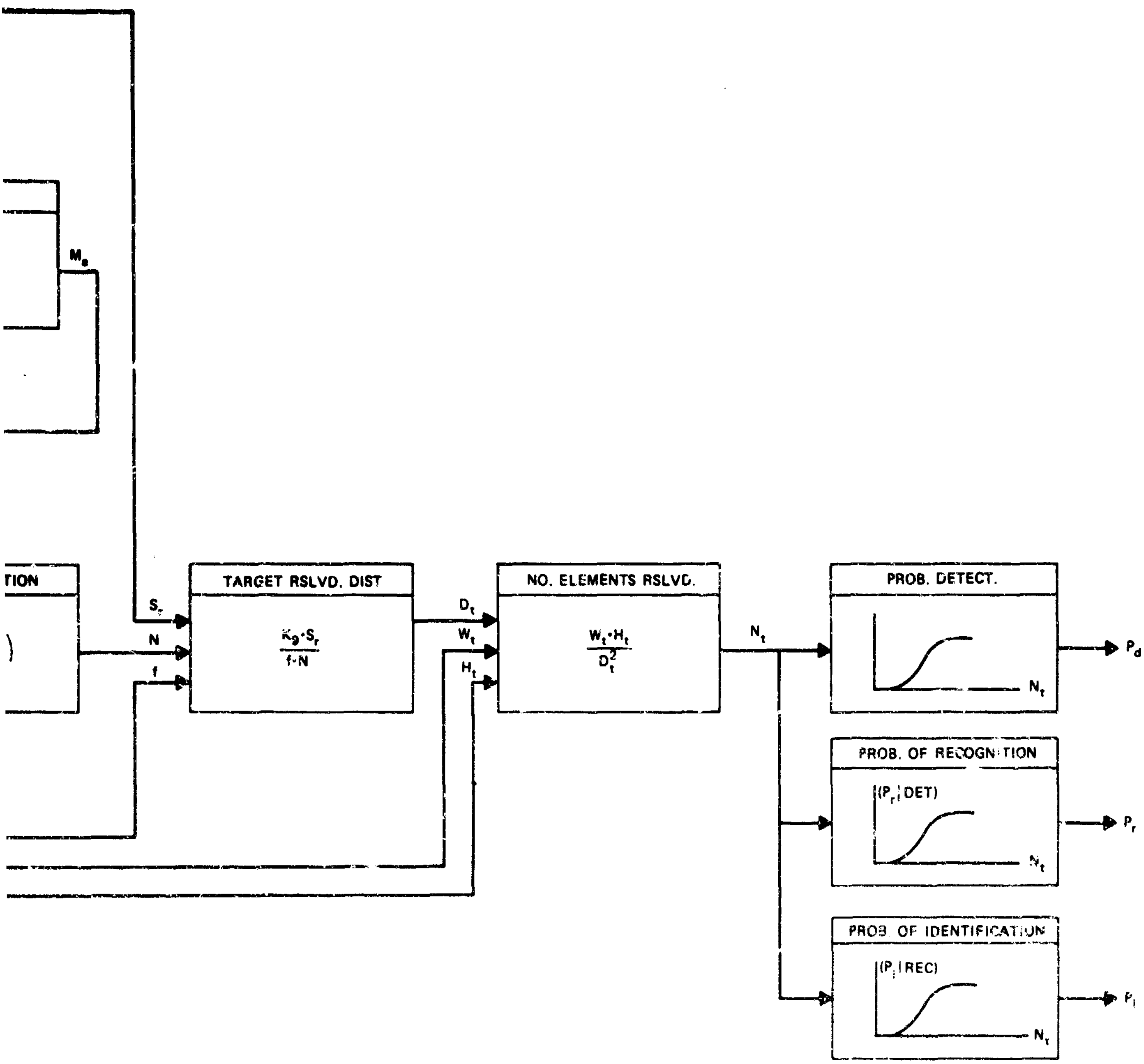


FIG. B-18 TELEVISION SE



TELEVISION SENSOR MODEL

B

cation possible. Furthermore, if detection occurs, then line of sight must exist. Recognition or identification probabilities are, therefore, not conditional upon line of sight and viewer efficiency.

Table B-VI lists the LLLTV model variables and their dimensions.

Table B-VI

TELEVISION MODEL--VARIABLES AND DIMENSIONS

A. Mission Variables

- I - Horizontal plane illuminance, foot-candles
- H - Altitude, feet
- Y - Lateral distance of target from flight path, meters

B. Atmospheric Variables

- V_r - Visibility range, kilometers
- τ_a - Atmospheric transmission coefficient

C. TV Parameters

- f - Focal length, inches
- f-number - Relative aperture
- λ_{pc} - Photocathode mid-response wavelength, microns
- τ_l - Lens transmission coefficient
- P_v - Viewer efficiency
- N'_{max} - Maximum possible resolution, TV lines

D. Target Characteristics

- H_t - Target height, meters
- P_{los} - Probability of line of sight
- R_h - Highlight reflectance (target or background, whichever is larger)
- R_l - Lowlight reflectance (target or background, whichever is smaller)

Table B-VI (Continued)

TELEVISION MODEL--VARIABLES AND DIMENSIONS

D. Target Characteristics (Contd.)

R_t - Target reflectance

W_t - Target width, meters

E. Variables Internal to the TV Model

C_a - Apparent target contrast (with atmospheric loss)

C_t - Intrinsic target contrast (no atmospheric loss)

D_t - Target resolved distance, meters

I_{pc} - Photocathode illuminance, foot-candles

M_a - Apparent contrast modulation

N - Effective operational resolution, TV lines

N_{max} - Maximum resolution (100 percent modulation at I_{pc}), TV lines

N_t - Number of target elements resolved

P_d - Probability of detection

P_i - Probability of identification

P_r - Probability of recognition

q - Visibility coefficient

F. Constants

K_1 - 1000 meters/kilometer

K_2 - 0.3048 meters/foot

K_9 - 4 inches (2 TV lines/line-pair x 2-inch screen width)

VII PASSIVE NIGHT-VISION DEVICE (PNVD) SENSOR MODEL

The passive night-vision device (PNVD) model is shown in Fig. B-19. Contrast at the target is first calculated and then attenuated by the atmosphere in a manner similar to the photo model. Note, however, that the target and background reflectance values must be those as viewed by the photocathode used, rather than panchromatic film or the eye. This is necessary because the spectral response range of many photocathodes differs from that of the eye or panchromatic film.

After apparent target contrast is obtained, the resulting contrast modulation is used to determine the intensifier-resolution ratio, R/R_{max}. The maximum or high-contrast resolution, R_{max}, of the intensifier is itself a function of photocathode illuminance. These functions are

$$R = R_{max}(0.33M_a + 0.67(1 - EXP(-20M_a)))$$

and

$$R_{max} = R'_{max} \sum_{j=0}^{5} b_j (\log I_{pc})^j, \quad 10^{-7} \leq I_{pc} \leq 10^{-3}$$

where

$b_0 = 18.7540$ $\qquad b_3 = 1.99002$

$b_1 = 20.3779$ $\qquad b_4 = 0.213402$

$b_2 = 9.08942$ $\qquad b_5 = 0.00900726$

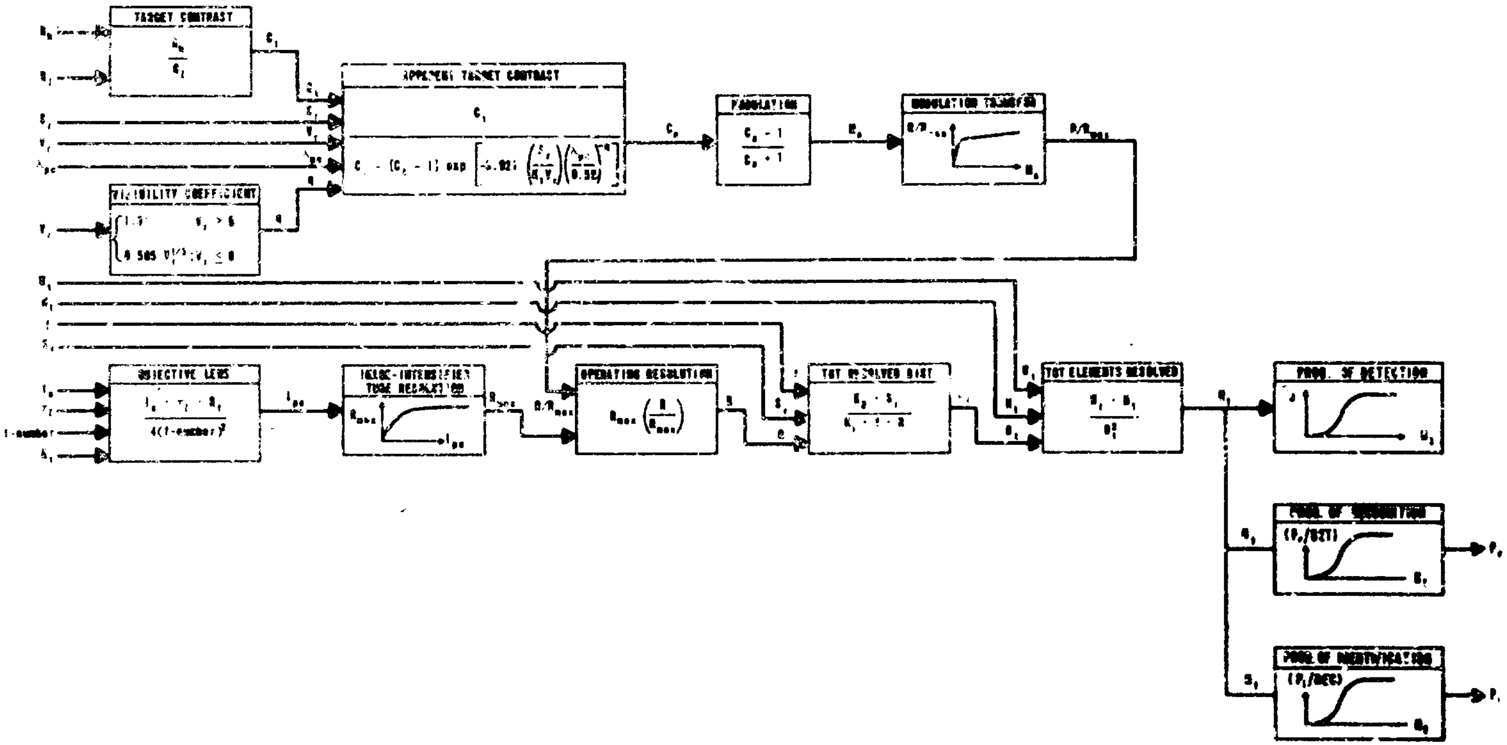


FIG. B-10 PASSIVE NIGHT-VISION DEVICE SENSOR MODEL

Photocathode illuminance is determined by scene illuminance (I_s), target reflectance (R_t), lens transmission coefficient (τ_1), and the lens relative aperture (f-number) as shown in Fig. B-19. The photocathode illuminance, intensifier maximum resolution, and resolution ratio are then combined to yield the PNVD operational resolution, R. Target resolved distance (D_t) is computed by dividing the target scale (slant range/focal length) by the PNVD operational resolution.

The detection probability (P_d) is dependent on the number of target elements resolved (N_t) and viewer efficiency (P_v).

Recognition cannot occur unless the target is first detected, and identification cannot occur unless the target has been both detected and recognized. It should be noted, however, that the printed probabilities of recognition and identification can have higher numerical values than the probability of detection. This can occur because the printed detection probability is conditional upon line-of-sight and viewer efficiency. Once a target is detected, it is assumed that the viewer will also recognize and identify it if sufficient resolution exists to make recognition or identification possible.

Table B-VII lists the PNVD model variables and their dimensions.

The PNVD sensors are generally assumed to be ground-based only. The recent introduction of image-stabilization techniques (Ref. 10), however, should make PNVDs feasible and desirable for vehicle and airborne employment early in 1969.

Table B-VII

PNVD MODEL--VARIABLES AND DIMENSIONS

A. Mission Variables

I_s - Horizontal plane illuminance, foot-candles

B. Atmospheric Variables

V_r - Visibility range, kilometers

C. PNVD Parameters

f - Focal length, inches

f-number - Relative aperture

λ_{pc} - Photocathode mid-response wavelength, microns

τ_l - Lens transmission coefficient

P_v - Viewer efficiency

R'_{max} - Maximum resolution of image-intensifier, lp/mm

D. Target Characteristics

H_t - Target height, meters

P_{los} - Probability of line-of-sight

R_h - Highlight reflectance (target or background, whichever is larger)

R_l - Lowlight reflectance (target or background, whichever is smaller)

W_t - Target width, meters

E. Variables Internal to the PNVD Model

C_a - Apparent target contrast (with atmospheric loss)

Table B-VII (Continued)

PNVD MODEL--VARIABLES AND DIMENSIONS

E. Variables Internal to the PNVD Model (Contd.)

C_t - Intrinsic target contrast (no atmospheric loss)

D_t - Target resolved distance, meters

I_{pc} - Photocathode illuminance, foot-candles

M_a - Apparent contrast modulation

N_t - Number of target elements resolved

P_d - Probability of detection

P_i - Probability of identification

P_r - Probability of recognition

q - Visibility coefficient

R - Effective operational resolution, lines/mm

R_t - Target reflectance

R_{max} - High-contrast resolution at operational photocathode illuminance, lines/mm

F. Constants

K_1 - 1000 mm/meter

K_8 - 39.37 inch/meter

VIII GROUND BASED MOVING TARGET INDICATOR (MTI) RADAR MODEL

SRI's simulation of the ground-based MTI radars utilize a model developed by Honeywell (Ref. 11). A flow chart of the ground-based MTI radar model is shown in Fig. B-20. A probability of detection conditional upon line of sight (P_d^*) was first determined by comparing target slant range (S_r) to the specific range capability of the radar set employed. Range capability against either personnel (S_{mp}) or vehicles (S_{mv}) was considered. Overall detection probability (P_d) was next computed as the product of P_d^*, a weather-degradation factor (K_w), and the MTI velocity-threshold factor (K_v). The velocity-threshold factor was obtained by comparing the target velocity (V_t) with the radar-threshold velocity, (V_{min}). Target velocity had to equal or exceed the MTI radar threshold velocity before detection was possible.

If an object is detected by a ground surveillance radar (GSR), it is assumed that the recognition class of the object can also be determined. Hence, the model sets $P_r = P_d$. Identification is considered impossible by a GSR, so that $P_i = 0$.

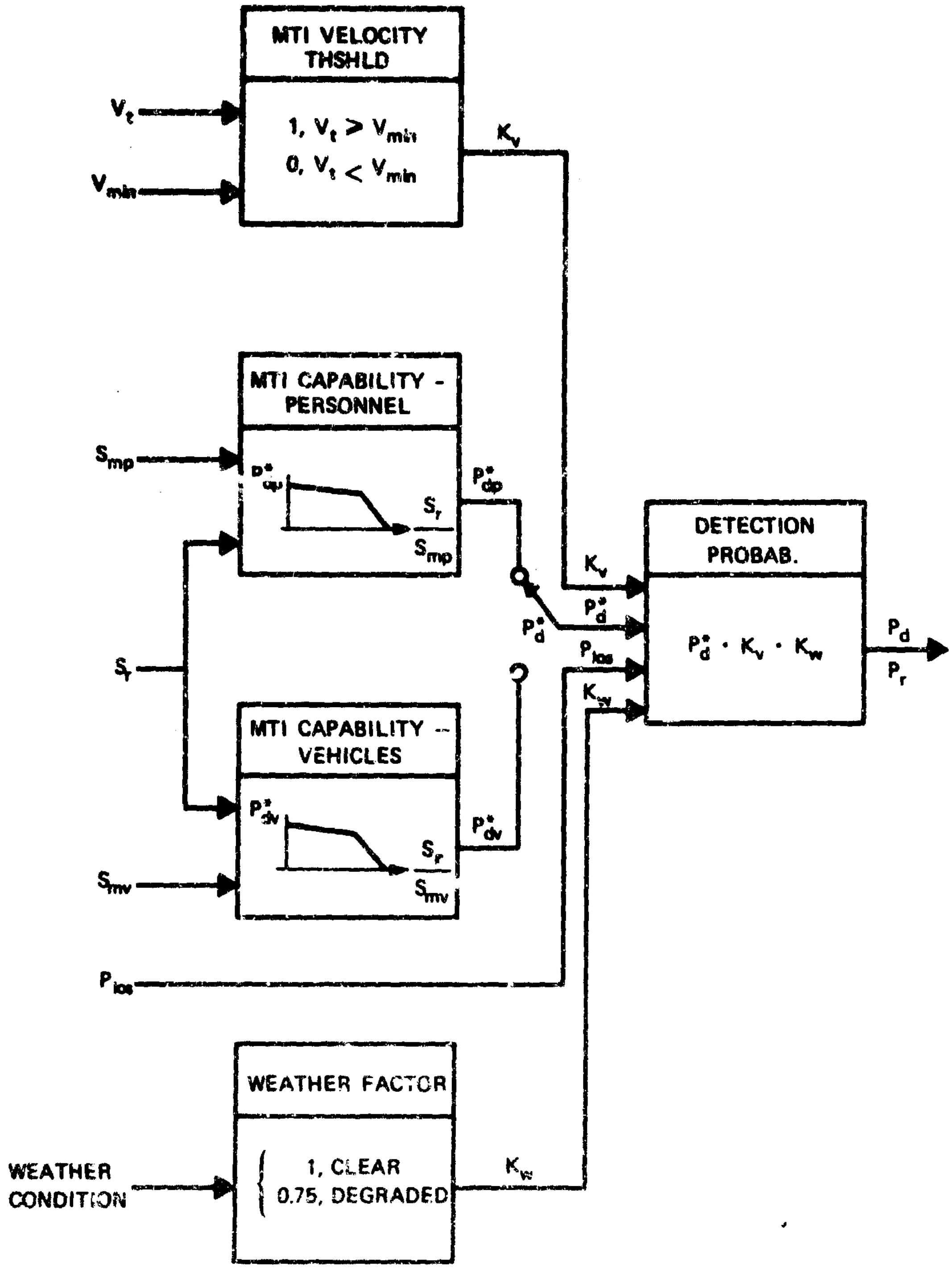


FIG. B-20 GROUND-BASED MTI RADAR MODEL

IX PROBABILITY CURVES

The mathematical model for each of the sensor types requires a set of curves for the probabilities of detection, recognition, and identification. With the exception of the visual models (both aerial and ground) and the ground surveillance radar model, these curves are given in empirical form, rather than as an equation. Table B-VIII lists the curves in digital form. The sensor model descriptions contain the definitions of the variables (axes) used for these curves. Table B-VIII also presents the probability of line-of-sight associated with terrain masking for smooth (PMS), rolling (PMO), and rough (PMR) type terrains. These probabilities are given as a function of distance from the target (YY) and altitude of the aircraft (HH).

These curves, given in digital form, were produced directly onto mats for reproduction by computer processes. Table B-VIII comprises the next 4 pages.

Table B-[illegible]II

PROBABILITY CURVES FOR DETECTION, RECOGNITION, IDENTIFICATION, AND TERRAIN MASKING

NNP

0.000	0.100	0.200	0.300	0.400	0.500	0.600	1.000	1.100
1.200	1.300	1.400	1.500	1.600	1.700	2.500	2.750	3.000
3.200	3.400	3.600	4.400	4.600	4.800	5.000	5.200	5.400
5.600	5.800	6.000	6.200	6.400	6.600	7.400	7.600	7.800
8.000	8.200	8.400	8.600					

PPPDS

0.000	0.013	0.033	0.066	0.114	0.190	0.290	0.720	0.793
0.838	0.868	0.885	0.894	0.898	0.900	0.900	0.900	0.900
0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
0.900	0.900	0.900	0.900					

PPPI

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.007	0.013	0.030	0.065	0.110	0.200	0.700	0.780	0.830
0.870	0.883	0.900	0.900					

PPPR

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.020
0.045	0.100	0.180	0.720	0.810	0.850	0.880	0.890	0.898
0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
0.900	0.900	0.900	0.900					

YY

0.000	305.000	610.000	915.000	1220.000	1525.000	1830.000	2135.000	2440.000
2745.000	3050.000	3355.000	3660.000					

HH

0.000	100.000	200.000	400.000	600.000	1000.000	1500.000	2000.000	3000.000

PMO

1.000	0.620	0.400	0.250	0.150	0.090	0.050	0.030	0.020

0.010	0.010	0.010	0.000	1.000	0.870	0.670	0.490	0.300
0.190	0.110	0.070	0.060	0.040	0.030	0.020	0.010	1.000
0.960	0.820	0.650	0.490	0.350	0.260	0.200	0.170	0.150
0.130	0.110	0.100	1.000	0.990	0.930	0.790	0.620	0.500
0.420	0.350	0.310	0.280	0.250	0.230	0.210	1.000	1.000
0.990	0.890	0.790	0.700	0.620	0.550	0.490	0.430	0.370
0.310	0.260	1.000	1.000	1.000	0.980	0.940	0.870	0.810
0.750	0.700	0.660	0.630	0.590	0.570	1.000	1.000	1.000
1.000	0.990	0.990	0.940	0.890	0.850	0.800	0.750	0.700
0.650	1.000	1.000	1.000	1.000	1.000	1.000	0.980	0.960
0.920	0.880	0.820	0.760	0.700	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	0.990	0.980	0.940	0.900	0.850

PMR

1.000	0.500	0.210	0.120	0.060	0.030	0.020	0.010	0.000
0.000	0.000	0.000	0.000	1.000	0.820	0.540	0.380	0.170
0.100	0.060	0.030	0.020	0.000	0.000	0.000	0.000	1.000
0.920	0.700	0.440	0.270	0.160	0.110	0.060	0.040	0.030
0.020	0.000	0.000	1.000	0.980	0.870	0.620	0.400	0.250
0.180	0.130	0.090	0.070	0.040	0.030	0.020	1.000	1.000
0.940	0.740	0.560	0.420	0.340	0.270	0.220	0.180	0.150
0.100	0.070	1.000	1.000	0.990	0.900	0.750	0.620	0.530
0.440	0.350	0.280	0.240	0.190	0.170	1.000	1.000	1.000
0.960	0.900	0.830	0.760	0.690	0.600	0.510	0.420	0.320
0.250	1.000	1.000	1.000	0.980	0.950	0.900	0.840	0.780
0.710	0.650	0.590	0.510	0.460	1.000	1.000	1.000	1.000
1.000	0.990	0.970	0.920	0.880	0.850	0.810	0.770	0.730

PMS

1.000	0.800	0.580	0.380	0.220	0.140	0.090	0.060	0.030
0.020	0.010	0.000	0.000	1.000	0.960	0.870	0.780	0.660
0.500	0.340	0.180	0.100	0.070	0.060	0.050	0.050	1.000
0.990	0.970	0.960	0.930	0.880	0.840	0.790	0.740	0.670
0.600	0.530	0.470	1.00	1.000	1.000	1.000	0.990	0.980
0.970	0.950	0.930	0.900	0.870	0.840	0.810	1.000	1.000
1.000	1.000	1.000	1.000	1.000	0.990	0.990	0.990	0.980
0.960	0.930	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	0.990	0.990	0.990	0.980	0.970	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

SSM

0.000	2.000	2.500	3.000	3.500	3.850	4.000	4.170	4.220
4.270	4.500	4.800	5.000	5.150	5.400	5.600	6.000	6.500

IIPDS

0.000	0.001	0.007	0.039	0.140	0.271	0.340	0.425	0.450
0.475	0.588	0.715	0.777	0.811	0.857	0.877	0.900	0.900

NST

0.000	0.010	0.040	0.090	0.160	0.250	0.360	1.000	1.210
1.440	1.700	1.970	2.250	2.560	2.890	6.250	7.580	9.000
10.200	11.600	13.000	19.400	21.200	23.000	25.000	27.000	29.200
31.300	33.700	36.000	38.400	41.000	43.600	54.800	57.800	60.800
64.000	67.200	70.500	74.000					

IIPR

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010	0.020
0.045	0.100	0.180	0.720	0.810	0.850	0.880	0.890	0.898
0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900	0.900
0.900	0.900	0.900	0.900					

IIPI

0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
0.007	0.013	0.030	0.065	0.110	0.200	0.700	0.780	0.830
0.870	0.883	0.900	0.900					

SSNR

0.000	6.000	8.000	10.000	12.000	14.000	16.000	26.000	28.000
30.000	32.000	34.000	36.000	38.000	40.000	42.000	44.000	

PPDRS

0.000	0.000	0.015	0.030	0.060	0.120	0.200	0.670	0.760
0.810	0.852	0.862	0.870	0.890	0.898	0.900	0.900	

NRE

0.000	0.010	0.040	0.090	0.160	0.250	0.360	1.000	1.210
1.440	1.700	1.970	2.250	2.560	2.890	6.250	7.580	9.000
10.200	11.600	13.000	19.400	21.200	23.000	25.000	27.000	29.200

```
 31.300  33.700  36.000  38.400  41.000  [illegible].600  54.800  57.800  60.900
 64.000  67.200  70.500  74.000
PPRR
-------------
  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.010   0.020
  0.045   0.100   0.180   0.720   0.810   0.8[illegible]   0.880   0.890   0.898
  0.[illegible]   0.900   0.900   0.900   0.900   0.[illegible]   0.900   0.900   0.900
  0.900   0.900   0.900   0.900
PPIR
-------------
  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
  0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000   0.000
  0.007   0.013   0.030   0.065   0.110   0.200   0.700   0.780   0.830
  0.870   0.883   0.900   0.900
SSNHYI
-------------
  0.000   6.000   8.000  10.000  12.000  14.000  16.000  26.000  28.000
 30.000  32.000  34.000  36.000  38.000  40.000  42.000  44.000
PPDMS
-------------
  0.000   0.000   0.015   0.030   0.060   0.120   0.200   0.670   0.760
  0.810   0.832   0.862   0.870   0.890   0.898   0.900   0.900
PPA
-------------
  0.000   1.000   2.000   3.000   4.000   5.000   6.000   7.000   8.000
  9.000  10.000  11.000  12.000  13.000  14.000  15.000  20.[illegible]  25.000
 30.000  35.000  40.000
RRI
-------------
  0.0001000.0001855.0002330.0002750.0003100.0003350.0003600.0003800.000
4020.0004230.0004380.0004510.0004630.0004760.0004890.0005310.0005720.000
6150.0006530.0006760.000
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Appendix C

TECHNICAL DEVELOPMENT OF CONCEPTS FOR CRESS-S

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I OBSTRUCTION CLEARANCE ALTITUDE

This appendix develops the general expression used in subroutine OBST for the computation of the corrected line-of-sight clearance height (H' in meters) for the two obstacles in the path card input data. If H' is positive the path is line-of-sight and if H' is negative, the path is non-line-of-sight. If there are two obstacles, both computed to be non-line-of-sight, this is classified as a multiple obstacle path for the microwave attenuation calculations.

Figure C-1 shows a diagram of the geometry (not to scale) assumed for the expressions to follow. In the real world environment, the path of a radio wave will be refracted in a curved path over a curved earth. However, for purposes of simplification, this model assumes that the radio wave actually travels in a straight line and that the earth radius (R_o) is adjusted to correct for refraction effects by the constant K (generally assumed to be 4/3).

It will be recalled that all obstruction data entered on the path cards give the obstruction distance from the sensor site and its elevation (h_3, in meters). In addition, the altitudes of the emitter and sensor antennas are read in meters above sea level.

The depression distance (AB) is the effective depression of the obstruction due to refraction effects caused by the change in effective earth radius which is modeled to intersect the true surface at the sensor and emitter site. As the maximum path length in this CRESS-S program is 500 km, a correction factor for the compression in the obstacle height dimension (h_3)

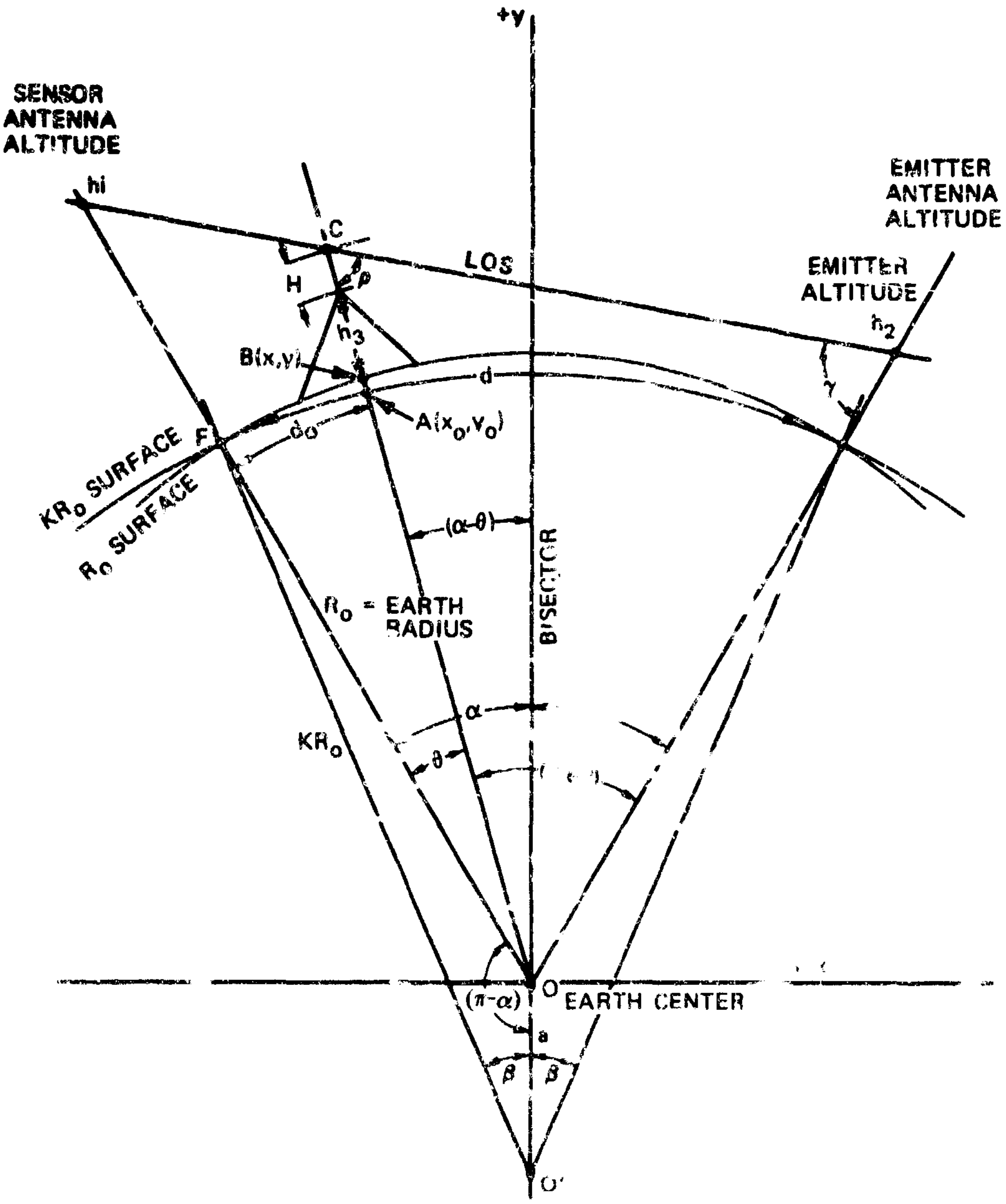

FIG. C-1 OBSTRUCTION CLEARANCE GEOMETRY

is not made. It amounts to a small fraction of a meter for typical terrain data.

Given: h_1', h_2', h_3, d, d_o, K, R_o

Calculate: $H' = H + AB = OC - R_o - h_3 + AB$

where

h_1 = Sensor antenna altitude, meters, ASL
$0 \leq h_1 \leq 30$ km

h = Emitter antenna altitude, meters, ASL
$0 \leq h_2 \leq 30$ km

h_3 = Terrain obstruction altitude, meters, ASL
$0 \leq h_3 \leq 30$ km

d = Sensor/emitter distance, km
$0 < d \leq 500$ km

d_o = Obstruction/sensor distance, km
$0 < d_o \leq 500$ km

K = Earth radius correction factor, (K = 4/3 nominal)

R_o = Earth radius = 6.37×10^3 km

H = Spherical earth LOS clearance height, km

AB = Line-of-sight correction for refraction, km

H' = Modified LOS clearance height, km
(where H = +, LOS;
H = -, NLOS)

$\alpha = \dfrac{d}{2R_o}$ radians

$\theta = \dfrac{d_o}{R_o}$ radians

Referring to Fig. C-2, consider the triangle $Oh_1 h_2$. The side

$$(h_1h_2)^2 = (Oh_1)^2 + (Oh_2)^2 - 2(Oh_1)(Oh_2)\cos(2\alpha) \qquad (1)$$

using the sine rule of triangles, the angle γ between the sides $(h_1 h_2)$ and $(h_2 0)$ is solved.

$$\frac{(h_1 h_2)}{\text{Sin } 2\alpha} = \frac{(Oh_1)}{\text{Sin } \gamma} \therefore \text{ Sin } \gamma = \left[\frac{(Oh_1)(\text{Sin } 2\alpha)}{(h_1 h_2)}\right] \qquad (2)$$

The angle ρ between the sides h_2C and OC is equal to $[180-\gamma-(2\alpha-\theta)]$ using the sine rule

$$\frac{(Oh_2)}{\text{Sin } \rho} = \frac{(OC)}{\text{Sin } \gamma}$$

$$\text{Therefore, } (OC) = \frac{(Oh_2) \text{ Sin } \gamma}{\text{Sin } \rho} = \frac{(R_o + h_2) \text{ Sin } \gamma}{\text{Sin } \rho} \qquad (3)$$

$$H = OC - R_o - h_3 = \text{unmodified clearance height} \qquad (4a)$$

$$H' = H + AB = \text{modified clearance height} \qquad (4b)$$

The distance, AB, is obtained by solving for the coordinates B(x,y) and for the coordinates A (x_o, y_o) obtained by the intersection of the circle, with the earth center as the origin,

$$x_o^2 + (y_o+a)^2 = (KR_o)^2 \qquad (5a)$$

with the straight line

$$y_o = x_o \text{ Tan } (\alpha-\theta+\pi/2) \qquad (5b)$$

and the circle

$$x^2 + y^2 = R_o^2 \tag{5c}$$

with the straight line

$$y = x \operatorname{Tan} (\alpha-\theta+\pi/2) \tag{5d}$$

Then

$$AB = \sqrt{(x-x_o)^2 + (y-y_o)^2} \tag{6}$$

In order to solve for a, use the law of cosines (triangle O′OF):

$$(KR_o)^2 = R_o^2 + a^2 - 2R_o a \operatorname{Cos}(\pi-\alpha) \quad . \tag{7}$$

Rearranging and solving for a,

$$a = R_o \left[\cos(\pi-\alpha) \pm \sqrt{\cos^2(\pi-\alpha)+K^2-1} \right] \quad . \tag{8a}$$

The geometry indicates that we should choose the plus sign; therefore, eq. 8a reduces to:

$$a = R_o \left[\cos(\pi-\alpha) + \sqrt{\cos^2(\pi-\alpha)+K^2-1} \right] \tag{8b}$$

The distance AB is calculated as follows. Substituting eq. 5b into 5a we obtain

$$y_o^2 \cot^2(\alpha-\theta+\pi/2) + (y_o + a)^2 = (KR_o)^2 \qquad (9a)$$

Equation 9a is equivalent to

$$y_o^2[\cot^2(\alpha-\theta+\pi/2) + 1] + 2ay_o + a^2 - (KR_o)^2 = 0 \qquad (9b)$$

Solving eq. 6b for y_o we obtain

$$y_o = \frac{-2a \pm \sqrt{4a^2 - 4[\cot^2(\alpha-\theta+\pi/2) + 1][a^2 - (KR_o)^2]}}{2[\cot^2(\alpha-\theta+\pi/2) + 1]}$$

(10a)

From the geometry of the problem we choose the plus sign; further simplification results

$$y_o = \frac{-a + \sqrt{a^2 - [\csc^2(\alpha-\theta+\pi/2)][a^2 - (KR_o)^2]}}{\csc^2(\alpha-\theta+\pi/2)} \qquad (10b)$$

$$x_o = y_o \cot(\alpha-\theta+\pi/2) \qquad (11a)$$

$$= \left[\cot(\alpha-\theta+\pi/2)\right]\left[\frac{-a + \sqrt{a^2 - [\csc^2(\alpha-\theta+\pi/2)][a^2 - (KR_o)^2]}}{\csc^2(\alpha-\theta+\pi/2)}\right]$$

(11b)

Substituting eq. 5d into eq. 5c, we obtain

$$y^2[\cot^2(\alpha-\theta+\pi/2) + 1] = R_o^2 \tag{12}$$

Solving for y and simplifying

$$y = R_o \sin(\alpha-\theta+\pi/2) \tag{13}$$

$$x = y \cot(\alpha-\theta+\pi/2) \tag{14a}$$

$$= R_o \sin(\alpha-\theta+\pi/2)(\cot(\alpha-\theta+\pi/2)) \tag{14b}$$

$$= R_o \cos(\alpha-\theta+\pi/2) \tag{14c}$$

Recalling eq. 6,

$$AB = \left[(X-X_o)^2 + (Y-Y_o)^2\right]^{1/2}$$

where

$$x = R_o \cos(\alpha-\theta+\pi/2) \tag{14c}$$

$$x_o = \left[\cot(\alpha-\theta+\pi/2)\right]\left[\frac{-a + \sqrt{a^2 - [\csc^2(\alpha-\theta+\pi/2)][a^2 - (XR_o)^2]}}{\csc^2(\alpha-\theta+\pi/2)}\right] \tag{11b}$$

$$y = R_o \sin(\alpha-\theta+\pi/2) \tag{13}$$

$$y_o = \left[\frac{-s + \sqrt{s^2 - [\csc^2(\alpha-\theta+\pi/2)][s^2 - (KR_o)^2]}}{\csc^2(\alpha-\theta+\pi/2)}\right] \quad (10b)$$

$$s = R_o\left[\cos(\pi-\alpha) + \sqrt{\cos^2(\pi-\alpha) + K^2 - 1}\right] \quad (8b)$$

$$\alpha = \frac{d}{2R_o}$$

$$\theta = \frac{d_o}{R_o}$$

II PROBABILITY OF DETECTION

The propagation equations and antenna characteristics are used in the calculation of hearability; namely, whether the signal that a given emitter located at A produces in a given receiver located at B is sufficiently greater than the background noise to be detectable. This section considers the factors that determine the probability that a hearable signal is actually detected in the situation under study. These factors are derived from the activity pattern of the emitter and the operating procedures of the receiver.

The emitter activity pattern is a description of how often and for how long the emitter is active ("up") during the time period being considered. In this model that activity pattern is summarized in a single activity factor, p, that is the fraction of the time period, T, during which the emitter is up. The total emitter up time, pT, is composed of an unknown number of transmissions distributed randomly. In the case of communications emitters, activity factors are usually determined for the nets in which the emitters operate rather than for the individual radios; emitter activity factors can then be based on specified knowledge of the net activity pattern, or on the assumption that the net up time is shared equally among the emitters.

The procedure used by the receiver in searching for signals is assumed to consist of a series of n periodic checks on frequencies known to be used by the signals of interest. If q is the fraction of time that the receiver listens on the emitter's frequency, each listening interval has a duration of qT/n (see

Fig. C-2). Detection occurs whenever a listening period overlaps an emitting period, even by an infinitesimal amount.

During each of the n sub-intervals containing a listening interval the expected duration of signal transmission is assumed to be pT/n, and the probability of detection during the first of these sub-intervals is the range of possible positions of this expected signal duration for which detection (overlap) occurs, divided by the total range of possible positions before the signal and listening phase relations repeat. Because the listening intervals occur regularly with period T/n while the transmissions occur randomly, the phase relations repeat in T/n, and detection occurs for an interval that is the sum of the listen and signal intervals; hence,

$$P_{D1} = \frac{p\ T/n + q\ T/n}{T/n} = p + q$$

Since the emitter has been assumed to be active in a random pattern, the probability of detecting it on any check is independent of the results of the other checks; hence, the probability of at least one detection in n checks is $P_D = 1 - (1 - p - q)^n$.

A key assumption in the preceding analysis is that the emitter activity pattern is such that the expected total duration of the signal transmissions is the same in each sub-interval. If this assumption is believed too stringent in a particular situation under study, the following more general analysis may be used. A single transmission interval of expected duration pT occurring anywhere in T is considered, and the total range of its possible positions is T. During the first sub-interval the probability of detection is

$$P_{D1}' = \frac{pT + qT/n}{T} = p + q/n$$

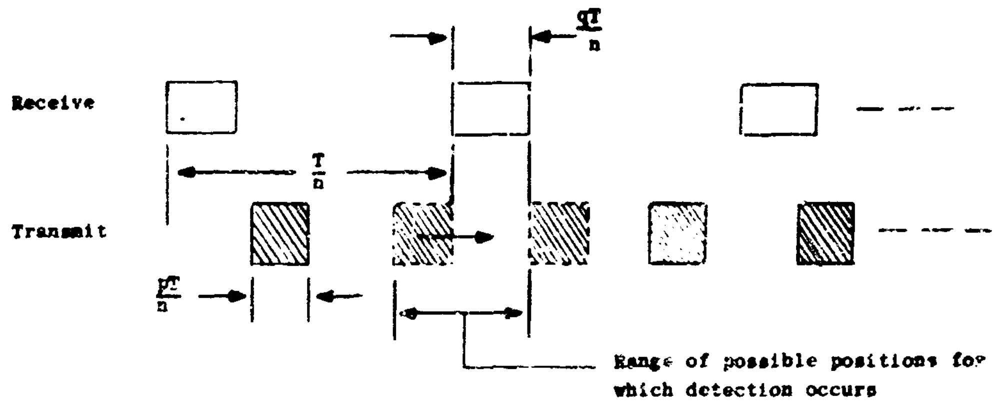

FIG. C-2 ACTIVITY DIAGRAM FOR MULTIPLE TRANSMISSION MODEL

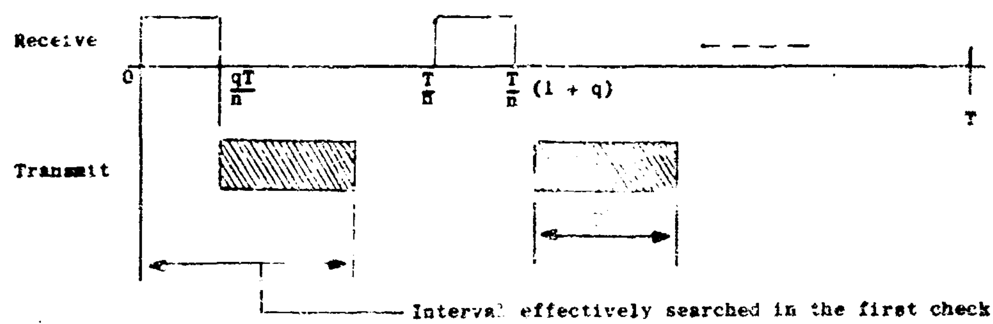

FIG. C-3 ACTIVITY DIAGRAM FOR SINGLE TRANSMISSION MODEL

The probability of a miss is $P_{M1} = 1 - P_{D1}'$. Since a miss on the first check implies that the signal was not up for an interval $(p + q/n)\,T$, the range of possible signal locations for the second check is less than the full interval T by that amount (see Fig. C-3). Hence, during the second sub-interval, the probability of detection given a miss in the first check is

$$P_{D2|M1} = \frac{p + q/n}{1 - (p + q/n)} = 1 - P_{M2|M1}$$

The probability of a miss on both the first two checks is

$$P_{M1M2} = P_{M2|M1} \cdot P_{M1} = 1 - \left[\frac{p + q/n}{1 - (p + q/n)}\right]\left[1 - (p + q/n)\right] .$$

Similarly the probability of at least one detection in T is one minus the probability of n successive misses, or

$$P_D' = 1 - \prod_{K=1}^{n}\left[1 - \frac{(p + q/n)}{1 - (K-1)(p + q/n)}\right] = 1 - \prod_{K=1}^{n}\left[\frac{1 - K\,(p + q/n)}{1 - (K-1)(p + q/n)}\right]$$

$$= np + q \quad .$$

While either of these expressions can be used as deemed appropriate for the situation, the first has been implemented in the model. To implement the second would require only a minor change in the program. Both show that while the probability of detecting a specific emitter at a particular time may be low, it increases with the number of independent checks made. The multiple transmission model shows that the probability of detection is unity for $q \geq 1 - p$, while the single transmission model requires q ≥ 1 - np for this limit; these limiting cases provide some guidance for intercept system design.

In the case of emitters that transmit at regular intervals, such as most radars, synchronization between the activity pattern and a periodic receiver search pattern can occur.* In the preceding models we assume that the receiver checks each frequency long enough each time so that this effect is eliminated.

It should be noted that in a particular scenario under study, specifying the number of emitters or nets to be monitored and the fractional coverage of each determines the number of receivers (monitoring positions) needed. This number must be compatible with realistic TOE limits for the situation and time frame considered.

In using either of the models described above, the necessary factors are specified by the user for each emitter and the probability of detection is calculated. This value is compared with a random number selected from a group of uniformly distributed random numbers, and if the probability of detection is less than the random number drawn, this emitter is judged detected in the simulation if it is hearable at the receiver in question.

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* This effect is analyzed in detail in several publications, including P. H. Enslow, Jr., "Some Techniques for the Analysis of Intercept Probability in Intercept Receivers," TR No. 516-1, Stanford Electronics Laboratories, Stanford, Calif., 4 June 1959, UNCLASSIFIED.

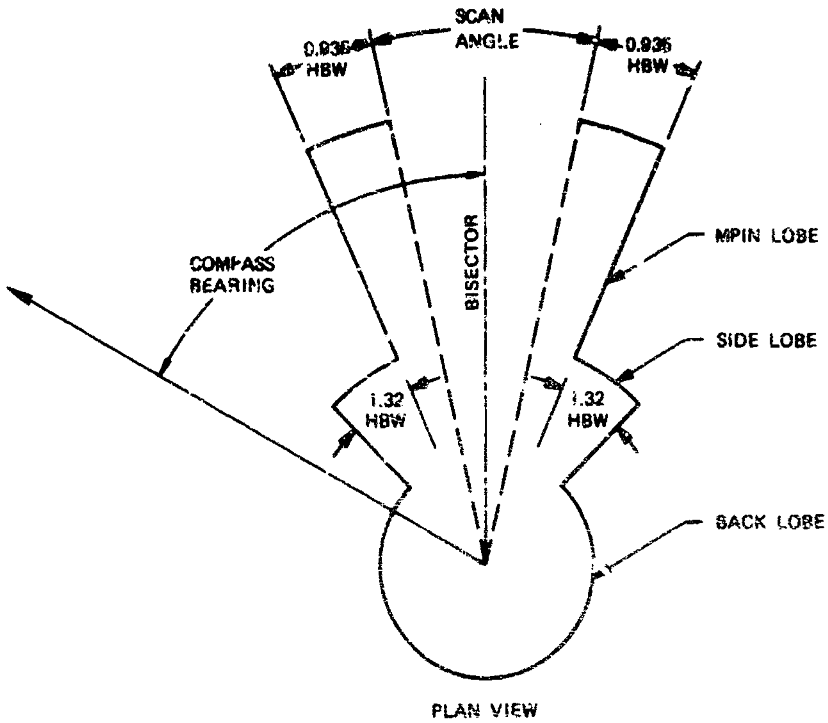
III ANTENNA PATTERN CHARACTERISTICS

The CRESS-S program develops a generic antenna radiation pattern which is used for generating all the sensor and emitter antenna patterns in the array. The detailed antenna descriptions are obtained from SIGINT sensor and target input data descriptions. In addition there is an antenna file where 11 generic type antennas are described. In this manner emitter and sensor antennas, HF through microwave, from whips to dishes can be simply modeled.

Figure C-4 shows the generic antenna pattern and defines the various antenna parameters. The plan view of the generic radiation pattern includes the scan angle (for the case of a sector scan antenna) as well as the compass bearing of the antenna mean scan angle. In this program, it is assumed that in the vertical plane the elevation angle of the main, side, and back lobes are 90 degrees, starting from the surface.

For the case of HF antennas, the antenna parameters generally assume the horizontal beamwidth as 360 degrees, thus removing backlobe, sidelobe, scan angle, and antenna bearing angles.

For the microwave antennas operating in the sector surveillance mode, it is tacitly assumed that the search time of the sensor is much longer than the scan rate of the emitter; thus the effect is to increase the horizontal beamwidth of the antenna by summing the scan angle. For the case of a microwave antenna scanning 360 degrees (such as a sensor antenna), the radiation pattern is assumed to be a hemisphere with antenna gain equal to the mainlobe gain, with the sidelobe and backlobes eliminated.



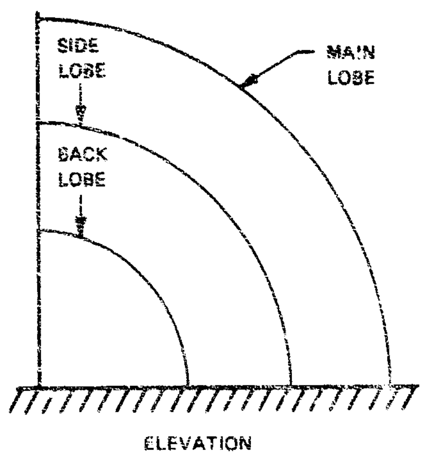


FIG. C-4 GENERIC ANTENNA PATTERN

Inputs from three decks of cards define the antenna characteristics for a given sensor/emitter path calculation. These are: emitter cards, sensor cards, and target cards.

IV PROPAGATION EQUATIONS

A. General

The electromagnetic propagation model used in this program is essentially the same model used in the ACCESS program (ASA Computer Controlled Environmental Simulation System) developed by HRB-Singer, Inc. and reported in Ref. 1. The propagation model is designed to provide rapid estimates of basic transmission loss referred to free space isotropic transmitting and receiving antennas. The radio frequency range of the model lies between 0.1 MHz and 40,000 MHz; transmission loss is computed for propagation path lengths up to 500 km and for stationary antenna altitudes up to 100,000 feet.

Because of differences between dominant propagation mechanisms at different radio frequencies and path lengths, the model has been divided into five frequency-distance (F-D) domains. Since the frequency boundaries selected for these five domains are constant values, this chapter has been divided into three major frequency regions on the basis of general propagation mechanisms. Within these frequency regions, the models are further divided and discussed according to additional frequency criteria and path length or distance criteria.

The five frequency-distance (F-D) domains are labeled below:

Domain	I	Near-shadow and line-of-sight region	0.1 to 60 MHz
Domain	II	Transition shadow region	0.1 to 30 MHz
Domain	III	Far-shadow region	0.1 to 60 MHz
Domain	IV	Skywave region	3.0 to 30 MHz
Domain	V	Microwave region	60 to 40,000 MHz

Figure C-5 is a graphic representation of the five frequency-distance (F-D) domains used for groundwave and obstacle diffraction modes of propagation, while the domain used for the ionospheric skywave mode of propagation is shown between the broken lines. The various model domains are labeled with roman numerals and are discussed below to indicate the assumed propagation mode of each F-D domain.

B. Ground Wave Propagation in the 0.1 to 60 MHz Band

1. Free Space Basic Transmission Loss

The free space loss, L_{bf} in dB, referred to loss less isotropic transmitting and receiving antenna gains can be written:

$$L_{bf} = 32.45 + 20 \log_{10} F + 20 \log_{10} D \qquad (1)$$

where

L_{bf} = Free space loss in DB

F = Frequency in MHz

D = Path length in km.

2. Domain I, Line-of-Sight and the Near-Shadow Region

In the first frequency-distance domain, the frequen[illegible]es between the constant values, 0.1 MHz $\le F \le$ 60 MHz. Propa[illegible] p[illegible]h lengths are in the line-of-sight and near-shadow regions from the transmitter between zero and a variable maximum distance depending on frequency, 0 km $\le D \le 80/F^{1/3}$ km. The mode of propagation in domain I is the groundwave, which is composed of two space waves--one direct and one ground reflected--plus the Norton (Refs. 2-7) surface wave. The equations adopted for this and the remaining two groundwave domains (II, III) are general with respect to the conductivity and dielectric constant, wave properties of a smooth earth, while the relative magnetic permeability of the earth is assumed to be unity.

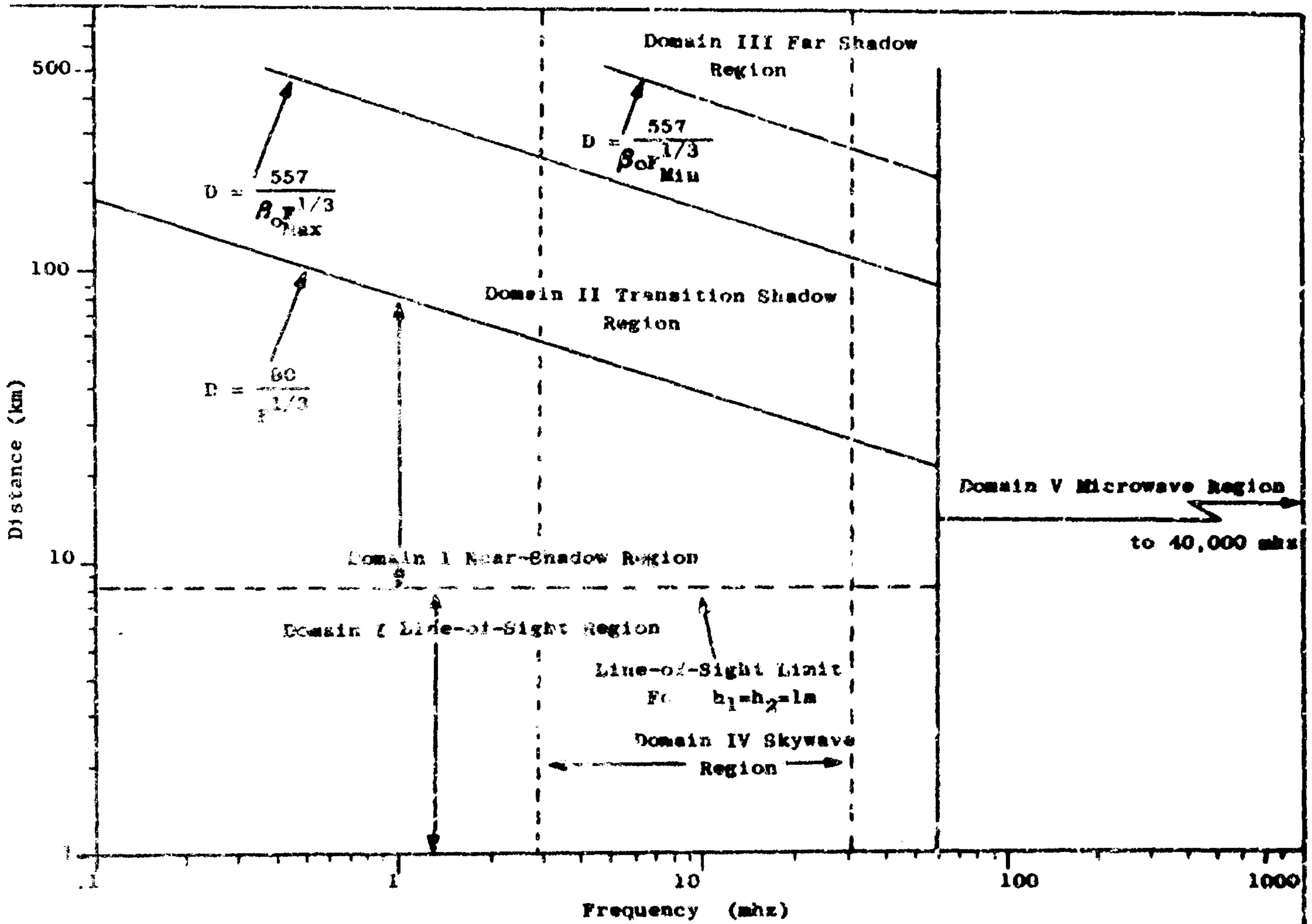


FIG. C-5 FREQUENCY-DISTANCE DOMAINS OF PROPAGATION MODEL

Some antennas may be carried by airborne platforms;* therefore, the upper limit of antenna heights, h, in all domains has been fixed at 100,000 feet, or expressed in terms of meters, $0 \leq h \leq 30,480$ meters. Since antenna heights may reach this order of magnitude, the possibility also exists that a modified distance formula different from $D < 80/F^{1/3}$ can be applied to find the maximum range of applicability for the loss equations used in domain I. The additional criteria is radio horizon distance. Since radio horizon distance is not frequency dependent, this height-dependent limit cannot be placed on Fig. C-5 in the form of a single line depicting the general case. Such data would appear as a family of lines, each line representing a specific combination of transmitter and receiver antenna heights. Nevertheless, the new general distance range can be restated to account for the dual criteria of frequency and antenna heights as follows:

$$0 \leq D \leq \text{Maximum}\left(\frac{\sqrt{2\,ka}}{1000}\left(\sqrt{h_1} + \sqrt{h_2}\right),\ \frac{80}{F^{1/3}}\right)$$

where

k = 4/3, earth radius correction factor to account for refractive bending of radio rays in the lower atmosphere

a = nominal earth radius, (6,370,000 meters)

h_1 = height of transmitting antenna above ground (meters)

h_2 = height of receiving antenna above ground (meters)

---

* Note that the present simulation model includes elevated antennas, but plays them as stationary emitters and/or sensors.

D = distance between transmitter and receiver antennas (km)

F = frequency (MHz)

The line-of-sight region is treated in the conventional manner, with the smooth spherical earth being modeled by a plane earth having the same conductivity and dielectric constant. However, the magnitude of the plane earth losses is obtained from a new simple empirical relationship in a real variable. This new function reproduces within necessary engineering accuracy the magnitude of the classical theoretical function (within about 1 dB). The theoretical function which has been replaced is the well-known flat earth loss function

$$f(P,B) = \left| 1 + j \frac{2\sqrt{Pe^{jB}}}{e^{Pe^{jB}}} \int_{-j\sqrt{Pe^{jB}}}^{\infty} e^{-u^2}\, du \right|$$

where the parameters are defined following eq. 5.

For the region of the near shadow, which lies beyond the radio horizon but extends only to a classical range of $D = 80/F^{1/3}$ km from the transmitter, the propagation model uses only the magnitude of the Norton surface wave expression. As before, the new empirical relationship for the magnitude of these plane earth losses is used in place of the more complicated theoretical expression.

The basic transmission loss over a plane finitely conducting earth is calculated as follows:

a. The basic plane earth losses, L_{bp} in dB, are found by adding to the basic free space loss, L_{bf}, the plane earth loss in excess of free space loss, L_{pe}. That is,

$$\begin{pmatrix}\text{Plane}\\ \text{earth}\\ \text{loss}\end{pmatrix} = \begin{pmatrix}\text{Free}\\ \text{space}\\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Plane earth loss}\\ \text{in excess of}\\ \text{free space}\end{pmatrix}$$

$$L_{bp} = L_{bf} + L_{pe} \quad (2)$$

where

$$L_{pe} = -20 \log \left| \frac{E_{pe}}{E_f} \right| \quad (3)$$

E_{pe} = Plane earth signal intensity

E_f = Free space signal intensity

$$\frac{E_{pe}}{E_f} = 1 + J\, Re^{-j\theta} + (1 - R)\, f(P, B)\, e^{-j\theta} \quad (4)$$

where

$Re^{-j\theta}$ = Complex reflection coefficient

$$R_V = R = \frac{\bar{E}_R}{\bar{E}_i} = \frac{(\epsilon - jx)\sin\psi - \sqrt{\epsilon - 1 - jx}}{(\epsilon - jx)\sin\psi + \sqrt{\epsilon - 1 - jx}} \quad \begin{pmatrix}\text{For vertical}\\ \text{polarization}\end{pmatrix}^*$$

x = $60\,\sigma\lambda$

ψ = Grazing angle

$\bar{E}_R$ = Reflected field strength

---

* The present simulation treats all emissions for domains I, II, and III as being from a vertically polarized electromagnetic wave. This limitation also exists in the ACCESS model.

$\overline{E}_i$ = Incident field strength

θ = Spatial phase lead of $\overline{E}_R$ relative to $\overline{E}_i$ at the point of incidence on the boundary surface.

ϵ = Dielectric constant of the earth

σ = Conductivity of the earth in mho/meter

b. For normal plane earth geometry

$$\left.\begin{aligned} J &= 1, \\ \theta &= \frac{4\pi h_1 h_2}{d\lambda}, \\ \text{and} \quad \tan\psi &= \frac{h_1 + h_2}{d} \end{aligned}\right\} \text{when } \frac{h_1 + h_2 - \frac{d^2}{2\,ka}}{d} \leq \sqrt[3]{\frac{\lambda}{2\pi ka}} = \frac{.01778}{F^{1/3}}.$$

c. Modified spherical earth geometry for long paths and high antennas.

$$\left.\begin{aligned} J' &= \frac{1}{\sqrt{1 + \dfrac{2\,d_1 d_2}{kad\,\tan\psi'}}} \\ \theta' &= \frac{4\pi\left(h_1 - \dfrac{d_1^{\,2}}{2\,ka}\right)\left(h_2 - \dfrac{d_2^{\,2}}{2\,ka}\right)}{d\lambda}, \end{aligned}\right\} \text{when } \frac{h_1 + h_2 - \frac{d^2}{2\,ka}}{d} > \frac{.01778}{F^{1/3}}$$

and $\tan\psi = \tan\psi'$

$$\tan \psi' = \frac{h_1 - \frac{d_1^2}{2ka} + h_2 - \frac{d_2^2}{2ka}}{d} = \frac{h_1 - \frac{d_1^2}{2ka}}{d_1} = \frac{h_2 - \frac{d_2^2}{2ka}}{d_2}$$

$$= \frac{\left(h_1 + h_2\right) - \left(d_1^2 + d_2^2\right)/2ka}{d}$$

where Fig. C-6 shows the normal plane earth geometry, while Fig. C-7 shows the modified geometry of ψ', d_1 and d_2 for the long distance high antenna combinations.

h_1	=	Transmitter antenna height in meters
h_2	=	Receiver antenna height in meters
λ	=	Free space wavelength in meters
d	=	Path length in meters, D = path length in km
f(P, B)	=	Plane earth surface wave attenuation function

$$f(P, B) = \left[\frac{.793}{P^{.0274}}\right] \left[\frac{1}{1 + 1.5446\ P^{.9168} - f_1(P, B)}\right]^{1.0609} \quad (5a)$$

where

$$f_1(P, B) = \frac{\left[1 - \frac{2}{\pi} B\right] \left[P^{.4771}\right] \left[1 + 3.179\ P^{1.3993}\right]^{0.1721}}{\left[1 + .003013\ P^{2.9778}\right]^{.6717}} \quad (5b)$$

and

$$Pe^{jB} = \frac{4pe^{jb}}{(1 - R)^2} = \text{Relative surface wave field}$$

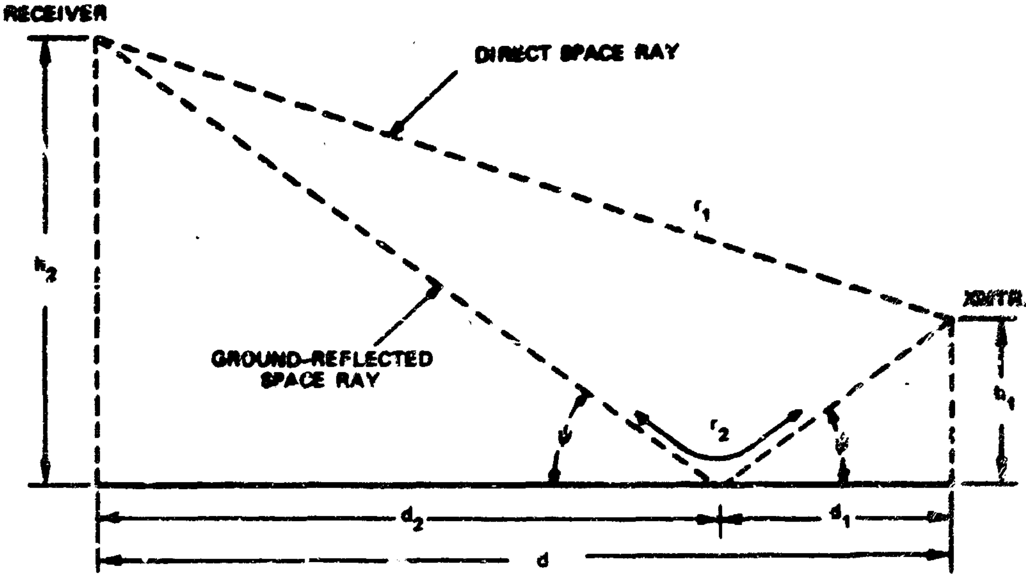


FIG. C-6 GEOMETRY FOR PLANE EARTH CALCULATIONS

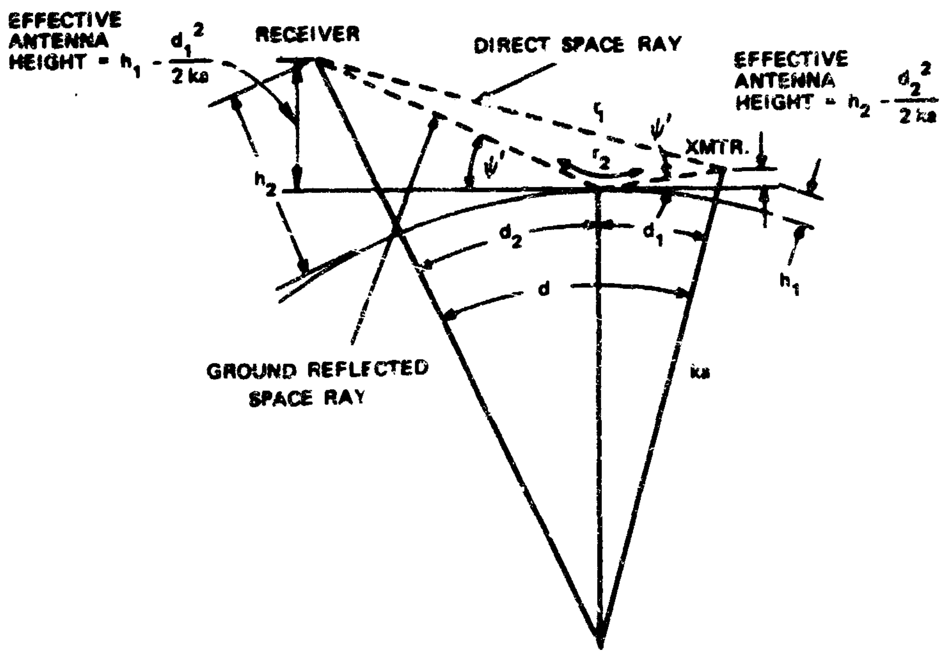


FIG. C-7 GEOMETRY FOR SPHERICAL EARTH CALCULATIONS AT POINTS WITHIN THE LINE-OF-SIGHT

$$\therefore \quad P = \frac{4p}{(1-R)^2}, \quad B = b$$

where

$$p = \frac{\pi d}{\lambda}\left[\frac{1}{L^2}\right] = 10.472\,\frac{fD}{L^2}$$

$$L = \sqrt{\frac{\epsilon^2 + x^2}{\sqrt{(\epsilon - 1)^2 + x^2}}}$$

$$b = \mathrm{Tan}^{-1}\left[\frac{\epsilon + 1 + (\epsilon-1)\left(\frac{\epsilon^2}{x}\right)}{x + (\epsilon-2)\left(\frac{\epsilon}{x}\right)}\right]$$

The above expressions are employed for the estimation of average* plane earth losses when the line-of-sight between transmitter and receiver is unobstructed by the bulge of the smooth spherical earth or by rough terrain. That is:

$$D \le 4.122\,(\sqrt{h_1} + \sqrt{h_2})$$

---

* The term average is used here in the sense of an average taken over a spatial selection of points in the vicinity of the receiver.

and

$$H' < \frac{D^2}{17} \quad = \quad \text{unobstructed line-of-sight}$$

where H' is the corrected line-of-sight clearance altitude. The derivation of H' is covered in Sec. II of this appendix.

Within this line-of-sight region of domain 1, the term J becomes less than unity only for large distances combined with large heights. J accounts for the added divergence of rays reflected from a sphere, compared with rays reflected from a plane. For the same large height-distance combinations,

$$\frac{h_1 + h_2 - \frac{d^2}{a}}{d} > \frac{.01778}{F^{1/3}}$$

ψ' is used in place of ψ to account for the difference in grazing angle between the spherical earth and the plane model.

When the path length lies beyond the radio horizon distance, but less than $80/F^{1/3}$ (km), the plane earth loss function simplifies considerably into the near-shadow function. Thus, in this range of distances,

$$4.122\ (\sqrt{h_1} + \sqrt{h_2}\ ) < D \leq \frac{80}{F^{1/3}}\ \text{(km)}$$

and

$$0 < H' < \frac{D^2}{17}$$

one finds that $L_{pe} \rightarrow L_{ps}$ = plane earth surface wave loss in excess of free space. Since the direct and ground reflected rays are blocked by the bulge of the earth, eq. 4 reduces in the new case to a single surface wave term.

$$R = -1, \; Pe^{jb} = pe^{jb} \quad ,$$

and the phase angle θ can be disregarded. Thus,

$$L_{ps} = -20 \log_{10} \left| \frac{E_{ps}}{E_f} \right|$$

E_{ps} = Field intensity of the plane surface wave

$$\frac{E_{ps}}{E_f} = 2\, f\, (p,b) \qquad (6)$$

with

$$f(p,b) = \left[\frac{.783}{p^{.0274}} \right] \left[\frac{1}{1 + 1.5446p^{.9168} - f_1(p,b)} \right]^{1.0609} \qquad (7)$$

where

$f_1(p,b)$ is defined functionally by 5b

where p and b are given with eq. 5. That is, eq. 7 is given for a zero-height antenna system, $h_1 = h_2 = 0$. In order that this same zero-height relation can be used to estimate losses for near-shadow heights, $h < 0$, a height-gain factor, f(q), is used for each antenna and is multiplied into the zero-height value obtained from eq. 7. Therefore, the basic near-shadow loss becomes:

$$\begin{pmatrix}\text{Near}\\ \text{shadow}\\ \text{loss}\end{pmatrix} = \begin{pmatrix}\text{Free}\\ \text{space}\\ \text{loss}\end{pmatrix} - \begin{pmatrix}\text{Excess of free-space}\\ \text{shadow loss}\end{pmatrix}$$

$$L_{bn} = L_{bf} - 20 \log_{10} \frac{E_{pn}}{E_f} \qquad (8)$$

where E_{pn} = Plane earth approximation of the near-shadow loss.

$$\frac{E_{pn}}{E_f} - 2 f(p,b) [f(q_1)] [f(q_2)] \qquad (9)$$

where

$$f(q) = \sqrt{1 + q^2 - 2q \cos\left(\frac{\pi}{4} + \frac{b}{2}\right)} \qquad (10)$$

where $q = 2\pi h/\lambda L$; b and L are defined in eq. 5.

3. Domain II, Transition-Shadow Region

The second frequency-distance domain lies between the wave frequency limits 0.1 MHz $\leq F \leq$ 60 MHz. Propagation path lengths lie between limits maximum

$$[4.122(\sqrt{h_1} + \sqrt{h_2}),\ 80/F^{1/3}] < D \leq 557\ 3/\beta_o F^{1/3}$$

(km) where β_o lies between limits $.681 \leq \beta_o \leq 1.607$ depending on F, σ, and e, and is defined in more detail later. The propagation mode of domain II is the groundwave and is composed of the Norton surface wave. This domain is commonly called the transition-shadow region. This name has foundations in the mathematics of the theoretical solution. That is, the transition-shadow region extends over the range of distances where no simple theoretical expression has yet been found to yield numerical results with a minimum of calculation effort. It extends between the two regions (near and far shadow) where simpler asymptotic solutions do exist.

The transition-shadow region is treated by a new empirical relation that provides numerical results for a zero-height antenna system compatible with the accuracy of Norton's (Ref. 2) classic graphical method of 1941.

The basic transmission loss for the spherical earth is calculated as follows:

a. As shadow distance increases beyond the useful range of the plane earth approximation, the region of the transition-shadow and of the far-shadow are found. In the transition-shadow region a smooth empirical function is used to find the spherical earth loss.

b. The form of the basic transition-shadow loss is

$$L_{bt} = L_{bf} + L_{st} \tag{11}$$

L_{st} = spherical earth transition-shadow loss in excess of free space

$$L_{st} = -20 \log_{10} \frac{E_{st}}{E_f}$$

$$\frac{E_{st}}{E_f} = \left\{ \frac{1.05\sqrt{l}}{p^m} \left[\frac{1}{1 + \left(\frac{1.24}{m + .45}\right)\left(\frac{p}{p_1}\right)^{3.83}} \right]^{.2611 l} \right\} [f(q_1)][f(q_2)] \tag{12}$$

where

$$P_1 = \left[\frac{s}{1}\right]^{\frac{1}{\ell}}$$

$$\ell = n - m$$

$$m = .0274 + \frac{p_o^{.9168} + \left[1.0609 f_1(p_o, b)\right] \cdot m_o}{\left[1 + 1.5446 p_o^{.9168} - f_1(p_o, b)\right]}$$

$$m_o = \frac{.006026 p_o^{2.9777}}{1 + .003013 p_o^{2.9777}} - \frac{.7656 p_o^{1.3993}}{1 + 3.179 p_o^{1.3993}} - .4771$$

$f_1(p_o, b)$ is defined functionally in eq. 5b.

$$p_o = \frac{.26487}{K^2}$$

$$b = \arc\tan\left[\frac{\epsilon + 1 + (\epsilon - 1)\left(\frac{s}{x}\right)^2}{x + (\epsilon - 2)\left(\frac{\epsilon}{x}\right)}\right]$$

$$p_s = \frac{\pi D}{\lambda}\left(\frac{1}{L^2}\right)$$ where L = (see eq. 19)

K = (See eq. 18)

$$n = 3.1905$$

$$\beta_o = \text{(See eq. 17)}$$

$$p_2 = \frac{28.247\gamma}{\beta_o^{4.1906} K^{6.3611}}$$

$$\gamma = \text{(See eq. 16)}$$

$$p_1 = p_o^{n} \left[\frac{1.586}{p_o^{.0274}}\right]\left[\frac{1}{1 + 1.5445\, p_o^{.9168} - f_1(p_o, b)}\right]$$

$$f(q) = \text{(See eq. 10)}$$

4. Domain III, Far-Shadow Region

a. The third F-D domain lies between the frequency limits 0.1 MHz $\leq F \leq$ 60 MHz. Propagation path lengths lie beyond the limit

$$D > 557.3/\beta_o F^{1/3}$$

(km) where β_o lies between the limits $.681 \leq \beta_o \leq 1.607$, depending upon F, σ, and ϵ, and is defined in more detail later.

b. The propagation mode of domain III is the ground-wave which, in this region, is composed of the Norton surface wave. The asymptotic exponential form for field strength in this far-shadow region is used to calculate the basic system loss.

The form of the basic deep-shadow (far-shadow) loss is

$$L_{bd} = L_{bf} + L_{sd} \qquad (13)$$

L_{sd} = Spherical earth deep-shadow loss in excess of free space

$$L_{sd} = -20 \log_{10} \frac{E_{sd}}{E_f} \tag{14}$$

$$\frac{E_{sd}}{E_f} = \left\{ 6.7888\gamma \cdot \sqrt{\frac{F^{1/3}D}{\beta_o}}\ e^{-.006622\beta_o F^{1/3} D} \right\} [f(q_1)][f(q_2)] \tag{15}$$

where the terms γ and β_o originate from the classical theoretical solution involving the sum of the Watson residue series. However, simple empirical relations have been found for these parameters in the variable K, neglecting their small dependence upon b, as follows:

$$\gamma = \frac{.07618K^2}{\left[1 + 19.05K^{6.578}\right]^{.3040}} \tag{16}$$

$$\beta_o = (1.607)\frac{\left[1 + 2.253K^{2.843}\right]^{.3517}}{\left[1 + 47.74K^{3.461}\right]^{.2889}} \tag{17}$$

while

$$K = \sqrt[3]{\frac{\lambda}{2\pi ka}}\,(L) = \frac{.01778L}{F^{1/3}} \tag{18}$$

$$L = \sqrt{\frac{\epsilon^2 + x^2}{\sqrt{(\epsilon - 1)^2 + x^2}}} \tag{19}$$

5. <u>Terrain Obstacle Losses for Groundwave Domains I, II, and III</u>

a. A mechanism for estimating system loss over rough earth (Refs. 12-20) has been incorporated in the propagation model. When the path line-of-sight is obstructed by terrain, a simple obstacle loss term is added to the plane earth loss function as an estimate of total losses. This obstacle loss term is proportional to the half-power of the electrical height, $2\pi H'/\lambda$, of the obstacle above line-of-sight level. When $H' > D^2/17$, the program will select the obstacle path formula, which yields generally greater losses at the shorter path lengths, and lesser losses at longer path lengths than would be estimated by the spherical earth formulas discussed earlier. This is true because the obstacle path formula is composed of the free space loss plus the plane earth loss plus the obstacle loss. Therefore, at some point in the transition region and beyond, it is expected that spherical earth losses would generally exceed the obstacle loss plus the plane earth loss, and the model would thus favor the obstacle formula when $H' > D^2/17$. This H'-D limit would override the normal shift from plane to earth to transition or shadow spherical earth formulas at the usual F-D limits discussed earlier.

b. The basic transmission loss for the plane earth path with a terrain obstacle is calculated as follows. When the height of the terrain exceeds the height of the line-of-sight ray by an amount H' which is larger than twice the bulge height of the smooth spherical earth, the path is classified as a plane earth path with a terrain obstacle. That is, the condition

$$H' > \frac{D^2}{17} \quad ,$$

where H' is in meters and D is in km, defines the H'-D domain of the terrain obstacle path for the $0.1 \text{ MHz} \leq F \leq 60 \text{ MHz}$.

The basic transmission loss for this type of path, like the near-shadow path, is much simpler than for the line-of-sight region. The total basic loss for the obstacle path becomes the basic free space loss L_{bf}, plus the plane earth loss, L_{pe}, plus the terrain obstacle loss L_{to}.

$$\begin{pmatrix}\text{Total}\\ \text{basic}\\ \text{loss}\end{pmatrix} = \begin{pmatrix}\text{Free}\\ \text{space}\\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Plane}\\ \text{earth}\\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Terrain}\\ \text{obstacle}\\ \text{loss}\end{pmatrix}$$

$$L_{bo} = L_{bf} + L_{pe} + L_{to} \quad . \quad (20)$$

However, since the line-of-sight path is obstructed, both the direct and ground reflected rays are eliminated from eq. 4. In addition, even the surface wave term can be further simplified by setting $R = -1$, $P = p$, $B = b$, and by disregarding the phase angle θ. Therefore,

$$L_{pe} \rightarrow L_{ps} = \text{Plane surface wave loss in excess of free space}$$

$$L_{ps} = -20 \log_{10} \frac{E_{ps}}{E_f}$$

$$E_{ps} = \text{Plane surface wave field intensity}$$

$$\frac{E_{ps}}{E_f} = 2\, f(p,b) \quad (21)$$

where

$$f(p,b) = \left[\frac{.793}{p^{.0274}}\right]\left[\frac{1}{1 + 1.5446\,p^{.9168} - f_1(p,b)}\right]^{1.0609} \quad (22)$$

where $f_1(p,b)$ is defined functionally in eq. 5b. The terrain obstacle loss becomes

$$L_{to} = .075\sqrt{H'F} \quad (23)$$

where H' is the terrain height (in meters) in excess of the height of the line-of-sight ray as derived in Sec. II, of this appendix.

6. Foliage Losses for Groundwave Domains I, II, and III

Foliage losses are treated by a simple empirical function relating the attenuation per meter of screen thickness resulting from the propagation of radio waves through a wooded screen path lying between the receiver and transmitter. The information yielding this relationship has been compiled from various literature sources (Refs. 8-12).

An examination of the literature on the problem of foliage loss has yielded a useful exponential relation for expressing the foliage loss in excess of free space and other independent factors, as a function of frequency and distance.

$$L_{fl} = .00139dF^{.767} \quad (24)$$

where F is the frequency in MHz and d is the sum of the path lengths in meters through the foliage screen between a given emitter/sensor path. The sum d is obtained at the same time manual map work is being performed to record the terrain obstruction data which is to be used for line-of-sight calculations elsewhere in the program. These input data are recorded in the path card deck.

7. HF Ionospheric Skywave Propagation, Domain IV

The fourth F-D domain of the propagation model lies between the frequency limits of 3 MHz and 30 MHz. However, it should be pointed out that these limits could be extended from 2 MHz to 50 MHz as the mathematics used are sufficiently accurate for this simulation to operate between these wider limits, if desirable. The mode of propagation in this domain is the ionospheric skywave. The methods for estimating skywave path loss over distance ranges to 500 km have been taken from the latest empirical methods used in modern computer routines (Refs. 13,14). Because of the shorter distances and time durations normally encountered in tactical warfare and therefore desired for the present program, new and simpler relations could be adopted in place of the more general relations used in these references. This simplification can be studied in subsequent follow-on simulation studies. In general, either a single-hop E-layer or a single-hop F-layer mode is possible from the routine.

Basic methods for graphically determining the probable path losses for HF ionospheric transmission paths have been well known for many years (Refs. 15, 16), but these methods are not suitable for direct utilization in a computer simulation program. Numerical methods for predicting these path losses have been developed recently; two somewhat similar computer schemes have been programmed to perform these computations (Refs. 13, 14). However, both of these programs are, general purpose routines which include provisions for computation of expected losses and other pertinent parameters of world-wide, 24-hour, multi-hop paths. These programs require an excessive amount of space and computing time per path to be incorporated directly into this simulation.

a. Program Simplification

There are two characteristics of this simulation program which permit a significant reduction in the complexity of the HF path-loss routine. These are

(1) with few exceptions, all path terminal points are located within a geographical area with a maximum dimension of about 500 km, and

(2) the time interval of interest for any single simulation should not overlap the sunrise/sunset transition interval. An approximate two-hour interval should be allowed for these transition times where the simulation results will be of insufficient validity for ionospheric propagation performance. This is not true for the other four domains of propagation in this simulation.

With these limitations in geographical area and time period, a number of parameters which normally are variables in the path loss equations may be regarded as fixed parameters in the main computing routine. These parameters must be precomputed or determined graphically, as desired, for each geographical area and time period and supplied as coefficients to the main simulation program.

To reduce the effects of fixing certain parameters, the center of the geographical area has been designated as the control point for all ionospheric paths between terminals within the region. Further, the time has been assigned as the mean time of the simulation period. The coefficients, together with a brief discussion of the probable effects of fixing the value for all paths within the area and time period of the simulation, are listed below:

- Sunspot Number (SSN). Time variation only; normally predicted as average or nonimal values for monthly periods. Short-term effects which might be significant for time periods of several hours, such as solar flares, are not considered in the present program.

- Sun Zenith Angle (ψ). Variation in time and geographical position, but effects are very small for an area and time period such as employed in the present simulation.

- Gyro Frequency (F_H). Maximum variation over the time/area being considered is on the order of ±0.1 MHz, which is within the probable error of prediction for future time periods.

- F-Layer Height (H_F). Maximum variation over time/area considered is normally less than about ±25 km, which is also within the probable error in prediction. Effects on computed path loss are on the order of 2 dB, maximum.

- F-Zero MUF ($F2_O$). Maximum variation for the areas considered is on the order of ±0.5 MHz, but will be less for many regions of the world. In general, the variation over the time/area of the simulation is within the probable error in prediction for future time periods. Possible resulting errors in path loss are on the order of 3 to 4 dB, maximum, with a possible error in the maximum propagated frequency of about 1.5 times the error in $F2_O$ for the path lengths involved.

b. Path-Loss Computing Procedures

(1) Basic Computing Procedures and Formulas

These were developed at NBS and the U.S. Army Signal Propagation Agency (Refs. 13, 15, 16). A priori data required for each simulation run and the formulas for path loss computation are listed in the following paragraphs.

(2) A Priori Data Required

The following data must be obtained from external sources (e.g., NBS programs or from CRPL prediction charts) and inserted in the program for each simulation run:

(a) LAT. Latitude of center of simulation area in degrees ($-90 < LAT \leq 90$)

(b) LON. Longitude of center of simulation area in degrees east of Greenwich meridian ($0 \leq LON < 360$)

(c) GMT. Mean time of simulation in GMT

(d) MON. Month of simulation ($1 \leq MON \leq 12$)

(e) $F2_o$. Zero distance F2 layer MUF, in MHz

(f) $F2_{3000}$. F2 layer--3000 km MUF factor, or

$F2_{4000}$. F2 layer--4000 km MUF, in MHz

(g) H_F. F2 layer virtual height, in km (if not supplied is set to a nominal value of 320 km)

(h) F_H. Gyro frequency at 100 km height in MHz (if not supplied, is set to a nominal value of 1.2 MHz)

(i) SSN. Sun spot number for date of simulation.

(3) Basic Path-Loss Formulae

(a) The total transmission loss (L) for a single-hop path neglecting focusing effects, may be expressed by

$$L = L_{bf} - A_T - A_R + A + P \qquad (25)$$

where

L	=	Total path loss, antenna terminal to antenna terminal, in dB
L_{bf}	=	Basic free-space propagation loss, in dB
A_T, A_R	=	Transmitting and receiving antenna gains, respectively, in dB reference isotropic
P	=	Loss, due to polarization, magneto-ionic splitting, etc., in dB
A	=	Nondeviative D-region absorption loss, in dB.

In the present program, antenna effects, A_T and A_R, are computed in the main body program, and only operating frequency (F, in MHz) and terminal-to-terminal ground distance (D, in km) will be supplied to the HF ionospheric path-loss subroutine. The total transmission loss computed in the subroutine will, therefore, be given by

$$L = L_{bf} + A + P \tag{26}$$

where symbols are as defined for eq. 27.

(b) When path length is specified in terms of actual ray path distances (RDIST, in km) the basic free-space propagation loss, L_{bf}, in dB, is given by eq. 1 where D now becomes RDIST (eq. 39).

(c) Mean values of absorpotion plus polarization and miscellaneous minor effects losses may be computed by use of the following expression:

$$A + P = \frac{615.5 \sec(\phi)[1.0 + (0.0037)(SSN)](\cos 0.881\psi)^{1.3}}{(F + F_H)^{1.98}} + 8.9 \tag{27}$$

where

A + P = Median value of absorption, polarization and minor effect losses in dB

ϕ = Angle between ray path and perpendicular to the earth at a 100 km height

SSN = Zurich sunspot number

ψ = Sun's zenith angle at ionospheric reflection point

F = Operating frequency, in MHz

F_H = Gyro frequency at 100 km height, in MHz.

The computed path loss between isotropic antennas is obtained from eq. 26, employing the results of eqs. 1 and 27. In the actual program approximations are employed for some of the factors of eq. 27 in order to reduce the space and computing time required.

(4) Miscellaneous Formulae

(a) In addition to the path loss, the radiation angle is also required for evaluation of antenna gains. Formulas for computing the cosine of this angle, coefficients required for the evaluation of eq. 27 above, and the E- and F-layer intermediate distance MUFs are listed below.

(b) The cosine of the sun's zenith angle (ψ), required for eq. 26 is computed from:

$$\cos \psi = [\sin (SLAT) \sin (LAT) + \cos (SLAT) \cos (LAT)] \times [\cos (15\ GMT - 180 - LON)] \quad (28)$$

where

LAT = Latitude of center of simulation area, in degrees

SLAT = Latitude of sun's subsolar point (supplied in preparatory program as table of coefficients--one per month)

LON = Longitude of center of simulation area, in degrees east of Greenwich meridian

GMT = Time of simulation, GMT hours.

(c) Both E- and F2-layer propagation modes are considered. If the E-layer will support propagation at the frequency-ground distance of the path, then the propagation loss and radiation angle for a single-hop E-layer path are computed and returned to the main body program. However, if the E-layer path is not available (frequency above E-MUF), and the F2-layer will support propagation, then the loss and radiation angle for the single-hop F2-layer path are computed and returned. Formulas for computing E- and F2-layer MUFs are as follows:

$$EMUF = M_E \, E_{2000} \tag{29}$$

where

EMUF = E-layer MUF, in MHz

M_E = MUF factor for E-layer

E_{2000} = 2000 km E-layer MUF, in MHz

and

$$M_E = 0.2085 + 0.12126481E\text{-}3(D) + 0.97618711E\text{-}11(D^2) - 0.60495454E\text{-}14(D^3) \tag{30}$$

where

D = Ground terminal-to-terminal distance, in km

$$E = E_{2000} = 3.345996 + 37.677361(I) - 52.411917(I^2) + 39.261511(I^3) - 10.66485(I^4) \tag{31}$$

where

$$I = \text{Absorption index}$$

$$= (1.0 + 0.0037SSN)\,(\cos 0.881\psi)^{1.3} \qquad (32)$$

$$= 0 \text{ for } |\cos 0.881\psi| \geq 90^{\circ}$$

(see eq. 27 for symbol definitions).

(d) A similar set of factors is employed for computing the F2-layer MUF for intermediate distances:

$$FMUF = M_F F2_o \qquad (33)$$

where

$FMUF$ = F2-layer MUF, MHz

M_F = F2 MUF factor

$$= 1.0 + (F_H/2F2_o)\,(1.0 - m) + m\,(F2_{3000} - 1.0) \qquad (34)$$

with

$$m = 0.21615813E - 5(D) + 0.15387001E-6\,(D^2) + 0.38728093E - 10(D^3) \qquad (35)$$

where

D = Ground terminal-to-terminal distance, in km.

(See eq. 31 for other symbol definitions.)

(e) When the $F2_{4000}$ MUF is supplied in lieu of the $F2_{3000}$ factor, the latter is derived from

$$F2_{3000} = (F2_{4000}\ MUF)/(1.1\ F2_o) \qquad (36)$$

(f) The cosine of the radiation angle (Δ; see Fig. C-8) and other factors required for eq. 28 are determined from the following expressions:

$$\cos^2 (\Delta) = \frac{\sin^2 (D/2r)}{1.0 + R^2 - 2R \cos (D/2r)} \qquad (37)$$

$$\sec (\phi) = \frac{1.0}{(1.0 - R^2 \cos^2 (\Delta))^{1/2}} \qquad (38)$$

$$RDIST = 2[h^2 + 2r (h + r)(1.0 - \cos (D/2r))]^{1/2} \qquad (39)$$

where

$$R = r/(r + h)$$

RDIST = Ray-path distance, in km.

(Other symbols as in Fig. C-8.)

8. Microwave Region, Domain V

a. The fifth F-D domain of the propagation model lies between the frequency limits of 60 MHz $\leq F \leq$ 10,500 MHz. Three possible types of propagation paths exist in this part of the model. The equations used to estimate path loss in this microwave region have been taken from an HRB-Singer, Inc., (Ref. 17) and were also used in the ACCESS simulation. In this study, empirical loss expressions derived from numerous sets of signal measurement data are presented. The three kinds of paths modeled are called

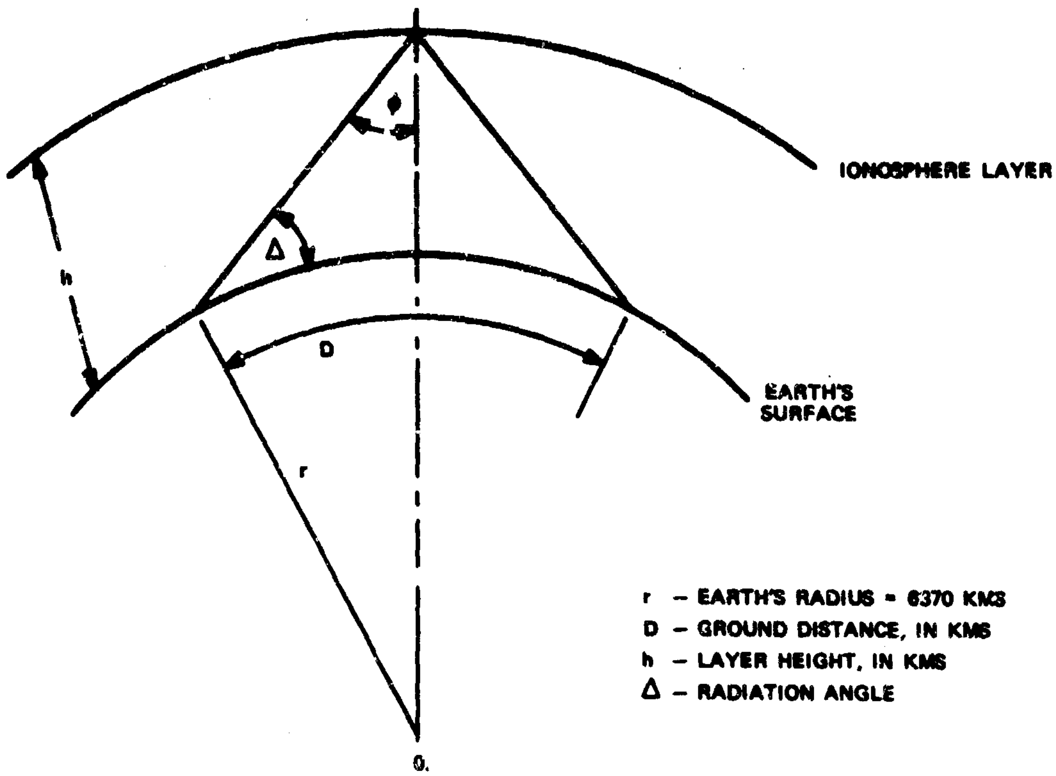


FIG. C-8 GEOMETRY OF IONOSPHERIC RAY PATH

(1) **Essentially Line-of-Sight Paths.** Defined as line-of-sight except for possible small obstructions near the transmitter antenna location (see Fig. C-9).

(2) **Single-Obstacle Paths.** As depicted in Fig. C-9.

(3) **Multiple-Obstacle Paths.** As depicted in Fig. C-9.

b. The basic transmission loss functions for the various kinds of paths are:

(1) Line-of-sight path

$L_{b\ell}$ = Basic line-of-sight path loss (dB)

$$L_{b\ell} = 23.0 + 30 \log_{10} F + 20 \log_{10} D \qquad (40)$$

(2) Single obstacle path

L_{so} = Basic single obstacle path loss (dB)

Let

$$A_s = 46.2 + 1070\left(\frac{H'}{D}\right) - 7500\left(\frac{H'}{D}\right)^2 + .00268\ (F) + 28.34 \log_{10}(F)$$

$$B_s = .879D - .00378D^2$$

$$C_s = .879\ (150) - .00378\ (150)^2 + 26 \log_{10}\ (D/150)$$

Then

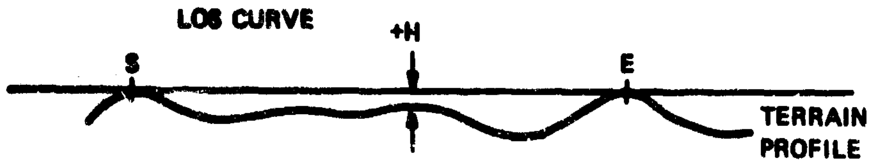
$$L_{so} = \begin{cases} A_s + B_s, & D \le 150 \text{ km} \\ A_s + C_s, & D > 150 \text{ km} \end{cases} \qquad (41)$$

(3) Multiple-obstacle path

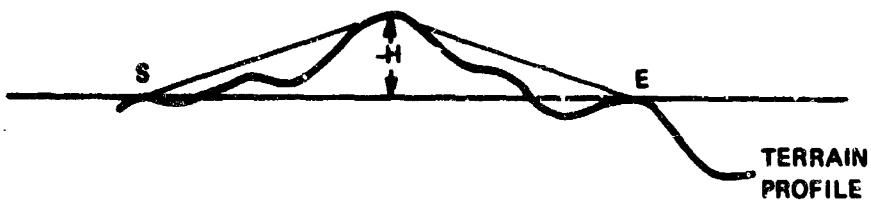
L_{mo} = Basic multiple path loss (dB)

Let

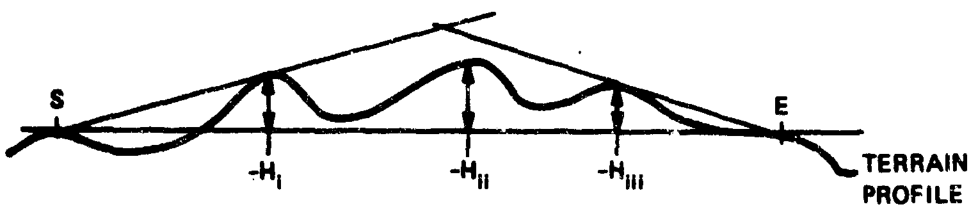
$$A_m = 119.9 + 287\left(\frac{H'}{D}\right) - 11000\left(\frac{H'}{D}\right)^2 + .00425(F) + 14.98 \log_{10}(F)$$



(a) LINE-OF-SIGHT (LOS) PATH



(b) SINGLE OBSTACLE PATHS



(c) MULTIPLE OBSTACLE PATH

E = EMITTER SITE

S = SENSOR SITE

H = HEIGHT OF OBSTACLE ABOVE LOS CURVE

FIG. C-9 CLASSIFICATION OF PROPAGATION PATHS

B_m = .541D - .00159 (D^2)

C_m = .541 (150) - .00159$(150)^2$ + 26 $\log_{10}$ (D/150)

Then

$$L_{mo} = \begin{cases} A_m + B_m, & D \leq 150 \text{ km} \\ A_m + C_m, & D > 150 \text{ km} \end{cases} \quad (42)$$

where

L = Total basic transmission loss in dB

F = Wave frequency in MHz

D = Path length in km

H' = Maximum obstacle height in km above 4/3 earth radius curve joining path terminals (see Sec. II of this appendix).

It should be noticed that for both the single and multiple obstacle equations that the last several terms are altered and added to for the crossover range of 150 km.

The determination of line-of-sight or number of obstacles in the path is made elsewhere in the simulation and is discussed in Sec. II of this appendix.

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13. ABSTRACT

This four volume final report for the development of a Combined Reconnaissance, Surveillance, and SIGINT Model (CRESS) contains a detailed description of the model, explicit instructions for using it, formats for the data, extensive lists of object and background characteristics, representative lists of sensor characteristics, and FORTRAN-IV listings of the computer programs. The description includes models for photography, IR, radar, visual, TV, PNVD, laser, and SIGINT sensors. These sensor models provide the core for the three major models (aerial, ground, and SIGINT) that constitute CRESS.

Methods of providing for the effects of navigation error, aircraft attrition caused by enemy ground AA weapons, attrition of ground observation posts, equipment failure, terrain masking, cloud coverage, vegetation coverage, camouflage, misrecognition and misidentification of target elements, false targets, multisensor interpretation, various report criteria, delay times for reports, and time ordering of reports and of grouping elements into possible area targets are also described. Instruction for the collecting, collating, and processing of the data necessary for running the computer programs are included, as are instructions for analyzing the computer output.

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Infrared						
Radar						
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Passive night vision devices						
Multisensor interpretation						
Timeliness						

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