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INFRARED SENSOR SIMULATION (IRSES) PROGRAM.(U)

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INFRARED SENSOR SIMULATION (IRSeS) PROGRAM

FINAL REPORT

SEQUENCE NO. 0002

18 NOVEMBER 1979

PREPARED FOR:

U.S. ARMY MISSILE COMMAND
REDSTONE ARSENAL, ALABAMA 35809

CONTRACT NO. DAAK40-79-C-0093

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NRC-79-IRSES-

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SECTION 1. INTRODUCTION

This report serves as part of the deliverables for the Infrared Sensor Simulation contract with MICOM, contract number DAAK40-79-C-0093. The contents of this report include a brief description of the accomplishments during the period of the contract, the results of a sensor noise analysis that was conducted, and includes a future growth plan using the tools that have been developed in meeting research requirements with reference to infrared sensors in the indirect fire scenario.

Figure 1 shows the relationship and interfaces of the tasks associated with this program. From the beginning of this program a plan was considered for growth which gave guidance to the development of the Infrared Sensor Simulation (IRSeS) Program. In general, the simulation was developed to be as general purpose as possible. The simulation was divided into two parts: (1) the part that represents the sensor scene and sensor motion and (2) the part that represents the signal processing, acquisition algorithms, etc. that would normally be performed by the electronic system or through a computer. These concepts are shown in the block labeled "Develop Plan for Growth." The plan for growth that was developed during this task is summarized and reported in Section 3.

Block 2 represents Task 2 that is called "Identify Significant Noise Sources," so that the results of this analysis can be incorporated into the sensor model in the simulation. Areas that were to be considered were noise introduced through spiders, baffling, or discontinuity in the optics system and noise introduced through the infrared detector and electronics. The results of this task are included in this report. In summary, a Fourier analysis was applied to the limited amount of data that we had and it indicated 1/f temporal dependency summed with a flat frequency response. The amount of data that we had, however, was extremely limited and significance of the results could be questioned. A 1/f and flat temporal frequency response were modeled in the simulation.

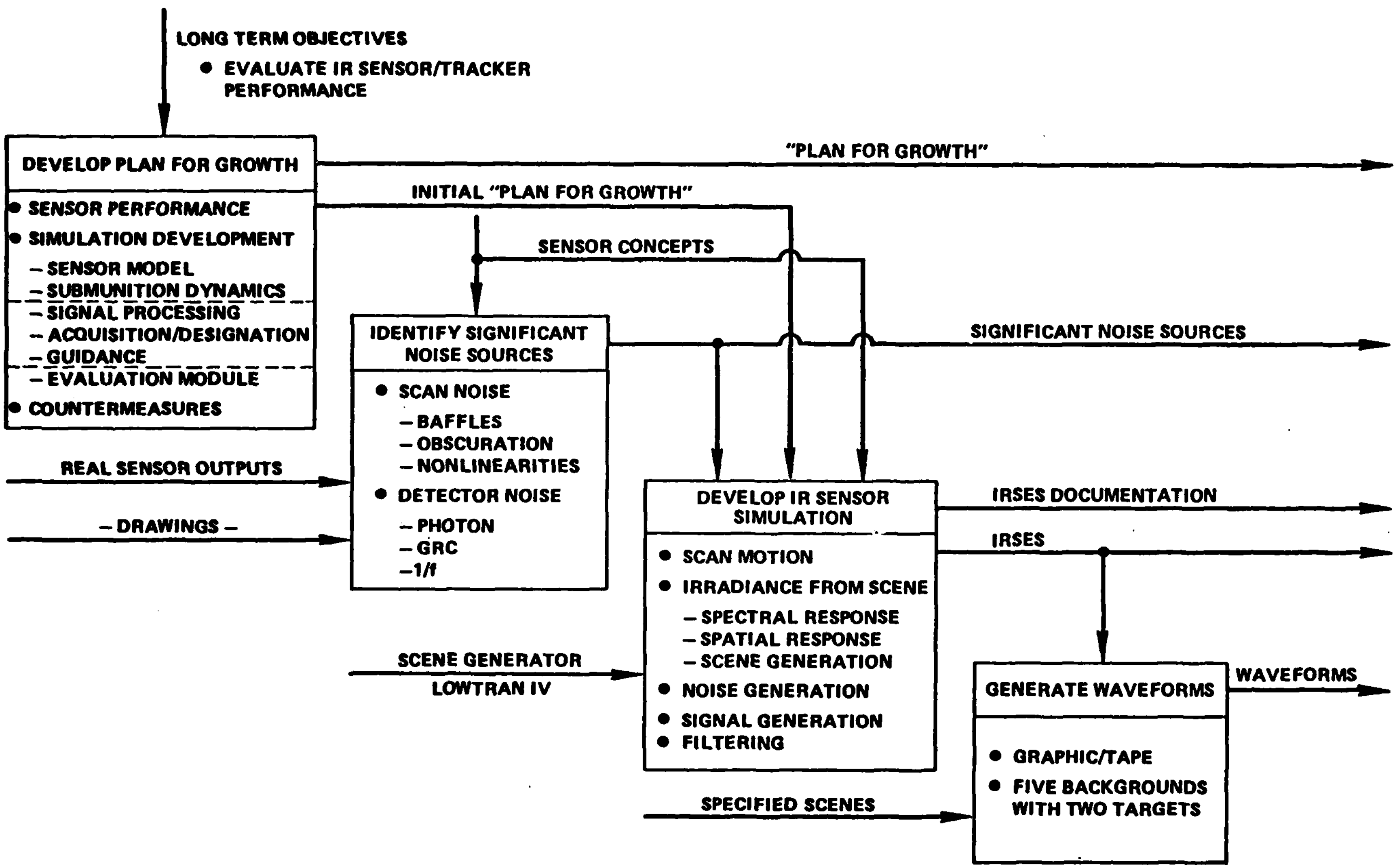


FIGURE 1. TASKS DURING THIS EFFORT

Block 3 represents task 3 which was to develop IR Sensor Simulation. The current simulation is composed of a sensor model that interacts with a synthetic scene model to give irradiance values and sensor voltages. The outputs of the three sensor models were based on the measured outputs for consistency between the simulated and real sensors. Figure 2 outlines the construction of the sensor model. The simulation and examples of the inputs and outputs are described in detail in a report under separate cover. This effort represented the majority of the work under this contract.

Block 4 represents Task 4, which was to generate waveforms or signal outputs from the simulation. These outputs were generated on two magnetic tapes and furnished with a description of the scenes and viewing conditions. The kinds of targets and scenes furnished were a tank in a grassy field, on a road, and natural features as a treeline, road, swamp bordering on a wooded area, etc., that are typical to the features on the five scenes that were modeled under this contract.

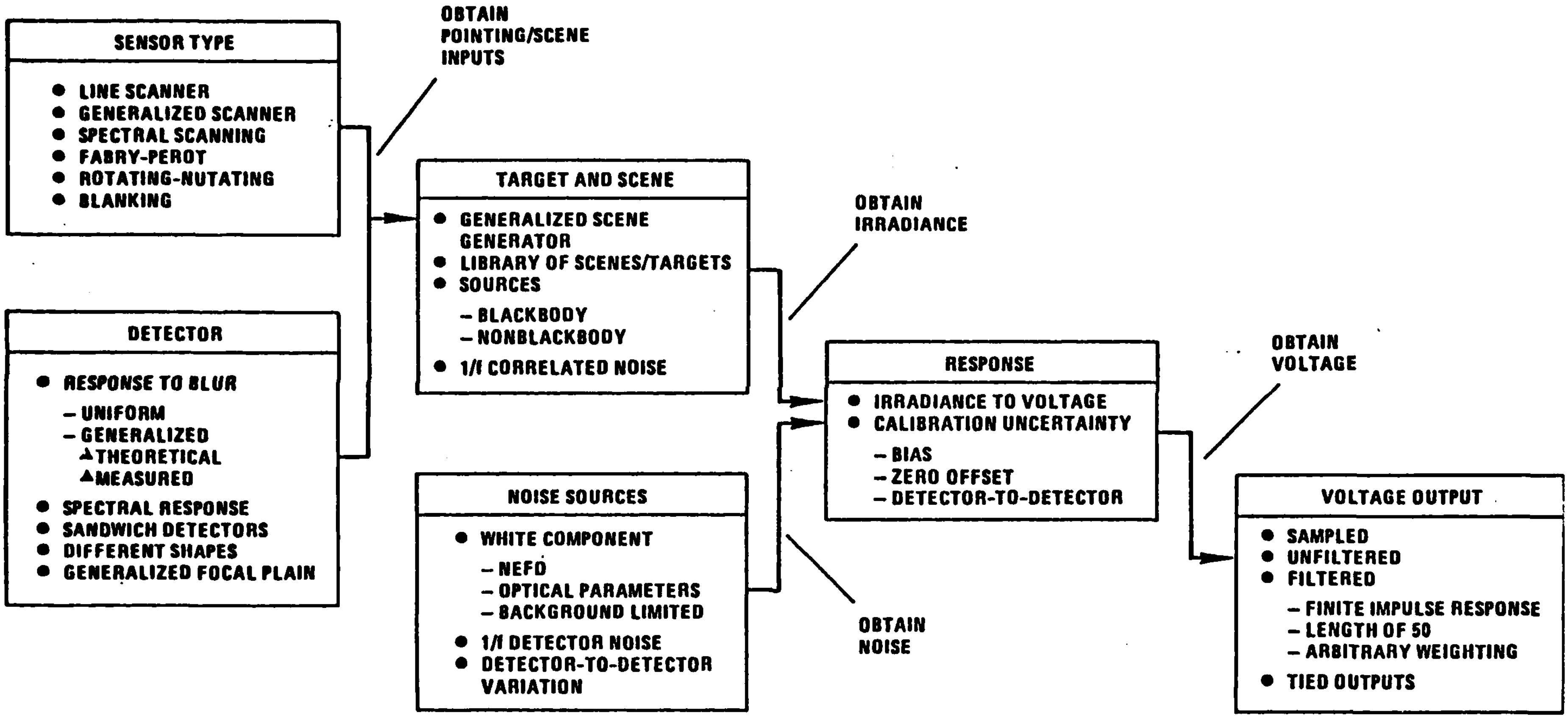


FIGURE 2. SENSOR MODULE PROCESS FLOW

SECTION 2. NOISE ANALYSIS

The noise analysis was conducted on all of the data furnished to NRC by the Army; however, the data were limited and were only available for Sensors A and C. Figure 3 shows the sensors of interest and the labels for each sensor. Figures 4 and 5 present the data and results of noise analysis for Sensor A. The data were in the form of a picture of an oscilloscope trace. The Fourier analysis of the post amplifier output (see Figure 4) shows that the spectral response is nearly flat. A 1/f component can be seen for the preamplifier output (see Figure 5) with a corner at approximately 25 Hz.

A Fourier analysis was possible for Sensor C post amplifier output; however, there was insufficient data for the preamplifier output to conduct an analysis. The results of the post amplifier Fourier analysis are indicated in Figure 6. The data indicate that the spectral response is nearly flat.

The confidence level in the results presented is small because of the limited amount of data. The data that were available came from the oscillograph traces presented in the figures. The number of samples was limited, which causes the oscilliatory type of frequency response. The data were extracted before the pulse picture, but there could be some contamination from the pulse. The statistical sample presented would be more satisfying if many groups of data had been used so as to obtain a better statistical sample and consequently greater confidence in the data.

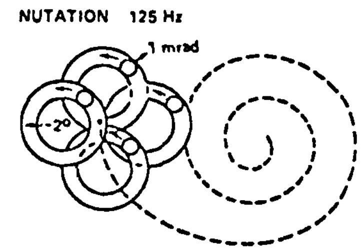
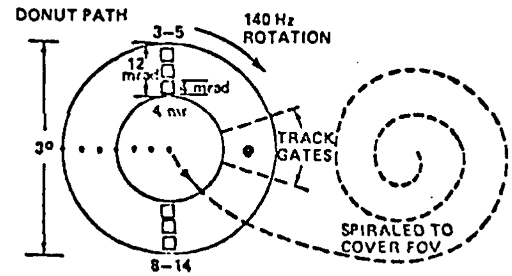
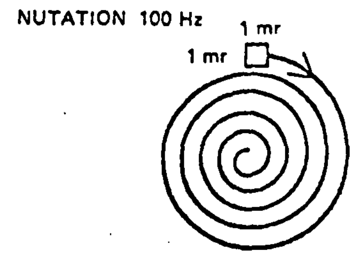
INDIRECT FIRE SENSOR/ SEEKER	OPTIC	BANDS (μm)	NO. OF DETECTORS PER BAND	SEARCH FIELD OF VIEW	FRAME TIME (SEC)	TYPE OF SCAN	SCAN PATTERN/FOV
A	CASSEGRAIN	2–3 3.4–4.5	4	20° CONE	4	SPIRAL	
B	CASSEGRAIN	1.4–1.8 3.4–4.5 8–14	3	20° CONE	4	SPIRAL	
C	CASSEGRAIN	3.4–4.5 8–14	1	20° CONE	2	SPIRAL	

FIGURE 3. SPECIFIC PARAMETERS FOR THREE SENSOR/SEEKER DEVICES

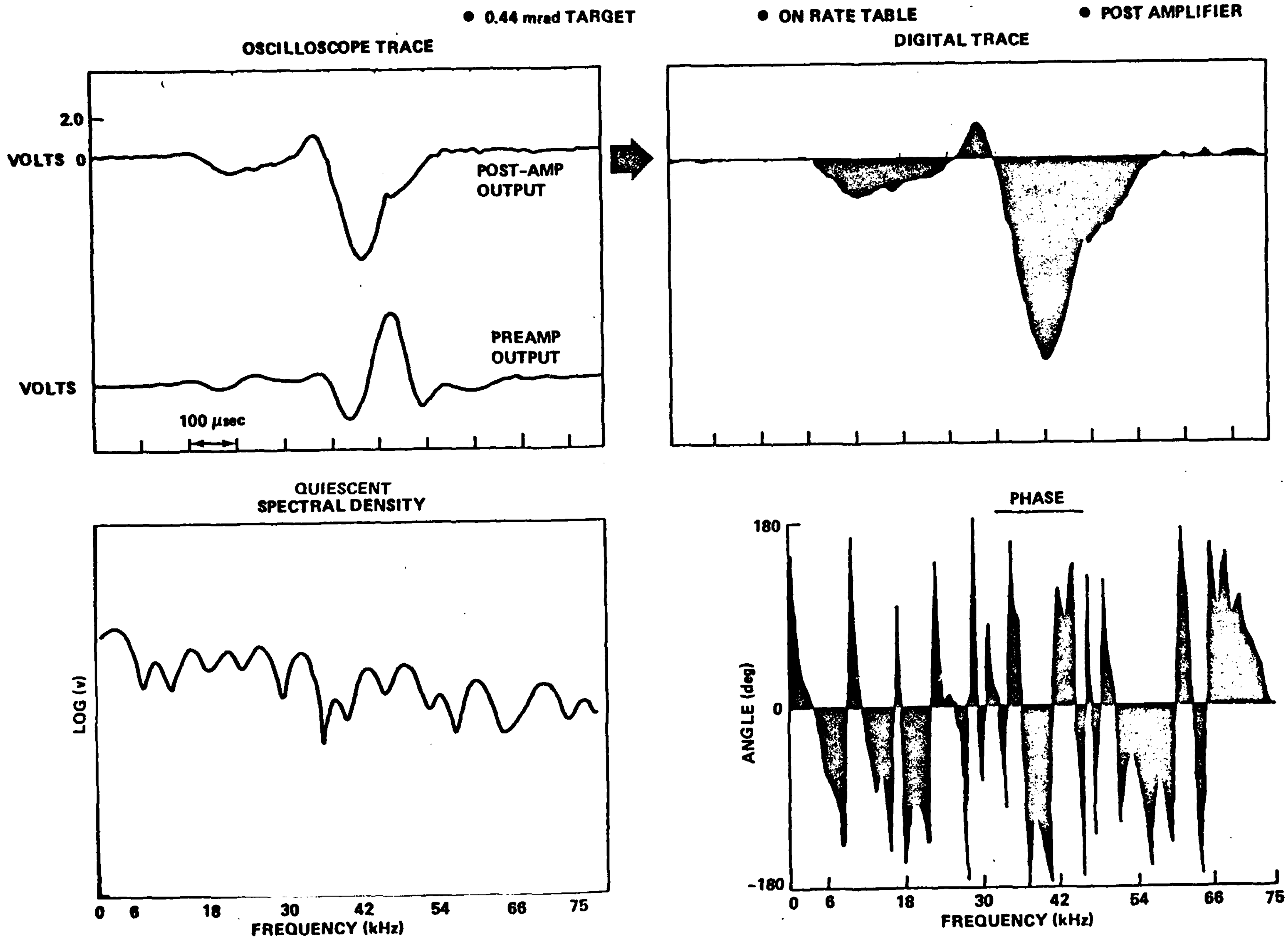


FIGURE 4. SPECTRAL ANALYSIS OF SIGNAL FROM SENSOR A

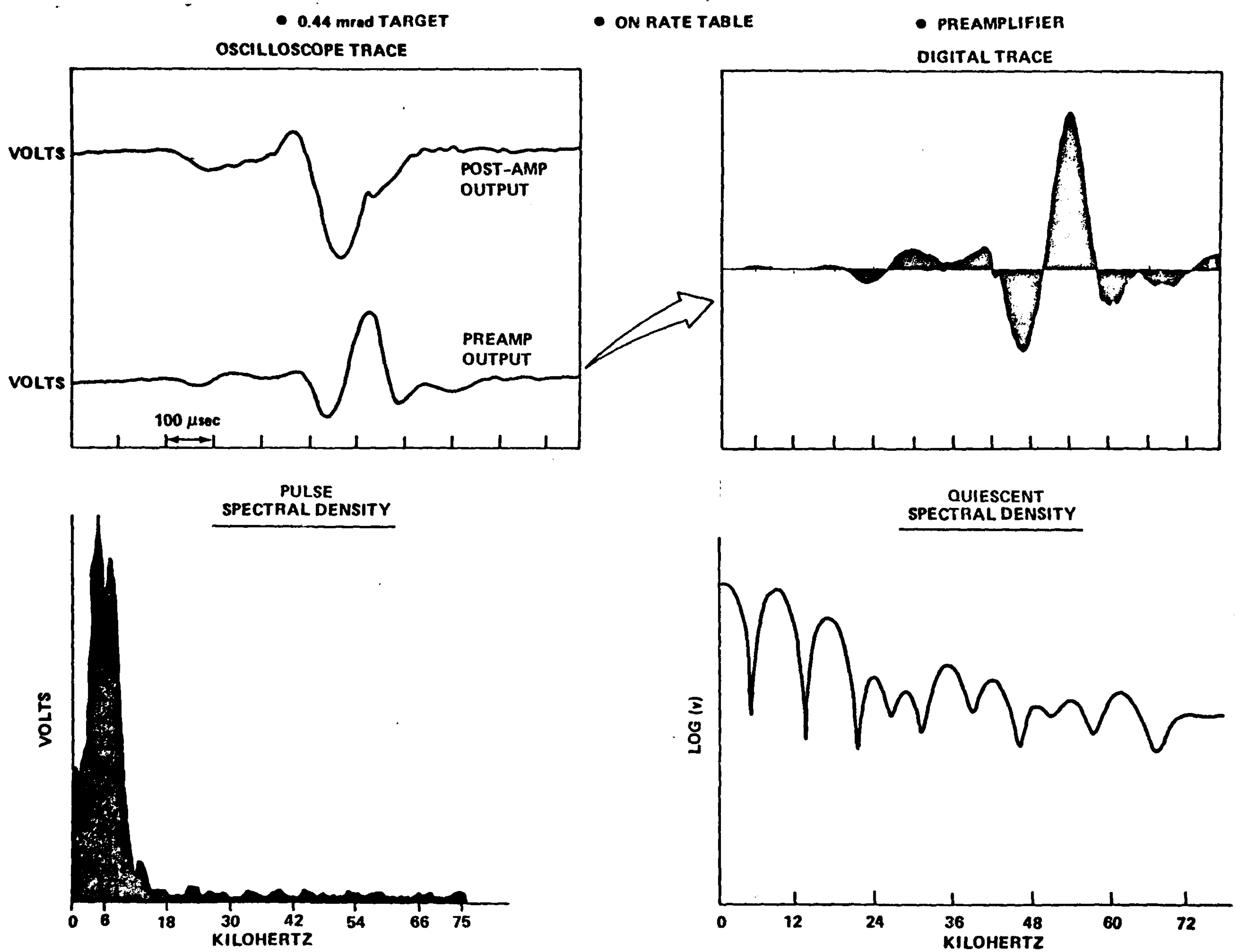


FIGURE 5. SPECTRAL ANALYSIS OF SIGNAL FROM SENSOR A

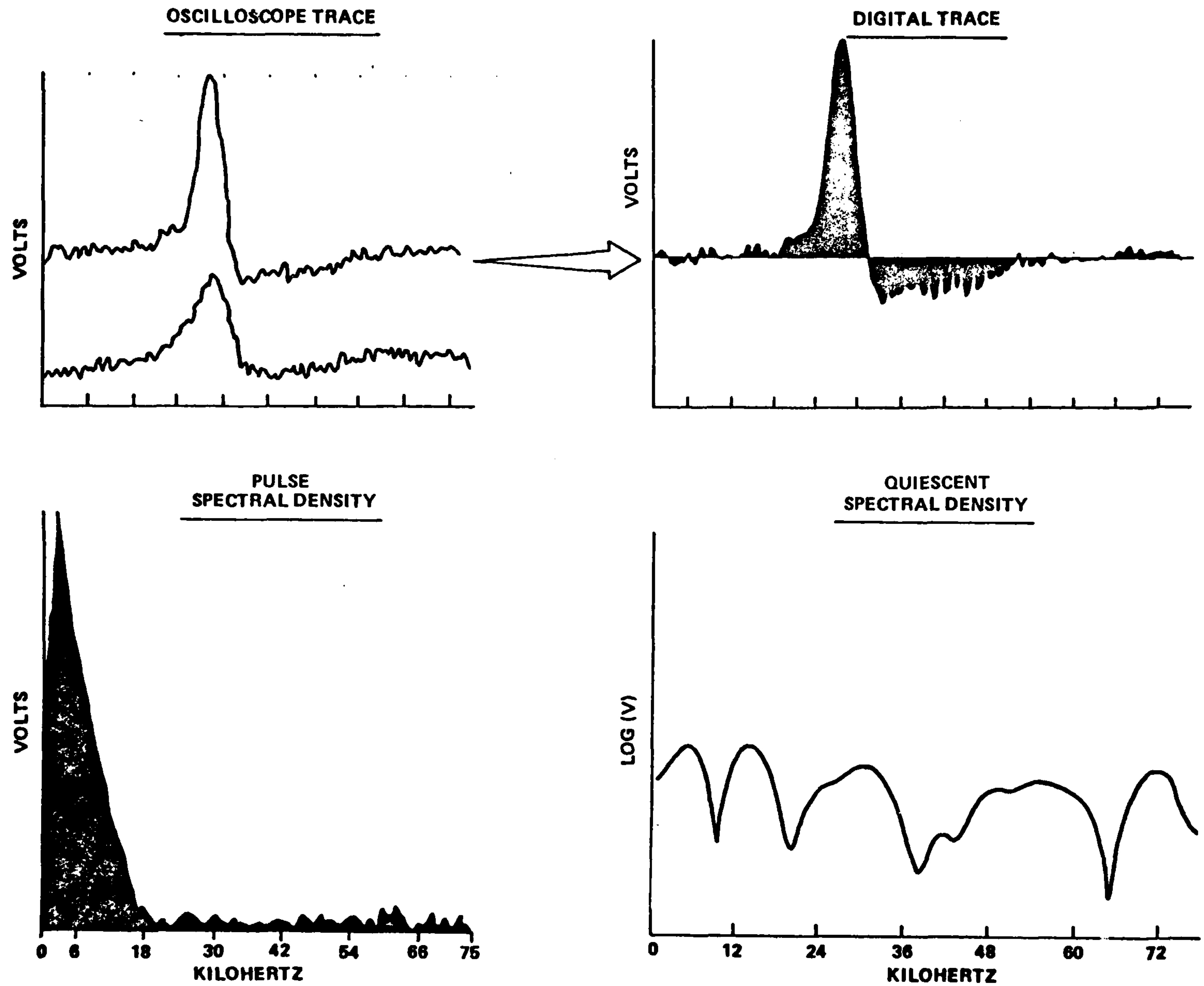


FIGURE 6. SPECTRAL ANALYSIS OF SIGNAL FROM SENSOR C

SECTION 3. DEVELOPMENT PLAN FOR SENSOR PERFORMANCE/OPTIMIZATION

3.1 INTRODUCTION

The completion of the sensor response module for the indirect fire IR submissile sensor simulation represents the first step towards generation of a complete sensor simulation system evaluation package. This writeup outlines a plan of growth to develop a complete sensor simulation systems package such that sensor performance can be evaluated and optimized with regard to sensor parameters, noise sources, countermeasures, etc.

Additional simulation modules are required to evaluate and optimize sensor performance. These are:

- Signal and data processing module
  - Target detection and location
  - Target discrimination
- Performance evaluation module
  - Monte Carlo statistical evaluation
  - Generate figures of merit (P_D, FAR, etc.).

These modules when coupled with the sensor respnse module, as shown in Figure 7, permit an evaluation of sensor performance under a given set of conditions. The plan for growth then entails development and proper interfaces of these three modules such that a statistical performance evaluation can be performed. Variation of sensor parameters, noises, and countermeasure techniques within an open-loop (due to closed-loop data processing implications) optimization sequence will provide for sensor system performance optimization for all sensor/seeker models.

Discussion of the signal and data processors, as well as performance evaluation module required for system performance/optimization follows.

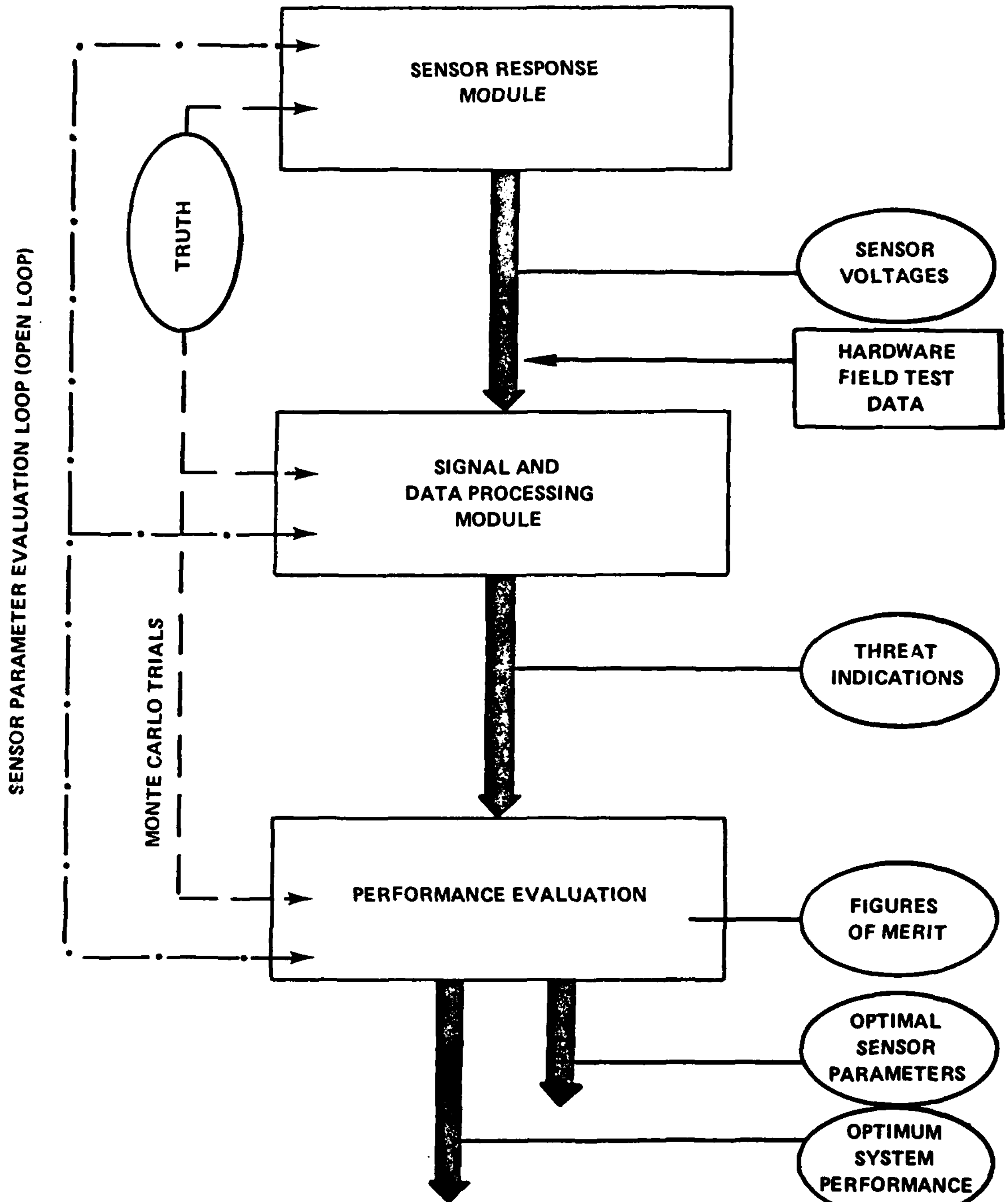


FIGURE 7. OPERATION OF THE PROPOSED SIGNAL AND DATA PROCESSING AND PERFORMANCE EVALUATION MODULES

3.2 SIGNAL AND DATA PROCESSING MODULE

The Signal and Data Processing Module will have the capability option of operating on simulated data or hardware field data. Types of signal processing techniques to be simulated, at a minimum, include bandpass filters and adaptive thresholds. Data processing techniques include discriminants and other decision rules. The module will be structured to have the capability to handle multiple discriminants and the flexibility to alter discriminants and decision rules.

A simple example of a two-color discrimination algorithm is illustrated in Figure 8. A typical sensor output might resemble the upper curves. It is assumed that the output is highly correlated spectrally (e.g., from graybody sources at similar temperatures), except at a time, t_0, when a noncorrelated spectral event occurs (e.g., a high-temperature body or a muzzle flash). Thus, the ratio of the output in the two bands (see middle curve) would exceed the threshold if a target were present:

$$\left. H_{\Delta\lambda_1}/H_{\Delta\lambda_2} \right)_{t_0} > \text{THRESHOLD} \Rightarrow \text{THREAT INDICATION} \quad .$$

These discriminants are very similar to multicolor discriminants proposed for BMD applications.

3.3 EVALUATION/PERFORMANCE MODULE

The Evaluation/Performance Module will be both flexible and efficient in order to expedite evaluation of the performance of each of three sensor/seekers with its associated signal processing and decision criteria. The desired outputs from the module are performance for the sensor/seeker system and identification of the associated system parameters which affect performance. The principal features of the Evaluation/Performance Module include: executive control in inputs, outputs, Monte Carlo loop, and automated sensor parameter evaluation loop; figure-of-merit (FOM) determination; and performance assessment via comparison of decision criteria to "truth."

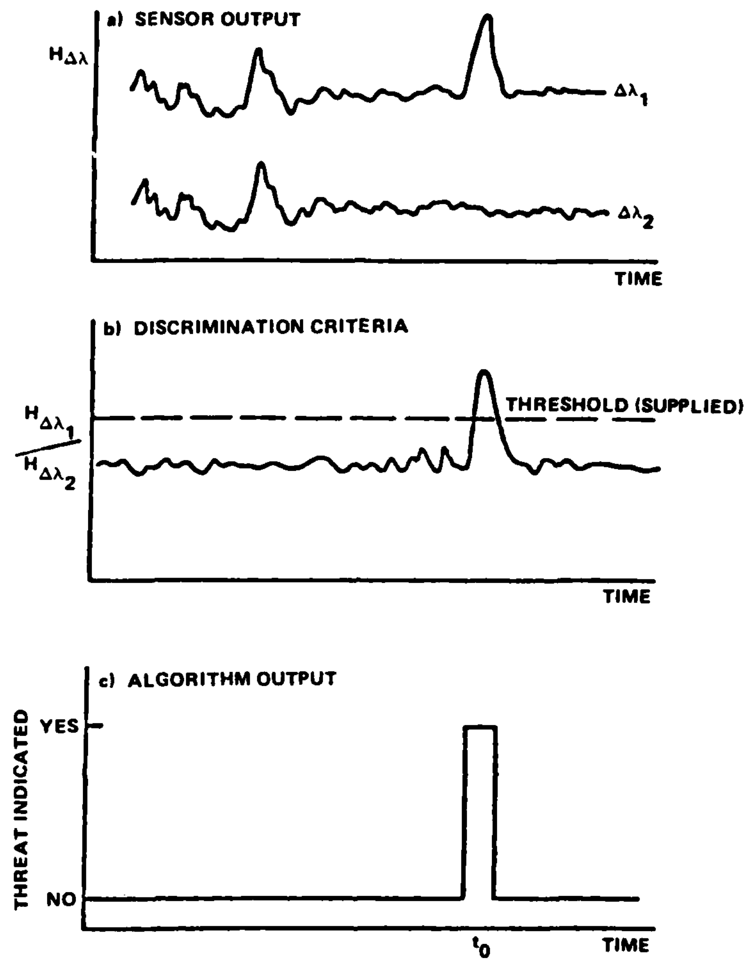


FIGURE 8. TYPICAL DISCRIMINATION ALGORITHM OPERATION

In order to evaluate the performance of the algorithms, FOM's must be defined for each decision algorithm. Likely FOM's would be detection probability (P_D), designation probability (P_{Des}), and false alarm rate ($\overline{FA}$); or if a single FOM is required, the ratio of detection probability to false alarm rate may be convenient ($P_D/\overline{FA}$). Other FOM's may be more pertinent for some scanners (e.g., false alarm probability per scan). The FOM's would be evaluated in a Monte Carlo fashion as indicated in Figure 1. That is, by statistically varying the random scene and sensor characteristics (e.g., background clutter and sensor noise) for a large number of Monte Carlo trials, the average system performance can be evaluated directly (see Figure 9). For example, P_D is simply the ratio of the total number of targets detected during all the Monte Carlo trials to the possible number. Similarly, the false alarm rate would be the ratio of the total number of false alarms indicated during the trials to the total observation time during the trials.

The sensor parameter evaluation method proposed would vary sensor characteristics until optimum performance is achieved. The code will have the flexibility to vary any sensor or decision factor (e.g., threshold) within a specifiable range. For economic considerations, the code will be designed so that characteristics will be evaluated in a particular order, depending on the expected relative importance of their effect on the system performance. For example, a factor such as instantaneous field of view (IFOV) is likely to affect system performance more than the f-number, and so IFOV would be optimized before the f-number.

A unique consideration for the spectral band evaluation is the computational time requirement. For two spectral bands, there are four independent characteristics which must be varied, so this evaluation will be stressing with regard to computer time. Thus, it would be most efficient to perform the spectral band evaluation after other factors are evaluated. Further, the slight modification of the spectral bands will not require reevaluation of the other factors, since their effects are not strongly coupled. On this point, it should be mentioned that it is possible to select reasonably good optimum bands manually (i.e., without the use of the computer). Thus, it is expected that the code will converge to the optimum point fairly rapidly. On the other hand, it is possible that the location of the optimum spectral bands will be strongly dependent on the scene statistics and radiometric characteristics, in which case additional computer time would be required.

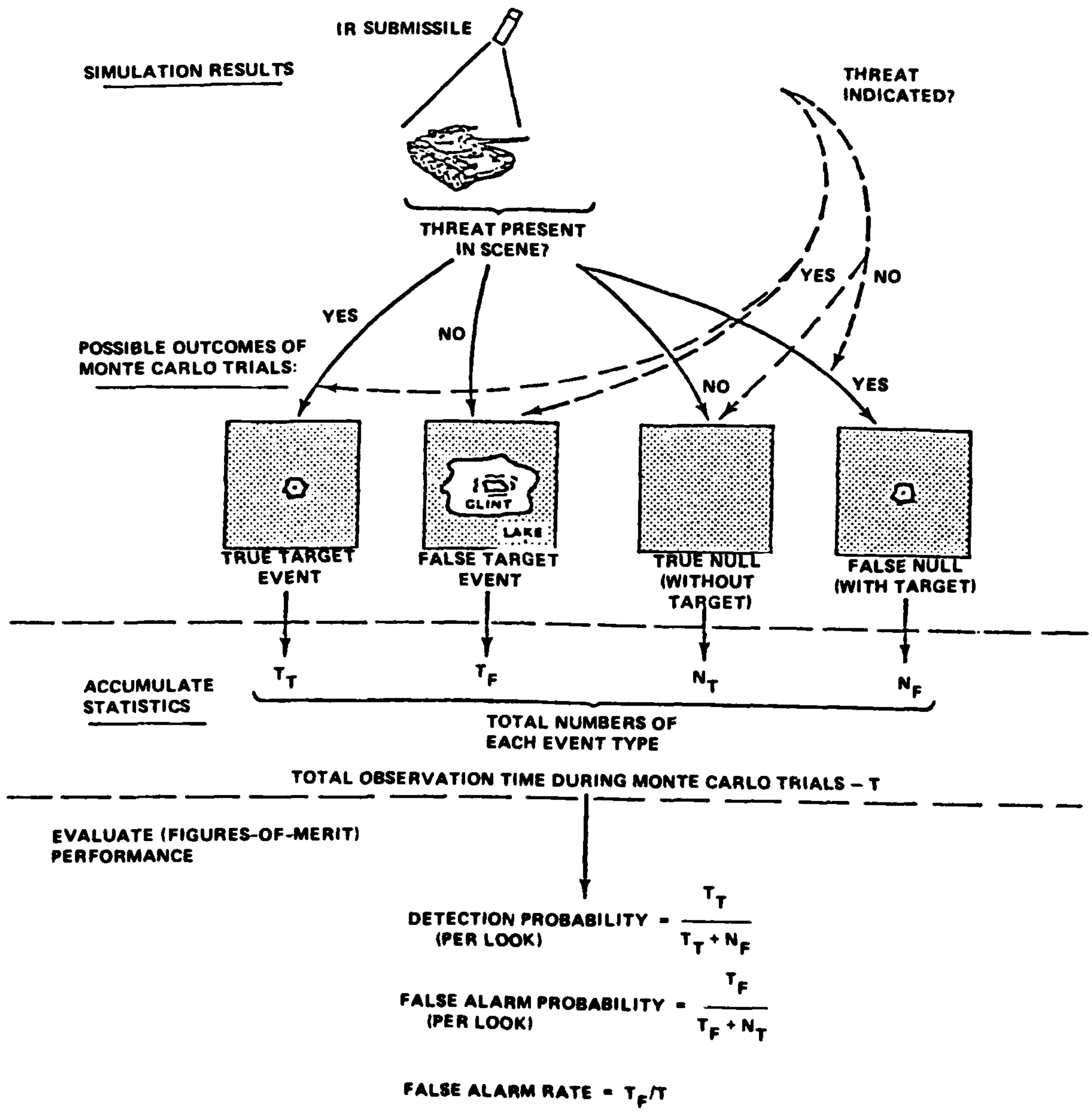


FIGURE 9. PERFORMANCE EVALUATION PROCEDURE

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