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Final Report

COMBINED RECONNAISSANCE, SURVEILLANCE AND SIGINT MODEL (CRESS)

Volume I: Summary Description

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

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SRI

November 1968

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SRI Project 5205

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Operations Analysis Division

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Since the Department of the Army review and evaluation have not been completed, this report should not be considered as having Department of the Army approval either expressed or implied. Recipients will be provided a copy of the Army evaluation of this report when review and evaluation are completed.

PREFACE

The development of the combined reconnaissance, surveillance, and SIGINT model has been conducted under Contract DA-49-092-ARO-10 for the Combat Developments Command, Institute of Land Combat. Project support and coordination was provided by the Institute of Land Combat, with Major James Walling, Lieutenant Colonel James Cannon and Major Ellsworth Besemer consecutively assigned as Project Officers over the period from June 1967 to October 1968.

Lieutenant Colonel Cannon and Major Besemer of the Institute of Land Combat, Major Phillip Ware of the Combat Developments Command Intelligence Agency, and Mr. Harry Lum of Eyler Associates, Inc., prepared the scenario data and target data, and deployed the sensors for the exercise used to test the model.

The study effort was conducted by members of the Operations Research Department, Arthur C. Christman, Jr., and the Systems Evaluation Department, Ernest J. Moore, Manager. The Project Leader was J. Roland Payne. Principal team members for developing the submodels for the aerial and ground based collateral sensor systems were J. Roland Payne, S. Willard Elieson, Jr., and G. William Moseley. Joseph G. Rubenson, Carl D. Herold, and Barbara J. Ripple were the principal researchers for the SIGINT submodel. The object and background characteristics data in Appendix A were collected and collated by Patricia Jones. Harold A. Malliot wrote the Stanford Research Institute Technical Note ORD-TN-5205-15 on position location errors.

This final report consists of four volumes. Volume I presents a summary, recommendations, and brief description of the model. Volume II, the User's Handbook, presents a detailed description of the model and explicit directions for its use. Volume III is a FORTRAN IV listing of the computer programs. Volume IV is a small classified (SECRET) compendium of appendices containing sensor characteristics, and a discussion of combined usage of SIGINT and collateral sensor systems.

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 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. 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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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).

"A great part of the information obtained in war is contradictory, a still greater part is false, and by far the greatest part somewhat doubtful. What is required of an officer in this case is a certain power of discrimination, which only knowledge of men and things and good judgment can give. The law of probability must be his guide."

Karl von Clausewitz, "Vom Kriege," 1827

I INTRODUCTION

The development of the Combined Reconnaissance, Surveillance, and SIGINT (CRESS) model has provided an analytic tool for studying a major portion of what von Clausewitz referred to as "information obtained in war." In modern military terminology, the focus of the model is on tactical combat intelligence, with considerable emphasis on target acquisition. In addition to providing mathematical models of several types of surveillance systems and of various aspects of their operational employment, the model provides inputs for simulating the G2/S2 intelligence function manually. Exercising the computer and manual portions of CRESS together combines the effects of that "certain power of (human) discrimination" with quantitative aids for assessing the germane probabilities prevailing in the situation being studied.

During the 141 years since the writing of "Vom Kriege," substantial progress has been made in many of the technologies applicable to tactical warfare. With the notable exception of the visual systems, all of the reconnaissance and surveillance

(R & S) systems modeled in CRESS are products developed after World War I, and many of them were not developed until after World War II. Substantial research and development work continues to improve existing R & S systems and to evolve new ones. Equally important, the laws of probability are better understood and are more widely applied to military problems. Target location accuracies are now specified in probabilistic terms such as circular error probable (CEP) and standard deviation. Other measures of effectiveness for R & S systems include probabilities of detection (P_d), recognition (P_r), and identification (P_i). The relatively ancient ideas of the Kriegspiel (war game), introduced into the Prussian Army in 1824 (Ref. 1), are currently studied using methodologies that make abundant use of mathematical models of stochastic processes.

However, the improvements in weapon systems have more than kept pace with the development of the R & S systems and provide increasingly more devastating power delivered to known targets with increasing accuracy. Similarly, the logistic systems are quickly becoming more responsive to the tactical commanders' needs. Communications systems also continue to improve their already rapid, reliable, secure, and complete service. In combination, these technologies make it possible for the commander to respond quickly and decisively to any known target in his area of responsibility.

A primary problem is knowing about the target. Even today, as in von Clausewitz' time, "a great part of the information obtained in war is contradictory, a still greater part is false, and by far the greatest part is somewhat doubtful." Since a primary limiting factor on utilizing the other resources has become knowledge about the enemy, the conduct and outcome of tactical warfare depends more heavily than ever before on reconnaissance, surveillance, and intelligence. The improving R & S systems are capable of providing many more data about the enemy than before, but the scientific aids and methods for quickly ascertaining the true intelligence contained therein have not kept pace. For this reason continuing emphasis is being placed on the development of possible methods that will yield insight into the intelligence process. CRESS has been developed as a tool for studies that require accounting for the effects of reconnaissance, surveillance, and intelligence, as well as for those studies that are directly concerned with these overlapping topics.

This final report documents the development of an analytic model of the reconnaissance, surveillance, and intelligence functions in tactical warfare. The objective of Phase I has been to develop and evaluate an advanced analytic model of R & S systems suitable for use by U.S. Army Agencies engaged in war gaming, simulation and analysis of alternative ground-based and aerial reconnaissance systems, ammunition-expenditure studies, or other research/analytical efforts that involve target acquisition, reconnaissance, surveillance, and intelligence/tactical operations center functions.

The emphasis of this study has been on developing a model capable of accurately simulating the performance of R & S systems. The interface between R & S and the intelligence processing based on the data generated by the R & S systems was studied, and parts of it were modeled analytically. However, the model developed relies heavily on the intelligence specialist who will have to analyze the simulated R & S date.

Further developmental work is needed to emphasize the intelligence processing functions, resulting in a Combined Reconnaissance, Surveillance, and Intelligence model (CRESSI). The objective in developing CRESSI would be to provide a man-computer model capable of producing combat intelligence estimates (particularly for target acquisition) quantitatively based on the parameters describing the R & S collection means, but at the same time incorporating the flexibility necessary to allow for that "certain power of discrimination" that humans must provide.

CRESS itself is composed on three major submodels: CRESS-A for aerial sensor systems, CRESS-G for ground-based sensor systems, and CRESS-S for SIGINT sensor systems. The computer portions of these models run independently. The models for the non-SIGINT sensors, CRESS-A and CRESS-G, represent another stage in their simultaneous evolution at SRI. The original concepts, for ground-based conventional and SIGINT sensors, were developed in the SRI study, "Contribution of Ground-Based

Reconnaissance and Surveillance Systems to Tactical Reconnaissance (U)," 1965 (Ref. 2). Mathematical computer models were developed, in conjunction with Honeywell, Inc., Minneapolis, for the non-SIGINT aerial and ground-based sensors during the SRI portion of the TARS-75 study, 1966 (Ref. 3). Many aspects of the operational deployment of these sensors were programmed also. The R&S models for non-SIGINT sensor systems were developed further during the SRI study, "Systems Analysis of Advanced Target-Acquisition Systems (U)," 1967 (Ref. 4). Thus, the present models of CRESS-A and CRESS-G are based on the experience and methodologies attained in these previous studies; in particular, they are based on the parametric computer models for the following systems:

- Photo
  - Vertical frame
  - Side oblique
  - Forward oblique
  - Panoramic
- IR Line Scanners
- Side-looking airborne radar
- Visual
  - Eye
  - Binocular
- Laser
- Low-light-level television
- Passive night-vision devices
- Ground surveillance radar

CRESS-A and CRESS-G both require many of the same types of input data. Therefore, most of the manual data preparation work is done once, to be used by both computer models. The output formats are also very similar. In addition, the concepts used for sensor deployment are quite analogous: complementary ground sensors are deployed in groups in observation posts (OPs) while the airborne sensors are similarly deployed in aircraft. However, the simulation of the flight path presents considerations that are not used in CRESS-G. Because of the large areas of similarity between CRESS-A and CRESS-G, the sections of this report on CRESS-G often reference the corresponding development presented for CRESS-A.

The computer portion of the SIGINT model, CRESS-S, was developed at SRI under this study contract to replace some of the operations previously done manually. This development is based upon careful study of existing computer SIGINT models (Ref. 5 in particular) by senior professionals experienced in SIGINT. The SIGINT model used in CRESS covers the frequency range from 0.1 to 40,000 MHz and considers both communications and noncommunications emitters. It differs in several respects from other SIGINT models that are available:

1. A feature of this SIGINT model that is believed to be unique is the handling of detection probability on other than an emitter "on-off" basis. Other models calculate detection of an emitter on the assumption that it is transmitting during the entire time interval under study; that is, the detection calculation is really a hearability calculation. This model extends the concept and considers the activity patterns of the emitters in the target array and the operating procedures of the SIGINT sensors to come up with a more realistic calculation of the probability of detecting an emitter.

2. This SIGINT model differs from others in that a certain amount of work is done manually with the aid of a map on which the target elements and SIGINT sensors are deployed. In this way, the requirements for computer storage space and running time are appreciably reduced and the analyst has the advantage of remaining in closer touch with the scenario than he would if he were dealing exclusively with the computer inputs and printouts.

3. Since the fundamental aim of this SIGINT model is target acquisition rather than intelligence collection, a number of other differences between this and other models result. One of these is that this model includes an identification module that utilizes a simple logic to determine whether an emitter that has been detected is identified, and likewise whether the target that includes this emitter is identified.

At present, the SIGINT model provides only for fixed-location sensors (although at altitudes up to 100,000 ft.); moving sensors would require a significant addition to the computer program.

The types of data needed and the methods of processing the data in CRESS-S are necessarily very different from the corresponding parts of CRESS-A and CRESS-G. For this reason, CRESS-S is to a large extent discussed separately from CRESS-A and CRESS-G in this report.

However, it is emphasized that the manual portion of CRESS, both the sensor deployment and the R & S data analysis, should stress the coordination of all three major submodels, CRESS-A, CRESS-G, and CRESS-S, whenever the entire scope of R & S is being studied. By considering the contributions of SIGINT, CRESS differs from other target acquisition models and is capable of providing more complete results.

II SUMMARY

CRESS is a model of the operational use of sensor systems based on parametric computer models of the following types of sensor systems:

- Photo
- Infrared (IR) line scanner
- Radar
- Visual
- Laser
- Low-light-level television (LLLTV)
- Passive night-vision devices (PNVD)
- SIGINT

The simulation of the operational use of any collection of sensors of these types produces (1) the target element detection capability, (2) the location and location accuracy, and (3) the timeliness of generated reports, as the basic measures of performance of the systems.

A large scale (65,000 (65K) words of core storage), high speed digital computer with a random access disk, and men knowledgeable in scenario development, sensor deployment and intelligence analysis are required to exercize all facets of CRESS. The use of the computer for all calculations, most of the bookkeeping, and printing of sensor system performance, combined with the flexibility provided by the men who deploy the sensors (both SIGINT and non-SIGINT) and analyze the resulting data, makes CRESS a powerful tool for large scale studies concerned with all aspects of reconnaissance, surveillance, and intelligence. To take advantage of all the capabilities of CRESS requires that the men and the computer alternate their functions as follows:

1. Men - scenario development, sensor deployment, data preparation
2. Computer - data processing, print out sensor systems' performance
3. Men - analyze simulated R&S data, make intelligence estimates, redeploy sensors
4. Computer - data processing for redeployed sensors
5. Men - repeat analysis functions.

However, CRESS is modular in design and can be used for special purposes with reduced manual participation, if desired. Each of the three major submodels of CRESS may be exercised individually and independently of the others, if desired. Additionally, there are many options that can be selected in CRESS-A and CRESS-G, so that it is not necessary to exercise their full capabilities.

Potential users of CRESS must understand thoroughly what CRESS can and cannot do before deciding how best to use the model in their studies. Since the manual portions of CRESS are quite flexible, the constraints and capabilities of the computer programs must be examined carefully to determine the possible uses of the model. Any use of CRESS that will not cause a violation of these constraints is possible. Table I lists the CRESS-A/CRESS-G computer-played items. The sizes of various constraining arrays are discussed in Sec. IV. Briefly, it is felt that CRESS will process simulations of the R & S functions adequately up through Division-size forces.

Table I

COMPUTER-PLAYED ITEMS

1. Shadows
2. Decision to make report
3. Assigning men to postures
4. Camouflage
    Nets
    Natural
5. Effects of weather
6. Position location error
7. Failures
    Aircraft
    Navigation systems
    Communication links
    Sensors
8. Attrition
    Aircraft
    OP
9. Flight path geometry
10. Selection of targets covered
11. Selection of AA sites
	12. Amount of imagery taken
	13. Timeliness of reports
	14. Real time flight
	15. Sensors on and off
	16. Terrain masking
	17. Vegetation masking
	18. Cloud masking
	19. Misrecognition, misidentification
	20. False targets
	21. Multisensor enhancement
	22. Cumulative looks by ground sensors
	23. Grouping of target elements near each other
	24. Reconnaissance by fire
	25. Output
	    Control Copy
	    Time-ordered Intelligence Copy

As indicated in the preceding paragraph, potential uses of CRESS are properly left to the ingenuity of the user who understands the capabilities and constraints of CRESS. As an aid to finding areas of study in which CRESS would prove to be a valuable tool, it is noted that the models from which CRESS-A and CRESS-G have evolved have been used in studies designed to:

1. Compare alternative families of R & S collection means
2. Test an advanced operational concept which was critically dependent upon the target acquisition capability of a Battalion and its supporting forces
3. Assess the capabilities of an armed-recce-helicopter.

CRESS is also being exercised to produce a list of acquired targets for a Division size force, for a six-hour time interval. Other possible uses of CRESS or portions thereof include:

1. To produce probability of detection tables for particular scenarios and representative values of germane parameters
2. To be used "online" in small scale computerized war games
3. To assess the enhancement to intelligence output, if any, that might be gained by closely coordinating the use of SIGINT and collateral sensors.

The computer programs are written in FORTRAN-IV for the Control Data Corporation 6400 computer, with 131K words of core storage and random access disk. On this machine, CRESS-A, CRESS-G, and CRESS-S require approximately .5,1.5, and .25 seconds per target processed, respectively. CRESS-A and CRESS-G can run on a 65K core storage machine, with random access disk, after relatively minor program changes that are specifically stated in the User's Handbook. CRESS-S can run on a 32K core storage machine, with random access disk. Running on these smaller computers will cost an additional .3 to .5 seconds per target processed because of the extra use of the disk.

In addition to developing CRESS, a study to assess the feasibility of developing a model of the intelligence functions of a Division TOC was completed. Work is being done by other contractors for the U.S. Air Force (Refs. 6 and 7) and the U.S. Navy (Ref. 8) on probabilistic information processing; the software is being developed by the Automatic Data Field Systems Command for TACFIRE and TOS; and a method is outlined in Sec. VI that designates tactical targets on the basis of sighted target elements. These studies indicate that the analytic tools are available to develop a model of some of the intelligence functions. A resulting model would not be completely automated but would be useful to systems studies (including war games) concerned with intelligence processing, particularly in the area of target acquisition. It would make use of the type of data produced by CRESS. It is felt that enough of the important tactical intelligence functions can be modeled and used in conjunction with CRESS to produce a combined reconnaissance, surveillance, and intelligence model of significant value to studies concerned with tactical reconnaissance, surveillance, and intelligence.

III RECOMMENDATIONS FOR FURTHER RESEARCH

During the course of the study, the following topics have been identified as needing further research and development:

1. Experimental quantification of the detection capabilities of stationary sensor systems in a tactical environment, as a function of time.

2. Experimental verification of the curves representing the image interpreter's ability to detect, recognize, and identify objects on a "snapshot" image produced by moving sensors of the types modeled in CRESS.

3. Experimental determination of the composition of false targets and the factors that cause them.

4. Experimental determination of the probability of misrecognizing or misidentifying an object as a function of the probability of correctly recognizing or identifying the object.

5. Experimental determination of the enhancement factors for probability of detection by a sensor, given a directed search. Also, determination of the synergistic enhancement factor for the probability of identification by a sensor, if another sensor has furnished some general data about the detected target (e.g., SIGINT indicates that a Tank Company is in an area where objects are subsequently detected).

6. Visual sensor model improvement.

7. Airborne SIGINT models.

8. Incorporation of terrain models into CRESS.

9. Jungle effects on propagation of vertically and horizontally polarized electromagnetic signals.

10. Identification of electromagnetic emitters and of targets containing emitters.

11. Effects of passive and active electronic countermeasures.

12. Patterns of emitter activity.

13. Methods of exploiting the combined capabilities of SIGINT and collateral sensor systems.

14. A model of intelligence functions which could be incorporated into CRESS.

IV CRESS DESCRIPTION

A. General

CRESS is a man/computer model designed to simulate the operational use and data output of R & S systems built around collections of sensors selected from the types listed in Table II. Figure 1 generally illustrates the tactical operational model that served as a basis for developing CRESS and, in particular, each of the three major submodels, CRESS-A, CRESS-G, and CRESS-S.

Table II

SENSOR TYPES

Aerial	Ground	SIGINT
Cameras	IRS	0.1 to 60 MHz
Vertical	Ground Surveillance Radars	Line of sight
Side oblique		Near shadow
Forward oblique	Passive night-vision devices	0.1 to 60 MHz
Panoramic		Transition-shadow
Infrared line scanners	Visuals	
Radars	Eye	0.1 to 60 MHz
MTI	Binoculars	Far shadow
Mapping	Laser line scanners	
MTI and mapping		3 to 30 MHz
	IR binoculars	
Visuals		Skywave
Eye		60 to 40000 MHz
Binocular		Microwave
Laser line scanners		
Low-light-level televisions		

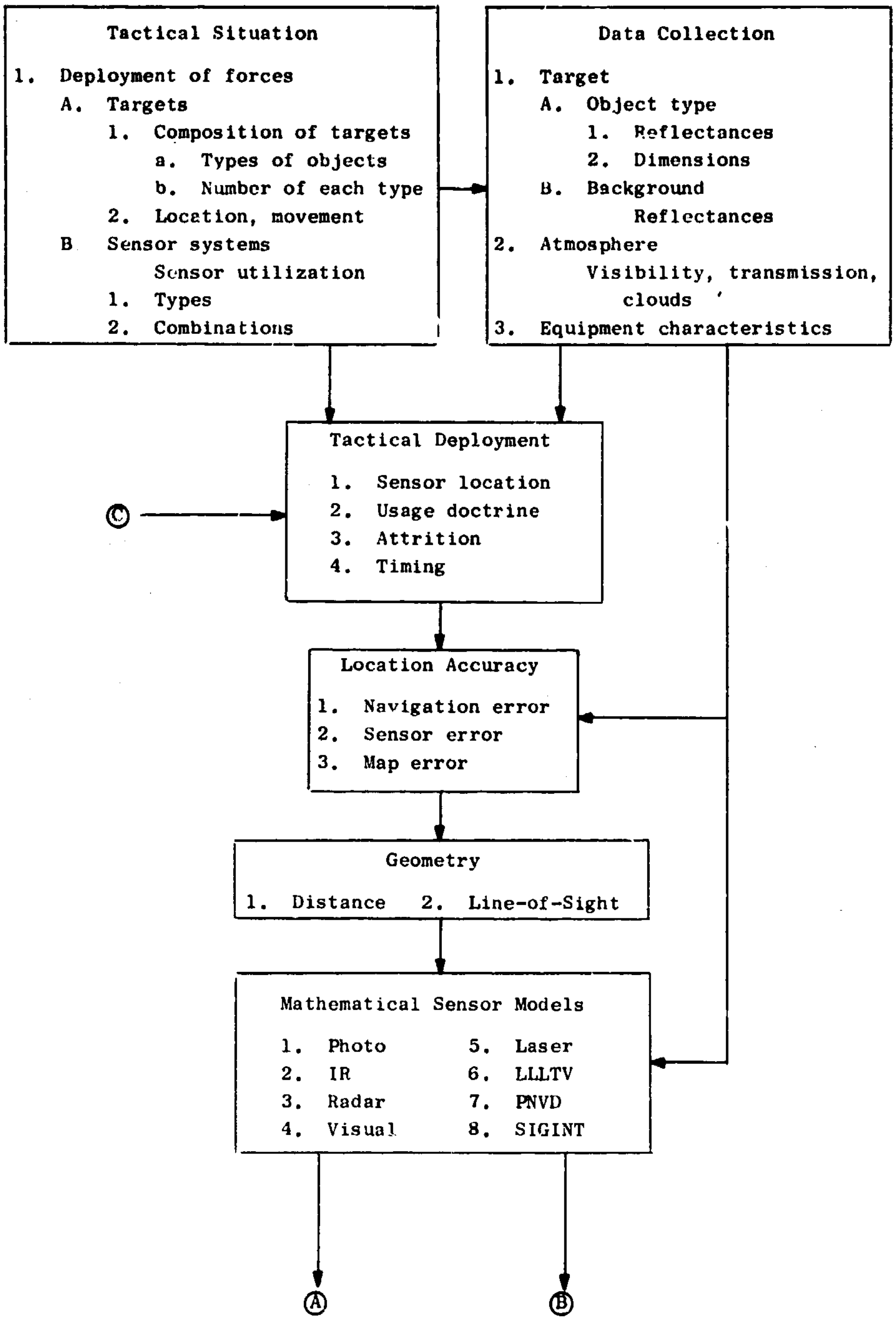

Fig. 1 OPERATIONAL MODEL

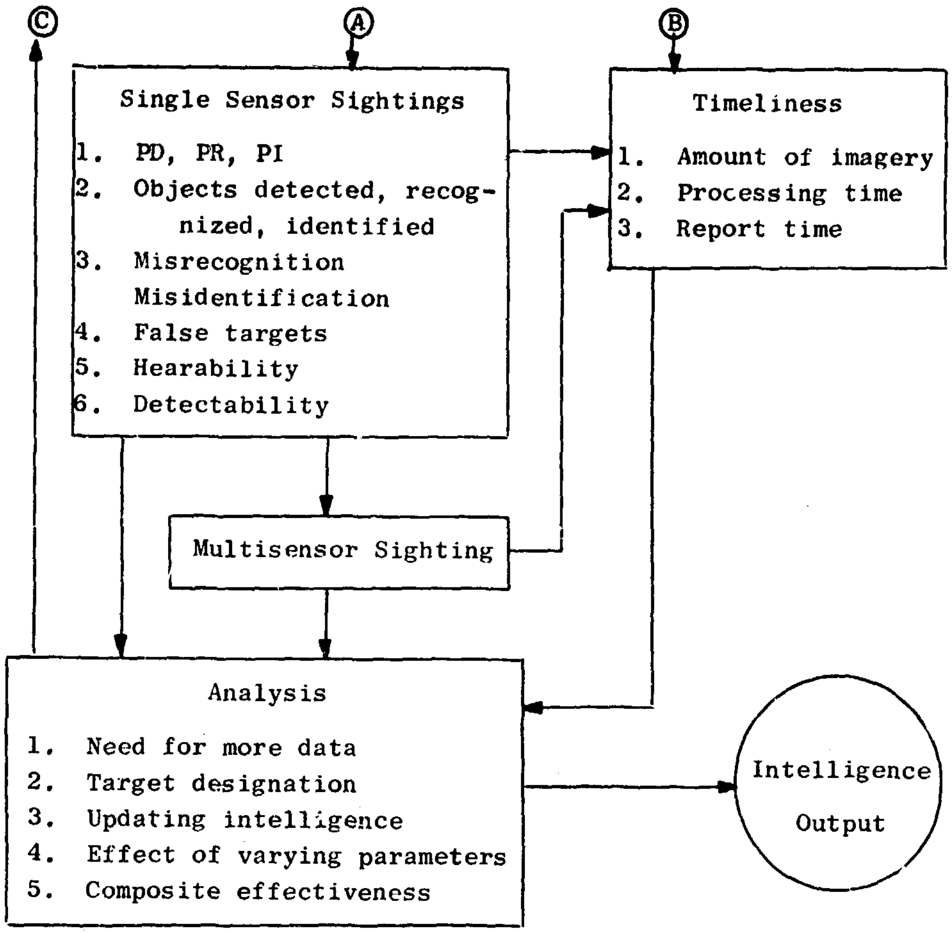

Fig. 1 (Concluded)

Each of these submodels embodies a large program that directs the computer to do all the mathematical calculations, most of the bookkeeping, and the printing of the sensor systems' output data (see Table I for CRESS-A/CRESS-G computer-played items). Although the computer programs bear the same names as the submodels, it is emphasized that the submodels should also be thought of as embodying the work of men knowledgeable in intelligence and tactical usage of airborne, ground, and SIGINT sensors. These men must provide the scenario development, collection plan, weather parameters, target and sensor deployment, and the intelligence analysis of the reported sensor generated data that is output by the computer. Further, the full capabilities of CRESS itself can be realized only if all its submodels are manually used in a coordinated, complementary fashion.

Exercising CRESS completely requires that men and the computer perform tasks alternately:

1. Men - prepare data
2. Computer - process data, print out sensor vs target performance
3. Men - analyze sensor performance, make intelligence estimates, redeploy sensors
4. Computer - process data for redeployed sensors
5. Men - repeat analysis.

The first tasks that must be done manually are developing a scenario (if it is not already developed for the study using CRESS); determining the collection means to be used; defining the target data; collating the target data, object type data, environment data, and equipment characteristics data for storing into the computer; and deploying the sensors. While this data preparation task is being performed, it is imperative that the limits imposed by the array sizes in the computer be kept in mind, for those limits and the amount of manual effort that can be afforded are the constraints that determine the maximum size reconnaissance/surveillance problem that can be simulated. The limiting sizes of the arrays are stated in Table III.

The amount of manual effort required in this data preparation task depends on (1) the detail and length of the scenario, (2) whether all submodels are being used, (3) the level of detail desired in target deployment, (4) the complexity of the map terrain, and (5) previous experience of the personnel performing the work. If the requirements of CRESS are kept in mind when the scenario is developed, then little additional work will probably have to be done to produce the required target data. One of the most time-consuming tasks is determining line-of-sight data for ground-based and SIGINT sensors. Higher speeds at this tedious task are achieved as experience is gained. If equipment is simulated whose characteristics are not catalogued in Vol. IV of this report, it may be necessary to obtain the required data from manufacturers or developers of the particular type of equipment.

To prepare the data for CRESS-A and CRESS-G for the test case of a Blue motorized rifle division reinforced by a tank

Table III

MAXIMUM SIZES OF ARRAYS

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 AA	30
Recognition classes	40
Detection classes	10
Atmospheric conditions	4
Background types	25
Aerial navigation systems	10
Special objects	10
Aircraft types	15
Aerial sensors	40
Sensors of one type (except visual)	10
Visual	5

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

MB	NB
MA	NA

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 III (continued)

MAXIMUM SIZES OF ARRAYS

Descriptor	Upper Limit
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 sensor.

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

e/ This includes ground patrols.

battalion vs a Red Combined Arms Army required approximately 1.25 professional man-months and 2.0 data-aide man-months. This data preparation was done primarily by inexperienced personnel and was used concurrently for instructional purposes. The target arrays used had been developed by the Institute of Special Studies for their ammunition expenditure rate study for 1973, without any regard to CRESS requirements. It is estimated that, with experience, the professional time could be cut in half and the data-aide time cut by 30 percent.

Data preparation for CRESS-S for the same test case required .25 professional man-months and .65 data-aide man-months.

Explicit instructions for each type of required data are contained in the User's Handbook (Vol. II). These instructions should be studied carefully to ascertain what is and what is not allowed.

To run the CRESS-A and CRESS-G computer programs, the data must be collated exactly as specified in Sec. III of the User's Handbook and then submitted to the Computer Center with the program deck. The Control Copy and Intelligence Copy are output. Running CRESS-S requires some data preprocessing before the final run that yields the two output copies. Instructions for this preprocessing are also found in Sec. III of the User's Handbook.

The Control Copy from each of the programs provides a rather complete account of the interactions of the sensor systems with each of the targets processed, whether or not any target elements are reported. This output copy is intended for the Control team when CRESS is being used for war games. However, it should also be useful in studies concerned with sensitivity analyses, preparing probability of detection tables, and purposes other than the simulation of the intelligence processing function. For example, the Control Copy should be used to prepare a table showing the probability of detecting a T-62 tank with a KS72A camera system, as a function of distance and altitude.

The Intelligence Copy presents the subset of information appearing on the Control Copy that would normally be known by the team using the sensor systems. In particular, it contains the reported target elements and their positions, the sensor, the location accuracy capability of the system, and the time of sighting. These reports are time-ordered. Information occurring on the Control Copy that does not appear on the Intelligence Copy includes: targets processed but not reported; probabilities of detection, recognition, and identification; and the objects in the target that are not sighted. Also, it is possible to discern on the Control Copy which reports concern false targets and which objects have been misidentified or misrecognized, facts which are not shown on the Intelligence Copy.

Examples of both output copies for CRESS-A, CRESS-G, and CRESS-S are found in Figs. 2 through 7. Detailed explanations of these output forms are found in Sec. IIF of the User's Handbook.

Although the CRESS-A and CRESS-G computer programs use many of the same input data, they are run separately on the computer, as is CRESS-S. The programs for all three major submodels are written in FORTRAN-IV for the CDC 6400 computer and each conforms to ASA standards, except for the machine dependent input/output disk instructions. Explicit instructions for changing the rpgorams to run on a smaller machine are given in the User's Handbook.

Table IV indicates the approximate rates of computer processing. The 65K machine is assumed to have the same processor speeds as the CDC 6400. The additional time for the 65K machine is required for the extended usage of the disk.

Table IV

TARGET PROCESSING RATES
(seconds)

Program	CDC 6400 (131K)	65K Machine
CRESS-A	.5	1.0
CRESS-G	1.5	2.0
CRESS-S	.25	.25

```
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    1115                          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    8489

                             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-62 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    35B     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 PERSONNEL15,7 -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 698822     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 PERSONNEL15,7 -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    45C     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 98  0  0  1   0  0  0  0  0  0   4  0  0  1  0  0   9 97 90  0  0  1
   26 STANDING PERSONNEL15,7  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                  11404               0                 11303              11404
REPORTED POSITION            MA 684818                 0           MA 684819          MA        0
CEP - , A , B , C            100 120 100 103     0  0  0  0        100 100 100 103    100 100 100 103

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

Fig. 2 CONTROL COPY--CRESS-A

```
RPT TIME 11356  RPT GRP  129  IMG TIME  11228  FLT AF-2                  AC RF4C          NAV ASN-56        DIST  4300
POSIT MA 811921  CEPS  248 248 248 249  RS   3  ALT 15000  SPEED  600  MD   0  RBF 0  SENSOR K56A
          IDENTIFIED                              RECOGNIZED                  DETECTED
              0                                    4 WHEELED VEHICLE             1 OO-MOB1+00.1000000

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

RPT TIME 11357  RPT GRP  130  IMG TIME  11228  FLT AF-2                  AC RF4C          NAV ASN-56        DIST  3379
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  11228  FLT AF-2                  AC RF4C          NAV ASN-56        DIST    66
POSIT MA 887966  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 887966  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  370  IMG TIME  11205  FLT AF-1SP                AC RF4C          NAV ASN-56        DIST  5346
POSIT MB 780478  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   420
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-60P                              0                            7 VERY SM LAND OBJ

* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
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Fig. 3 INTELLIGENCE COPY--CRESS-A

```
42R 46
O.P.  46   LOCATION-MA685812

        TARGET    42R      REPORT GROUP     236     DISTANCE      447      PLOS     89

                                     PPS9                      EYE                        BNC7
NBR 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    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-60P                 6.5    83100   0  1  1   0 68100100   1   1   1 87100100   1   1   1
  5 PHONE PERSONNEL        15.7    8310r   0  5  5   0 22100100   3   3   3 75100100   4   4   4
CONTACT TIME                       11430              11400                  11400
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
NBR 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-60P                 6.5     3100   0  1  1   0  3100100   1   1   1  1100100   1   1   1
  5 PHONE PERSONNEL        15.7     3100   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
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

 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-60P                 6.5     1100   0  1  1   0  1100100   1   1   1  0100100   1   1   1 90100100   1   1   1
  5 PHONE PERSONNEL        15.7     1100   0  5  5   0  0100100   3   3   3  2100100   4   4   4 90100 93   5   5   4
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. 4 CONTROL COPY--CRESS-G

```
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                                 28 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
```

Fig. 5 INTELLIGENCE COPY--CRESS-G

CONTROL COPY

INITIAL RANDOM NUMBER= .156700 RADIUS FACTOR=1.333333 MONTH= 7 TIME=2300.0 SSN= 50 ANOISE= -50.00

GYRO= 1.40 F-2 VIRT=275000 F-2 3000= 18.00 F-2 0= 6.00 MAX UF= 6.30 LAT= 50.00 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
R1	49.37	.13	F3	YES	MA755842	396		1L	1L*	1L*	0N	1N						
R1	49.37	.13	F3	YES	MA752844	396		1L	1L*	1L*	0N	1N						
R2	21.80	.05	F3	YES	MA752831	396		1L	1L*	1L*	0N	1N					0N	0N
R2	21.80	.05	F3	YES	MA752830	396		1L	1L*	1L*	0N	1N					0N	0N
R3	40.80	.08	F3	YES	MA751827	396		1L	1L*	1L*	0N	1N						
R4	21.80	.05	F3	YES	MA752844	396		1L	1L*	1L*	0N	1N					0N	0N

TARGET 106 TEST TARGET 2 ACTUAL LOCATION MB755 1

EQUIPMENT	FREQ	ACT	MOD	ID	RPT, LOC	CEP	SENSOR	1	2	3	4	5	6	7	8	9	10	11
R5	28.45	.12	F3	NO				0L	0L	0L	0L	0L					0L	0L
R6	2.00	.08	A1A3	NO				0L	0L	0L	0L	0L					0L	0L
R7	3.70	.08	A1F1	NO				0L	0L	0L	0L	0L					0L	0L
A1	11190.00	1.00		NO										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
R6	3.12	.03	A1A3	YES	MA829854	2905		1L	1L	1L	1N	1N*					0N	1N*
R5	40.20	.06	F3	YES	MA792859	516		0L	1L*	1L*	0N	0N						
R2	22.25	.04	F3	YES	MA793873	516		0L	1L*	1L*	0N	0N					0N	0N
R8	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. 6 CONTROL COPY--CRESS-S

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	MA792859			1*	1*								
R2	21.80	F3	MA752831		1	1*	1*		1						
R6	3.12	A1A3	MA829854		1	1	1	1	1*						1*
R8	3.12	A1A3	MA793864		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. 7 INTELLIGENCE COPY--CRESS-S

The next step in the use of CRESS is perhaps the most crucial. It is the analysis of the simulated R & S data. The manner in which the computer outputs are analyzed will necessarily depend on the objectives of the study using CRESS. No attempt has been made to devise aids, such as summary forms, for the analysis task; however, Sec. III.C of the User's Handbook does contain an example of an intelligence analysis form for war gaming purposes.

The human analysis of the outputs from the three programs CRESS-A, CRESS-G, and CRESS-S provides the man-computer model CRESS with the capability for being employed in the study of the effects of using differing R & S systems in concert, and of correlating their output data. It also allows the injection of non-R & S intelligence into the tactical intelligence process. It is important that the analysts view the computer results in the perspective of their own knowledge and experience, for it must be remembered that a model such as CRESS provides only an approximation to reality, and thus the results cannot be completely accurate. However, it is felt that the submodels within CRESS are sufficiently accurate that trends can be seen as parameters are changed and that the relative measures of performance arrived at are valid, whether or not the actual numbers are completely accurate.

If CRESS is being used to study the intelligence process as well as purely R & S concepts, then it may be desirable to simulate the collection of additional R & S data for a particular area after intelligence specialists have analyzed the computer output for that area. This is done by simply deploying the (few) required sensors as for the first computer runs and submitting the resulting data and the appropriate program(s) to the computer. An option exists in CRESS-A and CRESS-G to enhance the probability of detection to account for the effects of a more thorough, directed search than is usual for normal R&S.

Delineating and modeling all the potential gains that can be realized by integrating the utilization of the SIGINT and collateral sensors is a complicated task because of several factors. It appears that the development of the SIGINT sensors, the organizations responsible for them, and the tactics employed when using them, have evolved semi-independently from the corresponding lines of evolution for the collateral sensors. Security problems, which may have partly caused this division of effort, accentuate the resulting differences.

Another fundamental problem arises because each collateral sensor (except weapon locators) has some possibility of sensing any type of object in a target, whereas SIGINT sensors can only detect certain objects that might be in a target. Furthermore, each collateral sensor potentially senses different characteristics of the same object so that the synergistic gain that accrues from using two or more collateral sensors to detect the object can be measured experimentally at the image interpreter level. SIGINT sensors, except for the sensing of a radiating emitter, provide information that usually does not pertain to a single object directly. Thus, in general a collateral sensor and a SIGINT sensor generate different types of information on different types of things. Hence, the entire direct gain that may be realized cannot be analyzed at the same level as for the collateral sensors alone.

Despite these problems, there are significant gains to be derived by suitably integrating the SIGINT and other sensors. An investigation into current practices and some potential future ways of achieving this interaction is described in Vol. IV, Appendix G (SECRET) of this final report. The present model includes only a few fundamental effects of these interactions in the manner described below.

The SIGINT and collateral sensors can assist each other in several ways to produce a better or more complete intelligence fabric than could be attained by simply using their individual outputs. The first of these complementary effects is a reduction in search time needed for one sensor if the area to be searched can be localized by the use of the other. An example of this effect would be a SIGINT report in which an artillery unit was detected, identified and located within an area on the order of a kilometer square. With this information, a ground patrol could be directed toward the specific area for intensive search and pinpointing of the exact location of the target; alternatively an airborne photo-reconnaissance mission could be directed to the area.

A second effect of the sensor interaction is an increase in the probability of detecting a target when there is reason to believe that one exists in a particular area. An example of this effect would be to have a reconnaissance aircraft fly at a lower than normal altitude to produce high resolution imagery of a limited area in which a SIGINT report has indicated an artillery unit exists. In addition, the interpreter can be instructed to examine the improved imagery of the area with particular care.

The third way in which the sensors can complement each other is by verifying a target acquired by one of them. Such corroboration would minimize the probability of reporting false targets. An example of this effect is the SIGINT search for a signal from a structure which might otherwise appear to be an abandoned element or a decoy.

The way in which these effects are included in a simulation is by repetitive deployment of the sensors in the selected area with variation of the sensor and/or deployment parameters, and by having the analyst compare results, assess the gains derived, and initiate the next iteration. The modeling of these effects, therefore, is not built into the computer program in terms of an interaction routine, but rather comes as a result of the fundamental man-computer-man-computer-man use which is meant for this model.

B. Air Model (CRESS-A)

CRESS-A is that portion of CRESS which simulates the activities of aerial reconnaissance and surveillance systems. The first phase of CRESS-A consists of the scenario development and data preparation which are performed by the user. This includes the deployment of targets, sensor systems, and the collection of technical parameters.

This basic set of data is prestored in the computer and then referenced by the computer as the second phase is being accomplished. This second phase includes: computer simulation of aircraft flights; equipment failures and attrition due to enemy groundfire; performance of the set of sensors on board the aircraft platform, including the misidentification and misrecognition of target elements and the generation of false target reports; and the reporting of mission results. A brief description of how these items are considered is given below; the flow for computer processing is given in Fig. 8.

A set of data cards is read into the computer which indicates the proposed flight path of a reconnaissance platform carrying a system of sensors. Navigation errors are simulated so that the simulated flight path differs from the planned flight path. This flight path contains one or more reconnaissance/surveillance (RS) areas. These RS areas in turn contain from one to ten parallel flight legs. As the platform flies along one of these flight legs, each target coming within the field of view of the sensors is processed, the time and location are recorded, and the performance of the sensors against each target element within line-of-sight is calculated.

Some of these deployed ground targets may have an antiaircraft capability. CRESS-A simulates the attempts of any such targets,

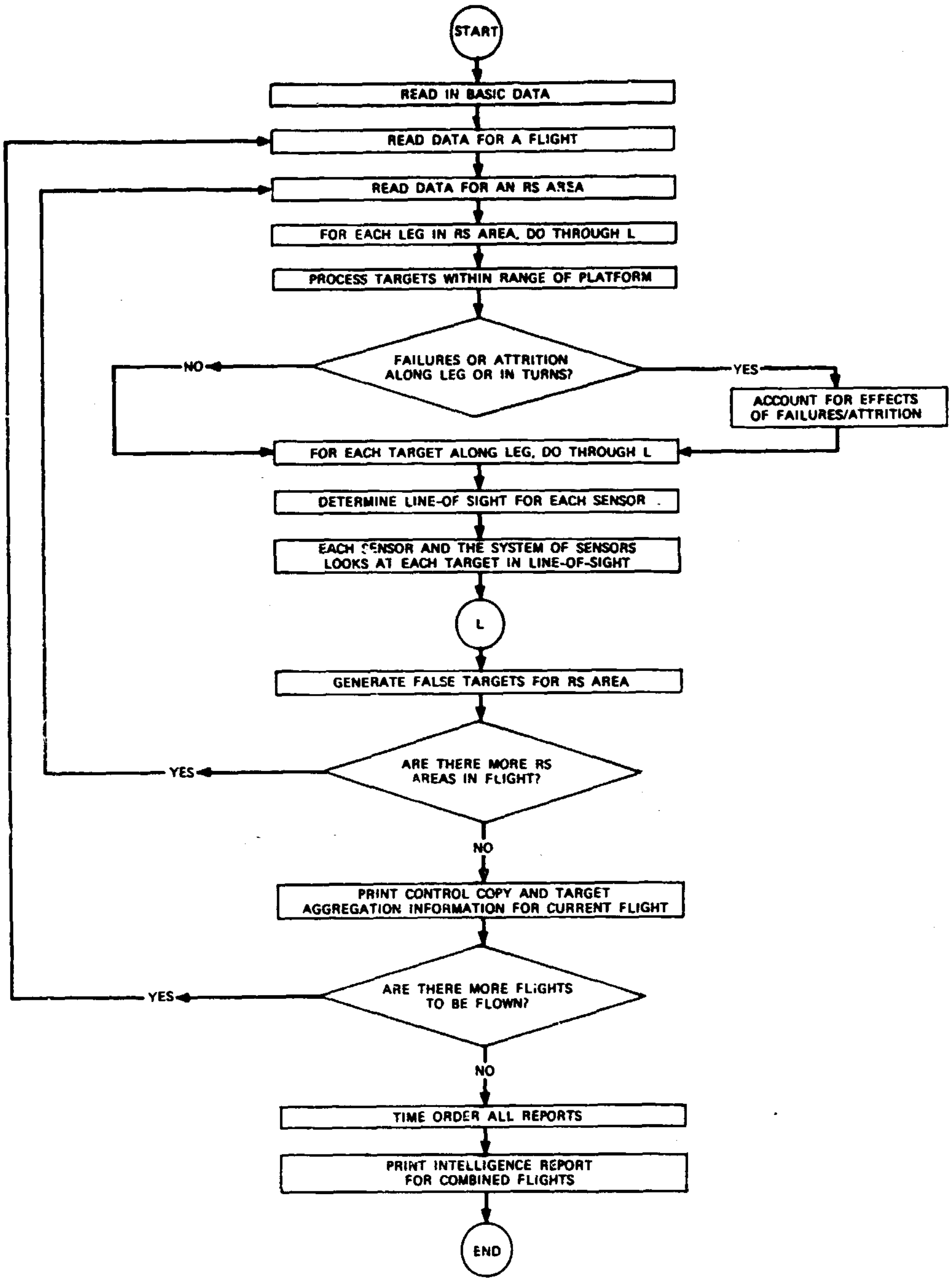

Fig. 8 CRESS-A FLOW CHART

within the RS area and the area overflown while the platform makes turns between flight legs to shoot down the reconnaissance platform. (No attrition caused by airborne antiaircraft weapons is simulated in CRESS-A.) If a platform is shot down, the mission is terminated at that point. Only data which may have been transmitted over communication links prior to that time will be reported.

Equipment failures of the sensors, data links, the navigation system, and the platform itself are also simulated. Any resulting failure causes loss of data, delay in receiving data, or termination of the mission, as appropriate.

As each target is overflown, the objects contained therein may be detected, recognized, identified, misrecognized, misidentified, or unnoticed. Each individual sensor is given a look at the target, and then the results of the system of sensors are calculated. These multi-sensor results come from two sources. The first is the independent-looks benefit which comes from having independent attempts to view the same object with different devices. The second is the synergistic benefit which comes from having complementary devices looking at the same object. For example, in the first case two sets of eyes will probably see more objects than either set viewing alone. This is because each set of eyes may see objects missed by the other set (i.e., the independent-looks benefit). For the second case, a radar set may note the presence of an object that the eyes would have overlooked alone, but now that the attention of the eyes is called to the object, they may be able to add information which the radar system did not acquire. This is due to the synergistic benefit, wherein the combination achieves greater results than the sum of the individual sensors working alone.

While viewing the terrain, the sensors (or the personnel interpreting the sensor output) may mistakenly inject false targets into the scene. In CRESS-A these false targets are generated at the end of each RS area, and the composition of any false targets reported is based on the composition of true targets sighted in the same RS area.

At the end of each flight, a Control Copy is printed out that indicates: which targets were overflown during that flight; their true location and reported location; the probabilities of detection, recognition, and identification by each sensor and the combination of sensors; and the number of objects detected, recognized, identified, misrecognized and misidentified by each sensor and the system of sensors.

The user may also elect to have printed out a list of target clusters. In each cluster are listed all of the targets seen on the flight which are within a specified distance of each other. The purpose of this output is to help the intelligence team aggregate targets into larger military units (e.g., companies or battalions). CRESS-A allows up to five different user-prescribed radii to be used in the clustering process.

At the end of the last flight, all of the individual target reports are ordered according to the time they would reach an intelligence team. These reports are then printed out to comprise the Intelligence Copy. This report contains the time of sighting, and the numbers of items seen by each sensor and the combination of sensors.

The third phase of CRESS-A is the user analysis of the computer output. This may lead to a redeployment of sensor systems and a consequent iteration of phases 2 and 3. The option is available to enhance the probability of detection to reflect the results of directed search and particular care in image interpretation.

A partial list of options available to the CRESS-A user is given below. These features of the model may be included or deleted by appropriate changes in the data cards.

- Navigation error
- Attrition due to enemy ground fire
- Equipment failures
- Misidentification and misrecognition of target elements
- Multi-spectral enhancement
- Generation of false targets
- Aggregation of targets into clusters
- Vegetation masking
- Cloud masking
- Reconnaissance-by-fire
- Different criteria for report generation
- Enhanced probability of detection
- Allocation of personnel to stances according to target posture.

C. Ground Model (CRESS-G)

CRESS-G is the portion of CRESS that simulates reconnaissance and surveillance performed from observation posts (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 upon this information to calculate the performance of each sensor in each OP, when attempting to sight all the targets within its field of view. It should be emphasized that the model performs this task in such a way that it is a simulation of the entire OP versus a target and not a set of independent simulations of the sensors in the OP versus a target. A brief description is given below of how the computer model simulates RS activity and considers the effects of equipment failures, attrition, misidentifications and misrecognition of target elements, false targets, multi-sensor enhancement, etc.

Having prestored information concerning all target characteristics, OP characteristics, object parameters, weather parameters, and background parameters, the basic unit of information upon which the computer then operates to determine ground reconnaissance performance is the information contained on an observation post/target (OP/TGT) card. The OP/TGT card contains the following: OP designation, OP location, target designation, and probability of line of sight between the OP and this particular target. If the OP is elevated, its elevation is given, and if the OP is actually a patrol, the time at which the OP is at the given location is also included.

OP/TGT cards are created for each OP for all targets within its field of view. For each OP/TGT combination, the probabilities of detection, recognition, and identification, the number and types of objects seen by each sensor and by the multi-sensor system (all sensors together) are determined by sensor models which consider object characteristics (e.g., size, reflectivity, temperature), background characteristics, weather conditions, camouflage, line-of-sight probability, and sensor parameters.

It is assumed that communication delays from an OP to the intelligence processing center are negligible as long as the OP communication link is operative. Therefore, the initial look of the OP at a target is the earliest time at which both are valid. It may be that an OP stops operating before a target becomes valid, or vice versa, since the manual work phase matches OPs and targets within OP viewing range, regardless of initial and final valid times. If a sighting is possible, the model simulates the increased amount of information gained over time by allowing for two other times of sighting using greatly decreasing probabilities of detection. Thus, while most of what an OP sees occurs at the first-look time, lesser amounts of information will possibly be gathered and reported at second and third look times. It is felt that this method of determining the total amount of information received from an OP over time better simulates actual reconnaissance by avoiding the unrealistically large amounts of information that are likely to result from the technique of using numerous independent looks at fixed increments of time (see Ref. 9).

The multi-sensoring capability of the model provides a means by which the unique number of objects detected, recognized, and identified by all sensors acting in concert can be determined in a probabilistic manner. The enhancement because of the synergistic effects of information obtained from sensors operating in different spectral regions and the gains resulting from the probability that a certain percent of the objects sighted by the various sensors are distinct objects are both considered

The model also provides for the possibility of OP attrition and link and sensor failures. Each OP is stochastically tested against its probability of attrition due to enemy action (user supplied input), and in the event of attrition, a time is randomly selected during the operating period of the observation post. When an OP link fails, no reports are made until the link again becomes operative or the end of the period that this OP is valid is reached. If sensors fail, reports are generated concerning lost contact and if the sensor again becomes operative and regains contact, this is reported also. In any event, all contacts lost because of target movement are reported.

Simulation of misidentification and misrecognition of actual objects in a target into similar types of objects and recognition classes is provided for, and depends on the probabilities of missighting various types of objects. In addition to mistakes that are made concerning real objects, a number of false targets are created which have types of objects similar to those that the OP actually sights correctly.

The Control Copy delineates, for each sensor and for multisensoring, the probabilities of detection, recognition, and identification and the numbers of objects sighted at each of those levels of detail.

The other output copy is an Intelligence Copy. For each OP/TGT pair, objects sighted by individual sensors and by multisensoring are measured against the selected report criteria (number of objects sighted, special objects sighted, percent of objects present sighted). If the numbers and types of objects sighted are sufficient to meet the criteria, an Intelligence Copy report is generated. Reports are issued in a time-ordered manner and list the number of things sighted in various detection and recognition classes, the number and types of objects identifiekd, the target location, and the location accuracy.

The flow chart in Fig. 9 summarizes the steps that CRESS-G takes to simulate ground reconnaissance.

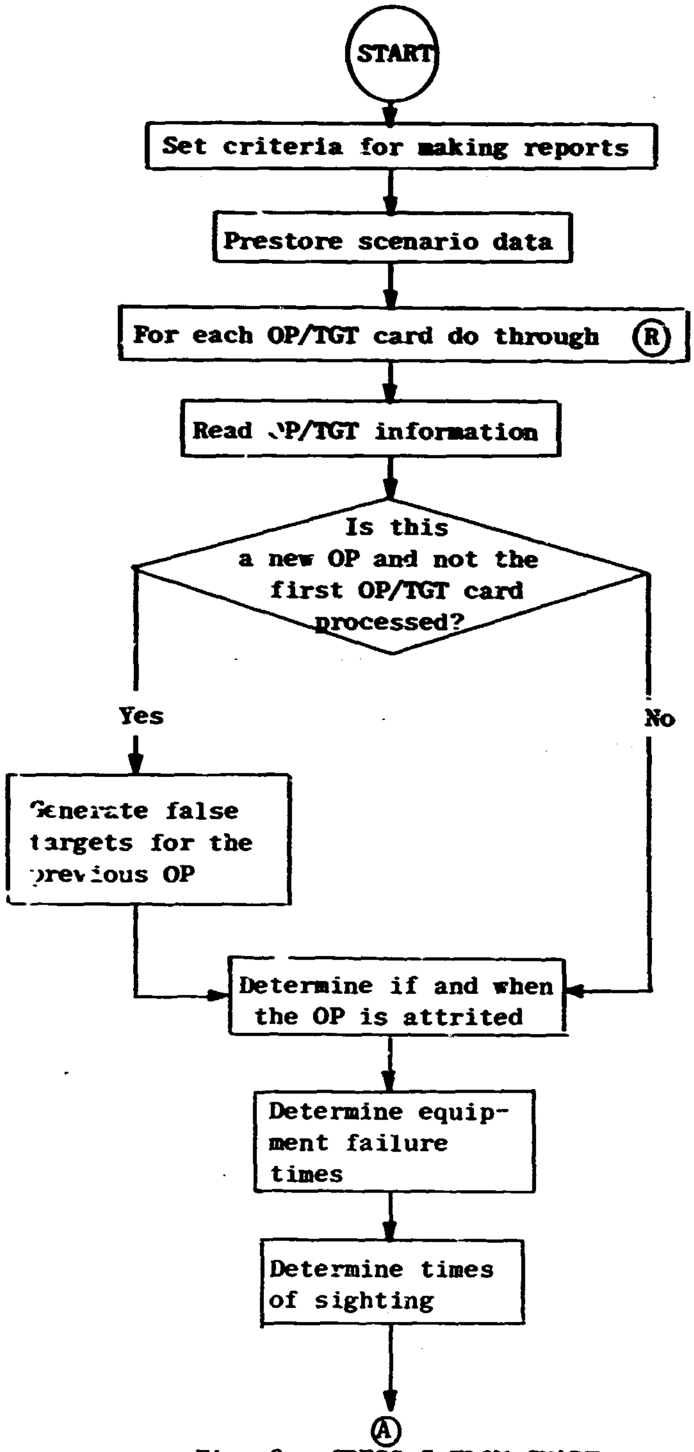

Fig. 9 CRESS-G FLOW CHART

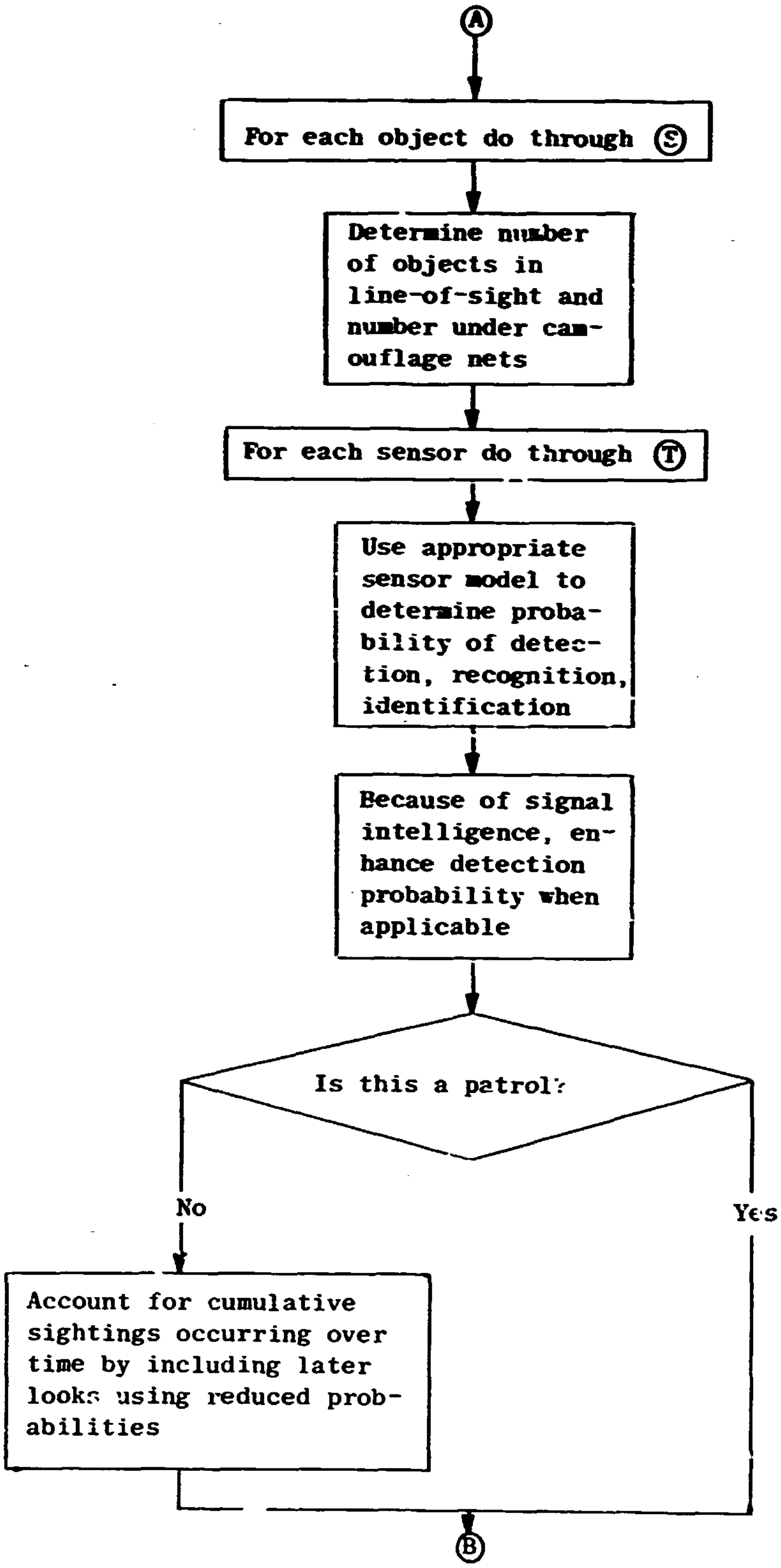

Fig. 9 (Continued)

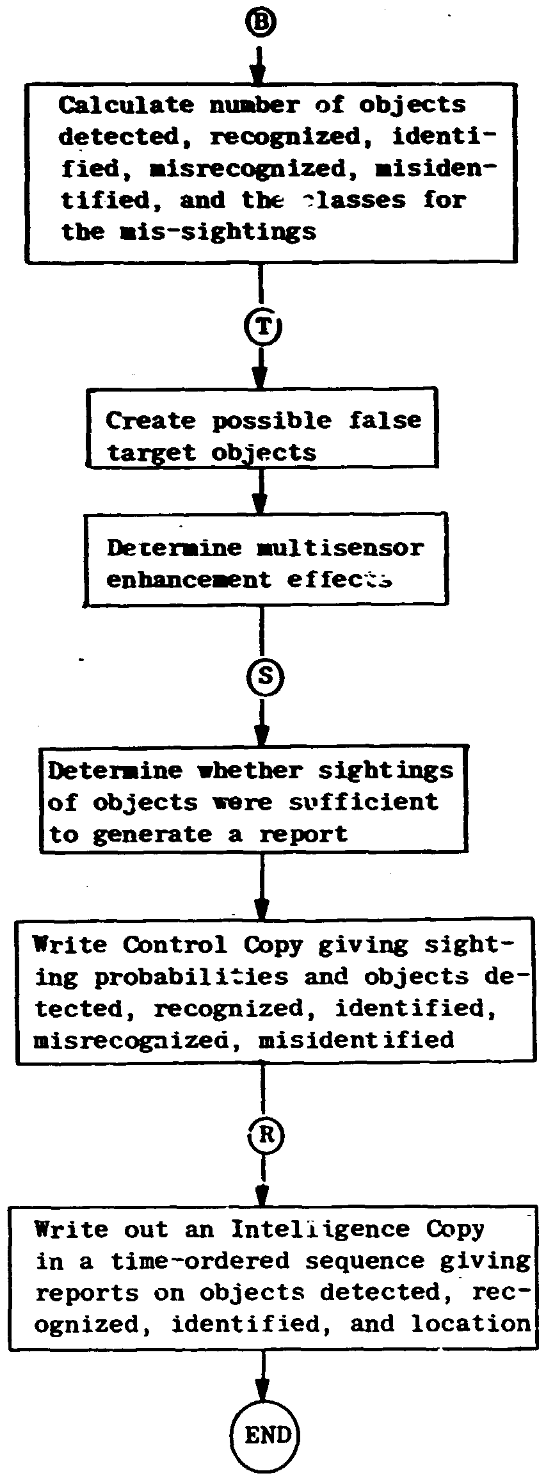

Fig. 9 (Concluded)

D. <u>SIGINT Model (CRESS-S)</u>

1. <u>Structure of CRESS-S</u>

CRESS-S is that portion of CRESS which simulates the collection of SIGINT R & S data. This is accomplished as follows: (1) the user deploys the targets and SIGINT sensors, (2) the computer provides the target/sensor combinations that operate on the same frequencies, (3) data-aides prepare propagation path terrain obstruction data, (4) the computer processes the data and prints the sensor performance, and (5) the user analyzes the computer output. Brief descriptions of these tasks are given below.

The preparation and running of the CRESS-S simulation are outlined in Fig. 10. After deciding upon 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 who are familiar with SIGINT deployment concepts and doctrine and who should have nominal detailed knowledge of the target array before them which is typical of a tactical deployment situation. Upon completion of this deployment effort work, four decks of cards are punched. They are the emitter cards (A and B), target cards (A and B), sensor cards (A and B), and the program HELP starter card.

The target cards (A and B), sensor cards (A and B), and the HELP starter card are input into 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. This sorting routine is done on the basis of compatible frequency coverage between all the emitters and sensors in the array. The printed output sheet contains a complete listing of all the target sensor paths that must be examined by data aides.

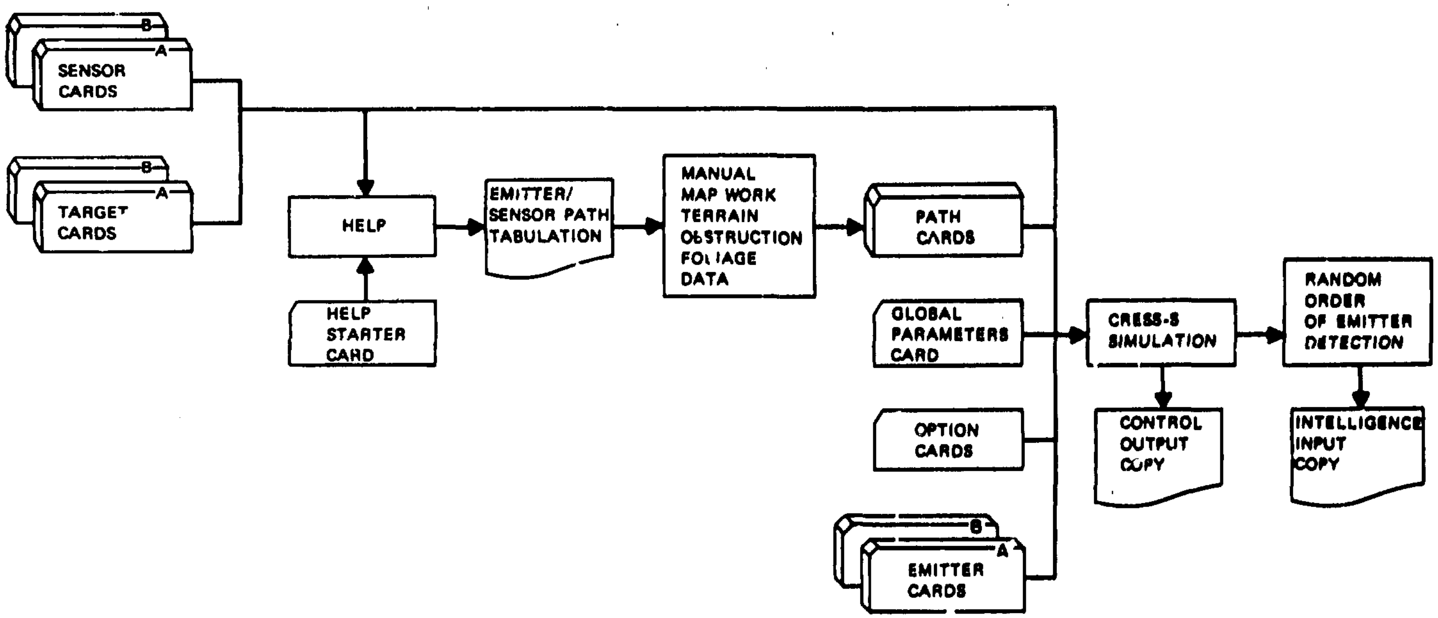

FIG. 10 CRESS-S PROGRAM FLOW OUTLINE

This printout is now used as a data sheet by data aides who return to the map and, for each target-sensor path noted, record the following data: (1) the two highest terrain elevation points on the path line connecting the target and sensor, (2) the distance of these high points from the sensor site in km, (3) the sum of the lengths of the terrain covered by tree foliage along the same path (the data aides do not have to be concerned about whether the path is line of sight), and (4) the electromagnetic characteristics of the terrain for the purposes of estimating ground propagation characteristics later in the program.

The results of the data aides' map work is punched on an additional deck of cards called path cards. Two additional cards, the global parameters card and the option card, must be punched prior to each running of the CRESS-S simulation.

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, online, the Control Copy output. Since the data to be printed on the Intelligence Copy are subsets of the Control Copy output data, those items to be printed in the Intelligence Copy are stored on a disk file until the Control Copy output is completed. At that time the reported sensor data is printed on the Intelligence Copy in a random ordering. Figures 11 and 12 are examples of the Control Copy and Intelligence Copy data.

The Control Copy output is a target by target record showing emitter by emitter, the results of the SIGINT collection system.

	TARGET 17 SGBN			ACTUAL LOCATION MB820850						
EMITTER	FREQUENCY	ACT.	MOD.	ID	RPT. LOC.	CEP	SENSOR	1	2	3
RABC	29.0	.75	FMV	NO	MB800870	1000		IL*	IL*	IL
	TARGET 34 RECO			ACTUAL LOCATION MB780830						
EMITTER	FREQUENCY	ACT.	MOD.	ID	RPT. LOC.	CEP	SENSOR	1	2	3
RABC	31.0	.50	FMV	NO	MB770820	1300		IL	IL*	IL*
	TARGET 51 ARTY			ACTUAL LOCATION MB800960						
EMITTER	FREQUENCY	ACT.	MOD.	ID	RPT. LOC.	CEP	SENSOR	1	2	3
RPT	9300.0	1.0	PULS	YES	MB790970	1600		IL*	IL*	IL

****** TARGET IDENTIFIED----ARTY ******

Fig. 11 SAMPLE CONTROL COPY

EMITTER	ID	FREQUENCY	MODULATION	LOCATION	CEP	SENSOR	1	2	3
		29.0	FMV	MB800870	1000		1*	1*	1
		31.0	FMV	MB770820	1300		1	1*	1*
RPT		9300.0	PULS	MB790970	1600		1*	1*	1

****** TARGET IDENTIFIED---ARTY---******

Fig. 12 SAMPLE INTELLIGENCE COPY

For each target it contains:

- a. Target number
- b. Organic unit description
- c. Actual location coordinates
- ** d. Emitter identification
- ** e. Operating frequency (MHz)
- f. Emitter activity factor
- ** g. Modulation
- h. Emitter identified (yes, no)
- ** i. Reported coordinates for the case of two detecting sensors. If only one sensor detects the emitter, then a reported bearing angle from the sensor is output
- ** j. CEP, error estimate in target location relative to true target for the case of two detecting sensors. If only one sensor detects the emitter, the standard deviation of the bearing inaccuracy is output
- ** k. Lastly, the sensor sites are listed with a summary description of the detection computations. The three character description (ABC) directly below the sensor numbers indicates the following:
  - ** A = 1, emitter detected
    blank, emitter not detected
  - B = L, line-of-sight propagation path
    N, non-line-of-sight propagation path
  - ** C = *, denotes the two sensor sites which have the highest received signal-to-noise ratio (SNR) which were used for the reported target location data.

The Intelligence Copy includes only those emitters which have been detected and the information which is printed are those items with a double asterisk in the tabulation given above. All of the detected emitters in the target array are, however, now listed in a random order to simulate the order in which the data are collected during the sample interval. In the case of item d, emitter identification, only when the emitter is a microwave device will the emitter be identified, and in general this will also identify the target. However, for all HF emitters no emitter or target will be identified. As the frequency allocation for all the HF emitters has been assigned on the basis of a netting doctrine, the printed frequency will provide tipoff information on each of the net elements and nets. In item k, the only output will be a 1 indicating the detection of an emitter, and for the case of more than 2 detecting sensors, the asterisk will be shown indicating the two sensor sites with the highest received SNR.

2. Propagation Model

a. General

The electromagnetic propagation model used in CRESS-S is essentially the same model used in the ACCESS program (ASA Computer Control Environmental Simulation System) developed by HRB-Singer, Inc. and reported in Ref. 5. The propagation model is designed to provide 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 transmitting and receiving 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. The frequency boundaries selected for these five domains are constant values dividing the radio frequency range of interest 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 60 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 13 is a graphic representation of the five frequency-distance (F-D) domains used for groundwave and obstacle diffraction modes of propagation. The domain used for ionospheric skywave mode of propagation is shown between the broken lines. The various model domains are labeled with roman numerals and are briefly summarized below to outline the assumed propagation mode of each F-D domain. More detailed descriptions of the propagation equations are contained in Appendix C of the User's Handbook.

b. Groundwave Propagation on the 0.1 to 60 MHz Band

1. Free Space Basic Transmission Loss

The free space loss, L_{bf} in dB, referred to lossless isotropic transmitting and receiving antenna gains is written:

$$L_{bf} = 32.45 + 20 \log_{10} F + 20 \log_{10} D$$

where L_{bf} = free space loss in dB
F = frequency in MHz
D = path length in km.

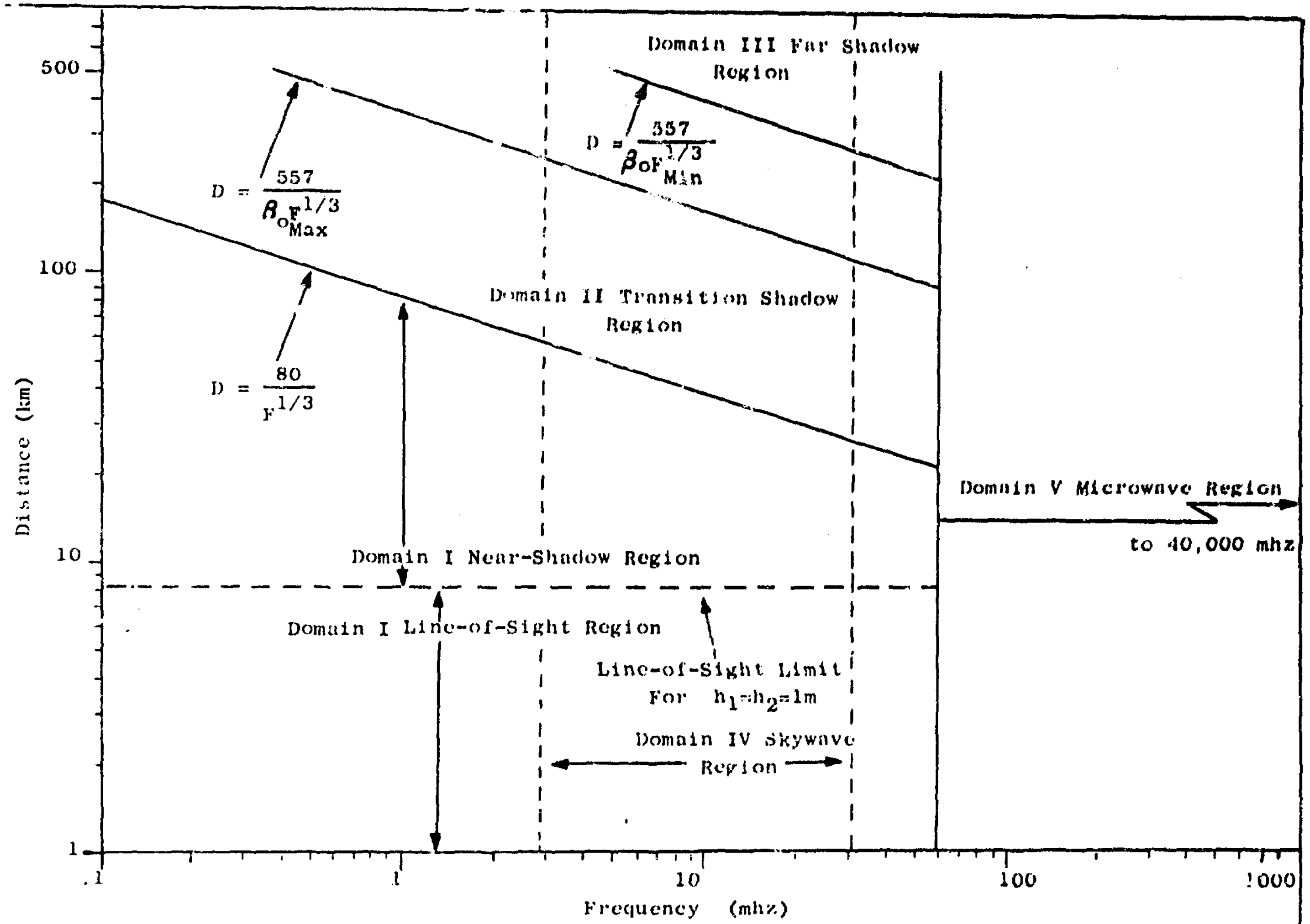

Fig. 13 FREQUENCY-DISTANCE DOMAINS OF PROPAGATION MODEL

2. Domain I, Line-of-Sight and Near-Shadow Region

Propagation path lengths are in the line-of-sight and near-shadow regions from the transmitter; i.e., between zero and a variable maximum distance depending on frequency, $80/F^{1/3}$ km. The mode of propagation in domain I is the groundwave, which is composed of two space waves, plus the Norton (Refs. 10, 11) surface wave. The equations developed for this and the remaining two groundwave domains (II and III) are general with respect to two wave properties of a smooth earth, conductivity and dielectric constant, while the relative magnetic permeability of the earth is assumed to be unity. They also assume that all propagated signals are vertically polarized.

All antennas are assumed to be immobile; however, the upper limit for antenna heights, h (meters), has been fixed at 100,000 feet in all domains. Since antenna heights may reach this order of magnitude, the possibility also exists that a modified distance formula different from $D \leq 80/F^{1/3}$ km can be applied to find the maximum range of applicability for the loss equations used in domain I. The additional criterion is radio horizon distance which is not frequency dependent but is dependent on sensor and emitter antennae height. This height-dependent limit cannot be placed on Fig. 13 in the form of a single line depicting the general case. Such data would appear as a family of lines, each line depicting the specific combination of transmitter and receiver antennae heights.

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 simple empirical relationship which reproduces, within engineering accuracy, the magnitude of the classical theoretical function. Thus;

$$\begin{pmatrix} \text{Plane} \\ \text{earth} \\ \text{loss} \end{pmatrix} = \begin{pmatrix} \text{Free} \\ \text{space} \\ \text{loss} \end{pmatrix} + \begin{pmatrix} \text{Plane earth loss} \\ \text{in excess of free} \\ \text{space} \end{pmatrix}$$

The above equation is employed for estimation of plane earth attenuation losses when the line-of-sight between the transmitter and receiver antennae is unobstructed by the bulge of the smooth spherical earth or by irregular terrain.

In domain I 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 in this near-shadow region due to elimination of the direct and reflected wave. Thus, the following expression results:

$$\begin{pmatrix} \text{Near} \\ \text{shadow} \\ \text{loss} \end{pmatrix} = \begin{pmatrix} \text{Free} \\ \text{space} \\ \text{loss} \end{pmatrix} + \begin{pmatrix} \text{Excess of free-} \\ \text{space shadow} \\ \text{loss} \end{pmatrix}$$

3. <u>Domain II, Transition-Shadow Region</u>

The propagation mode of domain II is the groundwave, which is composed of the Norton surface wave, and is commonly called the transition-shadow region. This complex region is bounded between the two regions (near and far-shadow) where simpler asymptotic solutions exist. The transition-shadow region is treated by a recently developed empirical relation that provides results compatible to Norton's classic graphical method (Ref. 10).

The transition shadow region lies beyond the distance where the plane earth loss (line-of-sight plus near-shadow) approximation degenerates and short of the far-shadow region where the propagation mode is groundwave. The form of this equation is:

$$\begin{pmatrix}\text{Basic} \\ \text{transition-} \\ \text{shadow loss}\end{pmatrix} = \begin{pmatrix}\text{Free} \\ \text{space} \\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Spherical earth transition-} \\ \text{shadow loss in excess of} \\ \text{free space}\end{pmatrix}$$

4. Domain III, Far-Shadow Region

The propagation mode is the groundwave which, in this domain, is composed of the Norton surface wave. This region extends from the transition-shadow region up to 500 km range for the CRESS-S simulation. The form of the expression for deep-shadow (far-shadow) loss is:

$$\begin{pmatrix}\text{Deep} \\ \text{shadow} \\ \text{loss}\end{pmatrix} = \begin{pmatrix}\text{Free} \\ \text{space} \\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Spherical earth deep-} \\ \text{shadow loss in excess} \\ \text{of free space}\end{pmatrix}$$

5. Terrain Obstacle Losses for Domains I, II, and III

A mechanism for estimating system loss over rough earth 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 the total losses. When the height of the terrain obstacle exceeds the height of the line-of-sight ray by an amount H (meters) which is larger than twice the bulge height of the smooth spherical earth (with radius corrected for refraction effects), the path is classified as a plane earth path with a terrain obstacle. The basic 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 becomes:

$$\begin{pmatrix}\text{Total}\\ \text{basic}\\ \text{loss}\end{pmatrix} = \begin{pmatrix}\text{Free}\\ \text{space}\\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Plane}\\ \text{earth}\\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Terrain}\\ \text{obstacle}\\ \text{loss}\end{pmatrix}.$$

6. Foliage Losses for Domains I, II, and III

Foliage losses for domains I, II, and III are treated by a simple empirical function relating the attenuation of radio waves (per meter of screen thickness) to the length of the path through the wooded areas. The sum of the lengths of the path through wooded areas is obtained from manual map work at the same time that terrain obstruction data are being obtained.

c. Domain IV, HF Ionospheric Skywave Propagation

The fourth domain of the propagation model lies between the frequency limits of 3 MHz and 30 MHz. The mode of propagation which defines 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. 12, 13). In general, either a single-hop-E-layer or a single-hop-F-layer mode is possible from the routine.

This simulation program has two assumptions which permit a significant reduction in the complexity of the HF path-loss routine:

1. With few exceptions, all path terminal points are located within a geographical area with a maximum dimension of 500 km, and

2. The time intervals of interest for any single simulation run do not overlap the sunrise/sunset transition interval. Approximately a two-hour interval should be allowed for each of these transition times.

With the above limitations in geographical area and time period, a number of parameters which are normally variables in the path-loss equations are reduced to constants, considerably simplifying the computing routine. The basic computing procedures and formulas are those developed at NBS and the U.S. Army Signal Propagation Agency (Refs. 12, 14, 15). The total ionospheric transmission loss is given by:

$$\begin{pmatrix}\text{Total}\\ \text{path}\\ \text{loss}\end{pmatrix} = \begin{pmatrix}\text{Basic}\\ \text{free-space}\\ \text{loss}\end{pmatrix} + \begin{pmatrix}\text{Nondeviative}\\ \text{D-region absorp-}\\ \text{tion loss}\end{pmatrix} + \begin{pmatrix}\text{Loss due to}\\ \text{polarization,}\\ \text{magneto-ionic}\\ \text{splitting, etc}\end{pmatrix}$$

d. <u>Domain V, Microwave Region</u>

The fifth F-D domain is the microwave region lying between the frequency limits of 60 and 40,000 MHz. Three possible types of propagation paths exist in this portion of the model. The equations used to estimate path loss for this domain have been taken from the ACCESS simulation, and one of three empirical path loss expressions is selected for each microwave sensor/emitter path. These are:

1. <u>Essentially Line-of-Sight Path</u>. Defined as LOS except for possible small obstructions near the transmitter antenna location.

2. Single Obstacle Path. Defined as a path obstructed by a single terrain obstacle, such as a single mountain or hill.

3. Multiple Obstacle Path. Defined as a path obstructed by more than one terrain obstacle such as two or more hills or mountains.

3. 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 outlines the factors used to determine the probability that a hearable signal is detected. These factors are derived from the activity pattern assumptions for the emitter and the operating procedures of the sensor.

The emitter activity pattern describes how often and for how long the emitter is active ("up") during the time interval being considered. In this model the activity pattern is summarized in a single activity factor, p, that is the fraction of the time period, T, that 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 specific knowledge of the net activity pattern, or on the assumption that the net up time is shared equally among the emitters. The concepts are elaborated on in greater detail in Appendix C.

4. Identification

In CRESS-S, identification has been considered both in terms of identifying the individual emitter from which a signal has been detected, and identifying the target with which this emitter is associated. For the present a relatively simple identification logic is being used.

It is assumed that the characteristics of radar types used in target arrays are sufficiently well known that their signals, when detected, identify with complete surety both the type of radar and the type of military unit (e.g., SAM, artillery, rocket forces) with which it is associated. A similar assumption is made for UHF or microwave radio relay equipment. In the case of HF and VHF communications SIGNALS, no attempt is made in CRESS-S to provide emitter or target identification. However, in the Intelligence Copy, frequency data are given, enabling recognition of components of the various communications nets.

E. Sensor Subroutine Descriptions

This section presents a brief description and data flow diagram for each of the sensor models in the CRESS-A and CRESS-G computer programs. Outputs for each sensor model are probabilities of target element detection, recognition, and identification. Line-of-sight has been determined to exist before a sensor subroutine is called. Probabilities of recognition and identification are conditional on detection and recognition, respectively. Detailed analytic models are presented in Appendix B of the User's Handbook.

1. <u>Photographic Sensor Model (Fig. 14)</u>

The photographic model provides for simulating the operation of vertical frame, side oblique, forward oblique, and panoramic cameras. High contrast system's resolution may be computed by the MTF (modulation transfer function) approach or may be input directly, as the user chooses. The effects of platform motion limitations are included in calculating the high contrast resolution. The atmosphere degrades the contrast between the object and background, and the resulting apparent contrast modulation is used to degrade the high contrast resolution to attain the operational resolution for the particular target element.

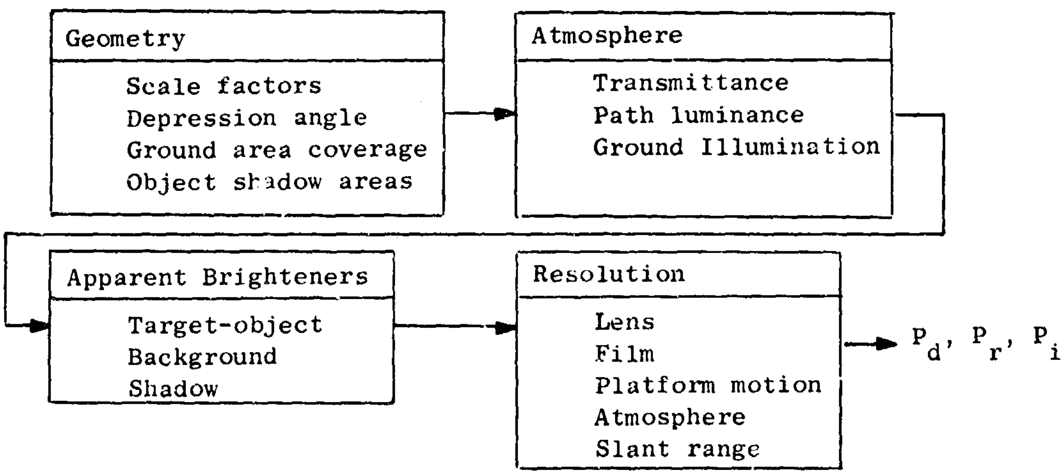

FIG. 14 PHOTOGRAPHIC SENSOR MODEL DATA FLOW

2. <u>Infrared (IR) Sensor Model (Fig. 15)</u>

The IR sensor model simulates line scanning type IR systems whose imagery is recorded, line by line, on photographic film. The forward motion of the aircraft causes successive scans to cover different strips of the rounu on the film, which moves after each scan. This yields a composite thermal map of the area being covered. System operation at any of the windows in the .3 to 15 micron range is allowed.

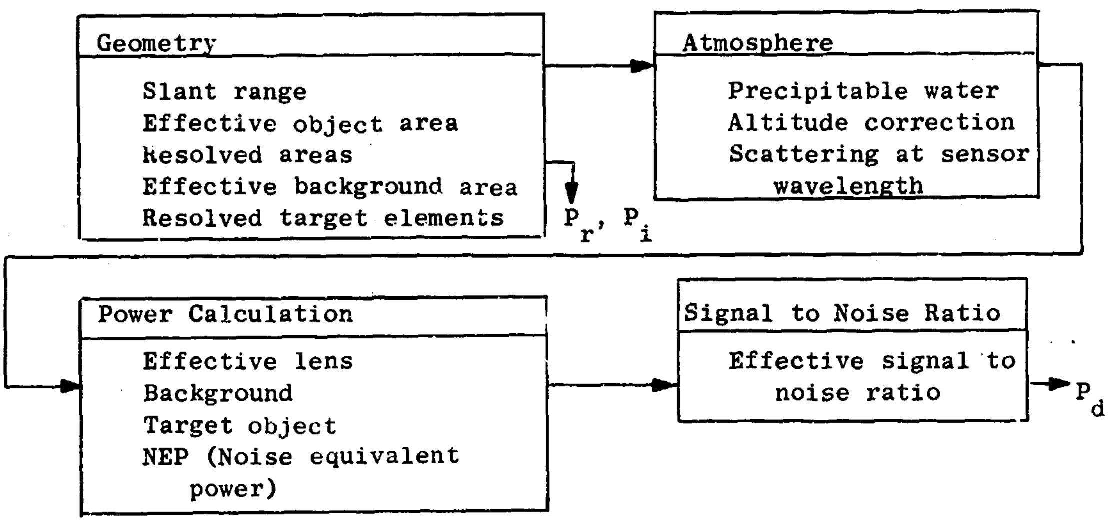

FIG. 15 IR SENSOR MODEL DATA FLOW

3. Aerial Radar Sensor Model (Fig. 16)

The radar sensor model simulates side-looking airborne radar systems of the following types: (a) synthetic-aperture, (b) conventional mapping, (c) MTI, and (d) mapping and MTI. Output of the radar system is assumed to be on a display scope or on film for subsequent image interpretation.

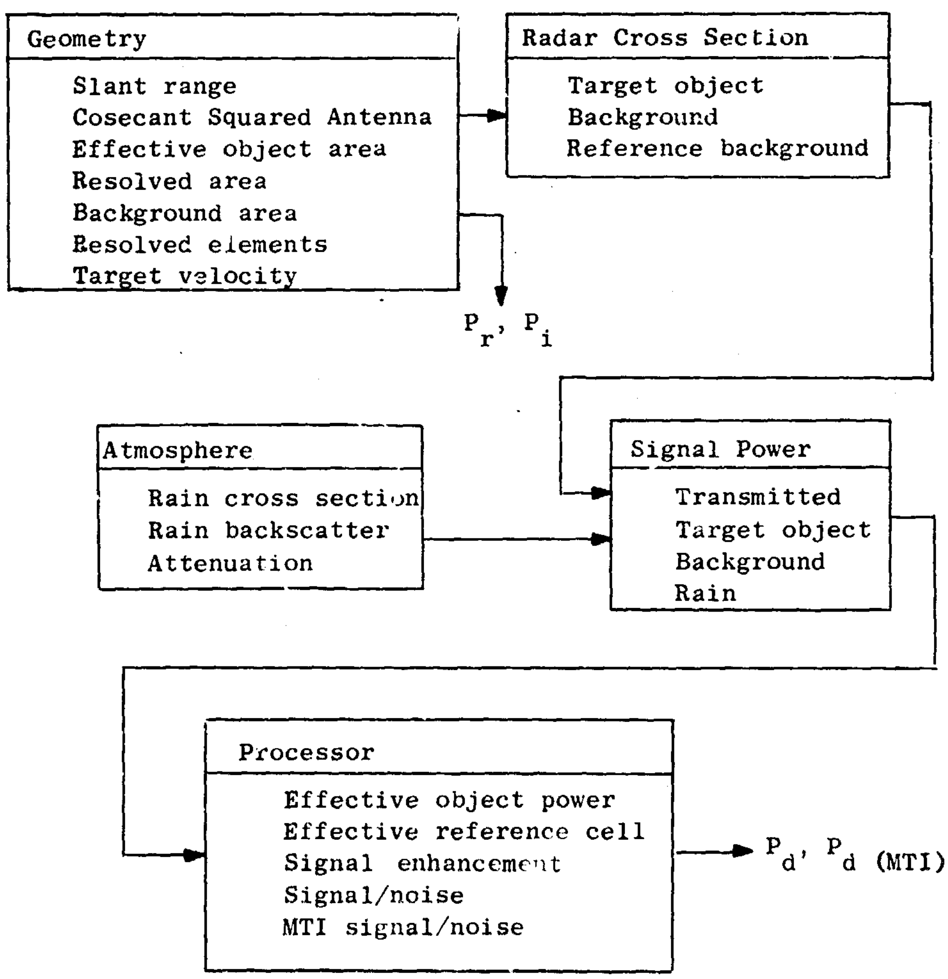

FIG. 16 RADAR SENSOR MODEL DATA FLOW

4. Visual Sensor Model (Fig. 17)

The visual sensor model simulates the unaided eye and the eye with magnification devices.

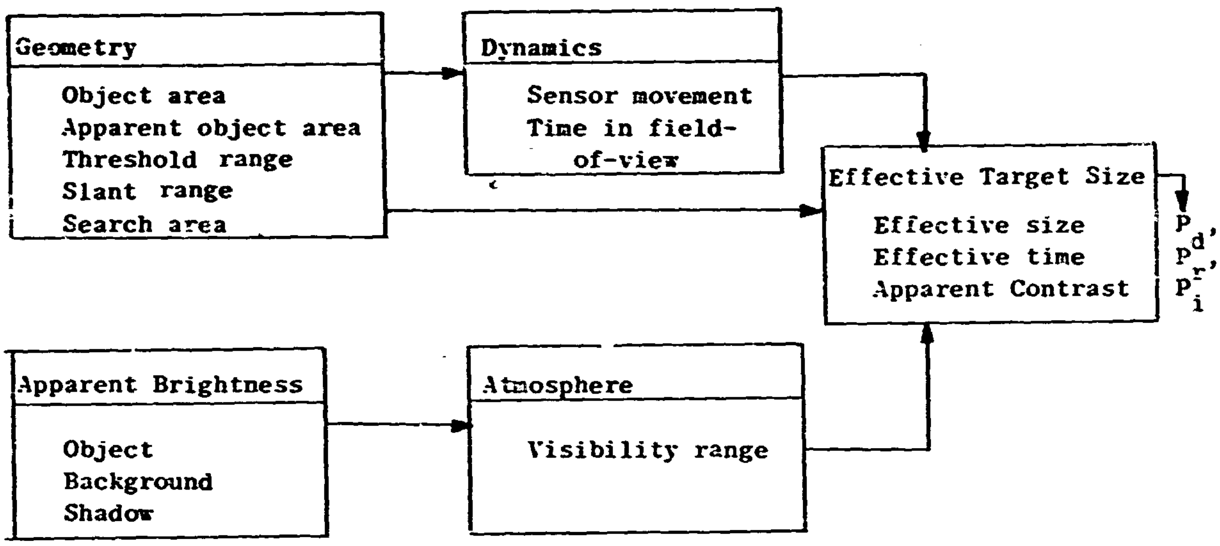

FIG. 17 VISUAL SENSOR MODEL DATA FLOW

5. Laser Sensor Model (Fig. 18)

The laser sensor model simulates a laser power source in the IR spectrum for illumination and a receiver similar to the IR line scanner, which records it imagery on film. The imagery is formed from reflected IR energy, not emitted energy.

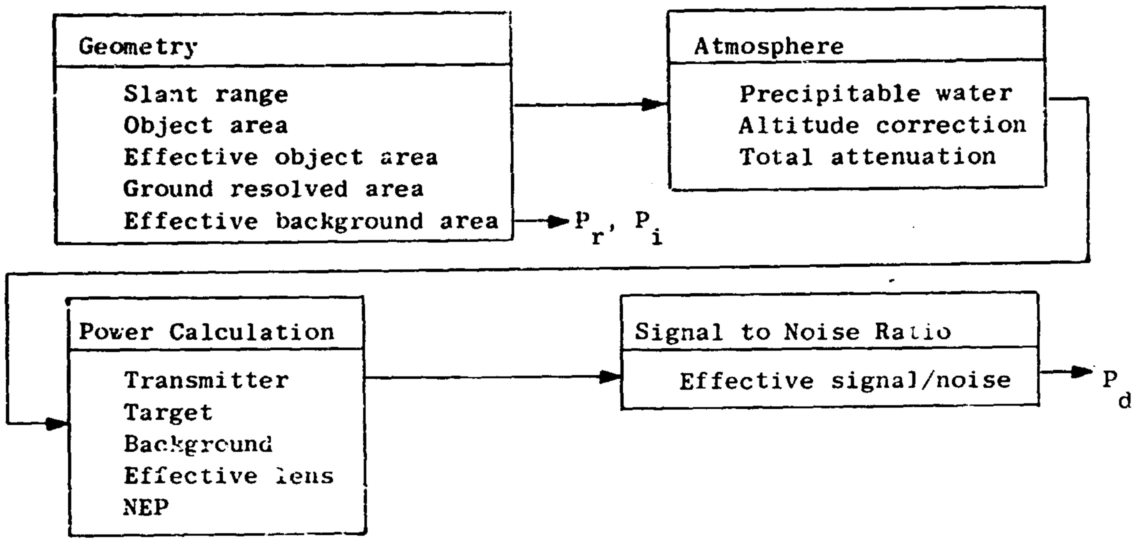

FIG. 18 LASER SENSOR MODEL DATA FLOW

6. Low-Light-Level Television (LLLTV) Model (Fig. 19)

The LLLTV sensor model simulates the general performance characteristics of an image intensifier-SEC vidicon tube. Resolution is assumed to be a function of photocathode illuminance and apparent contrast modulation at the photocathode.

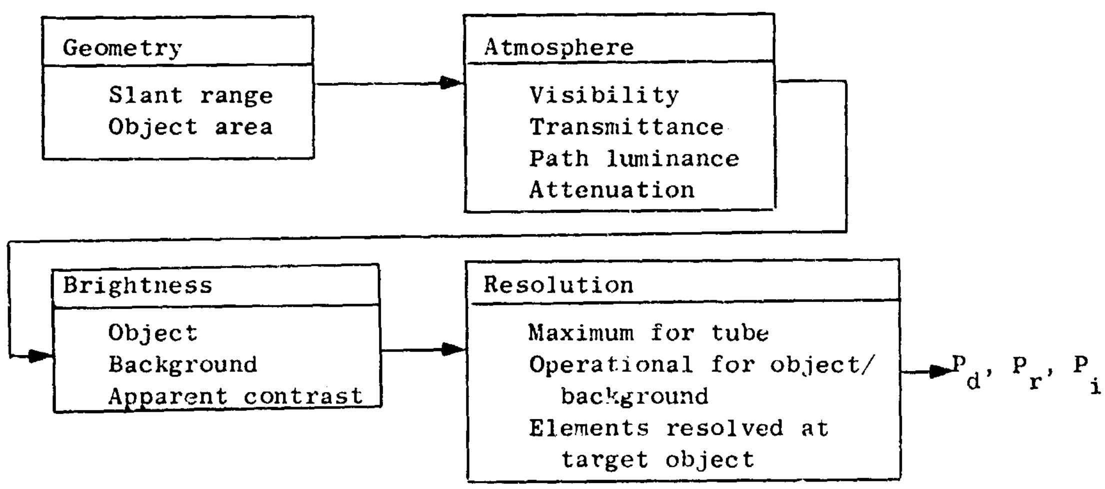

FIG. 19 LLLTV SENSOR MODEL DATA FLOW

7. Passive Night-Vision Devices (PNVD) Model (Fig. 20)

The PNVD sensor model simulates the general performance characteristics of a photocathode and image intensifier. Resolution is a function of photocathode illuminance.

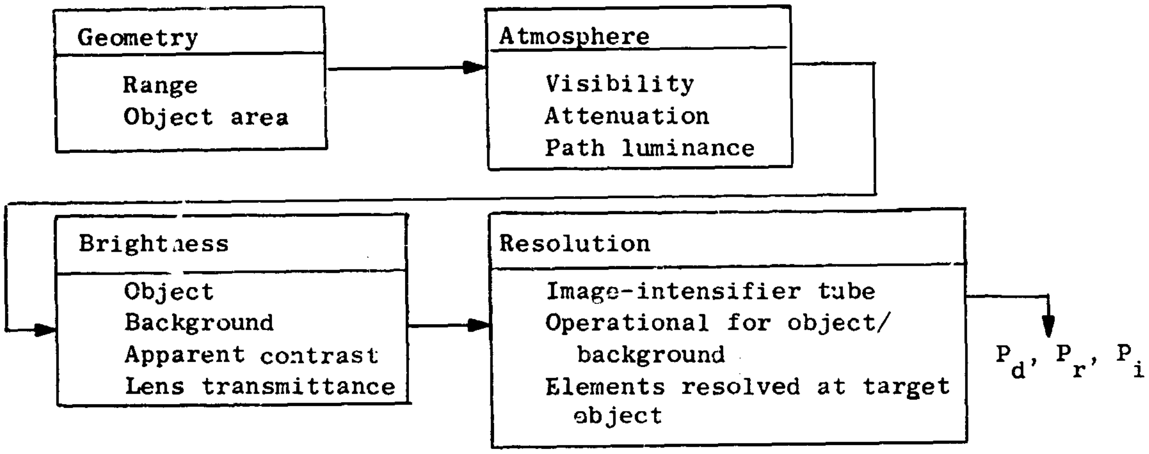

FIG. 20 PNVD SENSOR MODEL DATA FLOW

8. Ground Surveillance Radar (GSR) Model (Fig. 21)

The GSR sensor model simulates an MTI search radar with audio or audio and visual display.

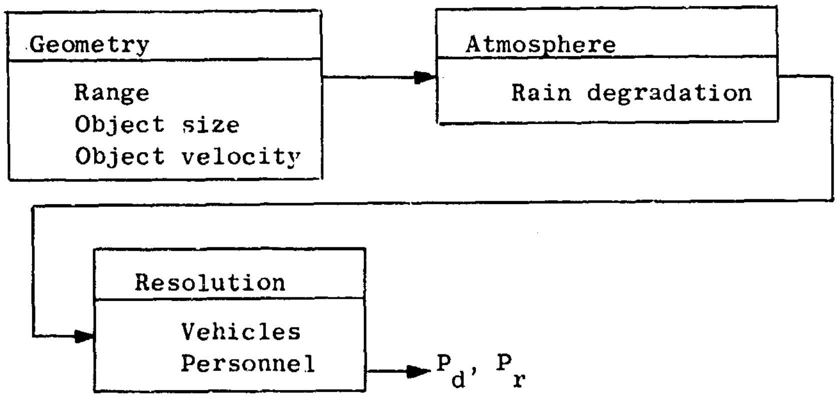

FIG. 21 GSR SENSOR MODEL DATA FLOW

V MODEL EXERCISE

To thoroughly check all aspects of CRESS, it was planned to exercise the model by simulating two six-hour periods (day and night) of the reconnaissance and surveillance activity of a Blue motorized rifle division reinforced by a tank battalion opposing a Red Combined Arms Army. The scenario chosen was developed for the ISS ammunition expenditure rate study--1973. A critical part of that study was to develop an acquired target list to be used in allocating fire power.

Although the primary reason for choosing a fairly large scenario was to ensure checking all parts of CRESS, a secondary objective was to provide something useful to the Institute of Special Studies in the event that the test of CRESS was successful.

The scenario that was used resolved the Red forces to company level near the forward edge of the battle area (FEBA) and to battalion level beyond 6 to 10 kilometers behind the FEBA, although some important units had been more finely resolved in both areas. To apply CRESS, it was desirable to resolve the companies near the FEBA, where ground-based sensors might sense them, into platoons. In addition, some of the battalions were resolved into companies. Movement within the six-hour period was additionally played and, as a result, several of the targets were given more than one position during each of the six-hour periods. (The two six-hour periods (day and night) were simulated separately. The Red units had the same positions for both day and night; the Blue sensors changed.) There resulted 510 targets for CRESS processing.

The scenario originally had been developed with no thought of using CRESS. The Tables of Organization and Equipment (TOEs) listed for each Red unit were derived by summing the numbers of target elements of the same type without regard to size (e.g., 20-ton trucks were grouped with 1-ton trucks). It was necessary to reference again the publications originally used, which listed the equipment by specific type.

The importance of understanding how CRESS works was made evident by the amount of extra effort that was expended in performing the tasks indicated above. To accomplish the first task, it was necessary to refer to the TOE tables for the Red units. However, the importance of the size of the target elements was not appreciated, and the numbers of all trucks were added to get a single number. When the importance of size was understood, the TOE lists once again had to be referenced for each target. Had the requirements for CRESS been met when the target lists were originally developed, the TOE lists need only have been referenced once instead of three times.

The target list resulting from the detailed listing of equipment contained 68 different types of target elements. These were classified into 18 recognition classes and 8 detection classes. The targets from the FEBA to 130 kilometers behind the FEBA were located on 15 different types of backgrounds.

The same types of sensors that were used in the original study were simulated by CRESS. A total of 28 reconnaissance aircraft sorties were scheduled for the six-hour period from 1200 to 1800 hours. A total of 87 day OPs and 64 night OPs were deployed. A probability of line of sight above zero was determined for each of 1729 target-OP straight-line paths.

The deployment of the airborne sensors would have been considerably faster had there been someone present who was thoroughly familiar with high performance reconnaissance aircraft and tactics, as there was for the Army aircraft. Since the results of an R & S mission are quite sensitive to the flight parameters, particularly altitude, it is important in many studies, such as the one for this model test, that realistic parameters be used for the combination of sensors being flown. An experienced flight planner should be used. (Note that a good operational use for CRESS would be to aid the flight planners in selecting those flight parameters that would yield a maximum amount of R & S data from the mix of sensors being flown.)

Few difficulties other than the ones mentioned above were encountered in preparing the data for computer processing.

Unfortunately, however, completion of programming and debugging was much slower than expected. The results of the computer runs will not be available in time to analyze them with members of the team that conducted the ISS ammunition expenditure rate study--1973 and to report the findings in this report.

VI TACTICAL OPERATIONS CENTER (TOC) INTELLIGENCE FUNCTIONS

A preliminary study of the intelligence functions of a TOC was conducted to assess the feasibility of developing a model for those functions in a Phase II study effort.

There is an evident need for the results of such a study, since many systems studies (including war games) that require tactical intelligence assessments currently do not have a sufficiently detailed intelligence-processing methodology to dependably reflect sensitivity to varying input R & S parameters. Although it is probably not desirable to take human participation out of the intelligence processes performed in systems studies, it is nevertheless desirable to have a documented methodology to guide the human analysts so that studies which are essentially repeated but use different analysts will yield approximately the same results. The methodology should also be such that any piece of output information can be specifically traced back to origins that are generally accepted as being accurate.

Critical areas to be considered in developing a model of the tactical intelligence functions for use in systems studies include: reconnaissance and surveillance collection means; topographical data; weather data; intelligence reports from agents, line crossers, and prisoners of war; current methods of collating, processing, and presenting data; the impact and capabilities of automated systems being developed; the existing models concerned with intelligence processing; and the essential elements of information (EEI) and other intelligence requirements.

The parts of a model that are to be exercised on a computer must be well defined in one of two senses: (1) the procedures followed by the men performing the function to be modeled can be explicitly defined and programmed to be executed by the computer (i.e., a heuristic model of the function can be built), or (2) the function to be modeled is possibly not well understood but a procedure suitable for computer usage can be constructed that yields approximately the same output as is achieved from the real function, when the same inputs are used as are used by the real function (i.e., an abstract model of the function is constructed).

Experience in constructing a computer model to produce a class-instructor-student-room time schedule for the U.S. Naval Postgraduate School (Ref. 16) has indicated that many quite complicated functions which people perform "subjectively" can be analyzed and heuristically modeled. Although the time scheduling problem was not nearly as complex as the combination of intelligence functions in a TOC, it did require the collation of large amounts of diverse types of information, the recognition of acceptable patterns, and the presentation of possible alternatives. It was successfully run on a computer.

The key to the success in that time scheduling problem derived from detailed discussions between the scheduler and a person deeply involved in the functions to be modeled. After these discussions, it was possible to derive explicit procedures for making "minor" decisions that the scheduler had previously thought to be the result of subjective judgments. Combining the procedures for the minor decisions led to a computer model capable of producing meaningful decisions that appeared to be a result of the person's prowess as a scheduler.

If a TOC in operation could be visited and detailed discussions could be held with an officer deeply involved and thoroughly familiar with the intelligence functions being exercised in that TOC, then it is felt that the heuristic approach can be successful for some of those functions. In particular, functions concerned with the collation of data, checking data for certain types of information, presentation of data, or dissemination of results hold promise of being amenable to this modeling approach.

The "abstract model" approach also holds promise of being useful. In particular, a preliminary methodology, based on binomial distributions and Bayes' theorem, has been outlined for determining the type of tactical unit to which sighted target elements probably belong. (A simple example of this function is given later in this section.) The generality of the probability tools used in this particular intelligence function makes it probable that they will apply to modeling other intelligence functions as well.

Research being carried out for the U.S. Air Force by W. Edwards (Ref. 6) at the University of Michigan and D.A. Schum, et al. (Ref. 7) at the Ohio State University Research Foundation is concerned with Probabilistic Information Processing (PIP) Systems based on Bayes' theorem, and is directed toward applications in military intelligence processing. Similar research is being conducted for the U.S. Navy by C. R. Blunt, et al. (Ref. 8), at HRB-Singer, Inc. Their work, as well as related work by J. R. Newman, et al. (Ref. 17), at Systems Development Corporation, has been primarily theoretical and experimental. Their publications indicate that the efforts to apply their work have been directed toward providing methods for enhancing military intelligence processing.

It is felt, however, that their methods, as well as the one outlined below, are also good analytic tools for building models of intelligence functions--models that would be used in systems studies of present and future reconnaissance, surveillance, and intelligence systems.

The following method for producing estimates of the target to which a group of detected elements belong is based upon the use of Bayes' theorem. In using this method the probabilities that different kinds of enemy units may be operating in the area are determined by the intelligence officer using prior intelligence or his best estimate of the situation. For each of the possible kinds of units the probability of detecting the particular elements actually sighted can be determined from the binomial distribution if the probability of sighting each of the individual elements is known. The latter probability can also be determined from a mathematical model of the sensor, apriori information, or from a subjective estimate. These probabilities can then be combined to give the probabilities that the actual unit sighted was one of each of the possible kinds of units.

To illustrate these ideas with a very simple example, suppose that the target units known to be operating in the area are a tank platoon, a tank company, and a tank battalion. Each of these units is composed of tanks, men and jeeps in accordance with the compositions shown in Table V. The probability of sighting the different elements and the probabilities that the different target units are in the area are given in Table VI.

Table V

EXPECTED COMPOSITION OF UNITS

Type of Element	Type Unit		
	Platoon(P)	Company(C)	Battalion(B)
T Tank	3	10	30
M Man	10	40	150
J Jeep	0	1	4

Table VI

PRIOR PROBABILITIES

Type of Unit	Prob. Type Unit is in Area	Element	Prob. of Sighting Element
Platoon	P(P) = 0.5	Tank	P_T = 0.8
Company	P(C) = 0.3	Man	P_M = 0.5
Battalion	P(B) = 0.2	Jeep	P_J = 0.6

Let S represent the event that two tanks and five men were sighted. We want to determine $P(P|S)$, and $P(B|S)$, where $P(P|S)$ stands for the probability that, given the sighting, it is a Tank Platoon. We do this by using the binomial distribution to calculate $P(S|P)$, $P(S|C)$, and $P(S|B)$ and then using these values and the probabilities in Table II to calculate the desired probabilities (likelihoods) by Bayes' theorem.

These probabilities can be stated as

$$P(C|S) = \frac{P(S|C)P(C)}{P(S)} = \frac{P(S|C)P(C)}{P(S|P)P(P)+P(S|C)P(C)+P(S|B)P(B)},$$

with similar expressions for $P(P|S)$ and $P(B|S)$.

The method of using the binomial distribution to calculate $P(S|P)$, $P(S|C)$, and $P(S|B)$ is illustrated as follows:

$$P(S|C) = P(2T, 5M, 0J|10T, 40M, 1J)$$
$$= P(2T|10T \text{ and } 5M|40M \text{ and } 0J|1J)$$

If the sighting of one object type is independent of the sighting of another object type, then this last probability is just the product of the indivudal probabilities.

$$P(S|C) = P(2T|10T) \bullet P(5M|40M) \bullet P(0J|1J)$$

Each of the three probabilities on the right side are just the indicated elements of binomial distributions, where the values of P_T, P_M and P_J are obtained from Table II. Similarly $P(S|P)$ and $P(S|B)$ can be calculated.

If a decision as to which type of unit was actually sighted is needed, it can be made on the basis of the alternative having the highest calculated probability using the procedure given above or by drawing a random variate from the distribution described by $P(P|S)$, $P(C|S)$ and $P(B|S)$. (Performing the indicated calculations for this example, the probability is nearly 1 that the elements belong to a platoon, nearly 0 that they belong to a company, and nearly 0 that they belong to a battalion.) As additional data and sightings come in revised estimates of the unit type can be made. This is done by another application of Bayes' theorem, where the previously calculated probabilities are now used for the prior estimates (P(P), P(C), P(B)) probabilities of finding the different types of units.

The very simple formulation of Bayes' theorem given above can also be expressed in terms of probability distributions for the different parameters rather than discrete probabilities. This additional degree of sophistication does not complicate the calculation significantly and frequently provides a more satisfying subjective basis for the assessment of prior probability. In addition, it provides the user with a mathematical formalism with which to express additional subjective data concerning his degree of confidence in his estimate of the prior probabilities.

This is one example of how a computer model can be designed for a particular intelligence function. The technique used should also prove useful in modeling other inferential functions whose results depend on diverse sources of information.

The Automatic Data Field Systems Command (ADFSC) is also developing data processing systems (TACFIRE, TOS) that include some automatic intelligence processing functions. Some of the models developed by ADFSC to implement actual intelligence processing should also be applicable to systems studies concerned with intelligence processing.

When the tactical intelligence functions within a division are modeled, those functions amenable to computer simulation should be emphasized; however, a methodology also should be developed carefully for the parts that would be played by the humans who are participating in exercising the intelligence model. This will be necessary because it is probably not possible (or desirable) to utilize properly all the areas critical to tactical intelligence processing in a computer (only) model.

Although models are usually built to assess existing theories and doctrines, model building is also valuable as a tool for helping to understand emerging theories and doctrines. It is felt that enough important intelligence functions for processing R & S data can be modeled by the two methods discussed above to make a Phase II effort worthwhile. Additionally, value may accrue to such a study because of (1) the applications it might have to actual intelligence processing, and (2) the additional development of the applicable theory it might produce.

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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 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 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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Radar						
Visual						
Television						
Passive night vision devices						
Multisensor interpretation						
Timeliness						