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NTIA Report 87-228

Investigations of Test Methodology for the Stress Loading Facility

R.D. Jennings

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U.S. DEPARTMENT OF COMMERCE
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for Communications and Information

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PREFACE

The Institute for Telecommunication Sciences (ITS) in Boulder, CO, (a laboratory that is part of the National Telecommunications and Information Administration, U.S. Department of Commerce) has performed the study reported here with funding support provided by the U.S. Army Electronic Proving Ground (USAEPG), Fort Huachuca, AZ. This support was provided under two Military Interdepartmental Purchase Requests--TO 46-85 and TO 47-85. Administrative and technical guidance to this study was provided by Mr. John Shaver of USAEPG.

The views, opinions, and findings contained in this report are those of the author only and should not be construed as an official position, policy, or decision of the U.S. Department of the Army, the U.S. Department of Commerce, or any other agency unless so designated by other official documentation.

The author is particularly indebted to Mr. N. B. Seitz and Mr. E. F. Linfield of the Institute. Mr. Seitz, as the leader of a group concerned with user-oriented performance standards for data communications, developed many of the original concepts applied in this study. Mr. Linfield contributed by preparing a major portion of Section 4. Together, these colleagues helped in developing the initial outline for the study and provided continuous encouragement and technical assistance throughout the study period.

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INVESTIGATIONS OF TEST METHODOLOGY FOR THE

STRESS LOADING FACILITY

R. D. Jennings*

The U.S. Army Electronic Proving Ground (USAEPG) is planning the development of a new test facility to be known as the Stress Loading Facility (SLF). This facility is envisioned as an integrated and automated test capability that will generate a dense electromagnetic threat test environment and simultaneously monitor key performance parameters of a system being tested. This capability is expected to become a part of the Electromagnetic Environmental Test Facility (EMETF), both physically and functionally. However, the SLF will be designed to provide self-contained operation that will be independent of the EMETF, if required. This report reviews current test capabilities that are relevant to the SLF, both within and outside of USAEPG, and develops test methodology for the SLF. The test methodology development follows a structured approach in the selection of parameters that are system independent and, therefore, may be used to describe the performance of various systems that may be tested using the SLF. The study then applies the structured approach to the development of performance descriptions for two typical electronic surveillance systems and develops the associated performance measurement methodology. This methodology covers test design, data collection, data reduction, and data analysis.

Key words: automated tests; electromagnetic compatibility; electromagnetic vulnerability; development tests; EMC; EMV; field tests; interference analysis; laboratory tests; simulation; SLF; Stress Loading Facility; system-independent performance parameters; test design; test facility; test methodology

1. INTRODUCTION

The Stress Loading Facility (SLF) under development by the U.S. Army [illegible] Proving Ground (USAEPG) is envisioned as an integrated test system [illegible] present an electromagnetic threat test environment to systems under [illegible] while simultaneously monitoring the responses of those systems by [illegible] performance parameters. The SLF concept includes the use of [illegible] to generate realistic slices of time-ordered electromagnetic [illegible], to control all aspects of real-time test and SUT [illegible] to expedite the reduction and analysis of recorded test data. [illegible] is applicable to the development testing (DT) of U.S. Army

* [illegible] with the Institute for Telecommunication Sciences, National [illegible] and Information Administration, U.S. Department of Commerce, [illegible]

radio frequency (rf) intercept, direction finding (DF), and jamming systems, as well as radio communication and radar systems. By maintaining positive control over the test process, the SLF will provide the tester with the ability to accurately replicate tests or portions of tests.

1.1 SLF Development Program and ITS Project Goals

As noted above, the Stress Loading Facility will provide an integrated testing system and facility to achieve a dense electromagnetic threat test environment and simultaneously monitor the performance of the system under test. Figure 1 presents a simplified block diagram of the overall SLF concept. The Communications (COMM) Threat, Non-Communications (Non-COMM) Threat, and Functional Systems Simulators combined with the Central Computer, Test Control Station, Test Data Monitoring Subsystem, and appropriate Interface Unit (to the SUT) comprise the SLF. USAEPG's Electromagnetic Environmental Test Facility (EMETF) (shown with dashed lines in Figure 1) is not part of the Facility. It will be important, however, to integrate the SLF and the EMETF to the maximum extent practical. Capabilities of the EMETF, with some enhancement of current capabilities, will be particularly useful in preparing deployment data and technical characteristics of all communications-electronics (C-E) equipment for large, complex (both static and dynamic) test scenarios.

The COMM Threat Simulator (CTS) will be used to replicate the communications threat environment encountered by various SIGINT/EW systems. The Non-COMM Threat Simulator (NCTS) will be used to replicate the non-communications threat environment expected to be encountered by various SIGINT/EW systems. Each of the simulator subsystems will have control processor capabilities to operate independently of the Central Computer whenever test conditions or Central Computer inoperability dictate a need. The COMM and Non-COMM Threat Simulators will include appropriate modulators and rf sources with management of those equipments. The Functional Systems Simulator will generate appropriate "messages" (functional operations is a more generic term) for the COMM and Non-COMM Threat Simulators to use in managing the modulators and rf sources. The Institute for Telecommunication Sciences (ITS) has accepted responsibility for assisting with the development of utilization methodology for conducting functional performance testing of complex rf systems using the SLF. The work undertaken by ITS encompasses three tasks directed to development of utilization methodology: (1) review existing SLF-type capabilities,

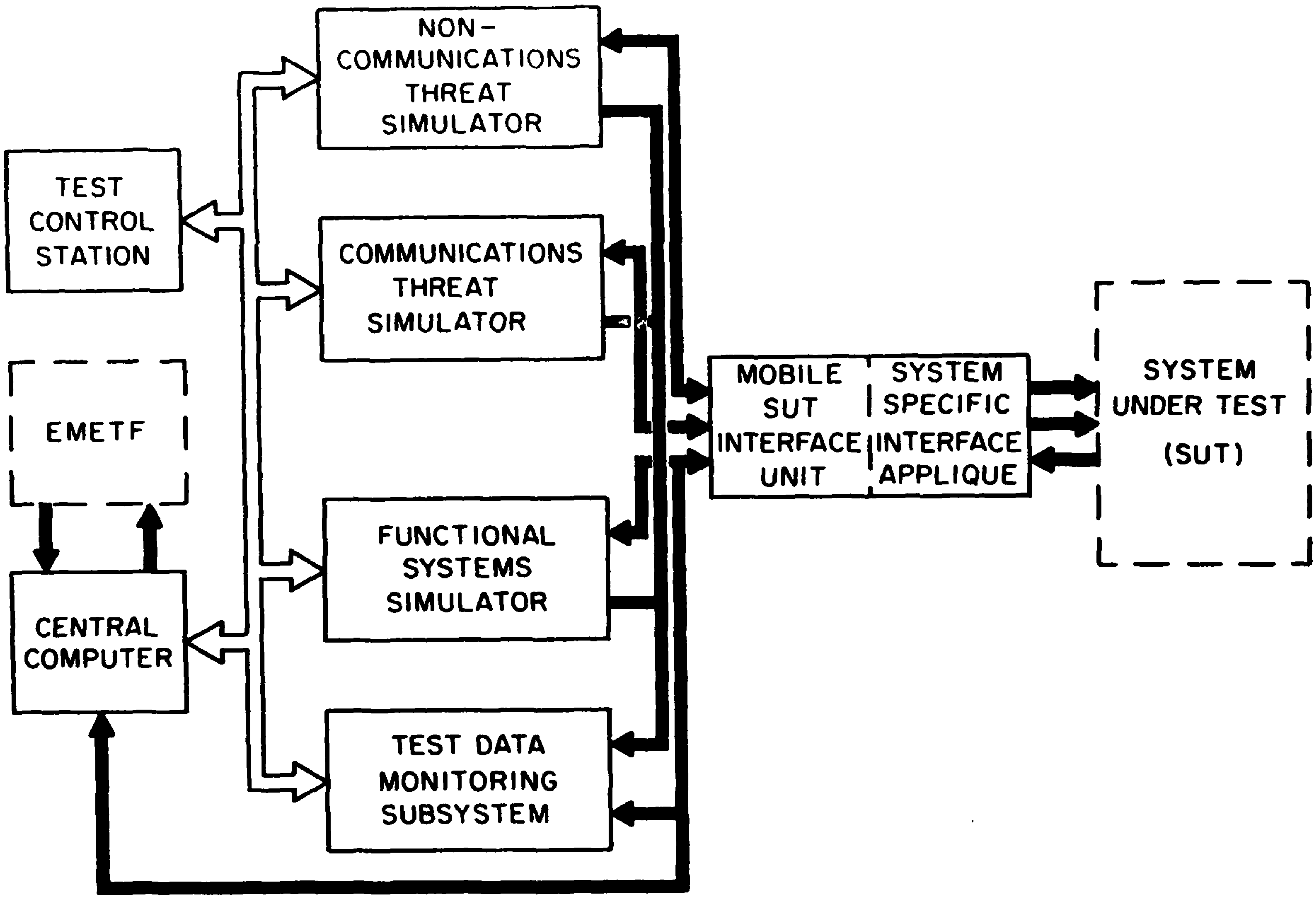

Figure 1. Simplified block diagram of the Stress Loading Facility (SLF) concept.

(2) develop measures of functional performance (MOFPs) for two EWI (electronic warfare and intelligence) systems selected by USAEPG, and (3) develop a framework for general SLF utilization methodology.

The results of Tasks 1 and 2 are presented in Sections 1 through 5 of this report. The Task 3 results include application of the functional approach to system-independent testing and specific application of the methodology to typical electronic surveillance systems. General application of the functional approach includes test design, data collection, data reduction, and data analysis. The specific application to typical electronic surveillance systems includes the development of a Detailed Test Plan (DTP) Outline for SLF testing and examination of interrelationships between bench testing, field testing, SLF testing, and computer simulations. These topics are covered in Sections 6 and 7 and Appendix C. Conclusions and recommendations as a result of this study are presented in Section 8.

1.2 ITS Approach

A structured approach that establishes uniform methods for specifying, assessing, and comparing the performance of Army C-E systems from the point of view of functions that each system is to perform as defined and then used to develop performance parameters and measures of functional performance. This structured performance parameter development process, illustrated in Figure 2, is built around the fact that a C-E system is designed and placed in service to perform a number of explicit functions while operating in some expected environment. The system (in use) will perform each of its intended functions with only one of three possible outcomes being realized from each attempted use. The possible outcomes are (1) successful (or correct) performance, (2) incorrect performance, or (3) nonperformance. It must be recognized, however, that performance in the aggregate (over time) is the performance of real interest. This aggregate performance is established or evaluated on the basis of a sufficient number of attempts to use the system and measure the discrete function performance under known and/or controlled environmental conditions so that performance may be described in statistical terms. A comprehensive understanding of system performance is achieved by performing tests using various factor combinations for factors (conditions) that influence system performance, as discussed in Section 6.

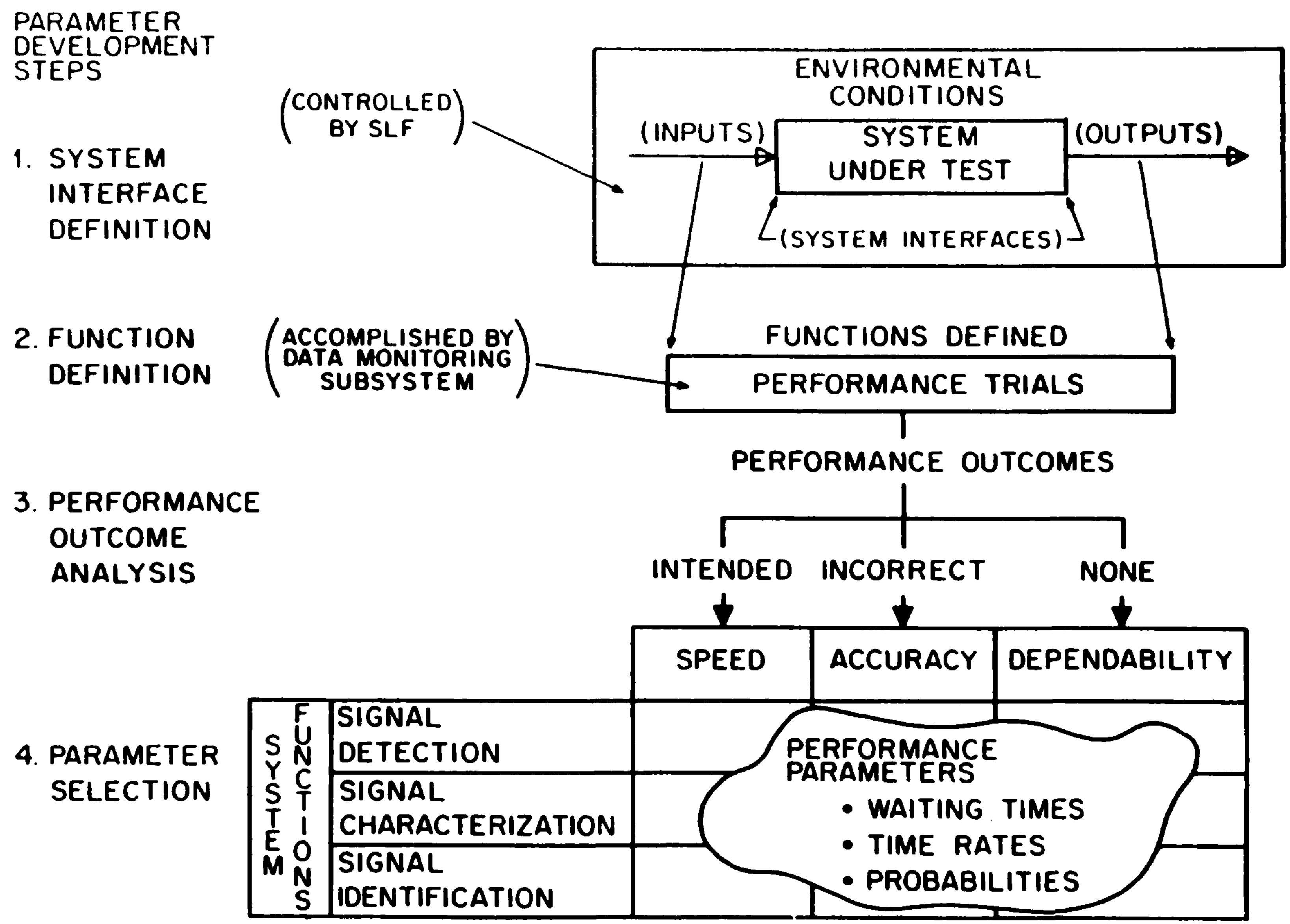

Figure 2. ITS approach to development of performance parameters.

In considering successful performance, one is concerned with the time required (or speed) to perform discrete functions. An aggregation of successful performance times, then, can be used to compute statistics such as mean time for successful performance. When incorrect performance is realized, one is concerned with the frequency of incorrect performance. Given a sufficient number of attempts with some fraction of the attempts being unsuccessful, one can compute the fraction of all attempts that were unsuccessful. The fraction of attempts that were successful, which is the complement of the fraction of unsuccessful attempts, then, can be computed to express accuracy. If nonperformance is realized, one, again, is concerned with the frequency of nonperformance. The complement of the fraction of all attempts that result in nonperformance is reliability. Measurements from a sufficient number of attempts can be used to compute predictions of performance outcomes, to some desired level of statistical confidence, for each parameter.

1.3 Report Organization

As noted in the preceding subsection, this report responds to three tasks that assist with the development of utilization methodology for conducting functional performance tests of complex rf systems using the SLF. Section 1 is an introduction to the SLF concept and the methodology development support provided by ITS. Section 2 reviews existing test capabilities and measures of performance used by non-USAEPG organizations as well as those within USAEPG. Section 3 discusses the SLF test concepts as defined currently by USAEPG. Section 4 outlines and discusses the structured approach that ITS has followed in defining system performance parameters. Section 5 describes two EWI systems that USAEPG has specified for this study, with measures of functional performance defined for each system in accordance with the structured approach set forth in Section 4 for defining performance parameters. Section 6 describes and discusses the approach to performance measurement that is required to provide sufficient performance data to allow statistical characterization of performance to some desired level of confidence. Section 7 discusses specific measurement methods for testing electronic surveillance systems using the SLF and other testing capabilities of the EMETF and examines the interrelationships between SLF testing, bench testing, controlled field testing, and computer simulation that pertain to complete development testing of Army rf intercept, direction finding, and jamming systems. Section 8 presents conclusions and recommendations from the work performed. Finally, Section 9 contains references to other material used in performing this study. Acronyms, abbreviations, and unique terms used in this report are defined in Appendix A. Appendix B is a summary of the structured approach applied to the development of performance parameters for digital communication systems. Appendix C is an expansion of the Detailed Test Plan Outline presented in Section 7.

2. REVIEW OF EXISTING TEST/MEASUREMENT CAPABILITIES

The SLF concept incorporates use of existing test/measurement capabilities to the maximum extent possible. These capabilities, developed by organizations other than USAEPG as well as within USAEPG, are reviewed and summarized in Sections 2.1 and 2.2 respectively.

2.1 Capabilities Developed Outside of USAEPG

The Naval Research Laboratory (NRL) developed the Tactical Electronic Warfare Environment Simulator (TEWES) concept in 1976 and produced the first operational system in 1979; this capability is described in Section 2.1.1 below. In conjunction with development and implementation of the TEWES, the NRL also has developed a state-of-the-art electronic warfare (EW) facility known as the Central Target Simulator; this capability is described in Section 2.1.2 below. RF energy coupling (other than "antenna-to-antenna coupling" techniques that are suited to far-field test conditions) using near-field techniques have been developed and are used for testing avionics systems on military aircraft. Such techniques have a number of limitations that will be especially difficult to overcome for test situations such as those for which the SLF will be used. Some of these near-field, rf energy coupling techniques are discussed in Section 2.1.3.

2.1.1 Tactical Electronic Warfare Environment Simulator

As noted above, the first, operational, NRL-developed TEWES system was produced in 1979. Since that time a variety of systems have been developed to meet specific requirements leading to the Advanced TEWES that became operational in 1983. An Advanced TEWES (ATEWES) currently is being developed by NRL for USAEPG to become part of the overall SLF test facility (NRL, 1985).

The TEWES is a general-purpose simulation system for evaluating receiving equipment. Operationally, the TEWES allows the definition of realistic tactical situations, the generation of complex and dynamic signal environments, and the evaluation of responses produced from EW systems under test. The TEWES consists of (1) a Scenario Control Computer, (2) a Digital Generator Subsystem, (3) an RF Generator Subsystem, and (4) Specialized Interfaces for the various systems under test (that are unique to each application). A functional block diagram for the TEWES is shown in Figure 3.

The Control Computer contains the programs and data that are used to simulate the environment, including platform dynamic motion for up to 256 platforms (participants) and the rf signal parameters. The single most significant feature of the TEWES is its ability to generate a dynamic electromagnetic environment consisting of up to 1023 simultaneous signals with a combined, average pulse density of 1,000,000 pulses per second (pps) and a peak pulse density of 4,000,000 pps.

The Digital Generator Subsystem receives instructions and data from the Control Subsystem and translates the electromagnetic environment information into real-time digital instructions to the RF Generator Subsystem. These instructions include the selection of appropriate frequency, pulse width, and required amplitude modulation along with the correct timing to simulate various simple and complex pulse repetition intervals (PRI's). The rf subsystem converts the digital instructions into actual rf signals and distributes the signals based on the characteristics and configuration/orientation of the SUT. General technical characteristics of the TEWES are given in Table 1. More detailed, general technical characteristics are given in an NRL report (NRL, 1984).

The TEWES being developed for USAEPG will be a programable environment generator with operator control over all simulation and hardware functions. The scenario simulation will be fully dynamic, providing for static or moving threats and sensor position. The scenario will be in the format of a Time-Ordered Event List. Signal parameters will be comprehensive and will be capable of being modified or duplicated in a flexible manner. Antenna and scan pattern effects will be updated on a pulse-by-pulse basis for each emitter. The performance of the simulator will be monitored internally and recorded. A standardized data analysis package will be available to support evaluation through correlation of simulator and SUT performance data. Complete performance, design, development, and general test requirements for the system are given in the System Performance Specification (NRL, 1985).

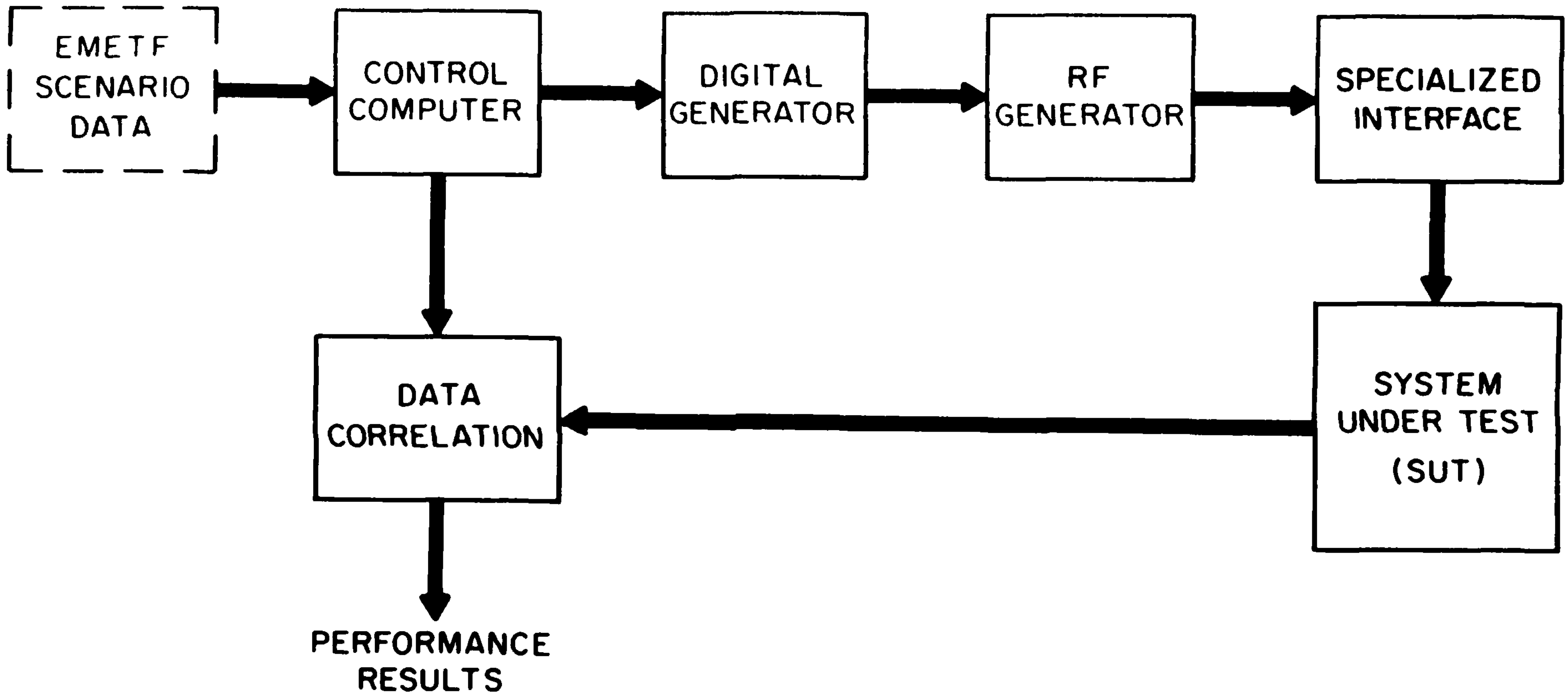

Figure 3. Functional block diagram for Tactical Electronic Warfare Environment Simulator (TEWES).

Table 1. General Technical Characteristics of the TEWES

SCENARIOS (Time-ordered event lists)	4+ Hrs
PLATFORMS (Participants)	256 Max.
SIMULTANEOUS SIGNALS	1023 Max.
PULSE DENSITY	1,000,000 pulses/sec avg. 4,000,000 pulses/sec peak
SIGNAL PARAMETERS	Range/Resolution
FREQUENCY	500 - 18,000/0.125 MHz
AMPLITUDE	0 to 10 dBm(typical)/1 dB
ANGLE OF ARRIVAL	360/0.36 deg
PULSE INTERVAL	0.050 - 32,767/0.05 μsec
SCAN RATE	1 - 7,200/1 RPM
PULSE MODULATIONS	Stable PRF, PRI Stagger, Switching, Continuous/Discrete PRI Jitter, Continuous/Discrete Periodic Patterns, Synchronization
RF MODULATIONS	Stable Pulsed, Sequence, Switching, Continuous/Discrete Agility, Continuous/Discrete Patterns, Multibeam, Chirp, CW
SCAN TYPES	Circular, Sector, Raster, Conical, Helical, Steady, Omni, Tracking

2.1.2 Central Target Simulator

The Central Target Simulator, also developed by NRL, is a state-of-the-art, EW, laboratory facility that includes a three-axis flight simulator, a centrally-located computer complex, and an rf environment simulator. Radiated rf emissions representing multiple moving targets, electronic countermeasures (ECM), and environmental phenomena are simulated and used to exercise (stress) systems under test. (TEWES functionally is the integration of these items, except the three-axis flight simulator.)

The basic CTS facility, additionally, consists of a shielded anechoic chamber with one wall containing a large spherical matrix array of antennas designed to create the rf environment to which SUT's are subjected. This shielded anechoic chamber creates a far-field, free-space propagation environment for the radiated rf fields (operating in the 8 to 18 GHz frequency range). The size (114 ft x 127 ft x 38 ft high or 34.75m x 38.71m x 11.58m high) and spherical geometry of the chamber enable accurate simulation of tactical environments. As observed from the chamber focal point, the maximum field is 78.75 deg by 18.75 deg in relative azimuth and elevation. The most recently developed facility includes only 225 antenna elements that provide "coverage" over a center sector that is 8.75 deg in elevation by 18.75 deg in azimuth plus a 1.25 deg strip over the remaining 78.75 deg in azimuth. Full field coverage would require 800 additional antenna elements.

The USAEPG SLF will require a facility of this type, but with substantially expanded capabilities to accommodate the COMM Threat Simulator as well as the expanded frequency range of the Non-COMM Threat Simulator. Since the expanded frequency coverage (for the COMM and Non-COMM Threat Simulators) is toward lower frequencies, appropriate facility expansion will require an unreasonably larger facility unless some direct or radiated near-field coupling techniques can be implemented at the lower test frequencies.

2.1.3 Radio Frequency Energy Coupling (Near-Field)

SLF testing of COMM systems will require rf energy coupling using techniques other than "antenna-to-antenna coupling" that are suited to far-field test conditions. Near-field techniques have been developed and are used for testing avionics systems on military aircraft. Such techniques have a number of limitations that will be especially difficult to overcome for test situations such as those for which the SLF will be used.

The near-field coupling test applications that we have examined are critically dependent on alignment of each antenna with respect to the other and the separation between the antennas. These physical requirements are controlled through the development and use of elaborate (and expensive) test sets that ensure repeatable test conditions. Other physical factors that will be important in SLF testing, if testing is attempted using antenna-to-antenna energy coupling in the near field, include transforming the SUT performance parameters for near-field test conditions to expected system performance under far-field (normal operating) conditions. Factors that are important in this regard include signal bandwidth, phase of the signal, and phase relationships to system performance.

2.2 USAEPG Capabilities

The U.S. Army Electronic Proving Ground includes a number of capabilities for testing and measuring the performance of communications-electronics equipment and systems. These capabilities include the Communications Data Measurement Facility, the Scoring Facility, the Spectrum Signature Facility, the Radar Weapon Systems Measurement Facility, and the Field Facility. A computer automated analysis capability complements these test/measurement capabilities and utilizes performance data obtained during testing in these facilities. A detailed description of these capabilities, which comprise the Electromagnetic Environmental Test Facility (EMETF), is given in a USAEPG [illegible]. Brief descriptions of these capabilities are provided in [illegible] through 2.2.3 which follow.

[illegible] Testing Capabilities

[illegible] discussion purposes only, in this report, the Communications Data [illegible] Facility, the Scoring Facility, the Spectrum Signature Facility, [illegible] Weapon Systems Measurement Facility are considered collectively [illegible] testing" capabilities, since the Statement of Work for this [illegible] development study asks for discussion of test mode interrelation-[illegible] between [illegible] testing, bench testing, field testing, and computer [illegible].

The Communications Data Measurement Facility is used to measure the performance of communications links subjected to selected levels of an interfering signal. The rf link consists of a transmitter and receiver (for the system under test) and an interfering signal source. The transmitter of the system under test is placed in one screen room and coaxially coupled, through [illegible] attenuators and a mixer into the receiver of the system under test [illegible] second screen room. The interfering transmitter, located in a [illegible] room, also is coaxially coupled, through appropriate attenuators [illegible], into the receiver of the system under test. By adjustment of [illegible], the degradation to performance of the system under test can be [illegible] function of the desired and interfering signal levels for [illegible] levels that vary from receiver threshold to saturation. This [illegible], along with appropriate scoring for the type of system being tested [illegible]-calibration and self-monitoring of test progress, is automated to [illegible] three tests simultaneously, as illustrated in Figure 4.

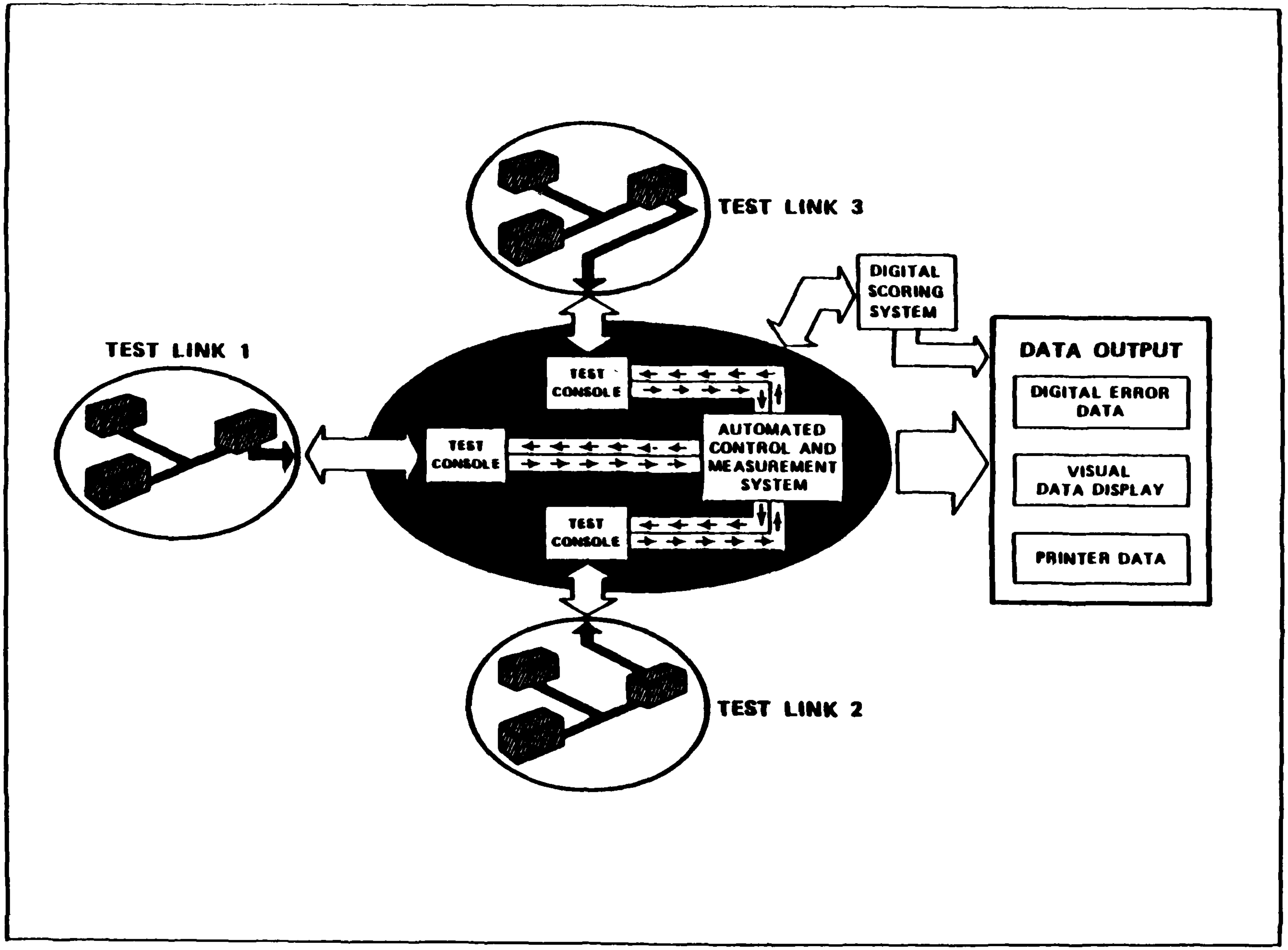

Figure 4. The EMETF Automatic Data Collection System (a "bench test" capability) (USAEPG, 1987).

The parameters normally measured include frequency, power levels, spectrum characteristics, transmitted bandwidth, occupied bandwidth, spurious rf products, and modulation parameters of the system under test and the interfering transmitter. The capability is known as the Automatic Data Collection System (ADCS).

The Scoring Facility includes capabilities to score both analog and digital communication systems. The performance of analog systems, as a function of desired and interfering signal levels, first is determined by transmitting phonetically balanced words over the system under test, recording the outputs, and using trained listeners to determine the percentage of words that are correctly understood (scoring). This measure of performance is known as word intelligibility or articulation score (AS). Subsequent scoring tests on similar systems can be conducted using a capability known as the Voice Interference Analysis System (VIAS). In this system, the speech frequency spectrum is divided into 14 equally contributing voice power bands. The noise or interference in each of these bands is measured relative to a known signal-to-noise ratio to determine a performance score known as the articulation index (AI). The AI scores must be correlated with articulation scores (for that system), but the VIAS provides a convenient and automated technique for estimating voice intelligibility for an analog system.

The performance of digital communication systems is scored using a capability known as the Digital Scoring System. This system provides automatic real-time measurements of the bit errors in the digital data stream. Measurements can include bit error rates, the total number of bits transmitted, and the numbers of specific types of bit errors. A typical test setup that involves security devices and error correction circuits is illustrated in Figure [illegible]. Note that digital data are monitored at six points in the system so that error data between any of these six points can be processed in analyzing performance of the system or portions of the system.

The Spectrum Signature Facility is used to measure detailed technical characteristics of transmitters, receivers, and antennas. The measurement capabilities include a fixed laboratory with screen rooms and a mobile laboratory for field work. Both the fixed and mobile laboratories are equipped to perform all spectrum signature and specialized data measurements under either screen-room or open-field conditions. Typical transmitter data that can be measured include:

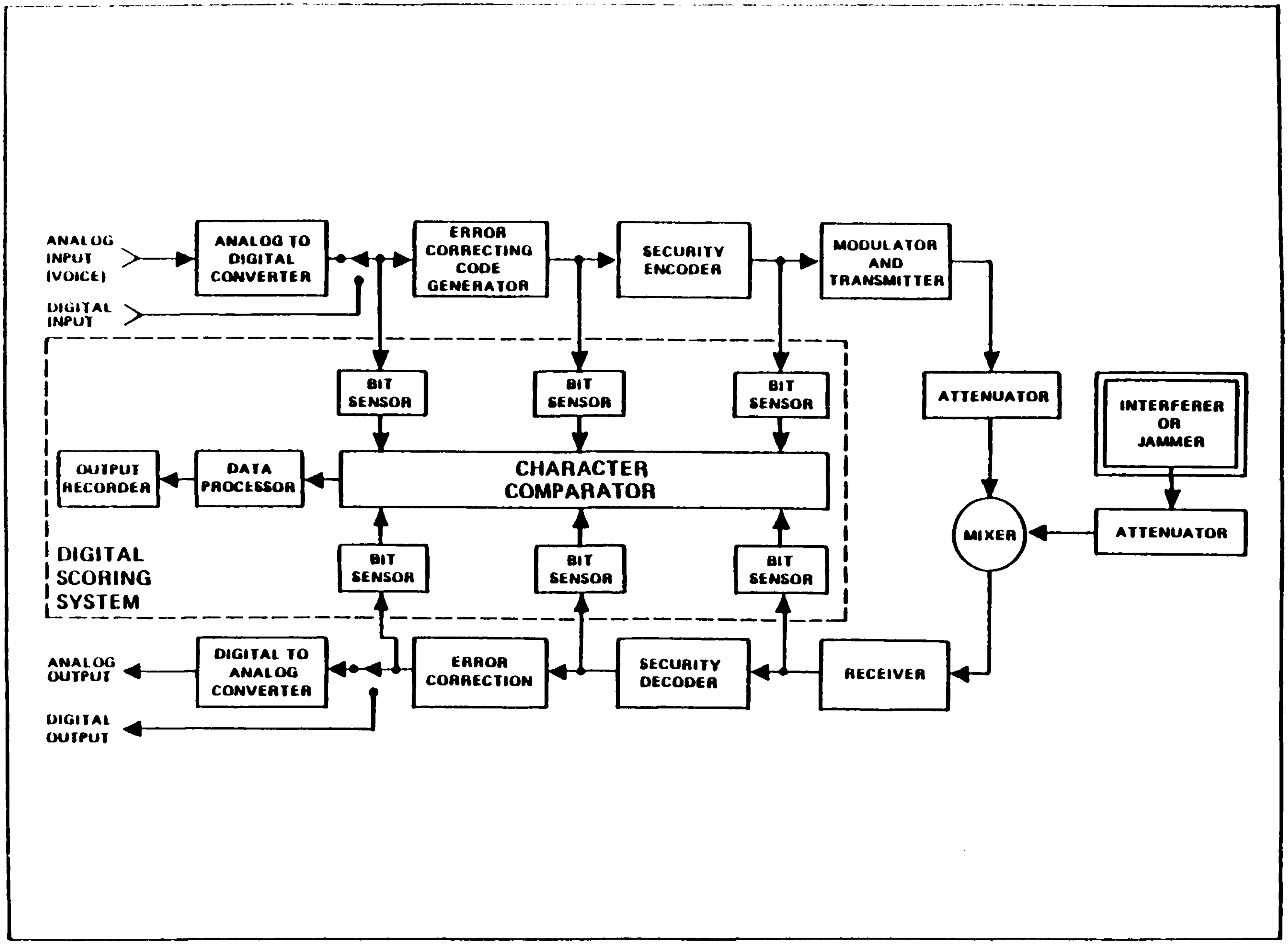

Figure 5. A typical test setup for the EMETF Digital Scoring System (a "bench test" capability) (USAEPG, 1987).

--power output
--modulation characteristics
--modulator bandwidth
--emission spectrum characteristics
--intermodulation
--carrier frequency stability.

Typical receiver data that can be measured include:

--sensitivity
--overall susceptibility
--false and continuous wave (CW) desensitization
--AGC characteristics
--noise figure
--audio selectivity
--selectivity
--intermodulation
--dynamic range
--discriminator bandwidth
--spurious response
--adjacent signal interference
--oscillator radiation.

Typical transmitter, receiver, and antenna gain measurements are illustrated in Figure [illegible]. Data obtained in the Spectrum Signature Facility are used as input data for computer simulations in addition to being reported as empirical data.

The Weapon System Electromagnetic Environment Simulator (WSEES), illustrated in Figure 7, is the major component of the Radar Weapon Systems Measurement Facility. A second capability is realized by combining the ADCS and the Digital Scoring System with the WSEES to form a versatile, electronic, [illegible]-attack, testing system. Under automated or manual control, the WSEES is capable of generating a variety of rf signals that include pulse, CW, [illegible], a combination of pulse and doppler CW, pulse burst pattern, chirp, and [illegible] jamming to represent a wide variety of battlefield C-E systems that [illegible] in the frequency range of 2 to 18 GHz. (Up to 32 pulse signals can be simultaneously simulated.) Control capabilities include a real-time controller that operates in a feedback loop with the system under test so as to produce a dynamic rf environment that responds to the electronic counter-countermeasure [illegible] capabilities of the system under test.

[illegible] Field Testing Capability

The Field Facility was established for use in conducting electromagnetic environmental tests under controlled but operationally realistic conditions. The facility is comprised of a central test site located near Gila Bend, [illegible], with several outlying sites (situated both north and south of Arizona [illegible]) that range in size up to 40 acres (see Figure 8). The area is [illegible] isolated and shielded from the urban centers of Phoenix and Tucson by [illegible]. Mobile test instrumentation facilitates the deployment of [illegible] equipment for testing in realistic simulations of operational

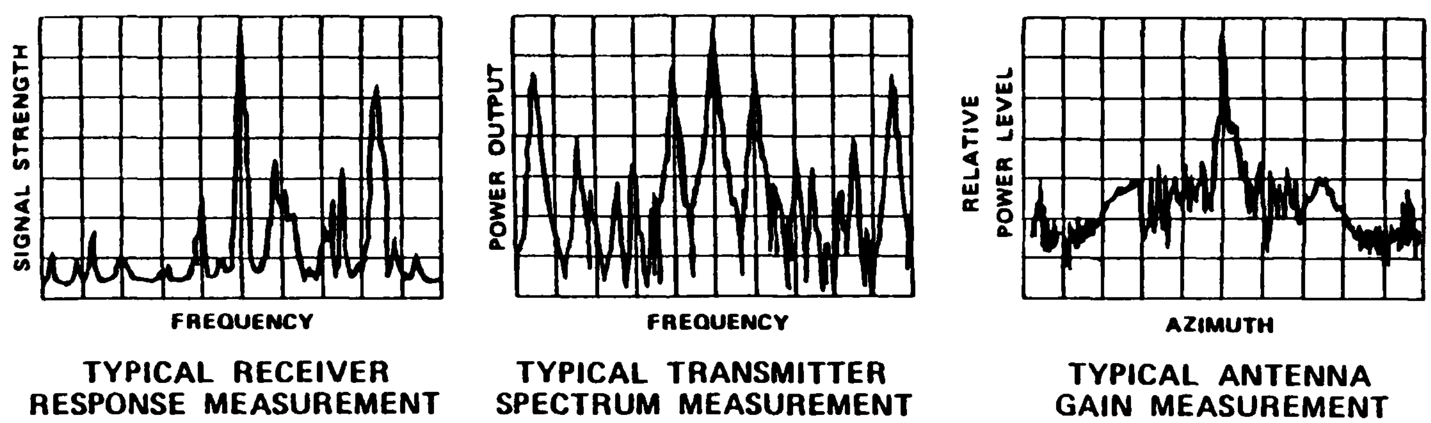

Figure 6. Illustrations of typical data measured in The EMETF Spectrum Signature Facility (a "bench test" capability) (USAEPG, 1987).

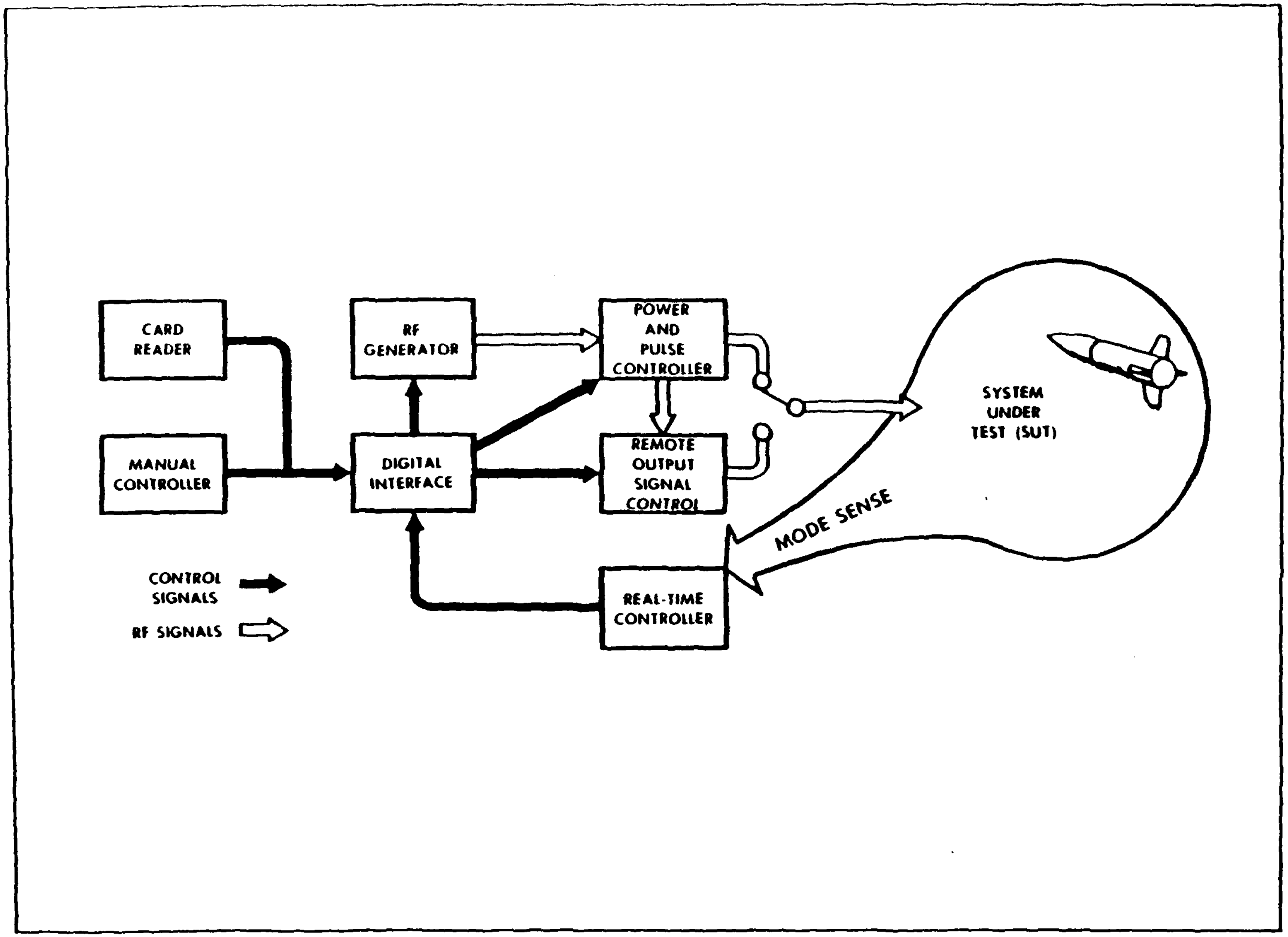

Figure 7. The Weapon System Electromagnetic Environment Simulator (WSEES), a major component of the EMETF Radar Weapon Systems *Measurement Facility* (a "bench test" capability) (USAEPG, 1987).

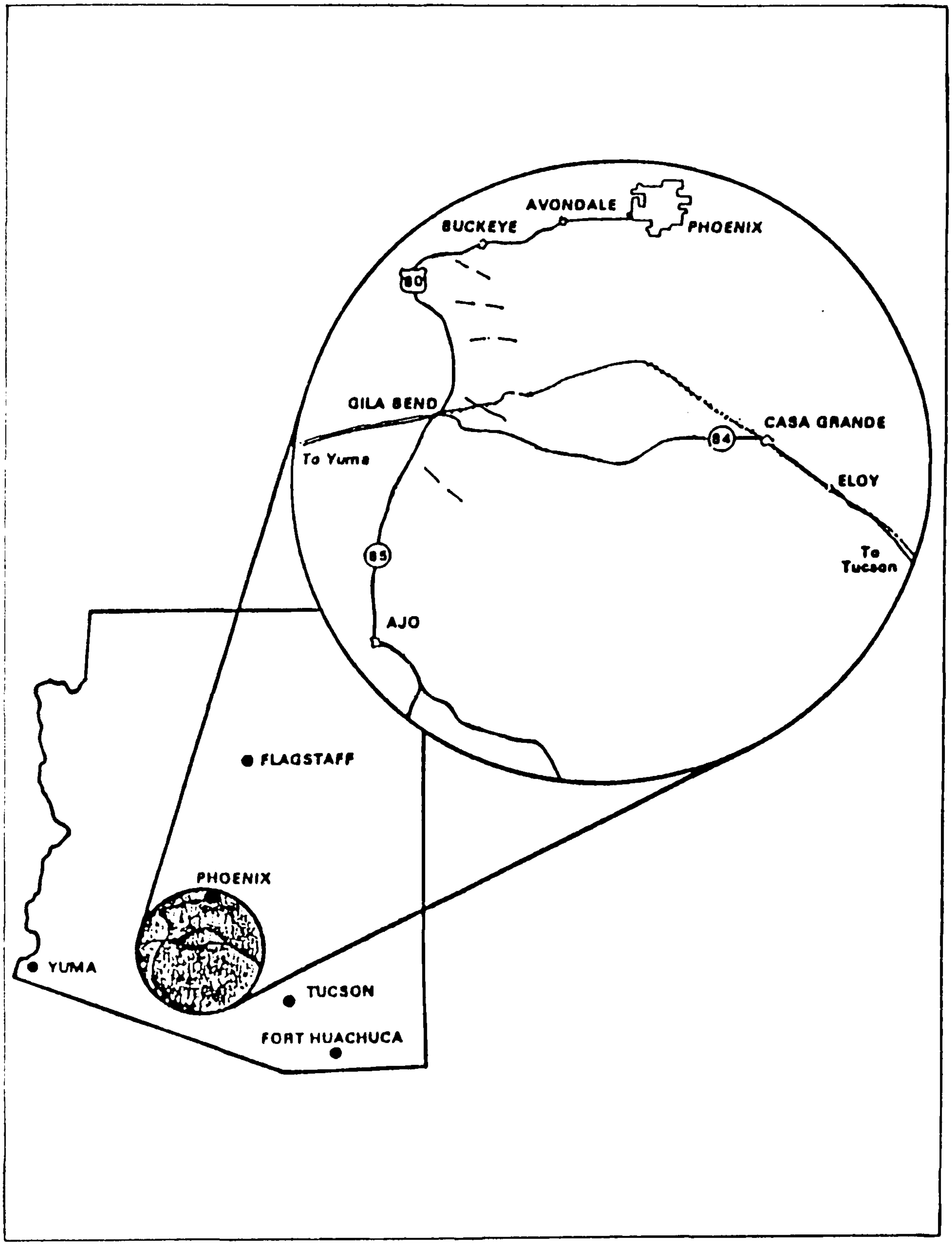

Figure 8. The EMETF Field Facility Near Gila Bend, Arizona (USAEPG, 1987).

situations. (In cases when the system or equipment to be tested cannot be moved from its installation site, the mobile instrumentation vans are moved to the system/equipment site for the tests.) The Field Facility capabilities are used to test large-scale deployments, antenna characteristics, propagation factors, over-sized systems/equipment, and other systems/equipment that cannot be brought into the laboratory test locations. The Field Facility also provides realistic conditions for acquiring and validating data in support of computer simulation analyses.

2.2.3 Computer Simulation Capabilities

Computer simulation capabilities of the EMETF consist of a library of computer models that operate on a dedicated Cyber 172 computer to perform electromagnetic compatibility and vulnerability analyses of C-E systems, equipment, and concepts in typical field tactical environments. The library of computer models, listed and described briefly below, is used in various combinations to perform a variety of electromagnetic system evaluations. The library includes:

1. the Network Traffic Analysis Model
2. the Performance Analysis of Communications-Electronics Systems (PACES) Model
3. the Intelligence and Electronic Warfare (IEW) Model
4. the Spectrum Integration Model
5. the Pseudoterrain Model
6. the Frequency Hopping Model
7. the Simulation Model for Mobile Subscriber Equipment
8. the Risk Assessment Model.

The Network Traffic Analysis Model is a time- and event-oriented dynamic computer model that simulates operation of individual items of equipment and their interaction within a system or network of equipment to provide network traffic analyses that are tailored to individual problems. The performance evaluations may focus on equipment, links and nodes, and the overall system. A block diagram of the Network Traffic Analysis Model is shown in Figure 9. The model is a dynamic and event-oriented simulation that is driven by various

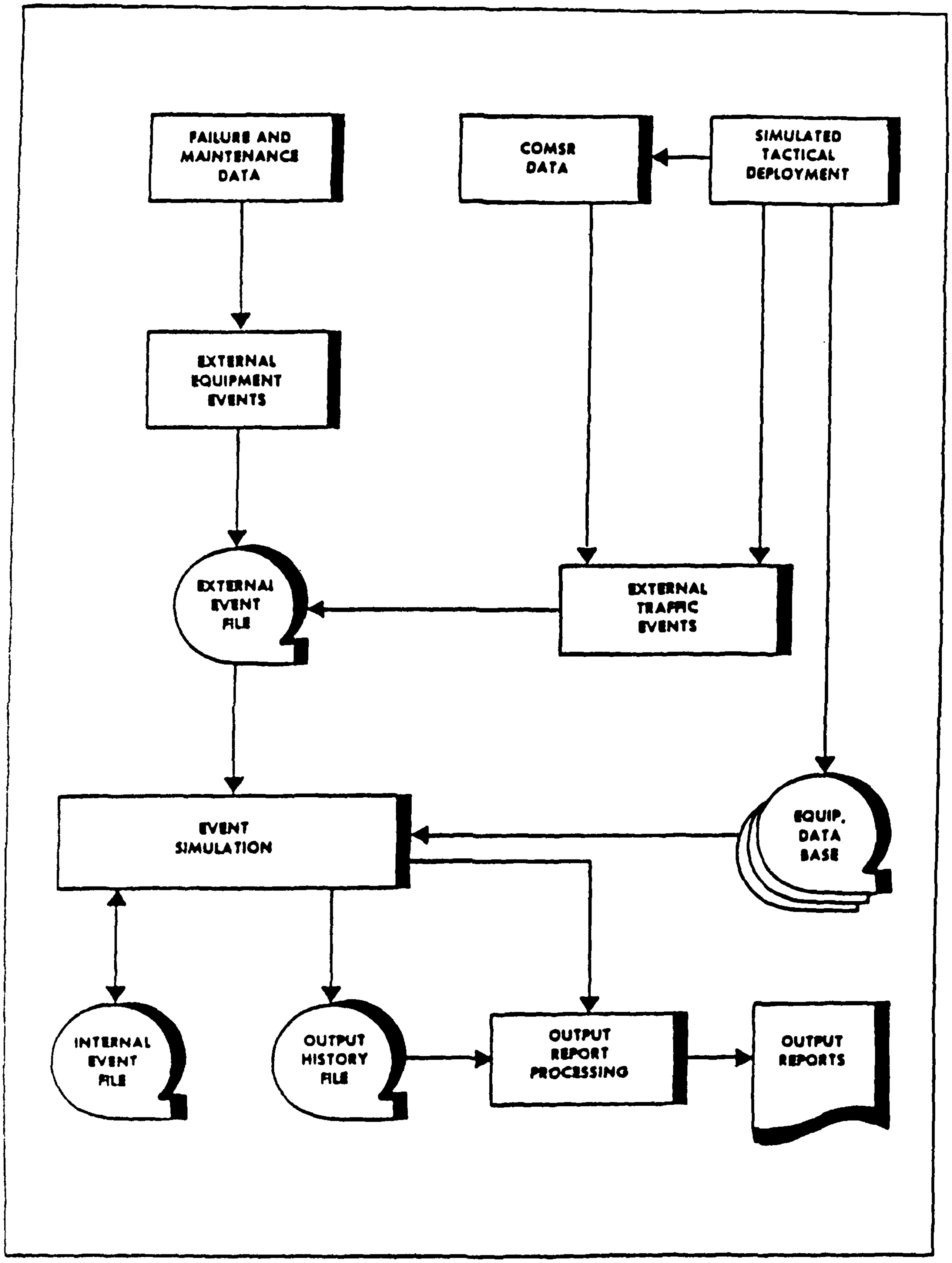

Figure 9. The EMETF Network Traffic Analysis Model (USAEPG, 1987).

events such as call placements, switchboard connections, and equipment failures that are processed (as part of the simulation) to produce new events called internal events. As this process continues, a history file is generated from which selected data are extracted to support specific evaluation requirements. The simulation uses traffic loading and flow between unit types and offices for each tactical deployment as defined by the U.S. Army Signal Center and School. Tactical deployments are based on information obtained from the Communications Research and Development Command. The model uses a static tactical snapshot of equipment and equipment locations as the background for the simulation and to reflect the dynamics of the flow between items of equipment.

The PACES Model is a collection of programs used to predict the EMC/EMV of C-E systems and equipments operating in a tactical environment. The electromagnetic environment is represented by tactical deployment snapshots that describe the geographical locations, networks, and characteristics of the systems and equipment being considered according to situations at particular instants of time in a force model sequence. The models and the input data used in the PACES Model, derived from applied theories that are supported where possible by empirical data, are grouped into the following functional groupings:

-- deployment visibility and analysis

-- preliminary data processing

-- link formulation and selection

-- interference identification

-- probability scoring

-- system effectiveness.

A flow diagram of the PACES Model is shown in Figure 10.

The deployment visibility and analysis group of programs provides a detailed presentation of the equipment and organizations included in the input data and verifies the form and content of the data. These programs provide the data necessary to convert the analysis design specifications into the detailed requirements for the PACES Model. The preliminary data processing group of programs checks input technical data against the deployment requirements, adds missing or updated information from existing files, notes missing

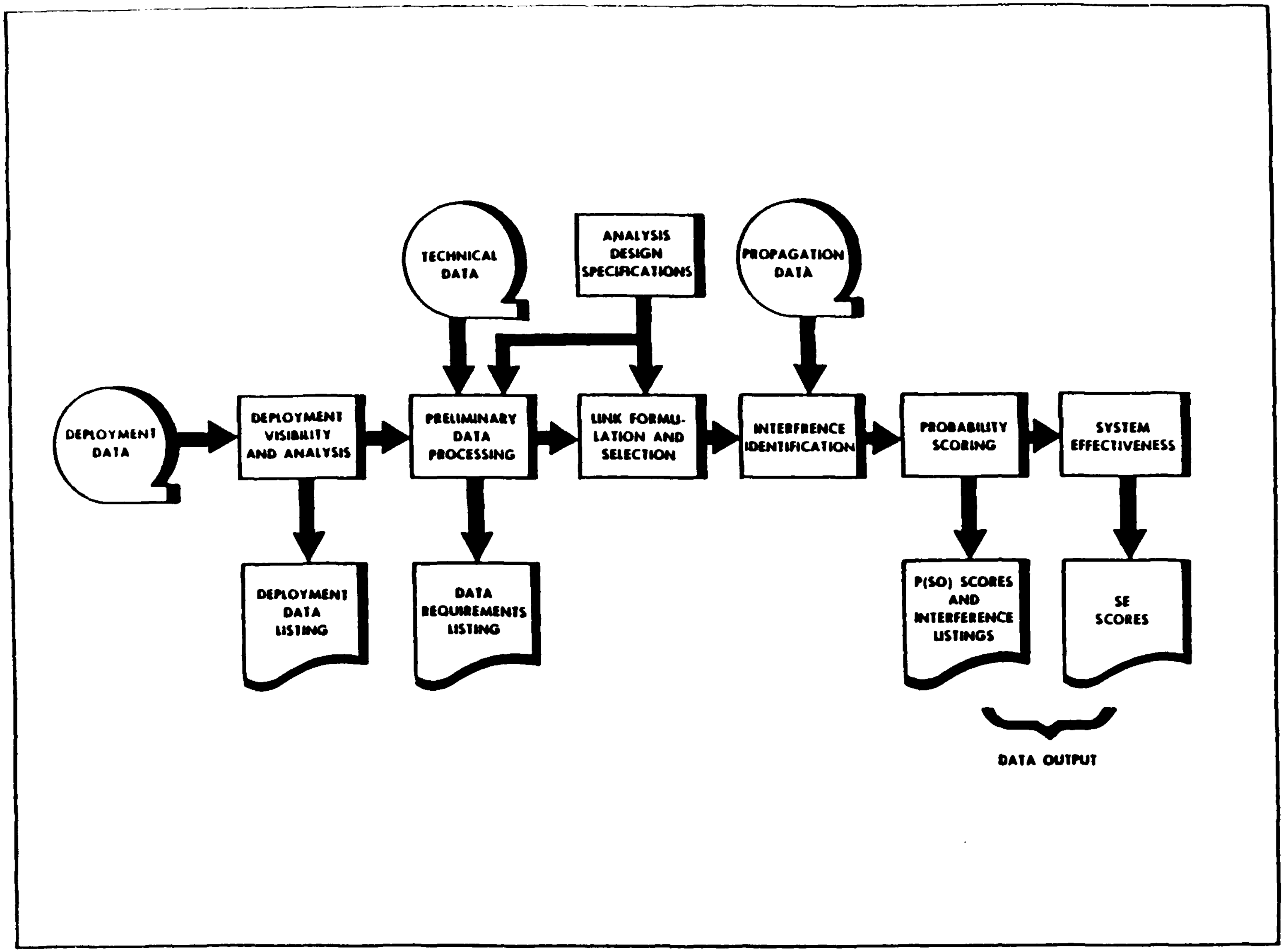

Figure 10. The EMETF Performance Analysis of Communications-Electronic Systems (PACES) Model (USAEPG, 1987).

information that is not in the file, and selects the data required as input in accordance with the analysis design specifications.

The link formulation and selection group of programs processes the input data in accordance with the analysis design specifications. A statistical sampling process is used to reduce the number of systems and equipments being evaluated to a practical number. This sampling process is weighted so as to select the systems and equipment that have the greatest relative importance in accomplishing the assigned tactical mission.

The interference identification group of programs calculates the statistics of the desired and interfering signal power levels at the input terminals of the link receivers being evaluated. Transmitters that are potential interferers to each system being evaluated are determined.

The probability scoring group of programs determines the probability of satisfactory operation for analog links and the probability of bit error for digital links selected for evaluation, based on desired signal power level, interfering transmitters' power levels, receivers' characteristics, and duty cycles of the interfering transmitters. The system effectiveness group of programs aggregates link performance probabilities in accordance with the analysis design specifications. The system effectiveness score then is determined, based on the relative weight assigned to each link for success of the military mission.

The Intelligence and Electronic Warfare Model is an analytical tool (which operates on either the CYBER 180 or a VAX 11/780 computer) designed to evaluate quantitatively the effects of electronic warfare on combat operations. The model is a dynamic, event-driven simulation of the operation of a set of sensor systems against an opposing force's electromagnetic environment. A block diagram of the IEW Model is shown in Figure 11. Operation of the sensor systems is modeled as sets of discrete events, either external or internal, that mark points in time when a significant change occurs. External events are [illegible] outside the simulation and result in a baseline loading for the [illegible]. Internal events are generated within the simulation and represent [illegible] of sensor operation and target operations. There are [illegible] modules in the model--the emitter environment module, which [illegible] characteristics and network organization of the emitters in [illegible]; the sensor module, which generates the tactical message that

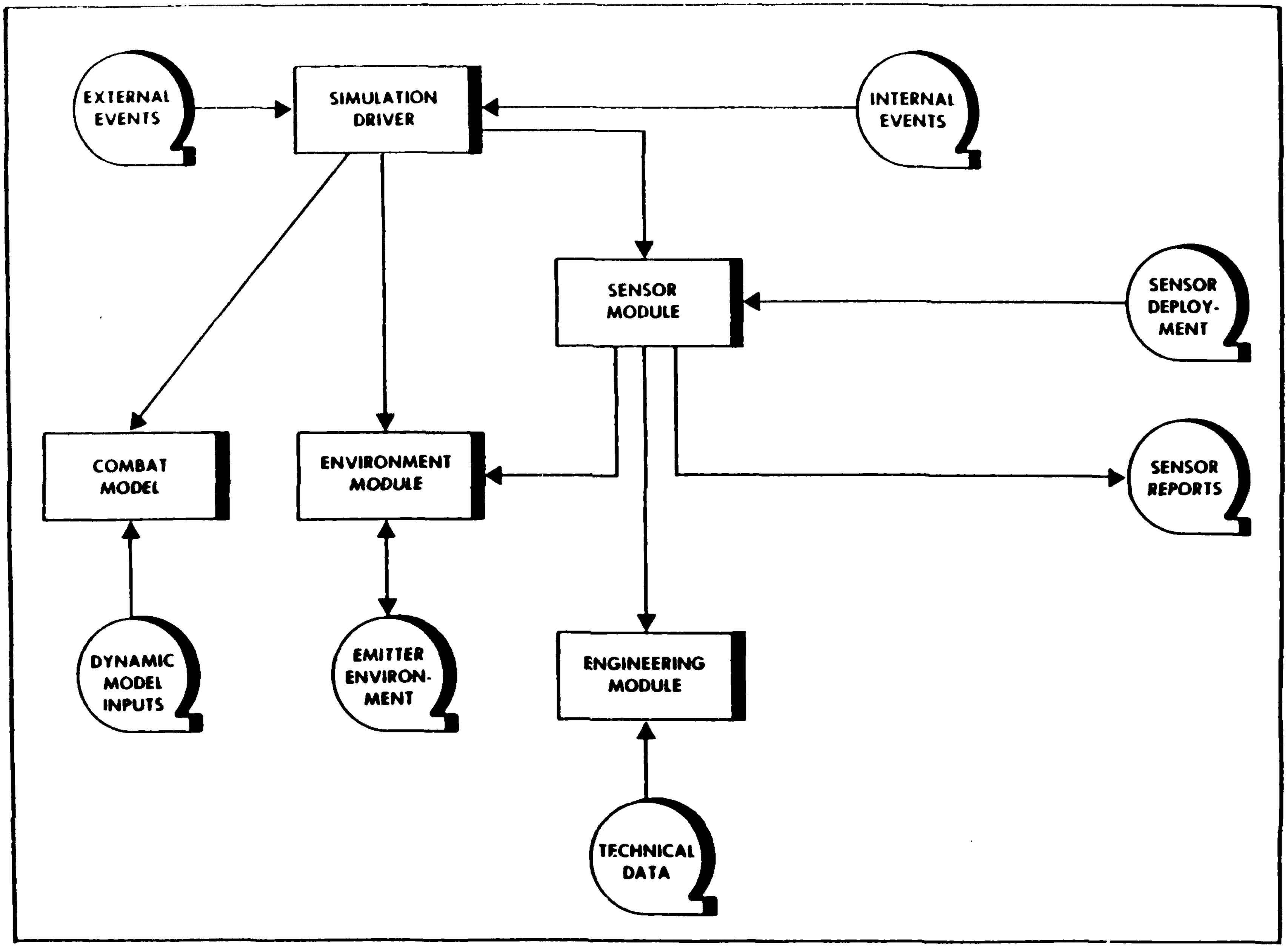

Figure 11. The EMETF Intelligence and Electronic Warfare (IEW) Model (USAEPG, 1987).

each sensor reports during the simulation; and the combat module, which provides a dynamic capability to the simulation.

The Spectrum Integration Model is used to calculate threshold signal-to-interference (S/I) values when empirical data are unavailable ("B" value scoring data). Input data for the model include the interference spectrum, the receiver selectivity curve, and the cochannel threshold S/I value for each system of interest and the frequency differences between the interferers and the receiver tuned frequencies for the desired systems. Details of the calculation process are given in the USAEPG (1987) report.

The calculation of propagation path losses between transmitters (desired and interfering) and receivers is a central requirement in estimating EMC/EMV. The name Pseudoterrain Model is given to the model that performs this vital function. The model used for the propagation loss calculations is the Longley-Rice Model ([illegible], revised in 1972) with modifications made by the EMETF. The Longley-Rice Model is one of the better models for predicting long-term yearly median radio transmission loss at VHF and higher frequencies over irregular terrain that is characterized by the use of statistical descriptors for terrain irregularity, surface refractivity, etc. The model is based on well-established propagation theory and has been verified using a large number of propagation measurements. The "heart" of the model is the calculation of median values of reference attenuation relative to free-space loss as a function of distance and the type of radio path, i.e., line-of-sight, diffraction, or tropospheric scatter. The median basic transmission loss, a function of distance, is combined with other parametric values that account for the variabilities in transmission loss due to long-term fading (time availability), path-to-path variations (location variability), and estimating (or prediction) confidence. Each variability is assumed to be approximately normally distributed with zero mean. The standard deviation for each variability (denoted as [illegible], [illegible], and [illegible]) has been determined empirically from measured data.

The Frequency Hopping Model contains logic to represent, realistically, the effects of frequency hopping systems in a deployment. The three conditions under which consideration of frequency hopping systems is important are:

1. the effect of interference from frequency-hopping systems to nonhopping systems

2. the effect of interference from nonhopping systems to frequency-hopping systems

3. the effect of interference from frequency-hopping systems to other frequency-hopping systems.

The effect of interference from nonhopping systems to other nonhopping systems is the situation normally considered by the PACES Model. The weighted influence to system performance scores when frequency-hopping systems are involved as interferers and/or receivers are determined by the Frequency-Hopping Model.

The Simulation Model for Mobile Subscriber Equipment is an event-sequence model that simulates mobile subscriber equipment system functions that form the basis from which to predict the EMC/EMV of mobile C-E equipments similar to the predictions calculated by the EIEM for nonmobile systems and equipments. The model includes modified algorithms for propagation loss calculations and equipment performance criteria that are tailored to mobile subscriber equipment operations and functions. The analysis output data are provided at two levels of detail--individual communications link scores (vulnerability and compatibility/vulnerability scores) and composite, system effectiveness scores for sets of links under specific interference conditions.

The Risk Assessment Model is used to evaluate the effects of unintended susceptibilities and emissions on the electromagnetic compatibility of systems and equipment operating in their intended electromagnetic environments. All systems and equipments that are purchased by the U.S. Department of Defense are required to operate in accordance with MIL-STD-461/462/463 with regard to electromagnetic characteristics. Susceptibilities and emissions that fail to meet the requirements of these standards may or may not affect the electromagnetic compatibility of the system/equipment when deployed in the intended operational environment. This model is used to develop a basis for a decision to "fix" a system/equipment or to field the system/equipment without change when testing reveals some susceptibilities and/or unintended emissions.

The various computer simulation capabilities are operational on a [illegible] 170/Model 730 computer that has been installed in a classified [illegible] approved for handling and processing classified information. [illegible] has central memory (RAM) of 514,000 60-bit words (5,141,000 [illegible] -nsec cycle time, which equates to a little more than [illegible] alphanumeric characters of fetch-and-retrieve cycles from RAM per [illegible] computer capability is illustrated in Figure 12.

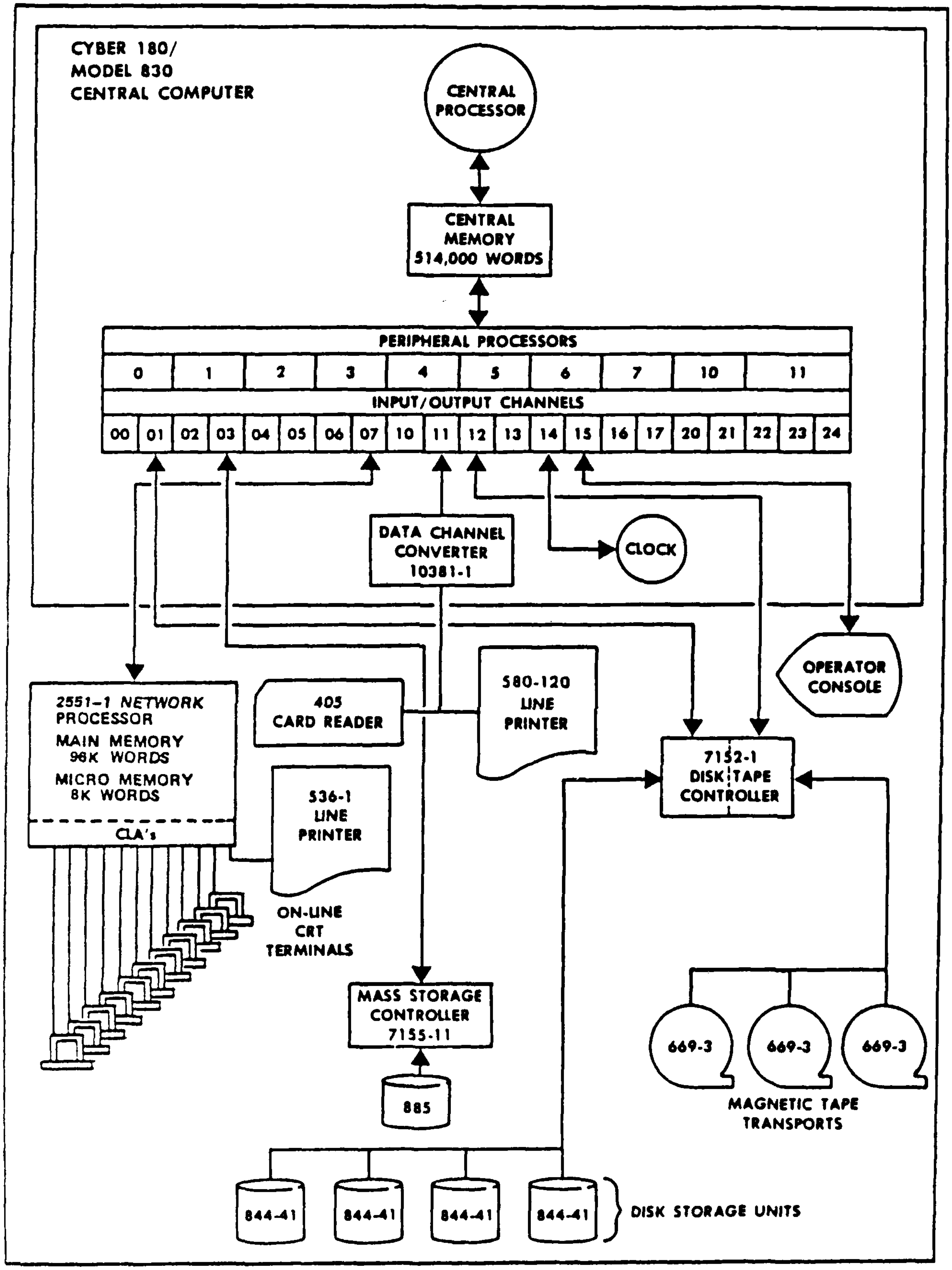

Figure 12. The EMETF dedicated computer for computer simulation analyses (USAEPG, 1987).

[illegible]. STRESS LOADING FACILITY (SLF) TEST CONCEPT

A brief description of the SLF is given in Section 1 with a simplified block diagram of the SLF concept shown in Figure 1. Additional description and discussion of the SLF test concept is given in this section, but reference material is very limited. The purpose of this section is to show (our understanding of) how existing and newly developed testing capabilities will be integrated (and automated further) to achieve the SLF testing capability.

As is noted earlier, the SLF is envisioned as an integrated (and [illegible]) test system that will be capable of generating a dense [illegible] threat test environment and simultaneously monitor key [illegible] parameters of the system being tested. It is expected that this [illegible] ultimately will be part of the EMETF, both physically and function[illegible], [illegible] will tend to encumber this discussion of the test concept to [illegible] fully differentiate between existing and new capabilities or [illegible] SLF.

[illegible] illustrates the potential role of SLF testing and the benefits [illegible] interrelationships of SLF and other modes of testing. SLF testing offers [illegible] advantages of complete security and precise control in developing [illegible] environment that may be highly stressed (many simultaneous but different [illegible] signal levels) with the ability to monitor and record data that [illegible] characterize the performance of the system being tested. Open range [illegible] testing offers the advantage of producing test results that often [illegible] credibility. In addition, such testing sometimes is the only or [illegible] for performing some tests, such as antenna pattern tests. There [illegible] of other tests that may be needed, useful, or simply interesting, [illegible] testing facilities will be necessary to perform these tests. The [illegible] for understanding system performance would be the ability and [illegible] perform all such tests. We realize, however, that it may be [illegible] or financially unrealistic to perform all the tests that [illegible]. It seems reasonable, therefore, to endorse the concept of SLF [illegible] control and comprehensive characteristics of such tests, [illegible] that some other complementary tests may be necessary on a [illegible].

[illegible] detailed, functional block diagram of the overall SLF [illegible] capability. Since it is expected that the SLF will be a part [illegible], [illegible] physically and functionally, some functional redundancy

POTENTIAL ROLE OF SLF

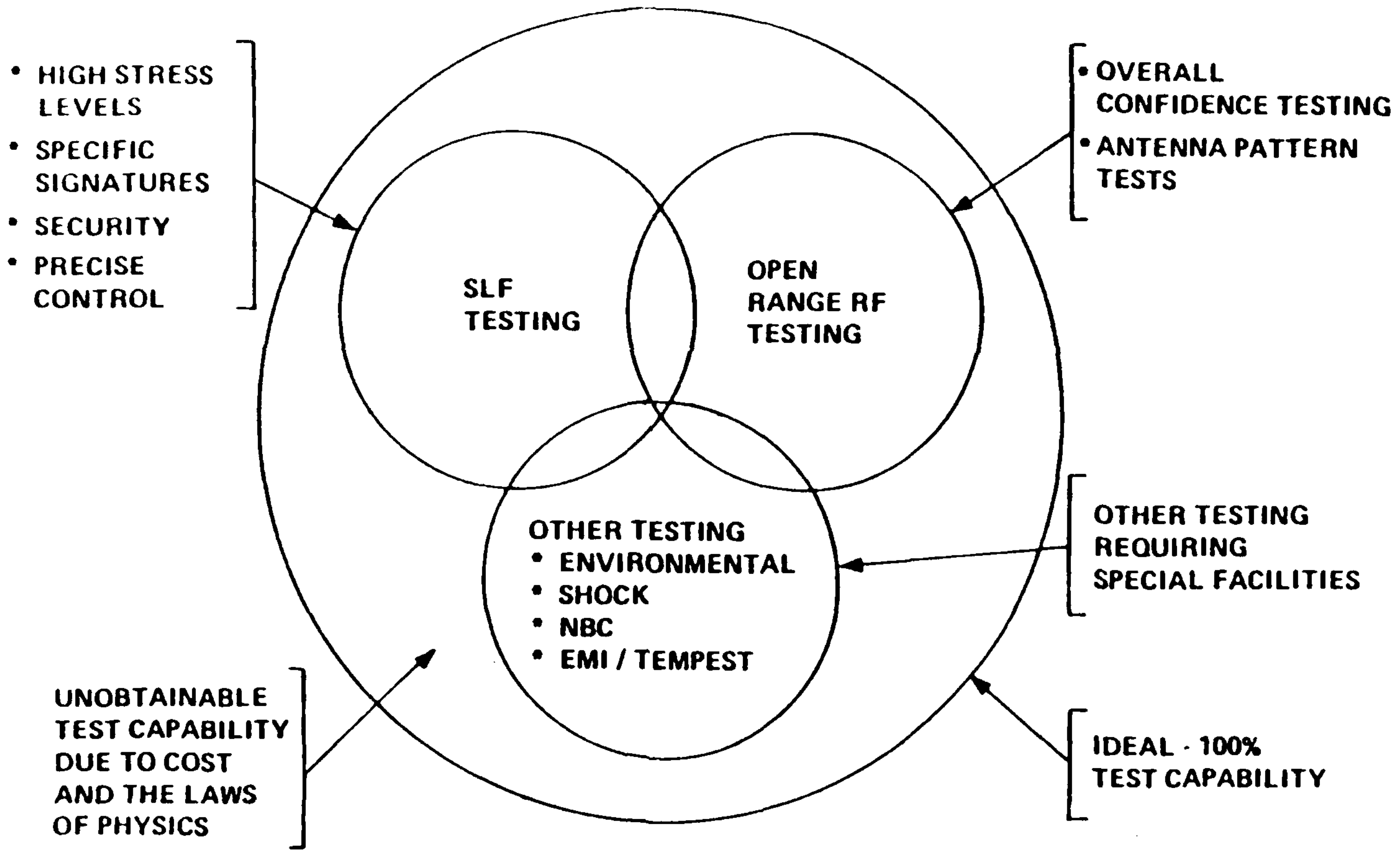

Figure 13. An illustration of the potential role of SLF testing in the context of other possible testing modes for U.S. Army C-E systems and/or equipment.

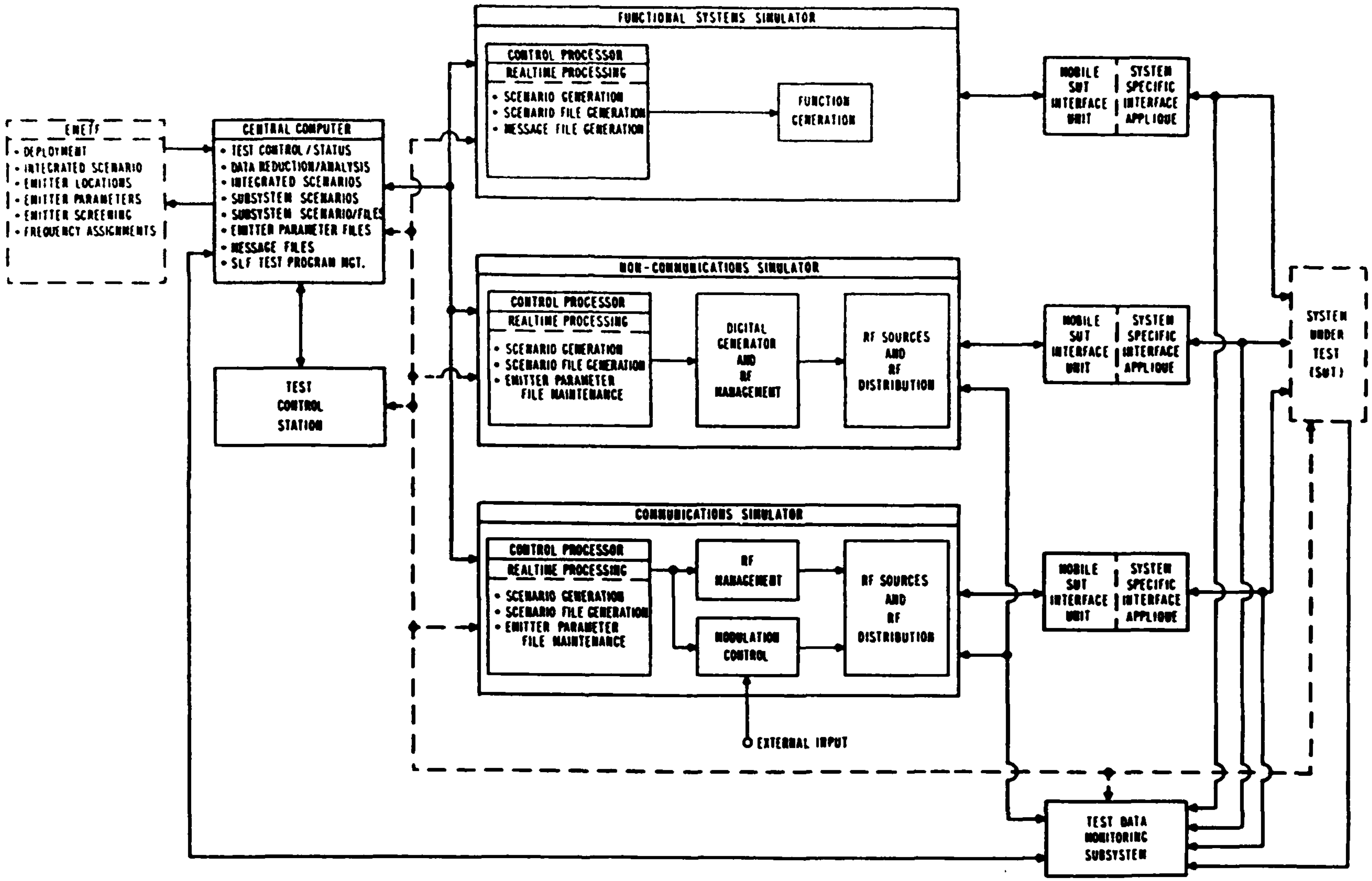

Figure 14. The functional SLF test concept and capability.

appears in Figure 14. The design concept does envision the SLF as being completely self-contained and capable of operating independently of the EMETF if required. This same concept applies to each of the SLF subsystems. Each of the simulator subsystems will have the capability to operate independently of the central computer subsystem, if required (by subsystem failure or location of the test, for example). Typical operation would be more efficient, however, by utilizing current and projected capabilities of the EMETF to generate integrated scenarios for complex tests that involve a simulated tactical deployment, generate the scenario file, generate and maintain required parameter files, etc. Specific examples of functions that the EMETF (with current and/or expanded capabilities) will be expected to provide for SLF tests include the following:

-- determine simulated tactical deployments of personnel, equipment, communications networks, and all associated electromagnetic emitters (COMM and Non-COMM) for both friendly and nonfriendly forces

-- determine (automatically) realistic frequency assignments for the deployed emitters

-- establish duty cycles for all deployed emitters

-- determine and assign the modulations and associated types of traffic (voice, data, etc.) to all networks in the deployment

-- create, update, and maintain the emitter parameter data base for use by the SLF central computer subsystem

-- generate integrated scenarios (time-ordered events) that will include both static and dynamic representations of the system under test and all other emitters (to include location changes and motion)

-- identify and cull out emitters from the simulated tactical deployment and the integrated scenario that realistically would not be detected by the SUT at the applicable point in the scenario

-- refine the integrated scenario based on the culling (described above) and download this scenario to the SLF central computer subsystem

-- create the individual SLF subsystem scenarios from the refined integrated scenario for downloading to the SLF central computer subsystem

-- create the scenario generation files required by the real-time processing software in each subsystem simulator

-- accommodate adaptive changes that would override the scenario generation files in real time, based on SUT performance and on-line EMETF files/processing (a future function that would be very desireable).

The SLF central computer subsystem is envisioned to provide at least the following functions:

-- perform integrated test control and provide test status

-- reduce and analyze test data to satisfy both real-time (quick-look) and post-test requirements

-- update and manage the data bases that contain the pretest calibration data and the real-time test data

-- generate the integrated scenario for the entire SLF test, including all of the time-ordered events for the SLF subsystems

-- generate the individual simulator subsystem scenarios, from the integrated scenario, in the proper time sequence

-- create, update, and maintain the emitter parameter data base for the SLF (the individual subsystem simulator emitter parameter files could be subsets of this data base)

-- create, update, and maintain a message file data base

-- create the individual subsystem simulator scenario generation files for downloading to the individual simulator control processors for use by the real-time processing software (these files would include the emitter parameters, emitter location/motion requirements, messages, and other data necessary for the real-time processing software in the correct time sequence)

-- manage, schedule, etc., the SLF program.

The primary function of the control processor in each of the simulator subsystems will be to support the real-time processing software for the subsystem. Each control processor may support additional software functions, either off-line or in a background mode, to provide a stand-alone capability for generating scenarios, generating scenario files for real-time processing, creating, updating, and maintaining emitter parameter files, and creating, updating, and maintaining message files. As has been noted, these off-line or background-mode software functions may be performed in the SLF central computer for the EMETF with only the scenario generation files necessary for the real-time processing software to function being downloaded to the appropriate subsystem control processor prior to the test.

The real-time functions and division of work in a subsystem simulator may be understood better by creating an example, using the Non-COMM Threat Simulator. The control processor/software tasks would include:

-- reading scenario events
-- maintaining emitter and receiver locations
-- representing emitter and receiver movements
-- reading emitter data
-- writing emitter data to the digital generator.

The digital generator tasks would include:

-- receiving emitter data from the computer
-- converting emitter data into pulse commands
-- representing dynamic changes in PRF/PRI, scan rates, and carrier frequencies on a pulse-by-pulse basis for each emitter
-- providing these pulse commands to the rf management section.

The rf management tasks would include:

-- allocating pulse commands to available rf sources
-- controlling rf sources to generate the pulses
-- distributing the rf signals.

A message-generating device known as the Test Item Stimulator (TIS) (current EMETF capability) will become the control processor of the Functional Systems Simulator. An advanced version of the TEWES (see Section 2.1.1) is being purchased by USAEPG and, in effect, is expected to become the Non-COMM Threat Simulator. The range of frequency coverage will be 500 MHz to 18 GHz. The COMM Threat Simulator will be a new capability. Modulation capabilities and rf source capabilities for this simulator are readily available. The minimum radio frequency for COMM Threat Simulator operation is not stated, however the upper limit is 500 MHz. The coupling of rf energy from the rf sources to the SUT is a problem with substantial challenge because of the longer wavelengths associated with the operating frequencies for typical COMM systems and equipments, which translate into very large test enclosures if normal far-field coupling of the rf energy is presumed. One consideration in this regard is that the rf sources and the rf distribution function may be located physically in the associated Mobile SUT Interface Unit (possibly for the Non-COMM Threat Simulator, as well) with direct coupling of rf energy rather than antenna-to-antenna coupling of radiated energy. Of course, the interface units to systems under test, the central computer and test control station, and the test data monitoring subsystem also are new capabilities that will have to be developed for the SLF or adapted from existing general-purpose capabilities.

4. STRUCTURED APPROACH TO PERFORMANCE DESCRIPTION

This section presents a structured approach to the problem of selecting a set of parameters to describe the performance of the various systems that may be tested using the SLF. The proposed approach is not theoretical or unproven; it is, in fact, widely used by national and international standards organizations responsible for defining performance measures and objectives.[1] The approach provides the step-by-step procedures required to ensure that the set of performance parameters selected to characterize a system is complete, efficient, and measurable.

Previous parameter development studies have been approached from two general perspectives: that of the user and that of the engineer or designer. The objectives of parameter development are fundamentally different in the two cases, and the appropriate parameter sets differ correspondingly. User-oriented performance parameters are intended to be applied in two principal ways: (1) in specifying the performance requirements for a system that is yet to be selected or designed and (2) in comparing performance among systems. To be appropriate for these applications, the user-oriented parameters should (1) focus on user-perceived performance effects, rather than their causes within the system and (2) not depend, in their detailed definition, on

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[1]The approach is being used by at least two Study Groups of the International Telegraph and Telephone Consultative Committee (CCITT), an organ of the International Telecommunication Union (ITU). For example, Study Group VII is developing quality of service parameters for communications via public data networks following the structured approach, and, Study Group XVIII has adopted the same matrix framework for the development of Integrated Services Digital Network (ISDN) performance parameters.

[illegible] about the system's internal design. Such parameters may be [illegible] as <u>system independent</u>.

Engineering-oriented performance parameters are intended to be used in the specification of individual system components and in relating such component specifications with the end-to-end performance objectives. To be appropriate for these applications, the engineering-oriented parameters should (1) be [illegible], and specifically tailored to, the internal architecture of the system, and [illegible] be useful in identifying the causes of user-perceived perform- [illegible]. In contrast to the user-oriented performance parameters, these engineering-oriented parameters are <u>system specific</u>.

The second application, identified above, for use of engineering-oriented [illegible] should be noted particularly. Most system specifications depend [illegible] use of engineering-oriented parameters to define required [illegible], with the (often implicit) expectation that the system will satisfy [illegible] these engineering-oriented parameter specifications [illegible], USAEPG will need to perform some engineering- [illegible] in order to understand some of the [illegible] results.

[illegible] parameters developed in this study will be [illegible] of systems (existing or under [illegible], measuring the time to detect and [illegible], therefore, focused on the develop- [illegible] parameters. However, it [illegible] system engineering applications [illegible] characteristics and operating [illegible] effective in detecting interference. A [illegible] is that it is useful in [illegible] greatly simplify the task of relating [illegible] engineering-oriented parameters. A clear definition of [illegible] to effective system design. The proposed [illegible] any system--whether it be used in communi- [illegible], remote sensing, electronic surveillance, or many other [illegible].

[illegible] divide both the user-oriented and the engineering-oriented [illegible] parameters into two categories: <u>primary parameters</u>, which describe [illegible] during periods of normal operation; and <u>secondary</u>

parameters, which describe the frequency and duration of outages (i.e., the system "availability"). The latter parameters are termed "secondary" to emphasize the fact that their values are derived from observed values for the primary parameters, rather than from direct observations of the system. The primary performance parameters are developed in four major steps: system interface definition, function definition, performance outcome analysis, and parameter selection. These steps are illustrated in Figure 15 and described in [illegible] through 4.4.1 below. Section 4.4.2 describes the proposed method [illegible] the secondary (availability) parameters.

4.1 System Interface Definition

The first step in developing parameters to describe the performance of a [illegible] define the system's interfaces or boundaries. This step should, [illegible] distinguish what is inside the system from what is outside the [illegible], identify the normal or intended interactions between the [illegible] its environment. Interface definition is straightforward in many [illegible] example, a portable field radio set has clearly defined electrical [illegible] boundaries, and each boundary has an associated "protocol," or set [illegible] that govern the interactions across it. In other cases, the defini- [illegible] what constitutes "the system" requires careful thought. For example, [illegible] interface to a packet switching system involves separate physical [illegible], [illegible] level, and packet level protocols that are implemented in computer [illegible] software at each end of a physical access line. Experts often [illegible] where "the packet switching system" ends and "the user" begins. In general, [illegible] single definition of system boundaries is right for all perform- ance assessment applications; the choice depends on the focus and objectives of [illegible]. What is defined as "the system" in one study might be a subsystem [illegible]. Similarly, the user of a system may be a single entity (e.g., the [illegible] or a collection of entities (e.g., the operator and the [illegible]), depending on where the system (or subsystem) boundaries [illegible].

[illegible] for selecting a system's boundaries? This depends, [illegible] performance measures of interest. In many instances the

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[illegible] used to describe a collection of user and [illegible] receive services from a subsystem.

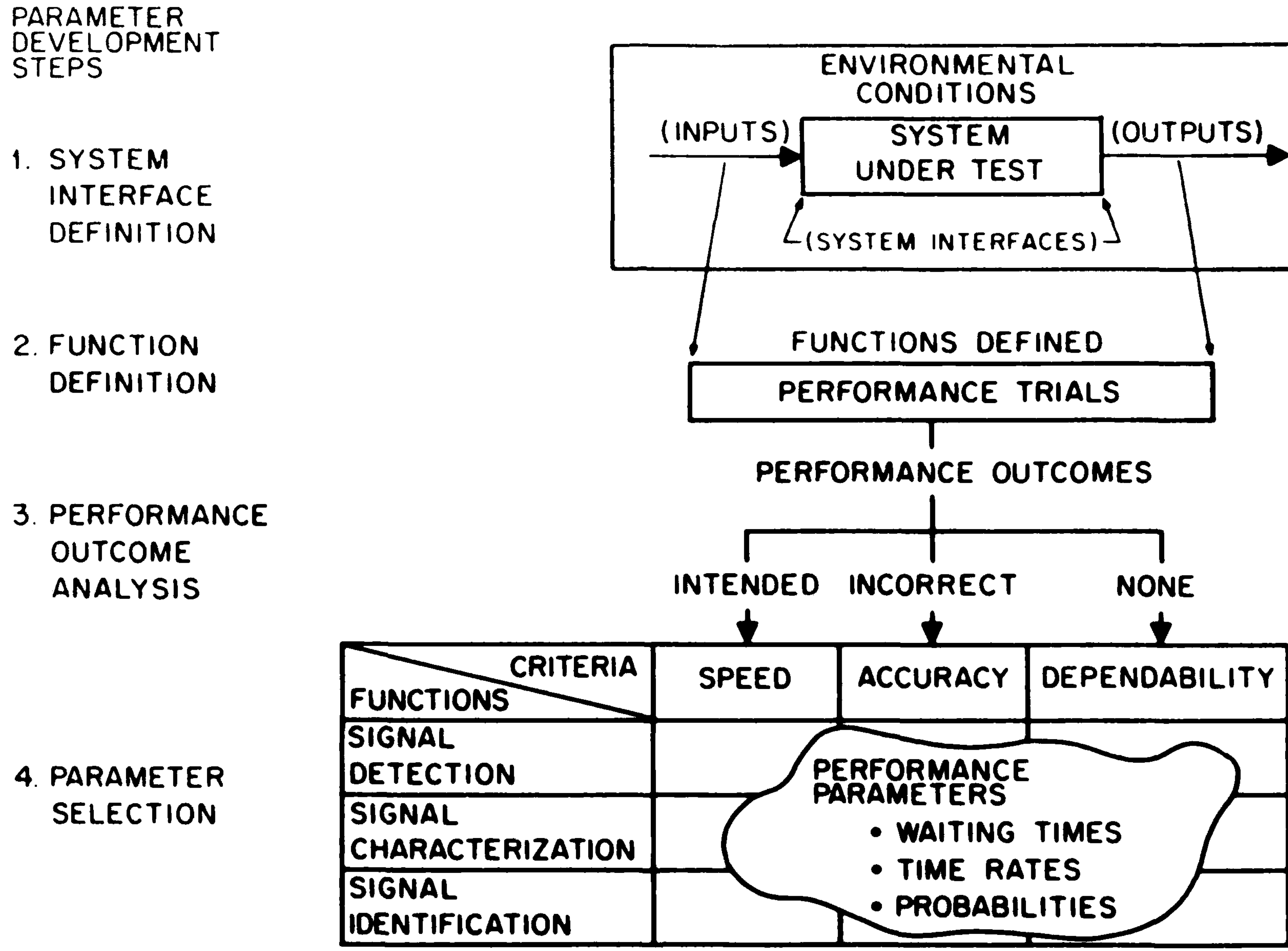

Figure 15. Steps involved in the parameter development process.

[illegible] of most interest is the user/system interface (sometimes called the end user interface). The user, however, may be a human operator or an application program. When the end user is the human operator, the user/system interface is defined as the physical interface between the operator and the terminal (i.e., the keyboard) or the operator's medium of inputing the terminal (e.g., punch card or tape). Outputs may be visual displays or recorded formats. When the end user is an application program, the user/system interface [illegible] the functional interface between that program and the [illegible] system.

[illegible] surveillance system, various interfaces are indicated in [illegible]. This figure depicts the surveillance systems in a field test [illegible] with bearing angles obtained from a remote site for use in locating [illegible]. The end-user interface is between the human and a display [illegible] interface is between the application program and the [illegible] control system which controls the generation of signals [illegible]. Performance parameters are measured by recording [illegible] of signals or events that occur at these interfaces. [illegible] time would be measured as the time between the event that [illegible] signal generator and the subsequent event that turned on the [illegible] signal detection. Other display times indicating signal [illegible], identification, and location would be measured over many [illegible] a relatively large sample of data could be obtained. These [illegible] serve as the basic units of observation from which overall [illegible] parameters will be defined. Note that other interfaces can [illegible] that subsystem performance parameters can also be measured. [illegible], the communication data link performance can be independently [illegible] events occurring at the input/output interfaces. These [illegible] synchronized clocks to time and record the occurrence of [illegible] interface.

[illegible] Function Definition

[illegible] performance ultimately refers to some particular [illegible]. The second step in developing system performance [illegible] define the specific function, or set of functions, [illegible]. These may comprise all functions the system [illegible] objectives of a particular study.

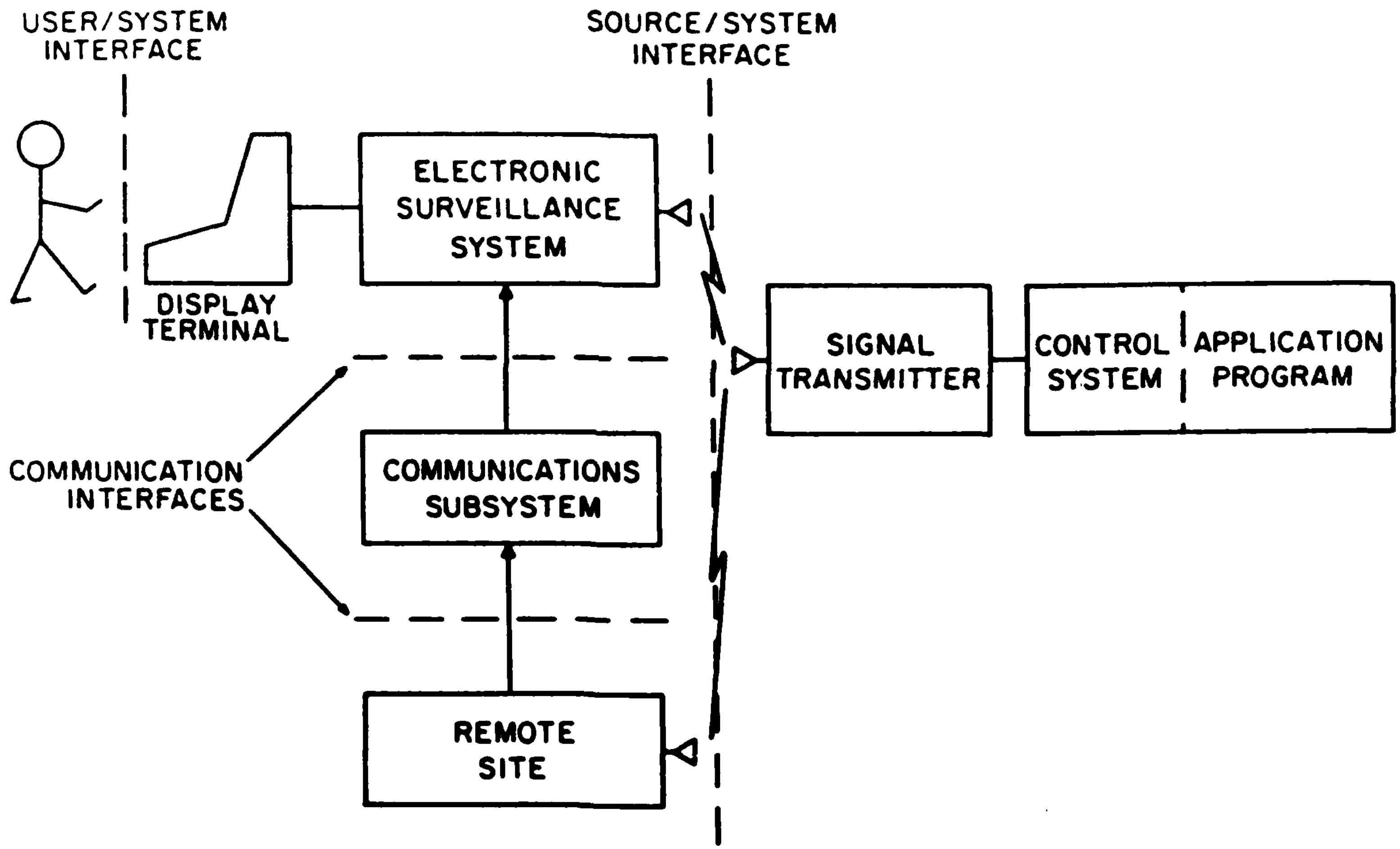

Figure 16. System interfaces for an electronic surveillance system.

[illegible] requires a clear definition of the term "function" as applied to [illegible] of system performance. A useful starting point is the [illegible] definition; a function is a set of ordered pairs of elements (x,y) [illegible] one and only one value y corresponds to each possible argument x. [illegible] possible arguments is the domain of the function; the set of [illegible] is the range of the function. The sets X and Y may include all [illegible] within the defined range and domain (thereby defining a [illegible]), or may include only certain selected elements (thereby [illegible] function). The mathematical definition of a function is [illegible] Figure [illegible], which portrays the function as a machine that converts [illegible] values.

[illegible] of a function can be applied very naturally to [illegible] of system functions for the purpose of performance description. [illegible] as a machine that performs a set of specified [illegible] inputs are the function arguments. The system's outputs [illegible] values. Thus, a system function is a set of ordered pairs of [illegible] system outputs such that one and only one expected or [illegible] corresponds to each possible input. Like mathematical [illegible], system functions may be continuous or discrete. In general, a [illegible] functions and may perform many different functions on a [illegible] its internal state. This "multistate" aspect of [illegible] represented by modeling the system as a finite state [illegible] by Seitz and McManamon (1978).

[illegible] method of defining system functions for performance [illegible] now be stated. Each function is defined by specifying one or [illegible] inputs and associated system outputs. There is a single expected [illegible] input. If the system must be in a particular internal state to [illegible] function, that state (and the inputs required to achieve it) should [illegible] defined.

[illegible] surveillance system, the primary functions are signal [illegible] intercept signals from a background of noise and [illegible] characterization (i.e., measuring specific attributes [illegible], bearing, etc.), and identification and location [illegible] emitter type, and position fixing).

[illegible] involves an evaluation of bearing angle measurements [illegible] obtained from a communications subsystem.

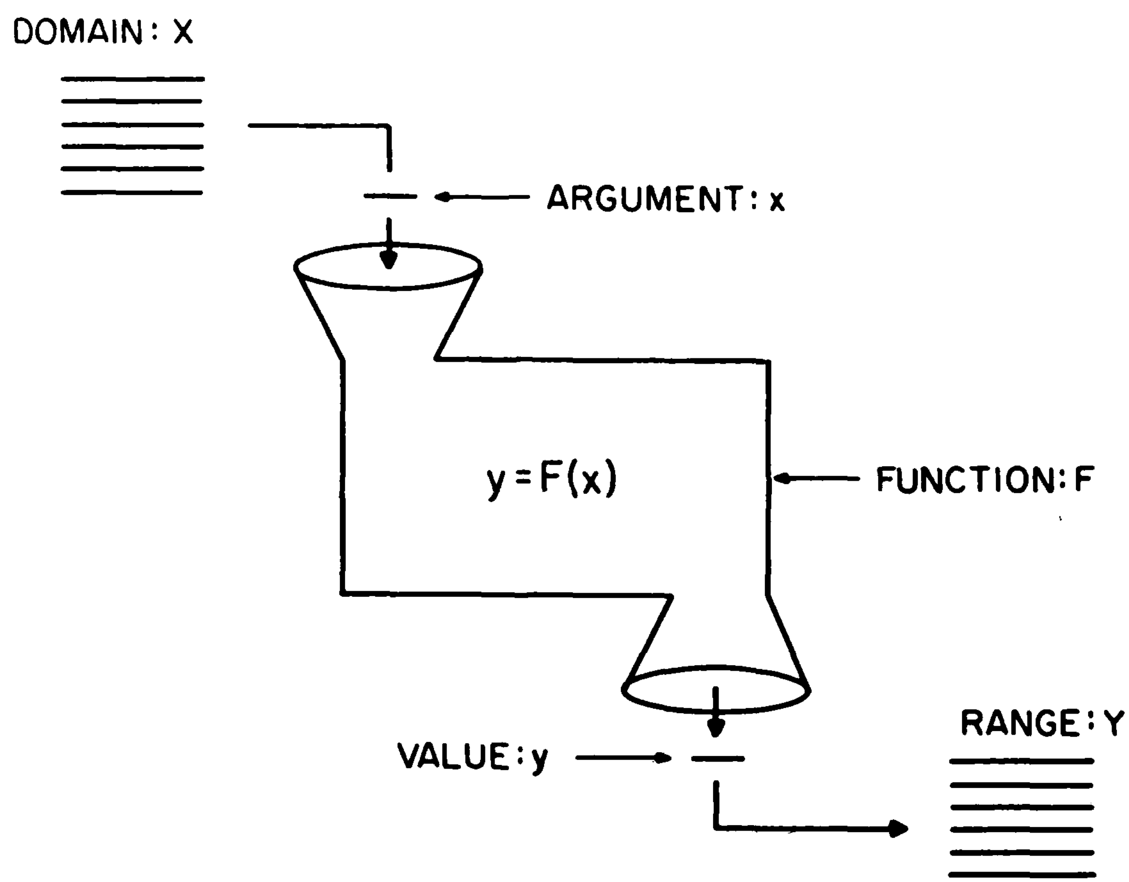

Figure 17. Illustration of the function concept as a "machine" that converts arguments with domain X (inputs) into values with range Y (outputs).

Usually a different set of functions pertains to different systems. For the communications link, three major functions have been defined by Federal Standard 1033 (GSA, 1985). First a path must be setup between the communicators. This connecting process is known as the access function. Then the information must be exchanged across this path--the transfer function. Finally the connection is broken so other connections can be made. This is the disengagement or release function. Examples for this and other specific systems are given in Table 2.

The selection of functions that characterize the system again depends on the [illegible] and performance description objectives. Thus, there is no need to be exhaustive--only the most pertinent functions are required. The important criterion to remember in selecting functions is that the input/output events be [illegible] observable at the appropriate interfaces. Two general classes of [illegible] considered. The first is when a single, unique input is [illegible] with each output--for example, when an emitter is detected and [illegible] frequency. The second class is when more than one input is [illegible] with each output--for example, when a location is determined based [illegible] several bearings.

4. Performance Outcome Definition

[illegible] step in performance parameter development is to specify, for [illegible], a set of distinct possible outcomes that may be observed [illegible] particular performance trial or attempt. Three possible outcomes can [illegible] distinguished:

> Intended Performance. The function is completed within a specified maximum performance time and the result or outcome is within the limits intended.
>
> [illegible] Performance. The function is completed within the [illegible] maximum performance time, but the result or outcome is outside the limits intended.
>
> [illegible] function is not completed within a specified [illegible].

[illegible] can be grouped into a sample space as illustrated [illegible], respectively, with the three general [illegible] most frequently expressed by system users [illegible] speed, accuracy, and dependability. Thus, if a

Table 2. Primary Functions of Specific Systems

	Communication	Navigation/ Timing	Remote Sensing	Electronic Surveillance
Major Function	Access (Path Establishment)	Acquisition and Phase Lock	Detection and Tracking	Signal Detection
	Transfer (Information Exchange)	Cycle Matching and Synchronization	Range and Doppler	Signal Characterization
	Disengagement (Path Release)	Position Fixing and Guidance	Target Identification	Emitter Identification and Location

system performs as intended, the user's concern is with speed. This is indicated by the system's delay in performing the function on an individual trial or the rate at which it can perform the function in a series of repeated trials. If the system performs incorrectly, the user's concern is with accuracy--the closeness of the output to the intended value. This is often expressed in terms of an error probability. Similarly, nonperformance outcomes are associated with a user's concern with dependability. Such outcomes may be described by a probability of function nonperformance within the specified maximum time.

As an example, the surveillance system is used again. Emitter location is one desired output. Obviously, if this is to be useful target information, the system's performance is judged on how fast and how accurately the location is given. If the location is incorrect, repeated trials may improve the precision but may increase beyond acceptable limits the time required to locate the emitter. If the emitter is undetectable, a case of nonperformance, then repeating the measurements may not suffice. These outcomes depend on the system and the desired performance description objectives.

Outcomes should be defined in terms that are easily understood (e.g., detection time, false detection probability, nondetection probability).

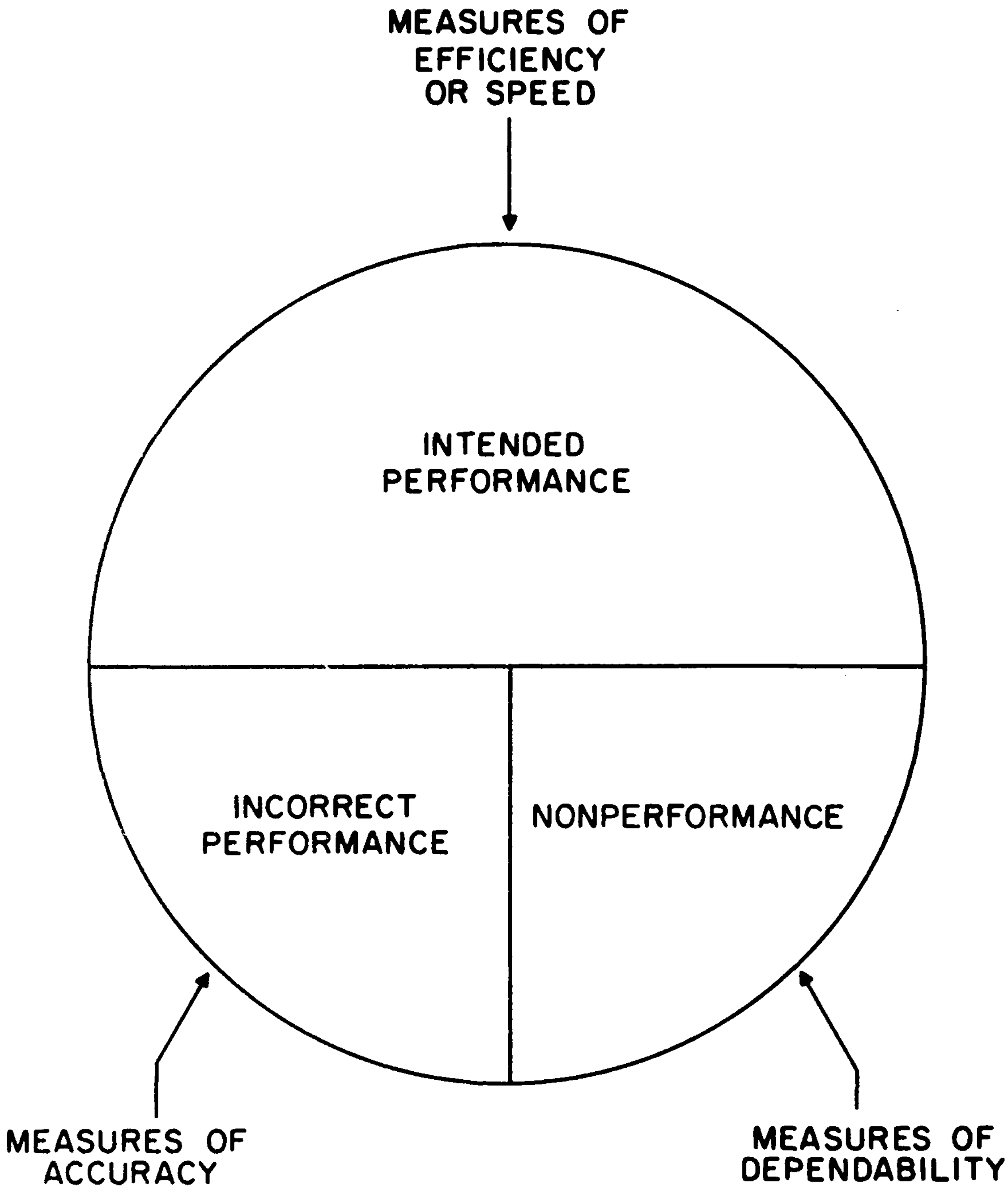

Figure 18. Possible outcomes of a performance measurement trial.

Successful performance is achieved if it meets specified criteria for the maximum time specified to achieve the outcome.

4.4 Parameter Selection

Parameter selection is the fourth step in the logical four-step process for developing performance parameters for any system. Primary parameters, described in Section 4.4.1, are required to characterize performance under expected (normal) operating conditions. Secondary parameters, described in Section 4.4.2, define performance over the long term. We apply this four-step process to the development of functional performance parameters for two specific EWI systems in Section 5. This structured approach applied to the development of performance parameters for digital communication systems is defined in Federal Standard (FS) 1033 (GSA, 1985) and American National Standard (ANS) X3.102 (ANSI, 1983) and explained in some detail in a report by Seitz and Grubb (1983). A summary of the approach applied to digital communication systems is given in Appendix B of this report.

4.4.1 Primary Parameters

The final step in parameter development is to select and define particular parameters to describe the performance of the system relative to each specified function and outcome. The parameters will normally be random variables defined on an outcome sample space (and associated performance time distribution). The parameters selected will, of course, depend on the system, the functions, and the outcomes considered. The set of selected parameters should have the following general attributes:

Completeness. As a set, the selected performance parameters should express all performance attributes of major significance to the study. Parameters should reliably reflect actual performance over the full range of possible values.

Efficiency. The selected parameters should be as few in number and as simply defined as is possible, consistent with the study objectives. The parameters should be nonoverlapping--each should express a different aspect of performance. The parameters should be directly relevant to those who will use them.

Measurability. The performance parameter definitions should be based on signals or events that are directly observable at the system's interfaces. The parameters should be measurable during normal system operation under various test scenarios. The parameter definitions should be mathematically compatible with statistical estimation techniques to enable the precision of parameter estimates to be quantitatively stated.

As an example, consider again the performance of an electronic surveillance system. The first major function of such a system is to detect the presence of a signal in a background of noise and interference. A basic model of the detection function and the associated outcome possibilities are [illegible] in Figure 19. The function input is either a signal, S, or no signal, $\overline{S}$. The output can be either an indication of signal detection, D, or [illegible], $\overline{D}$. Thus, there are four possibilities shown in the matrix in [illegible].

[illegible] possibilities are as follows:

1. [illegible] signal is present and is detected within a specified maximum [illegible] time. The relevant parameter is the detection time, [illegible], in the case where a succession of signal detection trials is [illegible], the detection rate.

2. [illegible] or interference pulse (or an equipment malfunction) is [illegible] for a valid signal when no signal is present. The [illegible] parameter is the false detection[3] probability, $P(D|\overline{S})$.

3. [illegible] is mistaken for a noise or interference pulse, or for [illegible] is not detected within the specified maximum [illegible] time. The relevant parameter is the nondetection[4] [illegible].

4. [illegible] is present, and no signal detection is reported within [illegible] observation period. Since no detection function [illegible], no performance parameter is necessary or appropriate.

The first three outcomes correspond exactly with the intended performance, [illegible], and nonperformance outcome categories defined earlier. [illegible] possibility is null and is correctly excluded in parameter [illegible] the proposed approach. Outcomes 2 and 3 correspond exactly [illegible] Type [illegible] errors defined in statistics.

[illegible] are summarized in the sample space diagram of [illegible]. [illegible] could, of course, be defined; but with the

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[3] [illegible] known as false alarm in radar detection theory.

[4] [illegible] known as miss detection in radar detection theory. The [illegible] more appropriate, since it is easier to interpret.

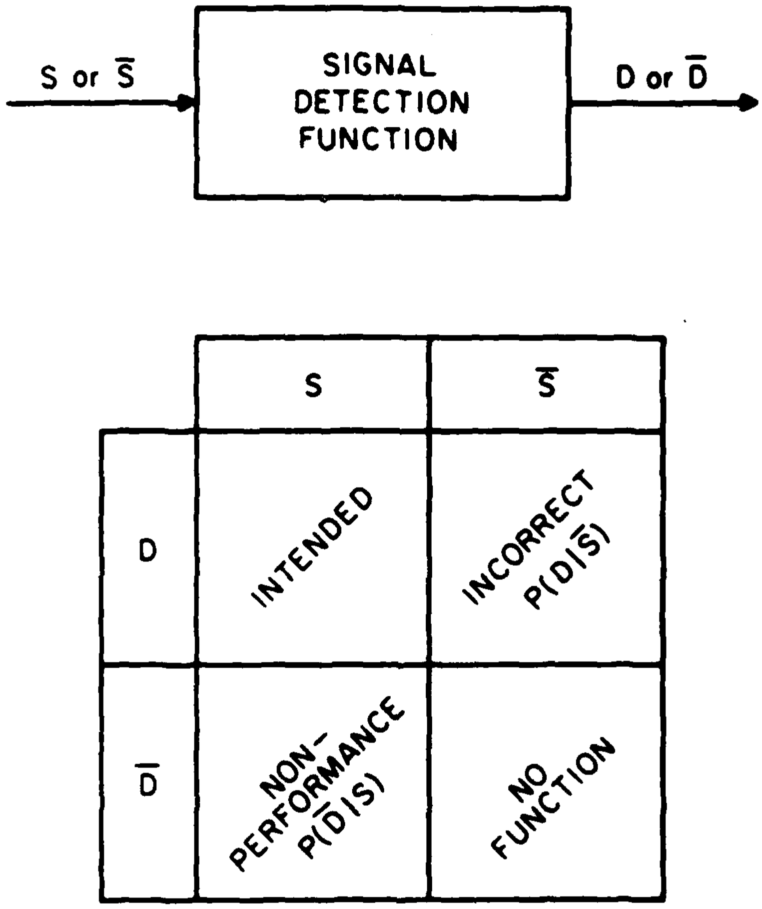


Figure 19. A model of outcome possibilities for the detection function for an electronic surveillance system.

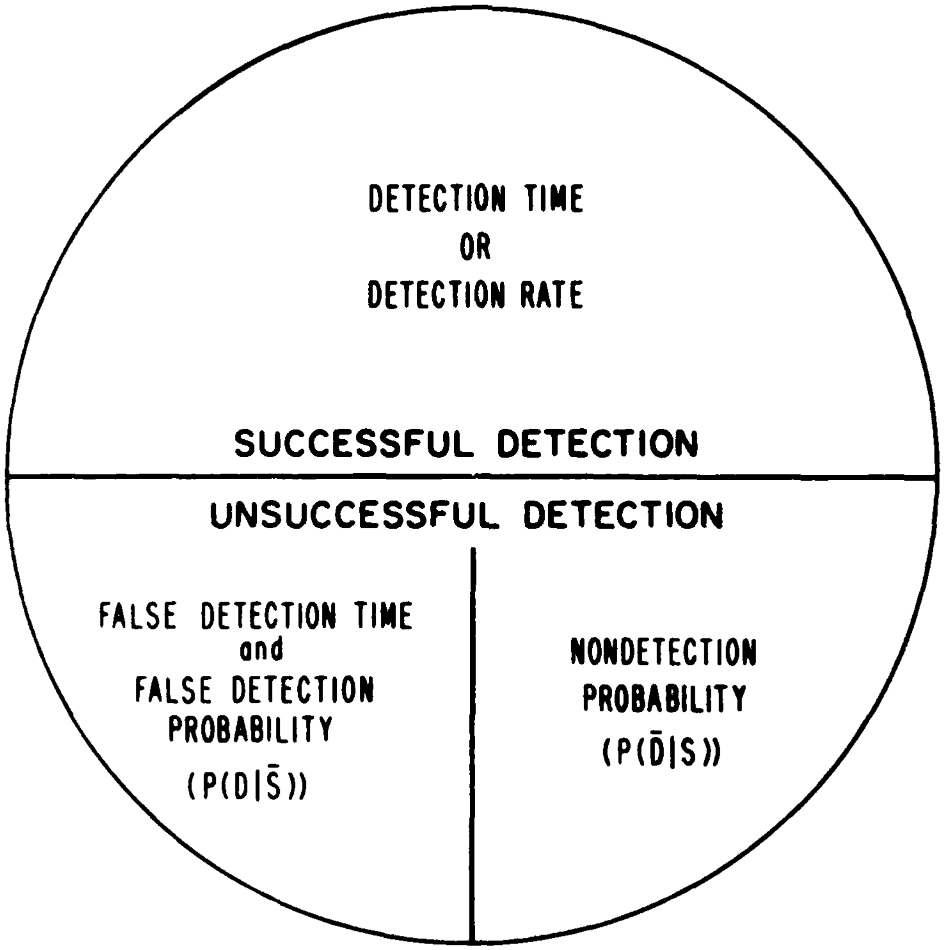


Figure 20. Definitions of parameters for the detection function for an electronic surveillance system.

exception of the need for availability measures, described below, these measures appear to satisfy the completeness, efficiency, and measurability criteria defined earlier. Presentation of the performance parameters in an outcome sample space emphasizes the relationships among them and can clarify the performance implications of system design decisions. For example, nondetection in many systems is a function of a bias setting or detection threshold. In general, nondetection probability can be traded for false detection probability by varying the threshold setting.

4.4.2 Secondary Parameters

Primary parameters of the type defined above can provide a very detailed description of performance during periods of normal system operation, but they do not meet the need for quantitative description of the frequency and duration of outages. A separate, typically smaller, set of "secondary" parameters can be defined to meet that need. The secondary parameters describe system performance from the more general, macroscopic point of view traditionally associated with the concept of availability.

Figure 21 illustrates the method for developing the secondary parameters. Outages are defined by comparing values for selected primary parameters with specified outage thresholds during successive performance periods. A defined availability function (e.g., inclusive or) maps threshold violations into outages. Key availability definition issues are the selected primary parameters, the outage thresholds, the performance period(s), and the availability function. The proposed approach reflects the view that an outage is an unacceptable degradation in system performance that may or may not involve a total service cutoff or equipment "crash."

Figure 22 illustrates a simple two-state availability model and the associated parameters. Under the (common) exponential assumption, transitions between the available and unavailable states are represented by the failure rate λ and restoral rate μ--or equivalently, by their reciprocals, the Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR). The availability (A) and unavailability (U) may be calculated directly from these quantities as shown in the figure. The parameters λ, μ, MTBF, MTTR, A, and U are all candidate availability parameters. Specifying any two nonreciprocal parameters defines the rest. All six parameters may be calculated from a single related parameter, the outage probability, in the special case where (1) the

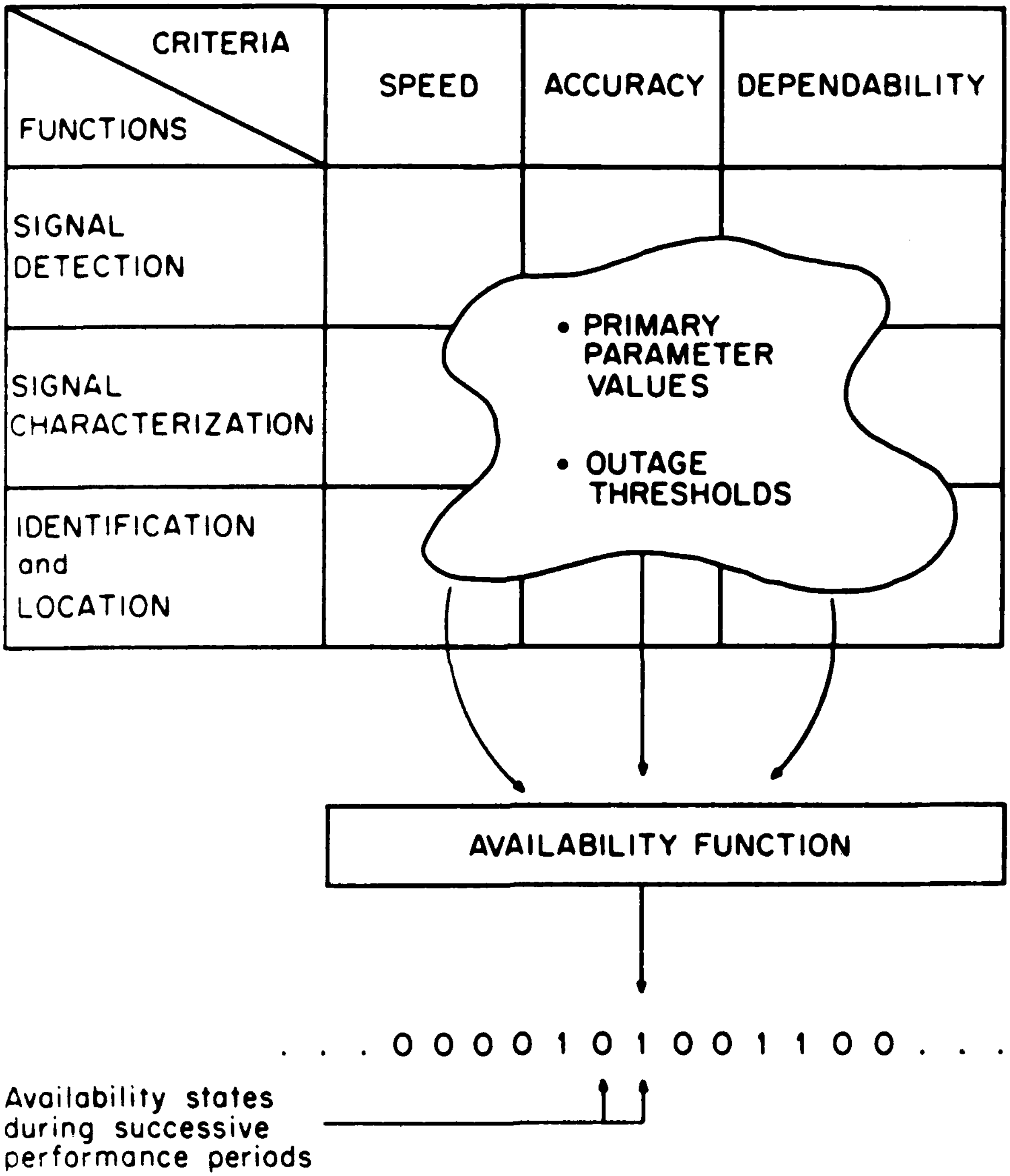
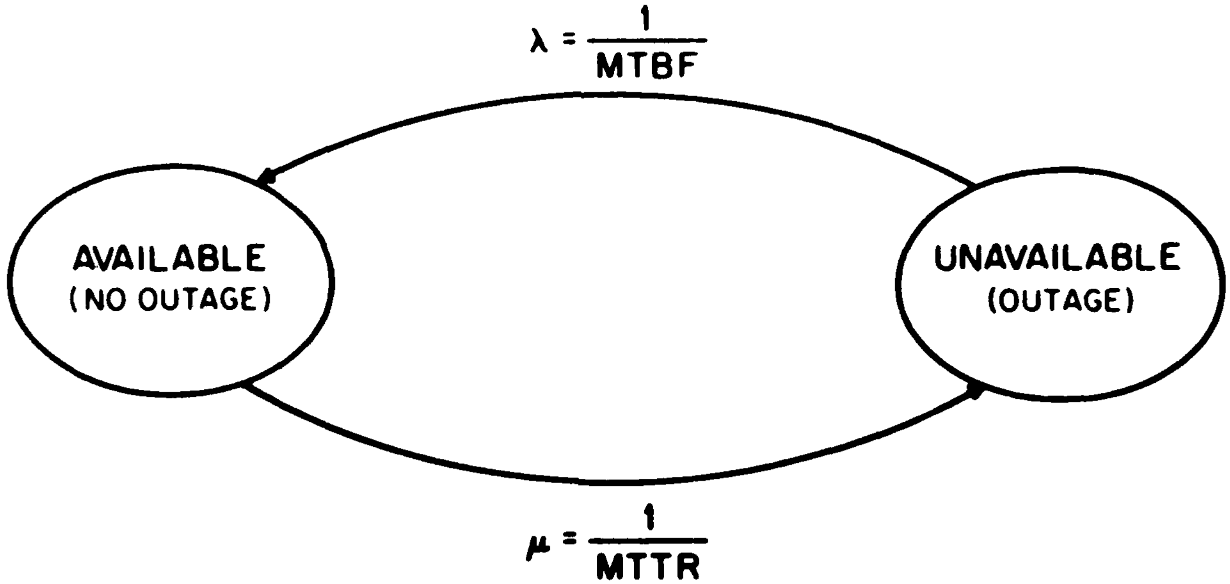


Figure 21. Determination of availability states.



$$\text{AVAILABILITY} = \frac{MTBF}{MTBF + MTTR} = \frac{\mu}{\mu + \lambda}$$

$$\text{UNAVAILABILITY} = \frac{MTTR}{MTBF + MTTR} = \frac{\lambda}{\mu + \lambda}$$

Figure 22. Definitions for availability and unavailability.

performance periods are of equal duration, and (2) successive outages are independent. Additional parameters may be defined to describe the dependence or "clustering" of outages if the exponential assumption is inappropriate.

As an example, assume that the surveillance system exhibits a high false detection probability that exceeds the user acceptability threshold due to an improper bias setting or some component failure. This acceptability threshold is somewhat arbitrary, but when exceeded, it means, to the user, that the system is unavailable for use; i.e., the system is in an outage state until adjustments or repairs are made. Of course the detection function failure is only one of several functions that impact outage in a surveillance type system. For example, loss of bearing measurement could preclude locating the emitters and identifying them--the ultimate system objective. The same processes are used to identify and define secondary parameters--namely interface definitions, function definition, performance outcome, and parameter selection. The availability function may be defined as the probability that the system will be in an operating state at time, t, during the total mission time, T. A reliability function is sometimes used that is the probability that a system will [illegible] acceptable thresholds throughout the total mission time (over the time interval zero to T). The user is particularly interested in the availability when the system is to be used and may not be particularly interested in [illegible] of times the system has failed and been repaired before. Both [illegible] and reliability depend on thresholds chosen for some or all of the [illegible] parameters and are not necessarily the result of total system failures.

5. PERFORMANCE DESCRIPTIONS FOR TYPICAL EWI SYSTEMS

Section 4 developed a structured approach to the problem of selecting sets of parameters to describe the performance of the various systems that may be tested using the CLF. This section applies that structured approach to two typical EWI systems. First, a description of each system is given in Section 5.1. Then, in Section 5.2, the structured methods described in [illegible] 4.1 through 4.4 are applied to (1) define system interfaces or [illegible], (2) define functions that describe performance that is of interest, [illegible] be "observed" at the system interfaces, (3) specify for each [illegible] of possible outcomes, and (4) select and define parameters to describe the system performance of interest relative to each defined function and outcome.

5.1 System Descriptions

Two electronic surveillance systems have been selected for this methodology development study. Functionally, these systems are quite similar (though not identical), but there is a great deal of difference in the complexity of these two systems. The simpler system is a ground-based system that identifies unfriendly emitters and determines the directions of arrival (true bearings) for signals from those emitters. The complex system consists of several airborne subsystems, connected by wideband data links with a ground data analysis subsystem, that perform the same functions of unfriendly emitter identifications and determinations of lines of bearing to these emitters. It also performs the additional function of using the LOB data to calculate the geographical locations of these unfriendly emitters. A description of the simpler system known as the AN/MSQ-103 Special-Purpose Receiver Set (or TEAMPACK Assembly) is given in Section 5.1.1. A description of the more complex system, known as the Advanced QUICK LOOK System, is given in Section 5.1.2. These descriptions may not represent the latest system configurations, or details may be omitted so that the system descriptions may remain unclassified. However, the descriptions are adequate for this development of test methodology for the SLF.

5.1.1 The AN/MSQ-103 Special-Purpose Receiver Set (TEAMPACK ESM)

As defined by the Bunker Ramo Corporation (1979) for the U.S. Army Signals Warfare Laboratory, the AN/MSQ-103 Assembly (TEAMPACK) is a ground-based (vehicle-mounted), electronic warfare support measures (ESM) intercept and direction of arrival (DOA) system for identifying and locating threat Non-COMM systems. The system includes a permanently mounted (on the vehicle), erectable antenna mast with heads that contain two omnidirectional antennas, three receiver heads (covering six contiguous bands) that each include two DF (direction finding) antennas, a masthead switch (for band selection and tuning), a three-way combiner, and a shaft encoder. Three frequency synthesizers, a frequency control unit, a pulse train separator (PTS), a video display unit (VDU), an indicator-processor unit (IPU), a teleprinter, and an [illegible] AN/UYK-12 computer are rack-mounted in the vehicle. Separate voice communication equipment that includes an AN/VRC-46 radio set and a TSEC/KY-38 encryption unit, along with the necessary power supplies for all of the electronic equipment noted above, also are mounted in the vehicle. (An rf test set and an azimuth gyro survey instrument are included as part of the assembly.

Interception is performed using the omnidirectional receivers. The information obtained includes:

-- initial intercept alarm

-- operating frequency

-- pulse width (PW)

-- pulse-repetition frequency (PRF).

Direction of arrival (or true bearing) measurements are accomplished using a two-channel, direction-finding receiving system that includes a two-antenna interferometer receiver that provides accurate but ambiguous bearing information, and coarse, amplitude-difference, direction-finding, two-channel receivers to resolve the ambiguity from the interferometer receiver data. A functional block diagram of the system is shown in Figure 23.

User-oriented system functions for the AN/MSQ-103 Special-Purpose Receiver include:

-- signal detection and the determination of--

-- operating frequency

-- pulse width

-- pulse-repetition frequency

-- true bearing (or direction of arrival).

Engineering-oriented functions that entail testing and validating signal data before they are used to provide information to the user include:

-- checking for adequate power level

-- determining that signals are within the proper field of view

-- determining that signals are within the selected frequency channel

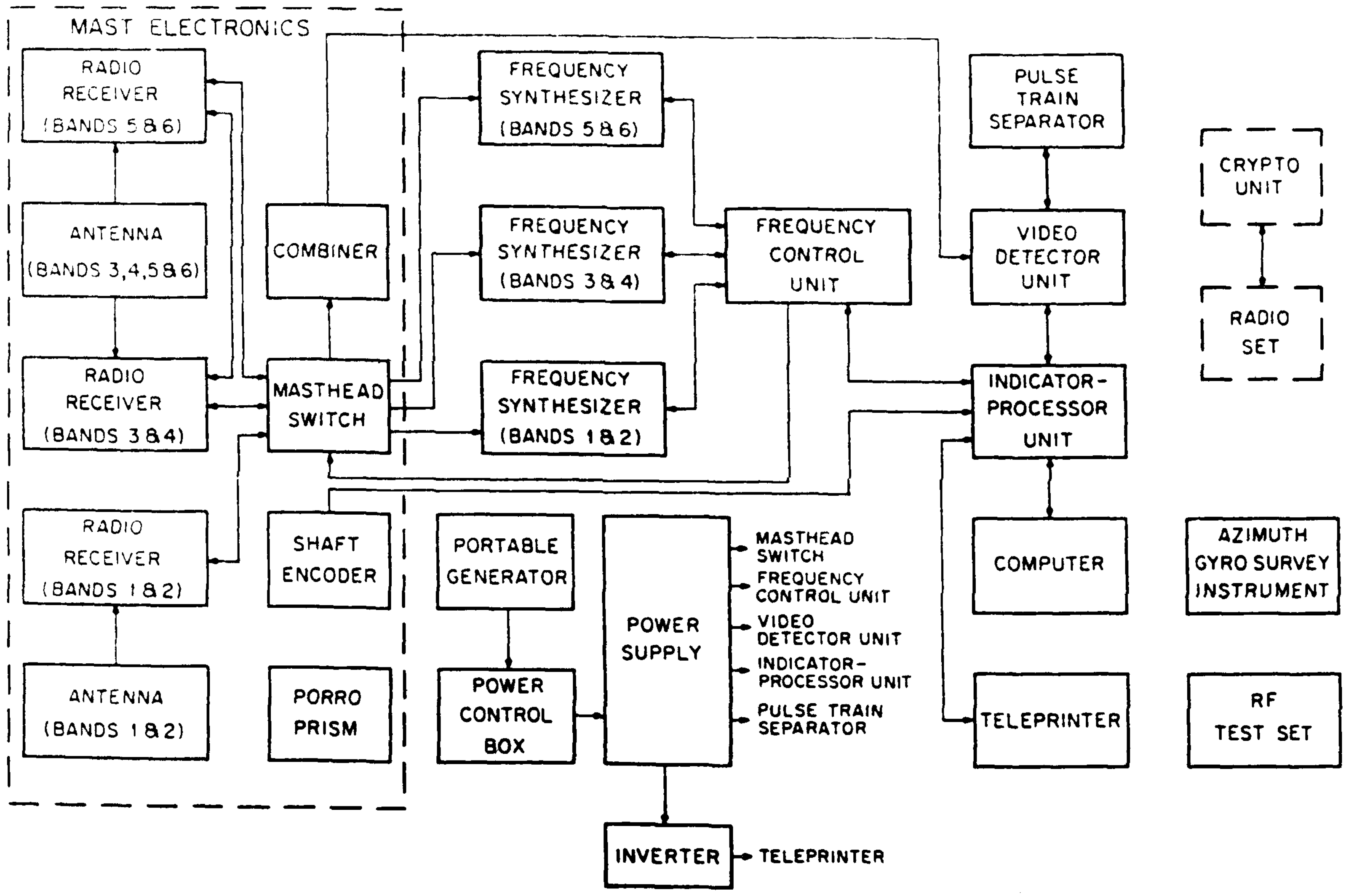


Figure 23. Functional block diagram of the AN/MSQ-103 Receiver Set, Special Purpose (TEAMPACK Assembly) (Bunker Ramo Corporation, 1979).

-- the capability to sort six different, validated signals that simultaneously occur within the IF pass band and perform the user-oriented functions for each.

These engineering-oriented functions, of course, are essential to the user-oriented functions noted above.

System characteristics that relate to functional performance and that will have to be measured using the capabilities of the IWS include the following:

-- discrete and scanning frequency selection capabilities

-- individual receiver and receiver set sensitivities

-- antenna calibrations that establish field of view (when combined with receiver thresholds and signal processing capabilities of the system)

-- dynamic range

-- image rejection

-- effective bandwidth of the receiving set.

[illegible] The Advanced QUICK LOOK System

The Development Specification (ERADCOM, 1982) defines an Advanced QUICK LOOK System to be a number (three maximum) of airborne, noncommunications (Non-Comm), electronics intelligence (ELINT) systems that are connected to a ground data analysis subsystem via special electronic mission aircraft (SEMA) wideband data links. The system is supported by maintenance subsystems, for each airborne subsystem and the (ground-based) data analysis subsystem, and mission [illegible] equipment.

Each airborne subsystem includes two Receiver Groups (to achieve 360° azimuth coverage), a Quantizer and Controller Group, (interface to and airborne components of a SEMA Wideband Data Link, a Navigation Unit, Mission Test Equipment, and a Maintenance Subsystem as shown in Figure 24. Each Receiver Group consists of two sets of radio frequency processor units with a low-band, a mid-band, and a high-band processor unit, each with an appropriate antenna array, in each set. Each Receiver Group also includes a direction-finding (DF) intermediate frequency (IF) processor unit, a frequency synthesizer/local oscillator unit, and a receiver power supply. The Quantizer and Controller Group consists of an interface unit between each Receiver Group and the other

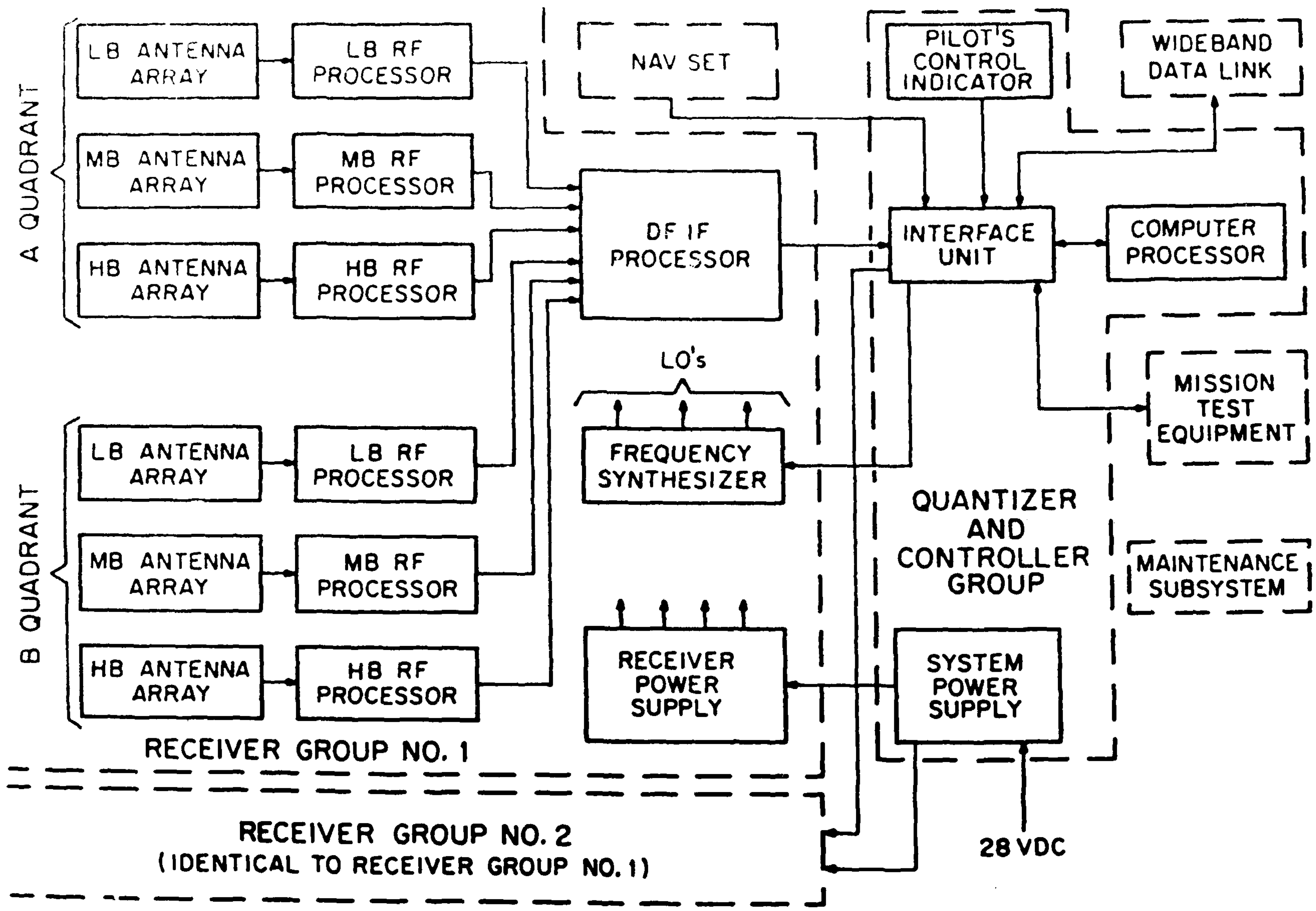


Figure 24. Block diagram of the Advanced QUICK LOOK airborne subsystem (ERADCOM, 1982).

components of the airborne subsystem, the computer processor, a pilot's control unit, and the system power supply.

The airborne subsystem is capable of both automatic and directed search modes of operation. In the automatic mode, the subsystem tunes through the frequency bands according to a preprogrammed search routine that is determined prior to a mission, but that may be dynamically reprogrammed by the ELINT supervisor via the SEMA wideband data link. In the directed search mode, the subsystem accepts tuning commands from the ELINT supervisor via the wideband data link to perform measurements at specified frequencies.

The airborne subsystem detection and hardware capabilities, employing phase interferometer direction-finding techniques along with software processing capabilities, provide detection and identification of the following types of emitters' signals:

-- continuous wave (CW)

-- stable pulse repetition frequency (PRF)[5]

-- jitter (±2 microseconds maximum)

-- stagger to 16 levels

-- nonperiodic random PRF

-- frequency hopper

-- swept frequency

-- FM chirp

-- phase coded

-- sub-pulse frequency step.

The principle signal-sorting parameters are angle of arrival, frequency, time of arrival, and pulse interval. Processed emitter data are sent via the wideband data link to the data analysis subsystem. These data include emitter frequency, pulse repetition interval (PRI), pulse width, emitter location (latitude and longitude, time of intercept, and direction of arrival for each

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[5] PRF and PRI are used interchangeably in the Development Specification (PAVCOM, 1982) without careful attention to the difference between these data.

signal, and platform self-location data (attitude and location, using an appropriate, but undefined, three-dimensional coordinate system).

The data analysis subsystem includes all processing capability necessary to perform all correlations of data received from up to three airborne subsystems necessary to determine locations of emitters. Appropriate operating mode requirements for the airborne subsystem are programed by the ELINT supervisor into the data analysis subsystem in response to requests from users in the field for (unfriendly) emitter location information. Intercept data, provided via the wideband data link, are processed. Following processing of these data, appropriate messages are prepared by an ELINT operator/analyst, approved by the ELINT supervisor, and forwarded to users as required. A block diagram of the data analysis subsystem is shown in Figure 25.

The data analysis subsystem provides control to and receives data from up to three airborne subsystems. The data analysis process includes correlations of intercepted data with stored information for known emitter types and locations, the calculations required to identify the type(s) and location(s) of new emitters intercepted during the mission, and processing and storage of uncorrelated line-of-bearing data.

Components of the data analysis subsystem include (three) wideband data link interfaces, a computer system (32-bit computer) with console, three information display and control units, a video hard copy unit, two disk storage units, a cartridge tape recorder unit, a reel-to-reel tape recorder unit (9-track), and a line printer. The information display and control units provide interactive keyboards with alphanumeric and graphic displays for access to the computer and accommodation of data transfer between ELINT positions. These units also provide digital display of (emitter operating) frequency, PRF (or PRI), PW, stagger levels, jitter ranges, latitude and longitude (of the intercepted emitter), military grid, semimajor elliptical error of probability (EEP), EEP confidence factor, number of intercepts, time of intercept, and assigned priorities.

Data that are preprogrammed into the system and that are measured, calculated, and/or stored by the airborne and data analysis subsystems are organized into three categories: the electronic-order-of-battle (EOB) category, the new emitter category, and the uncorrelated line-of-bearing (LOB) category. Table 3 shows the system data and the source and disposition of data according to these categories.

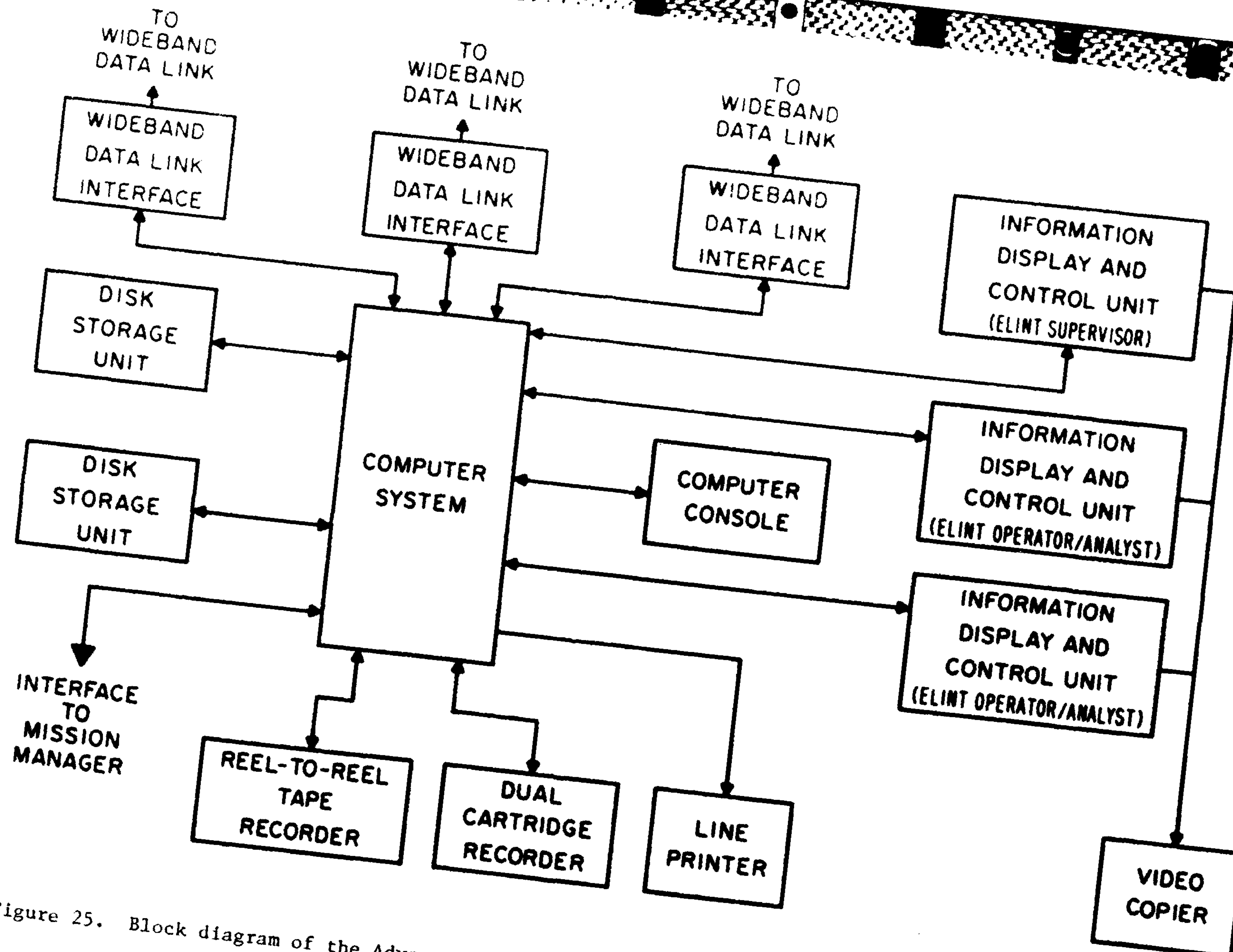


Figure 25. Block diagram of the Advanced QUICK LOOK data analysis subsystem (ground-based) (ERADCOM, 1982).

Table 3. Data That Are Preprogrammed (P) into or Measured (M), Calculated (C), and/or Stored (S) by the Advanced QUICK LOOK System

DATA	EOB Category	New Emitter Category	LOB Category
1. Emitter Identification (Name)	P	---	---
2. Frequency	P,M	M,S	M,S
3. PRF (or PRI)	P,C	C,S	C,S
4. PW	P,M	M,S	M,S
5. Emitter Location Latitude	P,C	C,S	---
6. Emitter Location Longitude	P,C	C,S	---
7. Time of Intercept (Last Confirmation)	M,(S)	M,S	M,S
8. Total Number of Intercepts	M,S	M,S	---
9. Platform (A/C) Self-Location Data* -Platform (A/C) Attitude (Heading) -Platform (A/C) Location (Using Appropriate Three-Dimensional Coordinate System)	C	C	C,S
10. Direction of Arrival (DOA)	C	C	C,S
11. Semi-Major Axis of EEP	---	C,S	---
12. Semi-Minor Axis of EEP	---	C,S	---
13. Orientation of Semi-Major Axis of EEP	---	C,S	---

*Provided by the CAROUSEL IV-E Inertial Navigation Set (INS)

Information on the signal parameters and locations of target emitters that have been established prior to a mission comprise the EOB category of data. Each known emitter is described with the following information: emitter identification (name), frequency, PRF/PRI, PW, location latitude, location longitude, time of last intercept confirmation, and total number of intercepts.

Information on the signal parameters and locations of target emitters that have been intercepted during a mission and that are not in the EOB category comprise the new emitter category of data. Data to describe the newly intercepted emitters include measured frequency, calculated location latitude, calculated location longitude, time of intercept, total number of intercepts constituting the fix, the semimajor axis of EEP, the semiminor axis of EEP, and orientation of the semimajor axis of EEP.

Finally, information on the signal parameters and lines of bearing to the intercepted target emitters that cannot be correlated with the EOB category emitters or the new emitter category intercept records comprise the uncorrelated line-of-bearing category of data. These uncorrelated line-of-bearing data include the following: measured frequency, measured PW, calculated PRF/PRI, time of intercept, aircraft location (using an appropriate, but undefined, three-dimensional coordinate system) at the time of intercept, and direction of arrival of the intercepted signal.

Even though the Advanced QUICK LOOK System is an airborne electronic surveillance system (with a ground-based data analysis subsystem and a connecting [illegible] wideband data link) that is much more complex than the ground-based TEAMPACK Assembly, very similar user-oriented system functions are performed by the Advanced QUICK LOOK System. These user-oriented functions are:

(1) Signal detection and the determination of--

(2) Operating frequency

(3) Pulse width

(4) Pulse-repetition frequency (or PRI)

(5) True bearing, with respect to the system reference location, or direction of arrival, with respect to another known location (for example, an aircraft's location)

(6) Emitter location.

Functions (1) through (5) above are common to both systems, though at least some of the technologies for performing these functions are different. For example, the TEAMPACK Assembly determines signal DOA by applying two-channel interferometer and separate two-channel received signal amplitude difference (to overcome direction ambiguity) technology, whereas the Advanced QUICK LOOK System uses phase interferometer direction finding technology. Function (6) is unique to the Advanced QUICK LOOK System, which has the additional capability to perform triangulation using multiple measurements of true bearing to determine emitter locations.

There will be a number of engineering-oriented functions, as yet undefined, for testing and validating measured signal data before they are accepted as confirming EOB data, new emitter data, or valid LOB data. An example would be the function of checking some number of sets of LOB data to determine if the EEP is within an acceptable limit that then would support the conclusion that a new emitter had been identified. Similar functions of testing measured frequency, measured pulse width, etc., to determine that measured values are within specified tolerance limits, also will be required of the system.

Many other (engineering-oriented) system characteristics that influence functional performance will be important to an initial determination that the system operates properly and can be expected to provide satisfactory, user-perceived performance. These characteristics, that will have to be measured using the capabilities of the IWS, include the following:

-- frequency range (for each receiver and the system)

-- acquisition (detection) noise bandwidth

-- frequency resolution

-- frequency accuracy

-- signal detection bandwidth

-- direction finding bandwidth

-- sensitivity (low, mid, and high bands)

-- DF accuracy (excluding navigation errors)

-- dynamic range

-- spurious rejection

-- image rejection

-- pulse width characteristics
  - range
  - resolution
  - accuracy
  - measurement amplitude

-- pulse repetition interval characteristics
  - range
  - resolution
  - accuracy

-- signal digitizing time

-- antenna characteristics
  - azimuth coverage (per quadrant and total)
  - polarization

-- system clock accuracy

-- EMI requirements (frequency, range, intensity, modulation).

5.2 Definitions of MOFPs

The structured approach to describing system performance from a user's [illegible], as developed in Section 4, now is applied in the definition of [illegible] parameters for the TEAMPACK Assembly and the Advanced QUICK LOOK [illegible]. This approach includes the definition (from a user-oriented perspec-[illegible] of input and output interfaces, system functions, performance outcomes, [illegible] selection and definition of parameters that describe system performance [illegible] observed at the system interfaces, relative to each function and [illegible].

[illegible] interfaces for the TEAMPACK Assembly are provided by the video [illegible] unit, the pulse train separator, the indicator-processor unit, and the [illegible]. Various data that constitute system control are provided by the [illegible] system through the data entry keypad and other controls of the IPU. [illegible] characterization of system operating status and visual read-out (LED [illegible] characterizations (frequency, PRF, PW, true bearing, and emitter [illegible] corresponds to stored characteristics of unfriendly emitters) for [illegible] emitters is provided to the user by the IPU. Primary power control [illegible] system is provided by the user through the VDU. An audio monitor of a [illegible] CW) signal being present is provided to the user by both the VDU and [illegible]. Uncalibrated emitter characteristics (frequency and DOA data for the [illegible] being processed) are provided by the PTS to the user using an LED [illegible]. [illegible] sort window being used by the PTS also is shown using an LED [illegible]. Mode control (SORT or DISPLAY measured data) is provided to the PTS [illegible] user. Up to 64 sets of the interception and true bearing data may be [illegible] in the computer memory. These same data, either as individual sets or [illegible] contents of the computer's mission memory, are provided in hard [illegible] user through the teleprinter.

[illegible] receiving antennas denote the interface between the system [illegible] emissions (source/system interface). For purposes of SLF [illegible], convenient access to the "source/system interface" may be realized by working at the interface between the control system for SLF transmitters and the overall testing control program (or application program) as shown previously in Figure 16. A simplified, functional block diagram of the TEAMPACK Assembly, denoting these system interfaces and the information that is provided to the system or to the user, is shown in Figure 26. Information shown (at the interfaces) in parentheses denotes information provided by the user to the system; the remaining information is provided by the system to the user, as described earlier.

Interfaces for the Advanced QUICK LOOK System are denoted in the simplified block diagrams of the system shown in Figures 27 and 28. Figure 27 is a simplified block diagram analogous in detail to Figure 26 for the TEAMPACK Assembly. Figure 28 incorporates further simplification, but also illustrates that the system could be tested as several separate subsystems, namely each of the airborne subsystems (A-1 through A-N), associated data link subsystems (DL-1 through DL-N), and the data analysis subsystem (DA). This methodology study assumes testing of the entire system, realizing that only one or two airborne subsystems may be used to form "the system."

User/system interfaces are provided at the pilot's control indicator unit and the (ground) information display and control units. Inputs to the system at the pilot's control indicator unit include power ON/OFF control, quadrant [illegible] for the intercept receivers, and initialization (zeroize) of system [illegible]. Outputs from the system via the pilot's control indicator unit are [illegible] and fault indications.

Inputs to the system through the information display and control units [illegible] reprogramming and all operational support and control for the airborne subsystems. Operating instructions include the definition of scan [illegible], system bandwidths, dwell times, revisit times, target priorities, and [illegible] data categories. Outputs from the system via the information display and control unit may be requested using various sort criteria such as frequency, PRF/PRI characteristics, size of the EEP major axis, and [illegible]. The data that are displayed, depending on the sort [illegible] frequency, PW, PRF/PRI, stagger levels, jitter ranges, [illegible] confidence factor, emitter location (latitude and longitude), [illegible], number of intercepts, time of each intercept, and assigned [illegible]. Data that may be displayed are stored both in the airborne [illegible], with capability for 2000 EOB records and 2000 new emitter records,

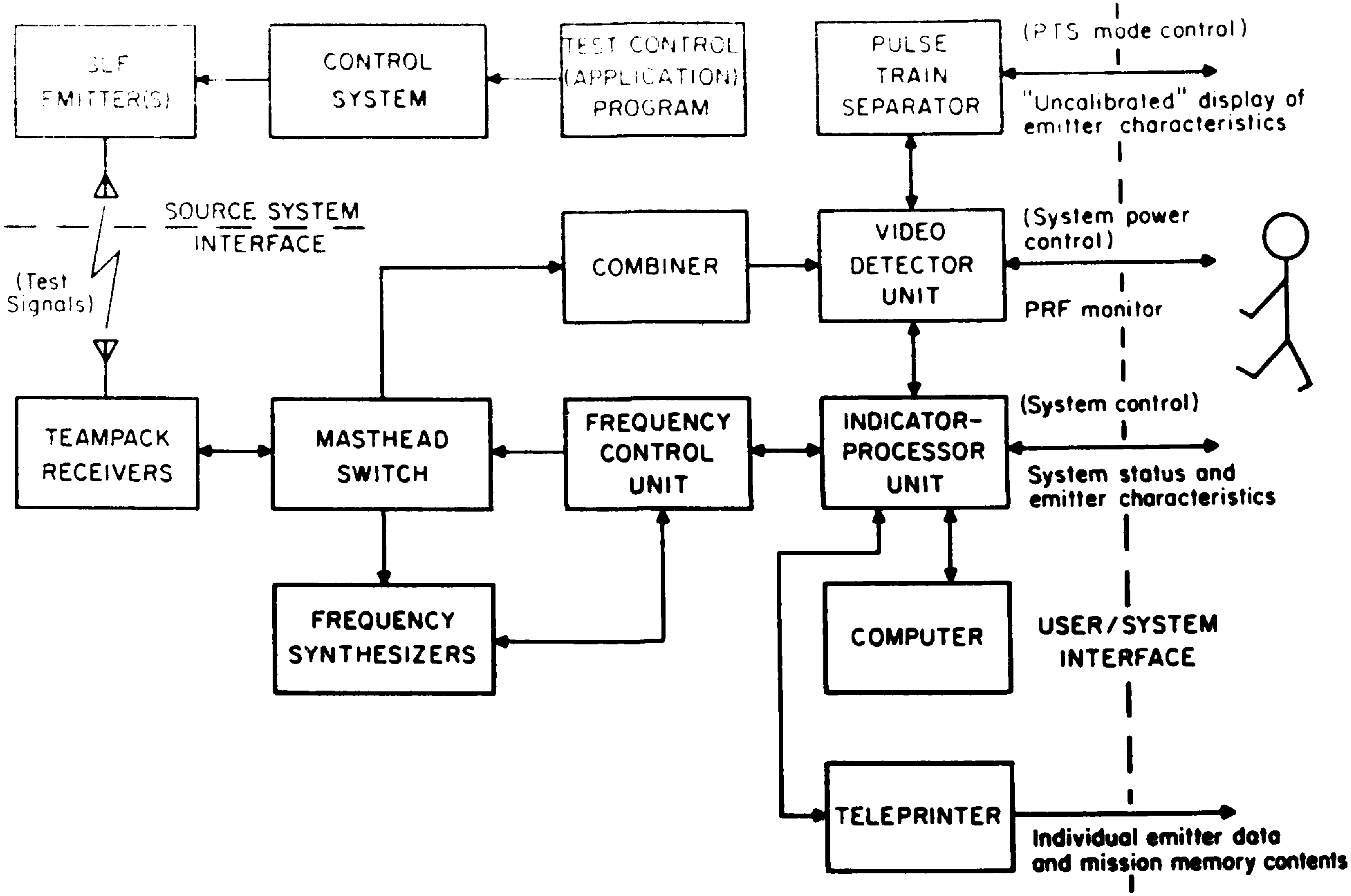


Figure 26. Simplified functional block diagram of the AN/MSQ-103 Receiver Set, Special Purpose (TEAMPACK Assembly) showing source/system and user/system interfaces and the (input)/output data.

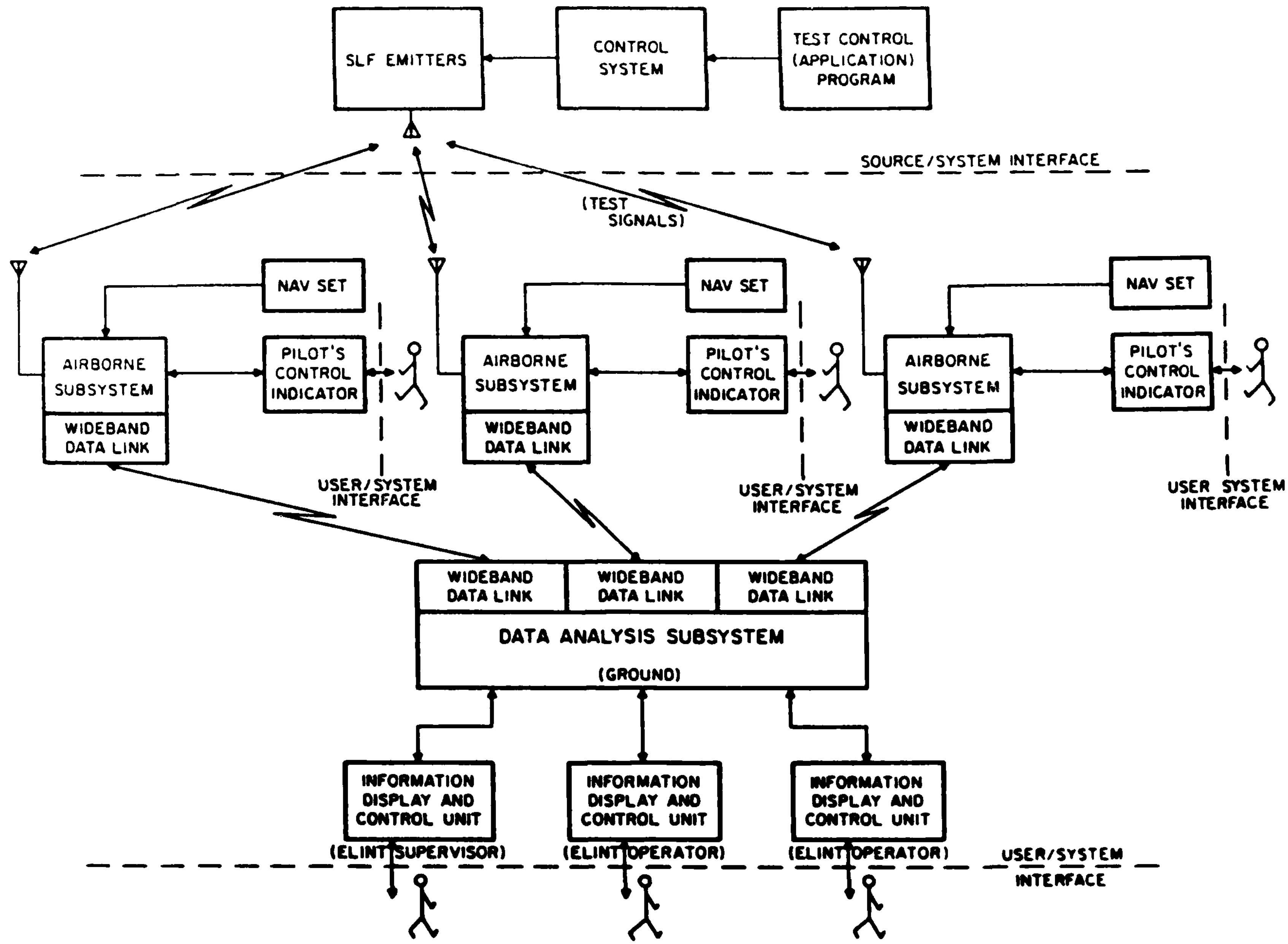


Figure 27. Simplified functional block diagram of the Advanced QUICK LOOK system showing source/system and user/system interfaces.

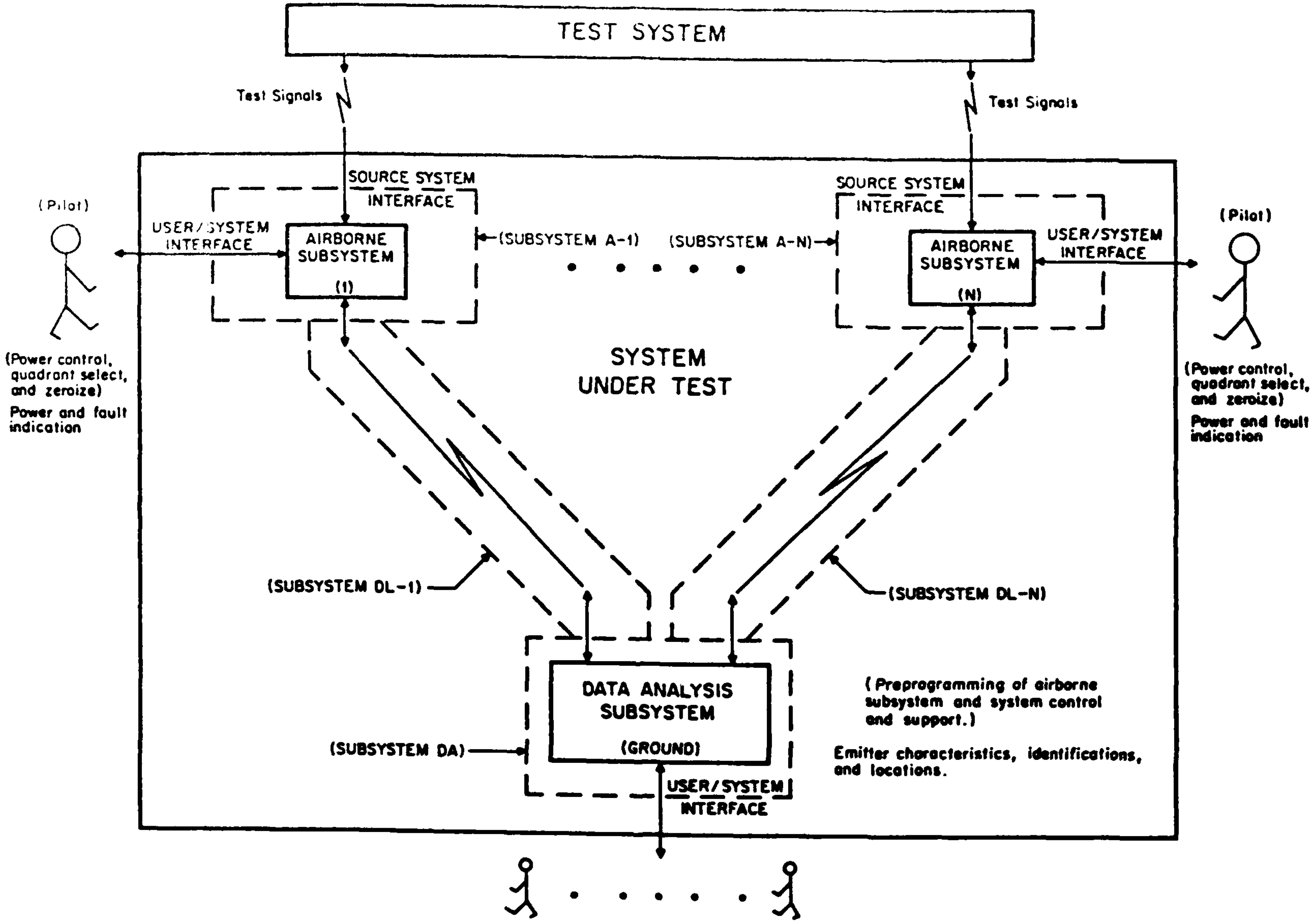


Figure 28. Further simplification to the functional block diagram of the Advanced QUICK LOOK System showing source/system and user/system interfaces and the (input)/output data.

and the data analysis subsystem, with capability for at least 10,000 EOB records and 10,000 combined new emitter and uncorrelated LOB records.

As with the TEAMPACK Assembly, the receiving antennas of the airborne subsystem denote the interface between the system and sources of rf emissions (source/system interface). As explained earlier, however, more convenient access to the "source/system interface" may be realized by working at the interface between the control system for the SLF transmitters and the SLF testing control program (or application program, shown in Figure 16). Information shown (at the interfaces), in Figure 28, in parentheses denotes information provided by the user to the system; the remaining information is provided by the system to the user, as described earlier.

Continuing to follow the structured approach to describing system performance and the development of measures of functional performance, user-oriented functions of the TEAMPACK Assembly and the Advanced QUICK LOOK System now are identified. The generic functions identified in Table 2 for electronic surveillance systems are applicable. These functions are:

-- signal detection

-- signal characterization

-- emitter identification and location

noting that only the Advanced QUICK LOOK System is able to determine emitter locations. (The TEAMPACK Assembly determines emitter identifications and by comparing these characteristics with stored data that include known locations of unfriendly emitters, the locations of intercepted emitters may be inferred.)

Consistent with the structured approach to describing system performance and as already noted, there are specific inputs and resultant outputs for each function. A generic set of outcomes is discussed in Section 4 and illustrated in Figure 13. The possible outcomes normally distinguished are:

> Intended Performance. The function is completed within a specified maximum performance time and the result or outcome is within the limits intended.
>
> Incorrect Performance. The function is completed within the specified maximum performance time, but the result or outcome in outside the limits intended.
>
> Nonperformance. The function is not completed within a specified maximum performance time.

For each generic outcome, specific parameters are defined that describe performance of the TEAMPACK Assembly and Advanced QUICK LOOK System relative to each defined function and outcome.

Consider, first, the signal detection function. Desired or intended performance occurs when a signal is present and is detected within a specified [illegible] time. Evidence, to a user (or test controller) of signal [illegible] may be an initial intercept alarm such as that provided by the [illegible] Assembly. Measured operating frequency also is provided as an [illegible] of the video detector unit of the TEAMPACK Assembly and [illegible] the indicator-processor unit. (Measured operating [illegible] must be within acceptable limits of the actual [illegible] for that emitter.) The relevant parameter is detection time [illegible], for a succession of detection trials) which, then, is a [illegible] detection efficiency (or speed).

[illegible] performance occurs when rf noise or interference is mistaken for [illegible] when, in fact, no test signal is present. The parameter that [illegible] incorrect performance is false detection probability, P(False [illegible]). This parameter can also be thought of as the probability of [illegible] the condition that no signal is present expressed as $P(D|\overline{S})$. [illegible], a useful measure of signal detection accuracy, is calculated [illegible] results as the ratio of the number of incorrect (false) [illegible] the total number of detection attempts.

[illegible] will be indicated when, because of noise, interference, or [illegible], a signal is not detected within a specified maximum detection [illegible]. A parameter that characterizes nonperformance and that can be calculated [illegible] data is the nondetection probability, P(NonDetection). In [illegible] sense, this parameter is the probability of nondetection given [illegible] that a signal is present, expressed as $P(\overline{D}|S)$. This parameter, a [illegible] of system detection dependability, is calculated from the test [illegible] the ratio of the number of nondetections to the total number of [illegible].

[illegible] system performance parameters for the signal [illegible] are illustrated in the sample space diagram shown in [illegible].

[illegible] testing conditions, the source/system inputs for signal [illegible] test signals and a "search command" to the SUT. The

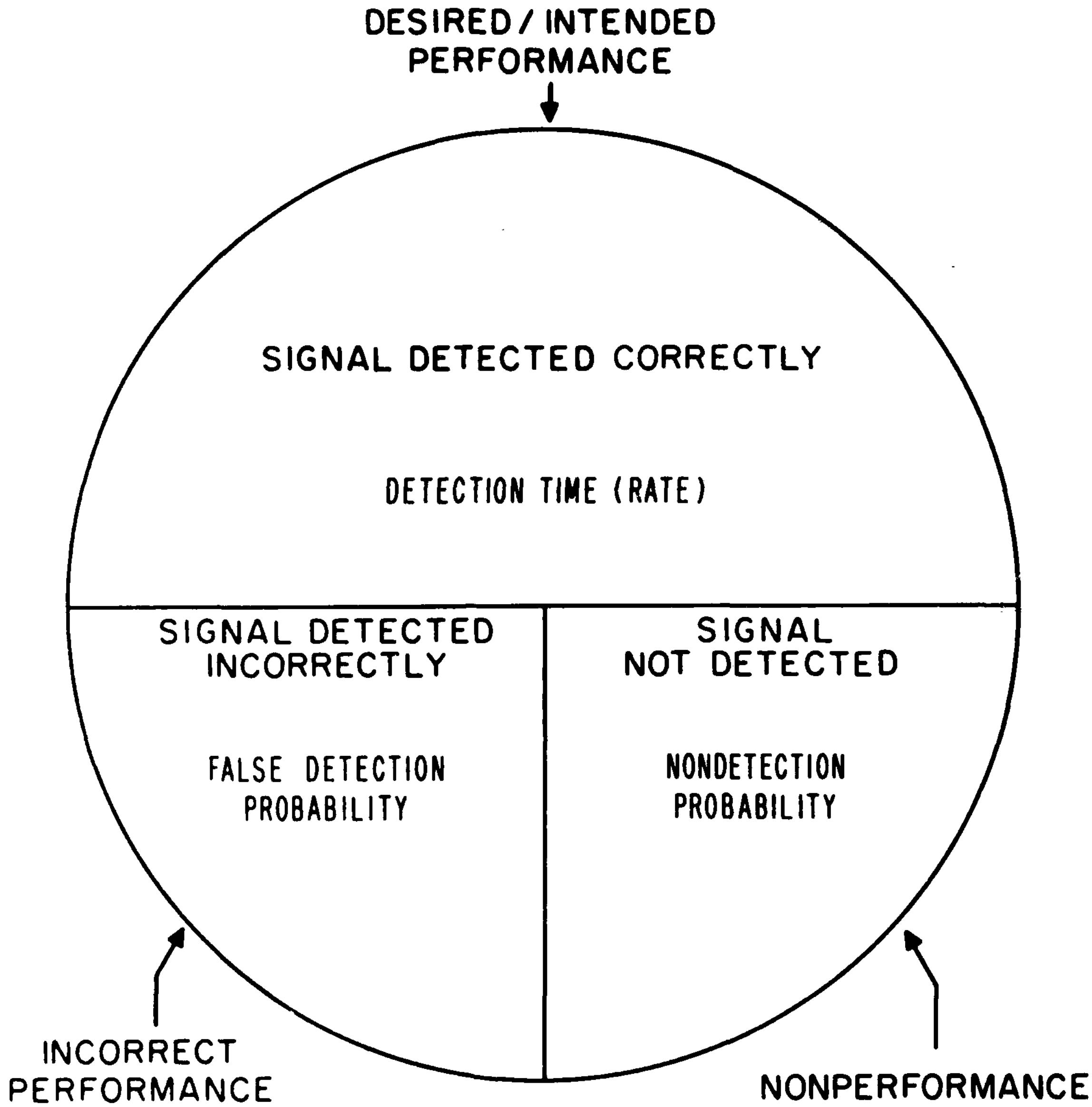


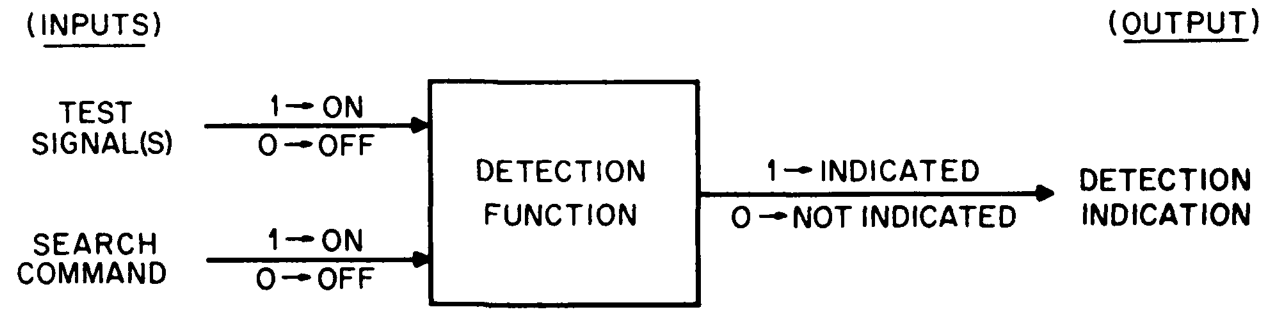
Figure [illegible]. Definitions of functional outcomes and system performance parameters for the TEAMPACK Assembly and Advanced QUICK LOOK System for the detection function.

user/system output for that function, as discussed above, is some detection indication for the intercepted emitter, for example, the initial intercept alarm or an indication of measured operating frequency as provided by the TEAMPACK Assembly. Operating frequency also is provided as an output via the information display and control unit for the Advanced QUICK LOOK System.

An illustration of the signal detection function with inputs and output and a truth table that relates input states with function outcomes is shown in Figure 30. Vector representations of the input states use "1" for the ON condition and "0" for the OFF condition. Similarly, in the output, "1" represents DETECTION INDICATED and "0" represents DETECTION NOT INDICATED. Input state (1,1), then, represents a trial condition in which the test signal is ON and a search command has been given to the SUT. An associated output condition (1) represents intended performance and condition (0) represents nonperformance. Some time limit, specified by the user (or test controller) or built into the system, is allowed for the detection function to be completed. When this time elapses without a detection indication, nonperformance is the outcome. Input state (1,0) is meaningless, since it represents a condition in which the test signal is ON but no search command is given--hence, there is no trial. Input state (0,1) represents a condition in which the test signal is OFF when a search command is given. An associated *output condition* (0) represents intended performance and condition (1) represents incorrect performance.

As discussed above, the parameter that quantifies intended performance for each trial is detection time, the elapsed time between issuing the search command and receiving a detection indication. Mean or average detection time would characterize a test. A succession of trials could be quantified by the parameter detection rate. Incorrect performance is characterized by the parameter false detection probability, P(False Detection), which is calculated from test results as the ratio of the number of false detections to the total number of detection attempts. Nonperformance is characterized by the parameter nondetection probability, P(NonDetection), which is calculated from test results as the ratio of the number of nondetections to the total number of detection attempts. (Of course, the complement of the sum of these probabilities is the probability of detection.)

Desired or intended performance for the signal characterization function is realized when, for a detected signal, signal characteristics (carrier



INPUT/OUTPUT TRUTH TABLE FOR DETECTION FUNCTION

FUNCTION OUTCOMES / INPUT STATE VECTORS	INTENDED (EFFICIENCY)	INCORRECT (ACCURACY)	NONPERFORMANCE (DEPENDABILITY)
(1, 1)	(1)	—	(0)
(1, 0)	MEANINGLESS		
(0, 1)	(0)	(1)	—

Figure 30. Illustration of the signal detection function and associated input/output truth table.

frequency and determination that the signal is either CW or pulsed and, if pulsed, the PW and PRF/PRI) are determined within a specified maximum time and the measured values are within acceptable limits for each signal characteristic. The relevant parameter is characterization time which, then, is a useful measure of signal characterization efficiency (or speed). Intended performance can also occur, logically, when the SUT is given a command to characterize a signal but does not because there is no test signal input.

Incorrect signal characterization performance occurs when, for any reason, such as of noise, interference, multipath, etc., the measured characteristics of the detected signal are not within acceptable limits for the test signal or measured characteristics are indicated though, in fact, there is no test signal input. The parameter that characterizes this incorrect system performance is the probability of incorrect signal characterization, P(Incorrect Characterization). As a useful measure of signal characterization accuracy, this parameter is calculated from the test results as the ratio of number of incorrect signal characterizations to the total number of signal characterization opportunities (trials for which a signal has been detected and the SUT has been "instructed" to perform the signal characterization function.

Nonperformance for the signal characterization function occurs when, for any reason, signal characteristics of a detected signal are not measured within a specified maximum performance time. The parameter that characterizes nonperformance for this function is the probability of signal noncharacterization, P(NonCharacterization). This parameter is calculated from the test results as the ratio of the number of nonperformance trials, for this function, to the total number of performance opportunities (trials for which a signal has been detected). The parameter is a useful measure of dependability for the signal characterization function.

Function outcomes and system performance parameters for the signal characterization function are illustrated in the sample space diagram shown in Figure 31.

Though the signal characterization function is a little more complex than the detection function, the source/system inputs still are known test signals and a "characterization command" to the SUT. The user/system outputs for the function, as discussed above, are the signal characteristics of carrier frequency and determination that the signal is either CW or pulsed and, if pulsed, the PW and PRF/PRI. For the TEAMPACK Assembly, these data are provided

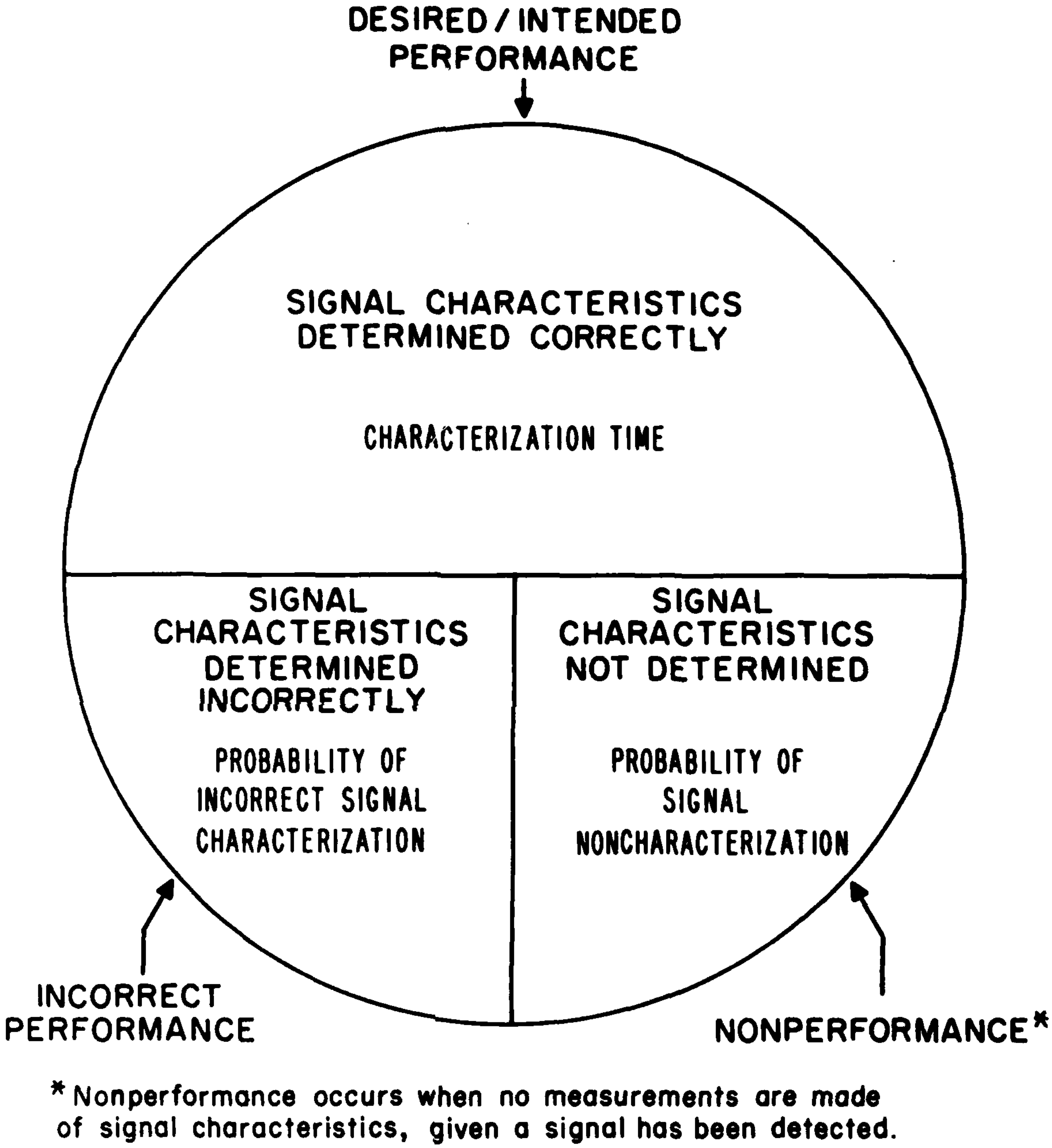
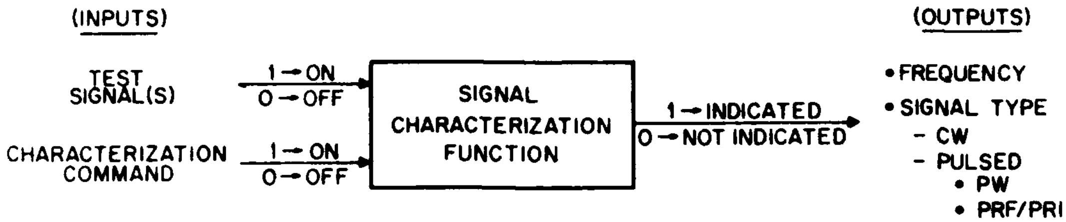


Figure 31. Definitions of function outcomes and system performance parameters for the TEAMPACK Assembly and Advanced QUICK LOOK System for the signal characterization function.

as "uncalibrated" visual outputs by the pulse train separator and as calibrated outputs by the indicator-processor unit. The IPU provides visual read-out of the data or the data may be directed to the teleprinter for hard copy. The video detector unit also provides audio output as a monitor of the PRF. Intercepted signal characteristics are provided by the Advanced QUICK LOOK System as output to the user via the data analysis subsystem's information display and control unit. Information, then, may be directed to the video [illegible] or the line printer for hard copy. (Information may also be directed to [illegible], reel-to-reel, or disk storage devices.)

An illustration of the signal characterization function with inputs and outputs shown and a truth table that relates input states with output states is shown in Figure 32. The same vector representations of the input states are [illegible] used for the detection function. In the output, "1" indicates the [illegible] characteristic to be provided and "0" indicates the signal character- [illegible] missing. Using the vector order as (FREQ,CW,PW,PRF/PRI), the [illegible] means characteristics for a pulsed signal have been measured, [illegible] vector (1,1,0,0) means characteristics of a CW signal have been [illegible]. Obviously, many of the logically possible output state vectors have [illegible], such as the vector (0,0,1,1) which would indicate that PW [illegible] were measured but there was no measurement of frequency.

[illegible] above, the parameter that quantifies intended performance, [illegible] signal characterization function, for each trial, is <u>characterization</u> <u>time</u>, the elapsed time between issuing the characterization command and receiving indication of signal characterization. Mean or average characterization would characterize a test. Referring to the information shown in Figure 32 of possible input and output information, intended performance occurs when the output information denoted by vectors (1,0,1,1) (for a pulsed signal) or (1,1,0,0) (for a CW signal) is correct for the input state denoted by vector (1,1), or the input state (0,1) results in an output denoted by [illegible]. Incorrect performance is characterized by the parameter <u>probability of incorrect signal characterization</u>, P(Incorrect Characterization), which is calculated from test results as the ratio of the number of incorrect signal characterizations to the total number of signal characterization opportunities. Referring to the information shown in Figure 32, incorrect signal characterization occurs when the output information denoted by vectors [illegible] or (1,1,0,0) is incorrect given the input conditions denoted by



POSSIBLE VECTORS OF INPUT INFORMATION

(TS, CC)	(Event Order)
(1, 1)	(O.K.)
(1, 0)	(No Trial)
(0, 1)	(O.K.)
(0, 0)	(Nothing)

POSSIBLE VECTORS OF OUTPUT INFORMATION

(Freq, CW, PW, PRF/PRI)	(Event Order)
(0,0,0,0)	(Correct or nonperformance)
(0,0,0,1)	
(0,0,1,0)	
(0,0,1,1)	
(0,1,0,0)	(Nonsense)
(0,1,0,1)	
(0,1,1,0)	
(0,1,1,1)	
(1,0,0,0)	(Incorrect or nonperformance)
(1,0,0,1)	(Nonsense)
(1,0,1,0)	(Incorrect or nonperformance)
(1,0,1,1)	(Correct or incorrect-CW)
(1,1,0,0)	(Correct or incorrect-pulsed)
(1,1,0,1)	
(1,1,1,0)	(Nonsense)
(1,1,1,1)	

INPUT/OUTPUT TRUTH TABLE FOR SIGNAL CHARACTERIZATION FUNCTION

FUNCTION OUTCOMES / INPUT STATE VECTORS	INTENDED (EFFICIENCY)	INCORRECT (ACCURACY)	NONPERFORMANCE (DEPENDABILITY)
(1, 1)	(1,0,1,1)(pulsed) (1,1,0,0)(CW)	(1,0,1,1) (1,1,0,0)	(0,0,0,0), (1,0,0,0) (1,0,1,0)
(0, 1)	(0,0,0,0)	(1,0,0,0) (1,0,1,0) (1,0,1,1) (1,1,0,0)	

Figure 32. Illustration of the signal characterization function and associated input/output truth table.

either of the input vectors (1,1) or (0,1). In addition, the output vectors (1,0,0,0) and (1,0,1,0) denote incorrect performance for the (0,1) input vector state. Nonperformance is characterized by the parameter <u>probability of signal noncharacterization</u>, P(Noncharacterization), which is calculated from test results as the ratio of the number of signal noncharacterizations to the total number of signal characterization opportunities. Again, referring to Figure 32, signal noncharacterization occurs when output information is denoted by the vectors (0,0,0,0), (1,0,0,0), or (1,0,1,0) given the input condition denoted by the vector (1,1).

The emitter identification and location function is still more complex. Desired or intended performance for this function is possible only when desired performance has occurred for the detection and signal characterization functions. Desired or intended performance for this function, then, requires the successful measurement or calculation of at least one true bearing for an intercepted emitter.

For the TEAMPACK Assembly, the function is completed when the system compares measured frequency, signal characteristics, and line of bearing data with stored data for known systems. Intended performance occurs when the bearing measurement/calculation and data comparison are completed within a specified maximum time and the measured/calculated line of bearing is within acceptable limits for the true bearing.

For the Advanced QUICK LOOK System, the process can extend to the successful measurement and calculation of several true bearings to calculate emitter location as the intersection of these lines of bearing, within the limits of acceptable EEP. As has been noted earlier, however, "successful" performance may produce data in three different categories, namely

-- frequency, signal characteristics, and location for <u>known emitters</u>

-- frequency, signal characteristics, and location for <u>new emitters</u>

-- frequency, signal characteristics, and true bearing for <u>known or new emitters</u>.

Intended performance is realized when the "expected outcome" (identification and location of a known emitter, identification and location of a new emitter, or identification and true bearing for either a known or new emitter) is completed within a specified maximum performance time and the measured/

calculated true bearing or location values are within acceptable tolerance limits.

The time required to measure/calculate one or more true bearings and/or the time required for the system to compare the measured data with stored data (this time would include the time to measure/calculate a true bearings), that is, the emitter identification and location (EIL) time is a parameter that can be measured/calculated as a useful measure of the efficiency (or speed) of the system in performing the EIL function.

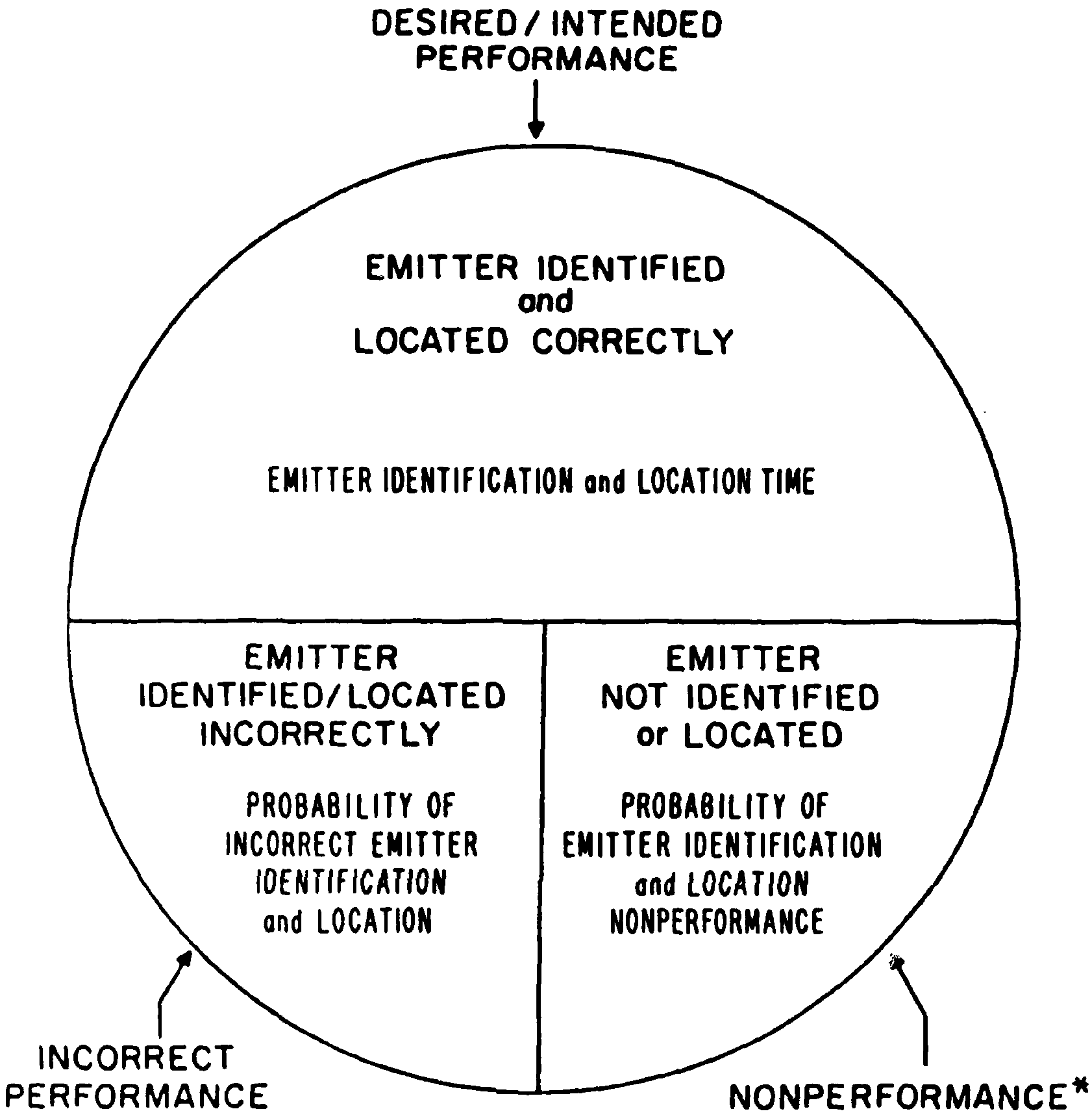
Incorrect emitter identification and location performance occurs when, for any reason such as rf noise, interference, multipath, etc., the individual measurement/calculation of true bearing for an intercepted emitter is not within acceptable tolerance limits for the true bearing of the emitter, though the detection and signal characterization functions have seemed to be performed successfully. In situations where several true bearing measurements are used to establish location as the intersection of these lines of bearing, incorrect performance occurs when the calculated EEP exceeds some maximum limit (specified by the user or test controller) or the measured lines of bearing do not even intersect. The parameter that characterizes this incorrect performance is the probability of incorrect EIL or P(Incorrect EIL). As a useful measure of emitter identification and location accuracy, this parameter is calculated from the test results as the ratio of the number of incorrect measurements/calculations of EIL to the total number of measurement opportunities during the test (trials for which the signal has been detected and characterized and the SUT has been "instructed" to perform the emitter identification and location function).

Nonperformance for the emitter identification and location function occurs when, for any reason, emitter "identification and location" are not determined within a specified maximum time when seemingly successful detection and signal characterization have occurred. Depending on the SUT, this function may be relatively simple or relatively complex. For example, the function may entail only the measurement of a line of bearing for a detected and characterized signal and the comparison of these measured data with stored data for known systems such as is done by the TEAMPACK Assembly. Or the function may require the measurement of at least two lines of bearing, the calculation of emitter location using triangulation techniques, and the comparison of the measured data with stored data for known systems to determine if the measured data represent a known or new emitter such as is done by the Advanced QUICK LOOK System. The parameter that characterizes nonperformance for the EIL function is the probability of non-EIL or P(Non-EIL). As a useful measure of system dependability in performing the emitter identification and location function, this parameter is calculated from the test results as the ratio of the number of EIL nonperformance trials to the total number of performance opportunities (trials for which the detection and signal characterization functions have been [illegible] successfully and the SUT has been "instructed" to perform the EIL function).

Function outcomes and system performance parameters for the emitter identification and location function are illustrated in the sample space [illegible] shown in Figure [illegible].

The [illegible]/system inputs for the emitter identification and location [illegible] the known test signal, measured signal characteristics for the [illegible] (from the signal characterization function), and an "EIL command" [illegible] the SUT. The user/system outputs for the function, as discussed above, are [illegible] signal characteristics and a line-of-bearing measurement or a [illegible] location and associated EEP, depending on the SUT. From a func-[illegible] viewpoint, the TEAMPACK Assembly actually provides only emitter identification, whereas the Advanced QUICK LOOK System provides both emitter identification and location, using data from the inertial navigation systems on [illegible] aircraft. It, therefore, is useful to discuss these systems separately for [illegible].

The TEAMPACK Assembly compares the measured frequency, signal characteristics, and true bearing with the stored parameters and locations of known [illegible] to establish emitter identification. The user/system outputs for [illegible] function, then, are indicated bearing and an emitter number that identifies [illegible] to which the measured characteristics and bearing compare, within [illegible] limits of tolerance for each parameter of each "identified system" or [illegible] that there is no emitter for which stored characteristics compare [illegible] data. Output to the user of these data is provided as "[illegible]" information on the VDU and as calibrated information on the IPU. All emitter frequency, location, and identification data provided by the IPU [illegible] printed by the teleprinter, either as single sets or as the total information stored in the computer's mission memory.



* Nonperformance occurs when no measurements are made of true bearing, measured signal characteristics do not match stored characteristics of known systems, or emitter location is not determined by triangulation.

Figure 33. Definitions of function outcomes and system performance parameters for the TEAMPACK Assembly and Advanced QUICK LOOK System for the emitter identification and location function.

The Advanced QUICK LOOK System also compares measured frequency and signal characteristics with stored information for known systems to perform emitter identification. In addition, triangulation calculations are performed using individual line-of-bearing measurements to establish line-of-bearing intersections and, thereby, to determine emitter location, within acceptable limits of [illegible] the differences between the measured frequency and signal character- [illegible] stored values and the elliptical error probability resulting from [illegible] intersections of lines of bearing. Data thus measured and calculated are [illegible] data for known systems (the so-called EOB data), (2) data [illegible] emitters at newly-determined locations, or (3) data for uncorrelated [illegible], i.e., measured frequency, signal characteristics, and true [illegible] not correlate with stored information for known emitters nor [illegible] bearing intersect to establish new emitter locations within [illegible] limits of EEP. These data are provided as visual read-out to the [illegible] analysis subsystem) information display and control units, or [illegible] directed to the video copier or line printer for hard copy. As [illegible], the data also may be stored on any of several magnetic storage [illegible] received and analyzed by the ELINT operator/analysts are relayed [illegible] communication systems that are not a part of the Advanced [illegible].

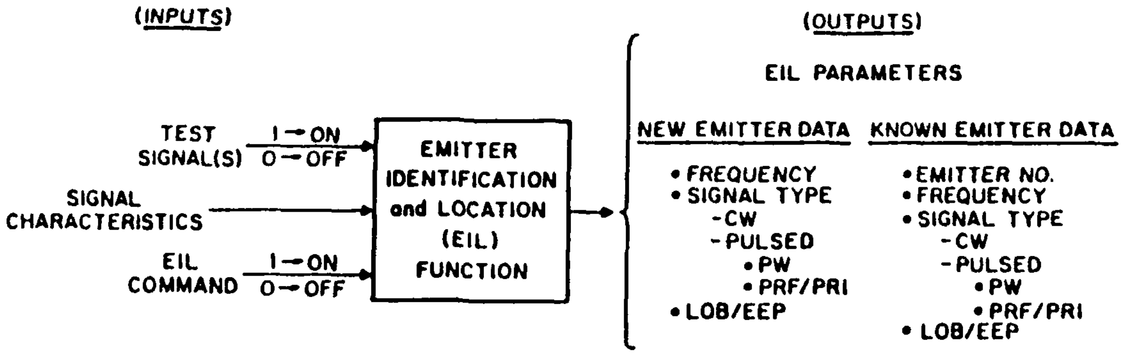
[illegible] of the emitter identification and location function, [illegible] outputs to the function, vector representations of these [illegible], and a truth table for evaluating the function outcomes, is [illegible] Figure 14. The output vectors show (EMTR NO,FREQ,CW,PW,PRF/PRI, [illegible] "1" or "0" to denote information is provided or missing, as [illegible] earlier. There logically are 64 possible output state vectors; [illegible], [illegible] of these states represent meaningful trial results. These [illegible]:

1. [illegible],0) representing nonperformance for the (1,1) input [illegible] correct performance for the (0,1) input state

2. [illegible],0) representing nonperformance for the (1,1) input [illegible] correct performance for the (0,1) input state

3. [illegible],0) representing nonperformance for the (1,1) input state or incorrect performance for the (0,1) input state

4. [illegible] representing, for the (1,1) input state, [illegible] performance in attempting to measure data for a pulsed or



POSSIBLE VECTORS OF INPUT INFORMATION

(TS, EC)	(Event Order)
(1, 1)	(O.K.)
(1, 0)	(No Trial)
(0, 1)	(O.K.)
(0, 0)	(Nothing)

POSSIBLE VECTORS OF OUTPUT INFORMATION

(EMTR NO., FREQ, CW, PW, PRF/PRI, LOB/EEP) (Event Order)
64 vectors logically are possible.
Only seven vectors denote meaningful trial outputs.

(0,0,0,0,0,0)	(Correct or nonperformance)
(0,1,0,0,0,0) (0,1,0,1,1,0)	(Incorrect or nonperformance)
(0,1,0,1,1,1) (0,1,1,0,0,1)	(Correct, Incorrect or nonperformance)
(1,1,0,1,1,1) (1,1,1,0,0,1)	(Correct or Incorrect performance)

INPUT/OUTPUT TRUTH TABLE FOR EVALUATING FUNCTION OUTCOMES

INPUT STATE VECTORS \ FUNCTION OUTCOMES	INTENDED (EFFICIENCY)	INCORRECT (ACCURACY)	NONPERFORMANCE (DEPENDABILITY)
(1, 1) (EIL data found in stored data)	(1,1,0,1,1,1)(pulsed) (1,1,1,0,0,1)(CW)	(1,1,0,1,1,1)(pulsed) (1,1,1,0,0,1)(CW)	(0,0,0,0,0,0) (0,1,0,0,0,0) (0,1,0,1,1,0) (0,1,0,1,1,1) (0,1,1,0,0,1) (1,1,0,1,1,1)(CW) (1,1,1,0,0,1)(pulsed)
(1, 1) (EIL data not found in stored data)	(0,1,0,1,1,1)(pulsed) (0,1,1,0,1,1)(CW)	(0 1 0 1 1 1)(pulsed) (0,1,1,0,0,1)(CW)	(0,0,0,0,0,0) (0,1,0,0,0,0) (0,1,0,1,1,0) (0,1,0,1,1,1)(CW) (0,1,1,0,0,1)(pulsed) (1,1,0,1,1,1) (1,1,1,0,0,1)
(0, 1)	(0,0,0,0,0,0)	(0,1,0,0,0,0) (0,1,0,1,1,0) (0,1,0,1,1,1) (0,1,1,0,0,1) (1,1,0,1,1,1) (1,1,1,0,0,1)	

Figure 34. Illustration of the emitter identification and location (EIL) function and associated output data truth table.

CW emitter that is in the stored data file, (2) correct or incorrect performance in measuring data for a pulsed emitter that is not in the stored data file, or (3) nonperformance in attempting to measure data for a CW emitter that is not in the stored data file and incorrect performance for the (0,1) input state

6. (1,1,1,0,0,1) representing, for the (1,1) input state, (1) nonperformance in attempting to measure data for a pulsed or CW emitter that is in the stored data file, (2) correct or incorrect performance in measuring data for a CW emitter that is not in the stored data file, or (3) nonperformance in attempting to measure data for a pulsed emitter that is not in the stored data file and incorrect performance for the (0,1) input state

7. (1,1,1,1,1,1) representing, for the (1,1) input state, (1) correct or incorrect performance in measuring data for a pulsed emitter that is in the stored data file, (2) nonperformance in attempting to measure data for a CW emitter that is in the stored data file, or (3) nonperformance in attempting to measure data for a pulsed or CW emitter that is not in the stored data file and incorrect performance for the (0,1) input state

8. (1,1,1,1,0,1) representing, for the (1,1) input state, (1) correct or incorrect performance in measuring data for a CW emitter that is in the stored data file, (2) nonperformance in attempting to measure data for a pulsed emitter that is in the stored data file, or (3) nonperformance in attempting to measure data for a pulsed or CW emitter that is not in the stored data file and incorrect performance for the (0,1) input state.

As has been discussed, the parameter that quantifies intended performance for the EIL function, for each trial, is <u>EIL time</u>, the elapsed time between issuing the EIL command and receiving indication of emitter identification and location. Mean or average EIL time would characterize a test. Referring to the output information discussed above, intended performance occurs when the output information denoted by vectors (1,1,0,1,1,1) or (1,1,1,0,0,1) is correct and correlates with stored data or when the output information denoted by vectors (1,1,0,1,1,1) or (1,1,1,0,0,1) is correct. (There are no stored data with which to correlate the measured data.)

Incorrect performance is characterized by the parameter <u>probability of incorrect EIL</u>, P (Incorrect EIL), which is calculated from the test results as the ratio of the number of incorrect emitter identifications and locations to the total number of EIL opportunities. The same output vector states apply as for intended performance. The difference is that the information is incorrect in that the information does not correlate with stored data when it should, or it does correlate with stored data when it should not.

Nonperformance is characterized by the parameter <u>probability</u> <u>of</u> <u>non-EIL</u>, P(Non-EIL), which is calculated from the test results as the ratio of the number of non-EIL trials to the total number of EIL opportunities. The output vector states that always denote nonperformance are (0,1,0,0,0,0) and (0,1,0,1,1,0); vector states (0,0,0,0,0,0), (0,1,0,1,1,1), (0,1,1,0,0,1), (1,1,0,1,1,1), and (1,1,1,0,0,1) sometimes also denote nonperformance, as shown in Figure 24.

Primary parameters associated with the system functions signal detection, signal characterization, and emitter identification and location have been identified and discussed. These parameters describe system performance under normal operating conditions. Each performance trial will produce an outcome for at least one function, as we have discussed. We recognize, however, that successful emitter identification and location is possible only when the signal detection and signal characterization functions have been completed successfully, and successful system performance is realized when this functional process is successfully completed for a specified fraction of the performance trials. That is, "successful" system performance is manifest, from a user's perspective, when the intended outcomes for all functions are realized for some specified fraction of the performance trials (a threshold or minimum number).

Characterization of the long-term system performance through aggregation of performance results over successive performance periods is accomplished through use of the availability function, as illustrated in Figure 21, and associated secondary parameters, defined in Figure 22. Successive performance periods of successful performance constitute an available state; similarly, successive periods of unsuccessful performance constitute an unavailable state. These operational states are related mathematically by system failure rate, λ, and restoral rate, μ (or their reciprocals, MTBF and MTTR, as discussed in Section 4.4.3).

The MOFPs for the TEAMPACK Assembly and the Advanced QUICK LOOK System, using the primary and secondary parameters, are summarized in Table 4.

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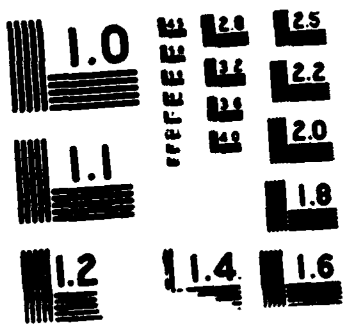
1.0
1.1
1.2
1.4
1.6
1.8
2.0
2.2
2.5

Table 4. Measures of Functional Performance (MOFPs) for the AN/MSQ-103 Receiver Set (TEAMPACK Assembly) and the Advanced QUICK LOOK System

FUNCTION	MOFP
Signal Detection	1. Detection Time (or Rate).
	2. Probability of False Detection.
	3. Probability of Nondetection.
Signal Characterization[6]	4. Characterization Time.
	5. Probability of Incorrect Characterization.[7]
	6. Probability of Noncharacterization.[8]
Emitter Identification and Location (EIL)	7. Emitter Identification and Location (EIL) Time.
	8. Probability of Incorrect EIL.[9]
	9. Probability of Non-EIL.[10]
System Operability States	10. Availability; (A) = $\mu / (\mu + \lambda)$. (Time that the System is in an Available State.)
	11. Unavailability; (U) = $\lambda / (\mu + \lambda)$.

[6] Signal characterization includes frequency (from the detection function) or, if required, determination of frequency, identification of the signal as CW or pulsed, and, if pulsed, determination of PW and PRF/PRI.

[7] Incorrect signal characterization occurs when measured values for signal parameters (frequency, PW, and PRF/PRI) differ from known values by more than acceptable tolerances or measured values are indicated when, in fact, no input test signal with those characteristics was present.

[8] Strictly speaking, incomplete signal characterization occurs when measured values for some signal parameters are missing. This condition is treated logically as noncharacterization.

[9] Incorrect EIL occurs when the measured value for a LOB differs from the known value [illegible] than an acceptable tolerance, measured values for several LOB's [illegible] intersections that yield an EEP that exceeds an acceptable tolerance [illegible], the measured values produce an incorrect identification when compared to an emitter's known characteristics, or a new emitter is identified as a known emitter.

[10] Strictly speaking, incomplete emitter identification and location occurs when values for LOB or EEP are missing. This condition is treated logically as non-EIL.

6. PERFORMANCE MEASUREMENT APPROACH

Communications-electronics (C-E) systems that will be tested using the Stress Loading Facility (SLF) will be very complex and usually will incorporate computer control. The structured approach taken in this study to defining performance parameters for these systems yields parameters that are characterized by events that must be either timed or counted. Both of these processes are done most conveniently by using a computer to record the event outcomes and tabulate or calculate system performance using the measures of functional performance developed in Section 5. In that section, three principal functions--detection, signal characterization, and emitter identification and location--are defined for electronic surveillance systems. Then, 11 parameters--9 defined as primary and 2 defined as secondary--are developed to describe functional performance of the system from the perspective of the user(s). These performance parameters (termed measures of functional performance) are shown in Table 4). The primary parameters describe system performance with respect to three general performance criteria, namely efficiency (or speed), accuracy, and dependability. The secondary parameters describe long-term or aggregate performance in terms of the operational state of the system as either available or unavailable.

The process for testing systems, using these parameters that are system independent, is illustrated in Figure 35. Inputs to the testing process consist of testing objectives, defined by the type of tests being performed, and trial outcomes observed at the user/system interface(s). Results of testing are the estimated (mean) values of timed events and the calculated results of ratios of counted events, i.e., estimated probability of detection (or nondetection), estimated probability of incorrect measurement of signal characteristics, etc. The testing process is accomplished in four phases which we have defined as test design, data collection, data reduction, and data analysis.

Test design, discussed in Section 6.1, applies general test objectives in the development of a detailed test plan that defines the test conditions and the specific system performance information that is to be collected. Data collection, discussed in Section 6.2, describes the test signals that are introduced at the source/system interface(s) and the corresponding trial outputs (events) that are monitored at the user/system interface(s). Data reduction, discussed in Section 6.3, is the merging and processing of the

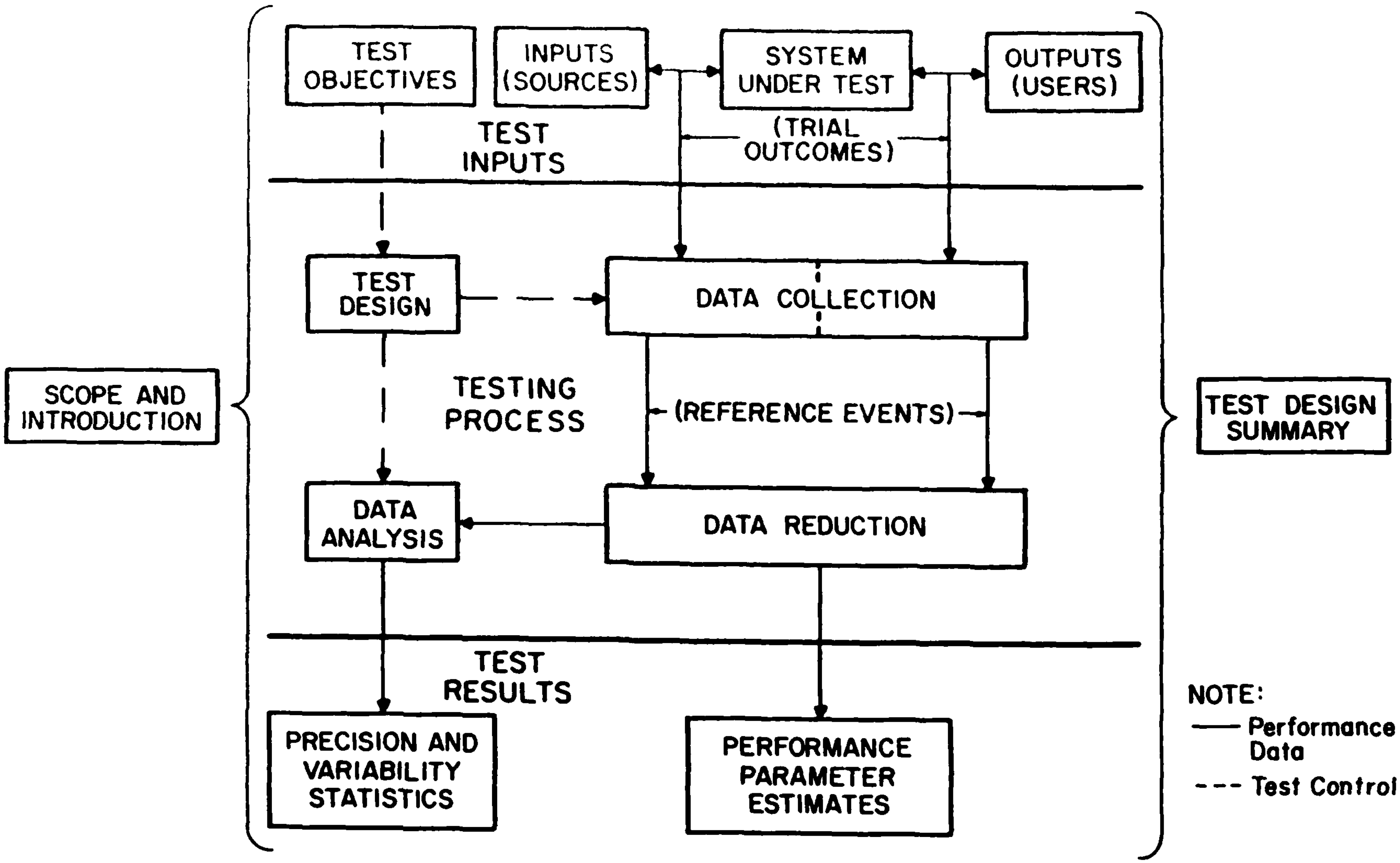

Figure 35. Generalized illustration of the system performance measurement process using system-independent measures of functional performance.

collected data, perhaps from several user/system interfaces, to produce the performance results, such as estimates of mean time (for an outcome) and the various probabilities. Data analysis, discussed in Section 6.4, is a process of statistical examination of the reduced data to determine the precision of estimated parameter values and other associated conclusions.

The measures of functional performance and the SLF test methods developed in this report focus on performance assessment from the user's perspective. These processes are quite general and independent of many implementation details. In addition, there are other important tests of the systems that may have to be performed using other testing facilities. An example is the measurement of many engineering-oriented parameters using the Instrumented Work Shop. We identify these test requirements in Section 7.

6.1 Test Design

This section defines general procedures for designing SLF tests, on Army C-E systems, that will provide estimates for the parameters used as measures of functional performance and the associated testing precision and variability statistics. The test design serves as a guide to the data collection process and to the subsequent data reduction and analysis processes from which performance parameters are estimated and associated precision and variability statistics are determined. A good test design will:

- establish well-defined connections between the test results and conclusions and decisions that will be made based on the test results

- seek to avoid bias in measured values (measurement accuracy)

- guide in obtaining the desired accuracy (precision in measured values) in test results

- assure efficient use of test resources (e.g., time and money).

The application of statistical methods that are central to this discussion of test design requires definitions of some specific testing (or measurement) terms. A trial is an individual attempt to perform the sequence of the system's functions, e.g., detection, signal characterization, and emitter identification and location for electronic surveillance systems. A population is a set of all trials of interest in a particular test. A sample is a subset of the population actually measured during a test. The relationship between these terms is illustrated in Figure 36.

A factor is a variable that describes system, application, or testing conditions that are expected to influence observed performance (measured values). Levels are the defined states or values for a factor during a test. A factor combination is a set of specified levels for each factor of interest. Finally, a test is a process of data measurement that is continuous in time and involves only one factor combination. Thus, all conditions existing during a test are defined by a specific factor combination.

To illustrate the meaning of these terms, consider testing of the TEAMPACK Assembly. The Functional Specification (Bunker Ramo Corporation, 1979) establishes engineering-oriented performance parameters for frequency sweep time, signal process time, parameter data print-out time, the separation of different, simultaneous signals, etc. These specifications, then, may be used to define a test, the factor combination for the test, each trial of the test, and the test sample or population used for determination of system performance. For example, several signals may be simultaneously irradiating the system under test. Each trial would be a single attempt to detect a signal (including measurement of the carrier frequency), measure characteristics (pulse width and pulse repetition frequency) of the signal, measure a direction of arrival for the signal, and compare these data with stored characteristics of known emitters ("identify" the emitter). The combined frequency sweep time, signal process time, data print-out time, etc., will determine the number of trials that are possible in a defined interval of time. All trials (the total number of opportunities for making these measurements) comprise the population of interest, and each subset of trials relating to attempts to detect, characterize, identify, and locate each irradiating system (emitter) comprise the samples of the population. Of course, signal levels for all signals must remain constant for each factor combination.

The test design process is understood most easily by defining and combining several steps. The first step is to define the test objectives. Test objectives often are determined most effectively by identifying the decisions that will be supported by the test results. Examples of decisions that may depend on the test (system performance) results are (1) buy/do not buy the system (system cost effectiveness), (2) product improvement objectives

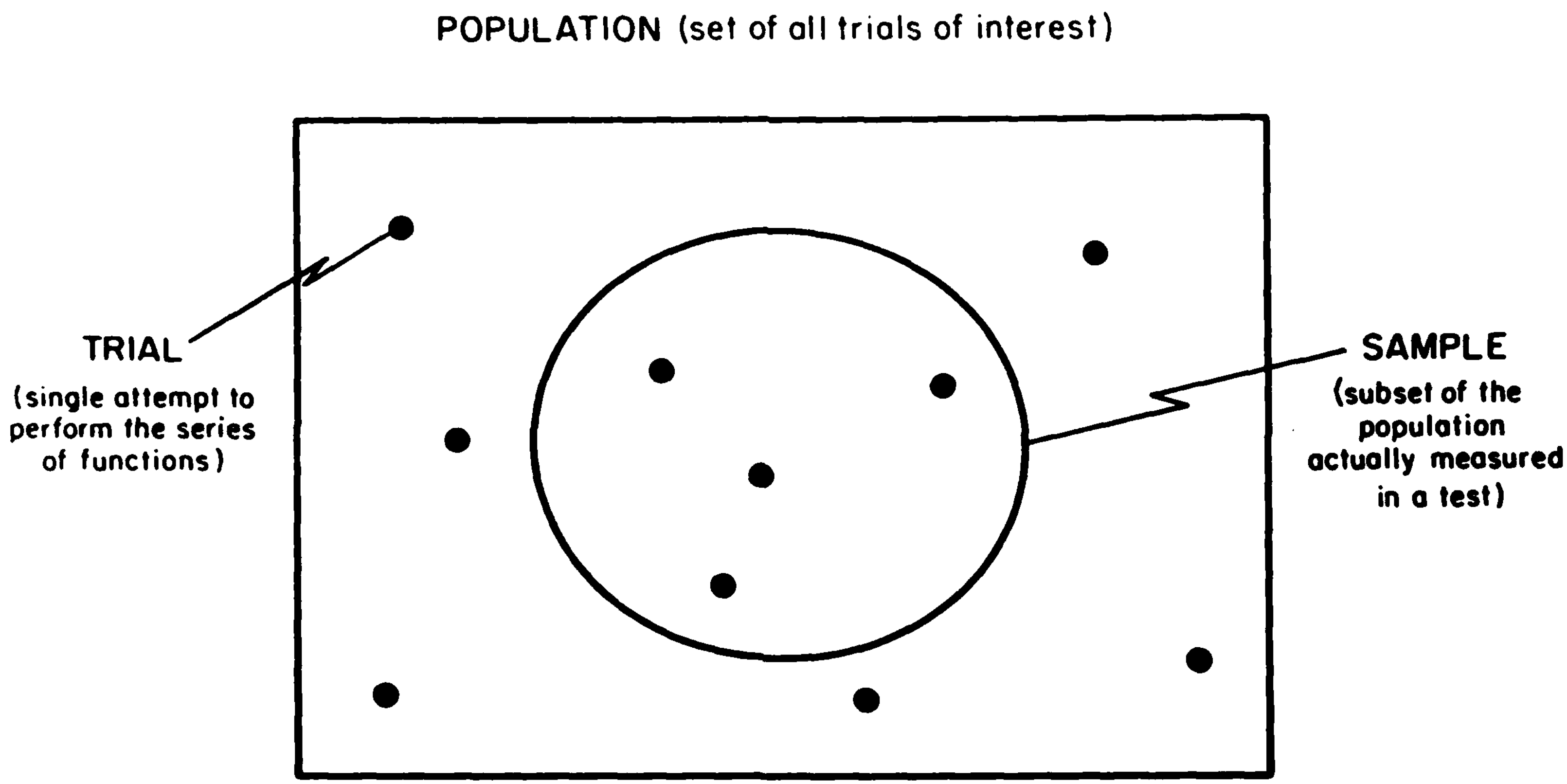

Figure 36. Illustration of the relationship between population, trial, and sample.

have/have not been achieved, or (3) measured performance meets/does not meet expected performance.

There are three general types of tests that may be conducted by following the methodology outlined in this report; these are absolute performance characterization tests, hypothesis tests, and analysis of factor-effects tests. Absolute performance characterization tests provide estimates of the values of selected performance parameters under a single factor combination without consideration of the effects of performance factors or other performance values. As implied, the results of such tests are used to characterize performance in absolute terms. Hypothesis tests also reflect performance under a single factor combination, but the purpose of such tests is to compare measured performance with expected performance (or previously stated values) rather than to characterize performance in absolute terms. The results of such tests may be used to support decisions concerning product improvement objectives being met/not met or performance meets/does not meet expected performance. In analysis of factor-effects tests, performance is compared for several factor combinations to examine, for example, the "sensitivity" of system performance to particular factors and levels for those factors. Such tests are useful in support of decisions concerning system cost effectiveness.

The second step in the test design process is to <u>select the parameters to be measured</u>. All or a subset of the parameters defined in Section 5 (Table 4) may be measured during a test. The principal constraints that influence the selection of parameters to be measured are measurement time, available data extraction and reduction facilities, and data reduction costs.

The third step is to <u>define the population of trials on which the tests will focus</u>. The following items of information must be specified in defining the population trials for each test:

-- Characteristics of radio signals constituting the radio environment of the SUT

-- Operation period(s) during which tests will be conducted

-- Characteristics of the source/system interface(s) to be monitored and the user/system interface(s) at which data (events) will be recorded

-- Test event profiles that define the event sequences, for successful trials, that occur at the user/system interface(s) at which data (events) are measured

-- reference events that correspond to each defined interface event

-- time-outs and thresholds that distinguish successful trials from performance failures.

The population must be defined in such a way that each trial can be given equal consideration and weight to avoid bias in the estimation of population parameters. "Equal consideration and weight" often are achieved by random sampling, however, the cost implications of random sampling may limit the population that can be used for a test.

The fourth step in the test design process is to <u>specify the factors, the levels (or values) for each factor, and the factor combinations</u> to be tested. No general, comprehensive list of relevant factors, levels, and factor combinations can be defined, because the appropriate factors, levels, and factor combinations depend on the specific system under test and the objectives of the tests. Some typical factors and associated levels for electronic surveillance systems are listed in Table 5.

The selection of factors, levels, and factor combinations in a test should be guided by the following principles:

-- Performance factors and levels should be distinguished in a test design only if their effects must be specifically determined to achieve the test objectives.[11]

-- Each defined factor combination should be tested at least once, and the entire test should be replicated to identify significant unaccounted factors.

-- When the number of defined factor combinations is too large to permit testing of each, the tested factor combinations should be chosen so as to provide maximum accuracy in comparing factor levels whose effects are expected to be most important. In general, the selected factor combinations should include combinations that differ only in these critical factor levels.

A test in which every possible combination of the defined factor levels is used at least once is termed a <u>full factorial</u> test. A test in which some of the possible factor combinations are not used is termed a <u>fractional factorial</u> test. The ability to identify interactions among factors is lost in a fractional factorial test. The impact of this diminished factor interaction identification ability must be examined as part of the test design process.

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[11] As noted earlier, only one factor combination is used in absolute performance characterization and hypothesis tests.

Table 5. Some Typical Performance Factors and Levels for Testing Electronic Surveillance Systems

PERFORMANCE FACTOR	TYPICAL LEVELS
Radio signals that constitute the test environment	A number, n_1, that represents a nonstressed environment A number, n_2, that represents a marginally stressed environment A number, n_3, that represents a highly stressed environment
Strengths of radio signals that constitute the test environment	Strengths that represent nearby location, intermediate location, and distant location for each signal source A matrix of n signal sources and 3n signal strengths results from which an appropriate subset of signal sources and strengths are chosen
SUT Operating Mode	Manual Automatic Panoramic
SUT Receiver Sensitivity	Threshold Threshold + 10 dB (for example)
SUT Frequency Selection	Discrete Frequency, or *Scan Single Band (or parts thereof)*, or Scan All Bands (or parts thereof)
SUT Processing and/or Display Time	Specification Requirement Two Times the Specification Requirement (for example)

The fifth step in the test design process is to <u>select a representative sample of performance trials from the defined population</u>. The basic consideration in selecting performance trials to form the test sample is randomization. That is, the trials selected should constitute a random sample of the population. For a homogeneous population, this is achieved when each performance trial has an equal chance of being included in the sample. A second consideration in forming test samples is sample size. Sample size may be derived from measurement precision objectives or specified on the basis of practical constraints such as data storage capacity or a reasonable duration for the test. No matter whether measurement precision objectives or practical constraints are used to determine sample size, a desired confidence level or significance level for the test results should be specified in the test design. Confidence level is a numerical value, typically expressed as a percentage, that defines the likelihood that a confidence interval calculated from the sample data will contain the true value of the estimated parameter. Significance level, which is the complement of the confidence level, is the corresponding specification in hypothesis testing. Confidence levels of 90 or 95 percent (corresponding to significance levels of 10 or 5 percent) are used commonly. In general, the desired precision in a test should be determined by the cost of conducting the test and the potential impact of the resultant data.

The sixth step is to specify a factor combination for each test. Measurement accuracy, clearly defined applicability of the measurement results, and efficient use of test resources were noted earlier among the general objectives of a good test design. The objective here, then, is to define factor combinations (test conditions) that achieve a favorable combination of measurement accuracy and efficient use of test resources. In all, factor combinations should be assigned to each test as randomly as possible under the other constraints of each test. For example, measurement efficiency may restrict randomization in some situations, due to the additional time and cost associated with setting up a particular factor combination repeatedly, rather than once for all tests that may use the same factor combination.

Finally, the seventh step in the test design process is to describe the test design with an explicit mathematical model, if possible. Such a model provides a concise synopsis of the test design and a basis for estimating measurement precision and performance variability in the data analysis. Simple mathematical models often may be used to relate measured and statistical quantities such as

- an observed value of the factor in question
- the true (but unknown) population value of the factor
- factor effects observed in the tests
- random errors.

For example, observed values of the factors may be expressed as a function of the other three quantities. However, in the case of absolute performance determination and hypothesis tests, factor effects are not considered and the model takes the following simplified form:

$$Y_i = \mu + \varepsilon_i$$

where

Y_i is the value measured in the i-th observation,

μ is the parameter's true (population) mean, and

ε_i is the experimental error in the i-th observation.

Such a model might be used, for example, in describing a measurement of signal detection time or system identification and location time in an absolute performance characterization test of an electronic surveillance system.

Performance factors, such as shown in Table 5, may or may not be quantifiable. Tests involving several levels of a single, nonquantifiable factor may be modeled by an equation of the form

$$Y_{ij} = \mu + a_j + \varepsilon_{ij}$$

where

Y_{ij} is the value measured in the i-th observation at factor level j,

μ is the parameter's true (population) mean,

a_j is the performance effect of a particular factor level j, and

ε_{ij} is the experimental error in the i-th observation at level j.

If the factor levels are quantifiable, the factor effects can be described with a regression model of the form

$$Y_i = a + bX_i + \varepsilon_i$$

where

Y_i is the value of the dependent variable measured in the i-th observation,

a is a constant (the intercept of the regression line),

b is a constant (the slope of the regression line),

X_i is the value of the (quantifiable) factor level in the i-th observation, and

ε_i is the experimental error in the i-th observation.

The use of a mathematical model in describing performance measurements is recommended. Further information on the use of mathematical models in test (experiment) design is available in Cox (1958).

6.2 Data Collection

Tests conducted in accordance with the concepts described in this report require that certain raw performance data be collected at the source/system and user/system interfaces. Estimates of the functional performance parameter values are calculated from these raw performance data in accordance with the procedures described in Sections 6.3 and 6.4. We use the concept of a generic "interface monitor" as the mechanism for obtaining these data. In practice, this interface monitor would include both hardware and software components required to collect the data and, in general, would be unique to each monitored interface and the system being tested. In the context of Figure 1, this "monitor" is represented as the MOBILE SUT INTERFACE UNIT and the SYSTEM SPECIFIC INTERFACE APPLIQUE. The interface monitor must perform three major functions:

> Collect Interface Events. Detection and interpretation of transferred signals are interface events. Each event must be associated with a time of occurrence, or "time-stamped."
>
> Process Events. The time-stamped interface events are system specific data. These system-specific interface events must be mapped into system-independent reference events in accordance with the methodology described in Sections 4 and 5.
>
> Record Reference Events. Reference events, with associated time of occurrence, are recorded in a performance data file(s).

Each of these functions is discussed in the subsequent paragraphs. It should be noted that some applications may be relatively simple while other applications may be relatively complex, depending on the system being tested and the specific measures of functional performance that are used in testing the system. Users of this methodology will need to interpret and restrict the [illegible] of this methodology accordingly.

The data collection process begins with the collection of interface events [illegible] system and user/system interfaces. Each element of information [illegible] interface is defined as an interface event. Several types of [illegible] user/system interfaces are illustrated in Figure 37. In a

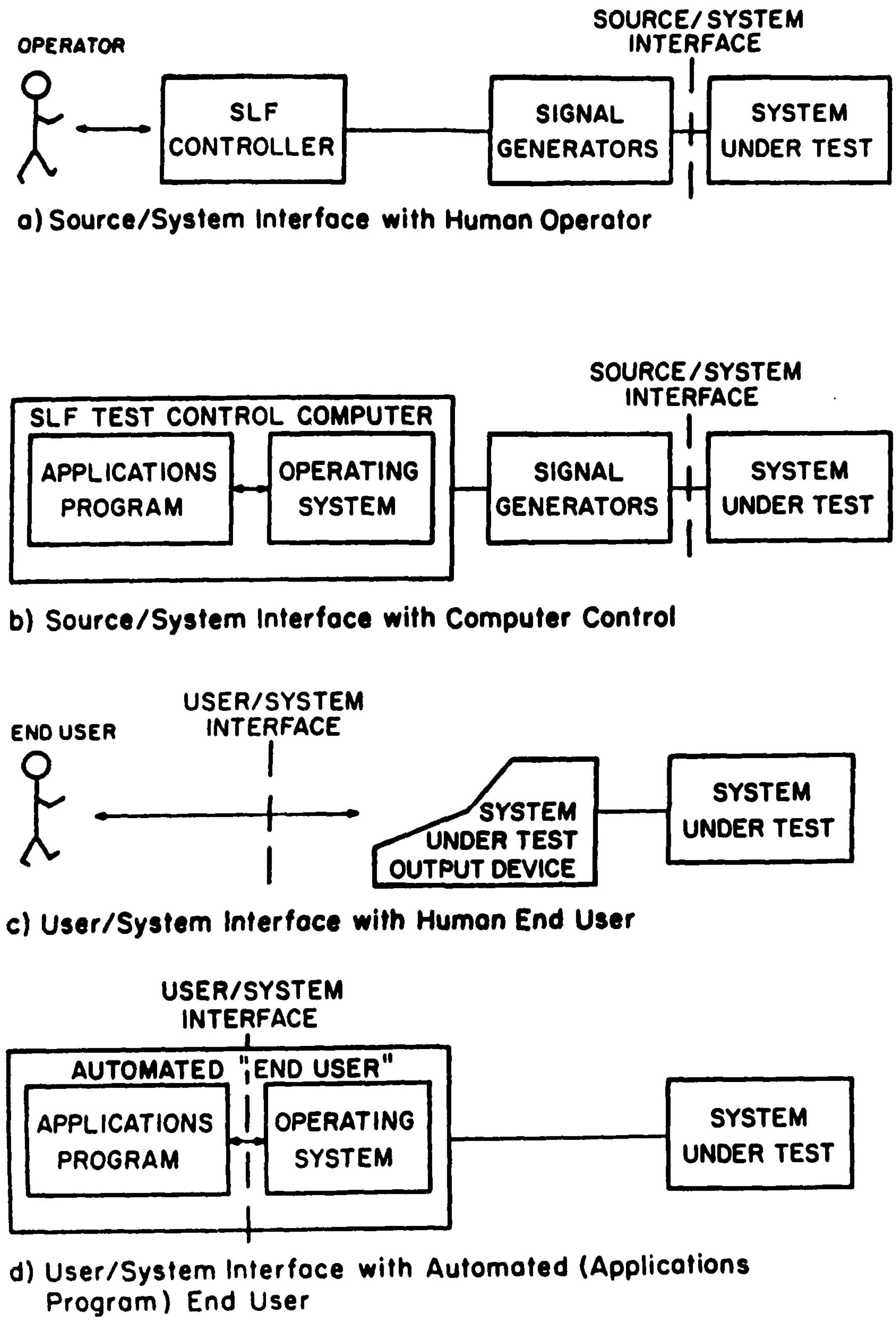


Figure 37. Simple illustrations of typical source/system and user/system interfaces (physical and functional boundaries).

controlled environment, the source/system interface(s) is(are) physical or functional boundary(ies) between the system under test and the source(s) of rf signals and system control commands to which the SUT is expected to respond. The user/system interface is a physical or functional boundary between the SUT and "users of information" produced by the SUT. Physical boundaries are illustrated by Figure 37a, 37b, and 37c; a functional boundary is illustrated by Figure 37d.

The interface monitor(s) must detect all signals transferred (in either direction) across these interfaces during the test period, determine the time of occurrence for each of these events, and interpret the transferred signals and associated times of occurrence into a sequence of discrete events that each has specific meaning. The "users of information" (sometimes termed the end users) produced by the SUT may be human operators of the system, a computer application program that utilizes the information, or a recording device that will store the information for later use. Typical recording devices are electronic memory devices, magnetic tape, magnetic disks, and a variety of information printing devices.

The interface events are system specific and, therefore, cannot be used directly in expressing system-independent, user-oriented, performance parameters. This problem was anticipated in defining the measures of functional performance in terms of system-independent reference events. Therefore, it is necessary to translate the system-dependent (specific) interface events into system-independent reference events. This translation capability of the interface monitor is the second function in the data collection process. Table 6 lists reference events for the three functions of an electronic surveillance system and provides brief discussion of the significance of these events. The table contains no system-specific interface events, but indicates by the blank column for listing those events that test planning for each specific system needs to include identification of the interface events that are to be monitored at the source/system and user/system interfaces and translated into the system-independent reference events. The 14 reference events for electronic surveillance systems defined in Table 6 are briefly discussed in the following paragraphs.

Search Command could be any of a number of actions (that would cause an interface event) that correlate with the start of a test and begins the [illegible] of signal detection time. Conceptually, an instruction from the test

Table 6. Reference Events and Event Significance for the Three Functions of an Electronic Surveillance System

FUNCTION	REFERENCE EVENT (Sys. Independ.)	EVENT SIGNIFICANCE	INTERFACE EVENT
Signal Detection	1. Search Command	The counting of signal detection time begins.	
	2. Indication of Detected Signal	Indication of detected signal may be system dependent, such as rf energy exceeding an rf noise threshold (e.g., a spectrum analyzer-type CRT display), or correspond to the delivery of a particular character to a user's display or a test control monitor.	
	3. Verify Indication of Detected Signal (i.e., compare measured with known test signal characteristics)	Favorable comparison of measured and known test signal characteristics confirms successful signal detection (DESIRED PERFORMANCE); unfavorable comparison indicates false signal detection (INCORRECT PERFORMANCE). Completion of the comparison stops the counting of signal detection time.	
	4. "Time-Out" Without Evidence of Test Signal Detection	When the signal detection function is not completed within an elapsed time that may be specified by the system user or test controller, "time-out" occurs and NON-PERFORMANCE is the outcome for the signal detection function during that trial.	

Table 6. (continued)

FUNCTION	REFERENCE EVENT (Sys. Independ.)	EVENT SIGNIFICANCE	INTERFACE EVENT
Signal Characterization	5. Characterization Command	Completion of the signal detection function or an explicit instruction, initiated manually or automatically, by the system user or test controller may initiate processing of the detected signal. Any of the interface events just mentioned could be used, as appropriate, to start the count of the signal characterization time.	
	6. Indication of Test Signal PW 7. Indication of Test Signal PRF or PRI	The conceptually straightforward notion of measuring carrier frequency, pulse width, and pulse repetition frequency (or pulse repetition interval) applies to narrow-band, swept-frequency receiving systems. However, this conceptual process may not be appropriate for broad-band receiving systems in which the measurement of carrier frequency, PW, and PRF (or PRI) may be an integral process. When available, these interface events may be useful as intermediate indications of the signal characterization function outcome.	
	8. Verify Characterization of the Test Signal (i.e., compare measured PW and PRF/PRI with known characteristics of the test signal)	Favorable comparison of measured and known test signal characteristics confirms successful signal characterization (DESIRED PERFORMANCE); unfavorable comparison indicates incorrect or incomplete signal characterization (INCORRECT PERFORMANCE). Completion of the comparison *stops the counting* of signal characterization time.	
(continued)			

Table 6. (continued)

FUNCTION	REFERENCE EVENT (Sys. Independ.)	EVENT SIGNIFICANCE	INTERFACE EVENT
Signal Characterization (con.)	9. "Time-Out" Without Indications of Signal Characterization	When the signal characterization function is not completed within an elapsed time that may be specified by the system user or test controller, "time-out" occurs and NONPERFORMANCE is the outcome for the signal characterization function during that trial.	
	10. Emitter Identification and Location (EIL) Command	Completion of the signal characterization function or an explicit instruction, initiated manually or automatically, by the system user or test controller may initiate processing of the characterized signal data. Any of the interface events just mentioned could be used, as appropriate, to start the count for the emitter identification and location time.	
Emitter Identification and Location (con.)	11. Indication of Line of Bearing (LOB) to the Emitter	Determining an LOB to the emitter is the first step in the EIL function. (Recall that the signal characterization function has preceded this function.) This information would be available as an interface event that could be used to provide an initial indication of the EIL function outcome. For systems like the TEAMPACK Assembly, this event would indicate completion of the "location determination" portion of the EIL function.	

(continued)

Table 6. (continued)

FUNCTION	REFERENCE EVENT (Sys. Independ.)	EVENT SIGNIFICANCE	INTERFACE EVENT
(continued)	12. Indication of Emitter Identification	For some SUT's (i.e., the TEAMPACK Assembly), the favorable comparison of signal characteristics (preceding function) and measured LOB data with stored data for known emitters will provide emitter location as well as identification (DESIRED PERFORMANCE). Measured data for new emitters should not compare with stored data, and only under SLF test conditions can DESIRED PERFORMANCE in measuring data for new emitters be distinguished from INCORRECT PERFORMANCE in measuring data for known emitters. For other SUT's, (i.e., the Advanced QUICK LOOK) *lines of bearing from multiple* locations are measured and used to determine emitter location (using triangulation methods) which, with signal characteristics (preceding function) are compared with stored data for known emitters. A favorable comparison corresponds with DESIRED PERFORMANCE. Again, measured data for new emitters should not compare with stored data, and only under SLF test conditions can DESIRED PERFORMANCE in measuring data for new emitters be distinguished from INCORRECT PERFORMANCE in measuring data for known emitters. Indications of emitter identification and location complete the EIL function and stop the counting of EIL function time.	
Emitter Identification and Location (con.)	13. Indication of Emitter Location		
(continued)			

Table 6. (continued)

FUNCTION	REFERENCE EVENT (Sys. Output)	EVENT SIGNIFICANCE	INTERFACE EVENT
Emitter Identification and Location (con.)	14. "Time-Out" Without Indications of Emitter Identification and/or Location	When the EIL function is not completed within an elapsed time that may be specified by the user or test controller (time-out), NON-PERFORMANCE is the outcome for the emitter identification and location function for that trial.	

controller, manually or automatically initiated, or an action such as turning on the SUT or turning on the signal generators that produce the test signals or initiating a new operational mode for the SUT could correspond to this reference event.

Indication of Detected Signal, likewise, may correspond to any of a number of interface events. If, for example, the SUT incorporates a narrow-band receiver that is operating in a swept frequency mode, this reference event could correspond to an indication of rf energy that exceeds an rf noise threshold (e.g., a spectrum analyzer-type CRT display), an indication of a carrier frequency on a user's or test control monitor, or some other character being delivered to the monitor.

Verify Indication of Detected Signal (i.e., compare measured carrier frequency with known carrier frequency) is the reference event that determines if the detection function outcome is successful or unsuccessful (false detection). This reference event also stops the counting of signal detection time. Detection time, then, is the difference between the time of occurrence for this event and the time of occurrence for the **Search Command** event.

"Time-Out" Without Evidence of Signal Detection occurs when the SUT attempt to detect the test signal is not complete within a time interval that may be specified by the system user or test controller. Nonperformance for the SUT, for the detection function, is the function outcome when this reference event is recognized. This event would end the trial. The ratio of nondetections to the total number of detection attempts (opportunities) would indicate the nondetection probability.

Characterization Command is the reference event that starts the count for signal characterization time. This event may, in fact, be coincident with completion of the detection function, or it may be an explicit instruction from the user or test controller. Processing of the test signal will provide pulse width and pulse repetition frequency/interval. The functions of detecting a signal and processing the signal to determine pulse width and pulse repetition frequency/interval are conceptually straightforward when considering narrow-band, swept-frequency receiving systems. This conceptual process, however, may not occur so straightforwardly in broad-band receiving systems in which the measurement of carrier frequency, pulse width, and pulse repetition frequency/interval may be an integral process.

Indication of Test Signal Pulse Width, conceptually, is the first step in characterization of the measured test signal. Indication of pulse width may be provided to the user's or test controller's system monitor and thus would be available as an interface event that can be monitored as an intermediate indication of the signal characterization function outcome.

Indication of Test Signal Pulse Repetition Frequency/Interval (PRF/PRI), conceptually, is the second step in characterization of the measured test signal. Again, indication of pulse repetition frequency/interval may be provided to the users' or test controller's system monitor and thus would be available as an interface event that can be monitored as a further, intermediate indication of the signal characterization function outcome. As noted earlier, the process of measuring carrier frequency and pulse characteristics may be an integral process in some systems.

Verify Characterization of the Test Signal (i.e., compare measured pulse width and pulse repetition frequency/interval with known characteristics of the test signal) is the reference event that determines if the signal characterization function outcome is successful or unsuccessful. Favorable comparison of measured and known test signal characteristics confirms successful performance; unfavorable comparison of measured and known characteristics indicates incorrect performance (incorrect signal characterization). This reference event stops the counting of signal characterization time. The signal characterization time, then, is the difference between the time of occurrence for this event and the time of occurrence for the **Characterization Command.**

"Time-Out" Without Indications of Signal Characterization occurs when the SUT processing of the detected signal, to determine signal characteristics, is not complete within a time interval that may be specified by the system user or test controller. Nonperformance for the SUT, for the signal characterization function, is the function outcome when this reference event is recognized. The ratio of signal noncharacterizations to the total number of signal characterization attempts (opportunities) would indicate the probability of signal noncharacterization.

Emitter Identification and Location (EIL) Command is the reference event that starts the count for emitter identification and location time. This event may, in fact, be coincident with completion of the signal characterization function, or it may be an explicit instruction from the user or test controller. The event identifies the initiation of the EIL function. This function may be relatively simple or relatively complex, depending on the SUT. For less sophisticated (perhaps, ground-based) types of systems, the function comprises the measurement of lines of bearing from single locations and the comparison of these measured LOB (and the measured and calculated signal characteristics data from the preceding function) with stored data for known emitters. For more sophisticated types of systems, which may include airborne subsystems, the function involves the measurement of lines of bearing from multiple locations, the calculation of emitter location as the intersection of lines of bearing that have been measured from multiple locations, and the comparison of these measured and calculated LOB/location data and the measured and calculated signal characteristics data (preceding function) with stored characteristics and locations for known emitters. (Emission characteristics and geographic locations of known emitters are stored in the memory of computer-based electronic surveillance systems.) When the measured/calculated data compare favorably with the stored data for known emitters, the system has performed satisfactorily. When the measured/calculated data do not compare favorably with the stored data, system performance may still be satisfactory if the measured/calculated data are for a new (unknown) emitter. However, performance is unsatisfactory if the measured/calculated data are for a known emitter. In the SLF test environment, signal characteristics and "apparent locations" would be part of the known test conditions that could represent either known or new (unknown) emitters, a condition controlled by the test controller. For systems such as the TEAMPACK Assembly, the typical process would involve use of signal characteristics and the measured LOB data. Alternatively, for systems such as the Advanced QUICK LOOK, the typical process would involve use of the signal characteristics and the measured/calculated location data.

Indication of Line of Bearing to the Emitter is the first step in "identifying and locating" an emitter. (Recall that the signal characterization function has preceded this function.) Data that define the line of bearing may be provided to the user's or test controller's system monitor and, thereby, may be available as an interface event that can be monitored as an initial indication of the emitter identification and location function outcome. In the case of systems like the TEAMPACK Assembly, this interface event would indicate completion of that portion of the EIL function pertaining to "location determination."

Indication of Emitter Identification would be the next step in "identifying and locating" the "unknown" emitter (or the test signal). The indication of emitter identification that is provided to the user's or test controller's system monitor would be available as an interface event that could be monitored as an intermediate indication of the emitter identification and [illegible] function outcome. Measurements of signal characteristics (preceding [illegible] location data for known emitters that compare favorably with [illegible] data indicate a satisfactory performance outcome. Measured data for [illegible] that [illegible] not compare favorably with stored data indicate an [illegible] performance outcome. However, measured data for <u>new</u> emitters should [illegible] with the stored data, and the performance outcome is indeterminate [illegible] satisfactory or incorrect. The available information is [illegible] determine. In the case of less sophisticated electronic [illegible] like the TEAMPACK Assembly, this interface event would [illegible] of the EIL function and, thus, stop the counting of emitter [illegible] location time, which would be computed as the difference [illegible] of occurrence for this event and the time of occurrence for [illegible] EIL Command.

Indication of **Emitter Location** is the final step in identifying and [illegible] "unknown" emitter (or test signal). The more sophisticated [illegible] surveillance systems will include the capability for measuring [illegible] from multiple measurement locations and applying [illegible] to determine emitter location as the intersection of [illegible] within the limits of some elliptical error probability that may be [illegible] test controller. The Advanced QUICK LOOK is an [illegible] type of system. The indication of emitter location that is [illegible] or test controller's system monitor (or an output [illegible] would be available as an interface event that could be [illegible] final indication of the emitter identification and location [illegible]. A measurement/calculation of emitter (identification and) [illegible] emitter) that compares favorably with stored data [illegible] factory) performance outcome. A measurement/ [illegible] identification and) location for a known emitter that [illegible] with stored data indicates an incorrect performance [illegible] emitter (identification and) location for a <u>new</u> [illegible] with the stored data. Therefore, the performance outcome is indeterminate--it may be either desired or incorrect. In the case of sophisticated electronic surveillance systems like the Advanced QUICK LOOK, this interface event would identify completion of the EIL function and, thus, stop the counting of emitter identification and location time, which would be computed as the difference between the time of occurrence for this event and the time of occurrence for the **EIL Command.**

"Time-Out" Without Indications of Emitter Identification and/or Location occurs when the SUT attempts to identify and locate the "unknown" emitter (or test signal) are not complete within a time interval that may be specified by the system user or test controller. In other words, one or more of the preceding, required reference events for the EIL function has not occurred. Nonperformance, for the emitter identification and location function, is the function outcome when this reference event is recognized. In the SLF testing of a system, the interface monitor would require additional logic to distinguish measurements for <u>new</u> emitters (that should not compare favorably with the stored data) incorrect measurements or time-out indicating no measurements.

Most, but not all, of the observed interface events will relate to the three primary functions. Some interface events, however, will translate into two reference events, in which case the second reference event may relate to the secondary *function of system operability* state (available/unavailable). The aggregation of successive primary function times for desired performance and acceptable incorrect performance and nonperformance trials comprise the time that the system is in an available state, whereas the aggregation of successive primary function times for nonperformance trials comprise the time that the system is in an unavailable state.

The third function of the interface monitor, noted earlier, is to record the reference interface events. There actually are two elements of information that should be recorded. These are:

1. a complete set of reference events relating to both primary and secondary SUT functions and the performance significance associated with each of these events and

2. the time of occurrence (absolute or relative) of each reference event.

5.3 Data Reduction

This section describes the functional requirements for a data reduction system that will transform the performance data collected by the interface monitors into estimates of the measures of functional performance. The process [illegible] recorded, primary, reference event data to estimate values for the primary parameters is described first. Then, the procedures for developing the [illegible] parameter data are described. Some applications of these procedures [illegible] simple; but, in general, the discussion assumes off-line [illegible] reference event information. The data reduction procedures [illegible] functional flow charts, outcome diagrams, and mathematical [illegible].

[illegible] conventions used in this section are shown in Table 7. Several [illegible] in defining these symbols are listed below.

- [illegible] represented by a lowercase mnemonic symbol [illegible] for detection, "c" for signal characterization, and [illegible] identification and location). The various [illegible] outcomes are represented by subscripted lowercase [illegible], "d_s" for successful detection, "c_s" for successful [illegible] characterization, and "i_s" for successful emitter [illegible] and location.

- [illegible] of function "opportunities" (less than or equal [illegible] trials) and function outcomes observed during a [illegible] by corresponding uppercase letters (e.g., [illegible] number of detection "opportunities" and "D_s" [illegible] of successful detections, "C" for the total [illegible] characterization "opportunities" and C_s for the total [illegible] characterizations, etc.).

- [illegible] event times are represented by the symbol t( ). [illegible] function performance times (one "opportunity" per [illegible] represented by the symbol w( ). Probabilities and [illegible] times are represented by the symbols P( ) and [illegible]. The argument ( ) in each case is the [illegible] of interest. For example, the expression [illegible] average time for successful detection.

- [illegible] values are distinguished from the [illegible] values by the upper case subscript R. For [illegible] $W_R(d_s)$ denotes the specified (required) [illegible] for successful detection.

[illegible] parameter values for the detection function [illegible] procedure assumes as its input a sequence of [illegible] system and

SYMBOL CATEGORY / PRIMARY FUNCTION OUTCOMES	SUPPORTING SYMBOLS						PARAMETER SYMBOLS				
	Function Symbol	Outcome Symbol	Total Number of "Opportunities"	Outcome Totals	Function Start Time	Function Stop Time (Successful)	Function Elapsed Time	Function Performance Time (per trial)	Average Performance Time (per test)	Specific (Required) Average Performance Time	Outcome Probability
DETECTION	d		D		$t(d)$		$w(d_e)$				
Successful		d_s		D_s		$t(d_s)$		$w(d_s)$	$W(d_s)$	$W_R(d_s)$	
Incorrect (false)		d_f		D_f							$P(d_f)$
Nondetection		d_n		D_n							$P(d_n)$
SIGNAL CHARACTERIZATION	c		C		$t(c)$		$w(c_e)$				
Successful		c_s		C_s		$t(c_s)$		$w(c_s)$	$W(c_s)$	$W_R(c_s)$	
Incorrect		c_f		C_f							$P(c_f)$
Noncharacterization		c_n		C_n							$P(c_n)$
EIL	ℓ		L		$t(\ell)$		$w(\ell_e)$				
Successful		ℓ_s		L_s		$t(\ell_s)$		$w(\ell_s)$	$W(\ell_s)$	$W_R(\ell_s)$	
Incorrect		ℓ_f		L_f							$P(\ell_f)$
EIL nonperformance		ℓ_n		L_n							$P(\ell_n)$

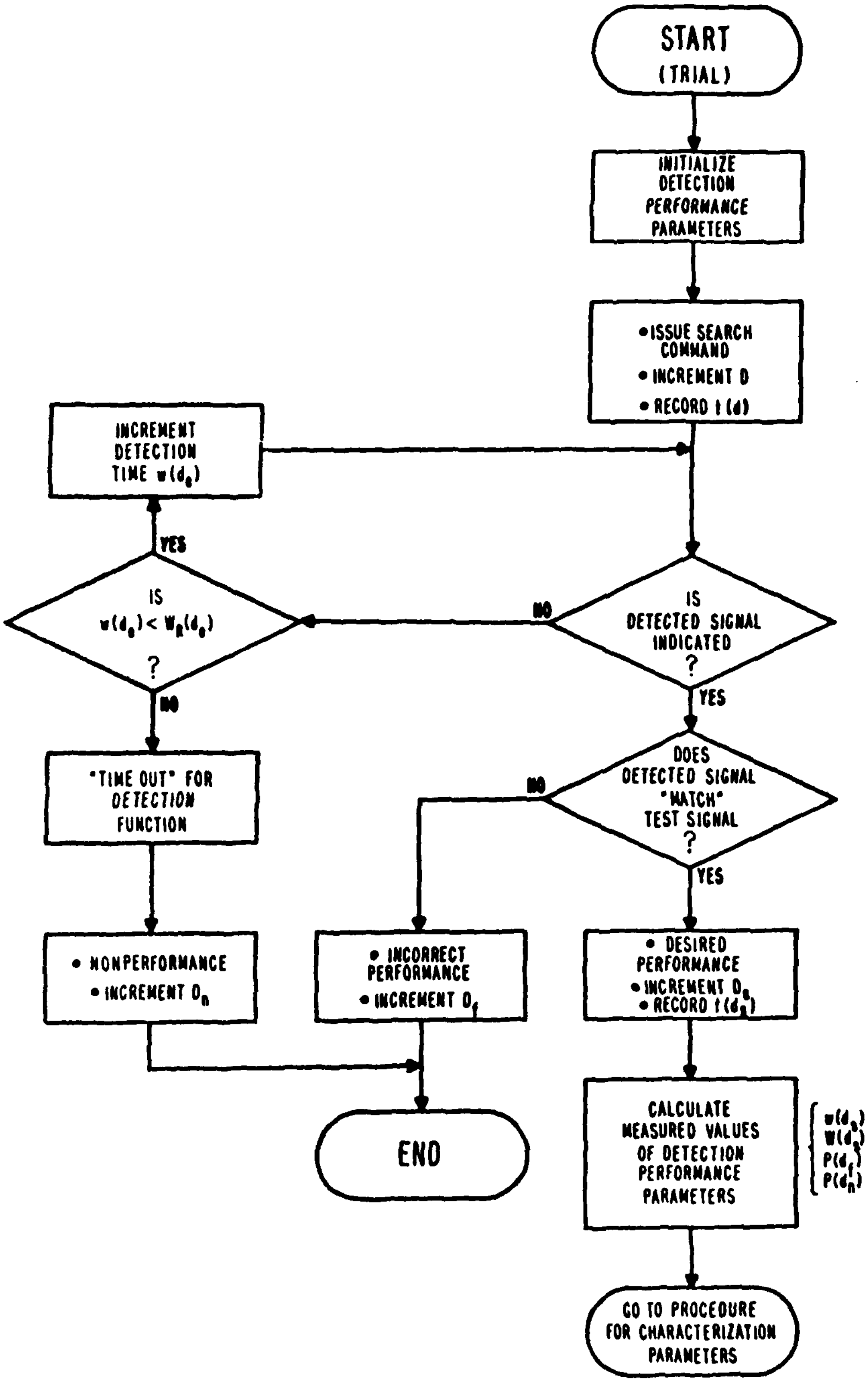


Figure 38. Procedure for estimating detection function parameter values.

user/system interface interactions during the trial being considered. (The total number of consecutive trials constitute the test.) The procedure produces as its output an estimated value for each of the three detection performance parameters, $w(d_s)$, $P(d_f)$, and $P(d_n)$, and the updated average detection time, $W(d_s)$.

The first step in the data reduction procedure for the detection function is to initialize the variables used in recording the detection function outcomes. Each detection "opportunity" (or attempt) is the result of a search command being issued manually by the test operator, automatically by the SLF, or automatically by the SUT as a normal part of operation during testing. The search command will increment the detection "opportunity" counter, D, and mark the start of detection time, t(d).

Following issuance of the search command, there is, conceptually, a logical and recurring check for indication of a detected signal. If there is no indication of a detected signal, the elapsed time in attempting to detect the signal is checked to determine if the specified (required) performance time for detection, $W_R(d_s)$, has elapsed. When the elapsed time, $w(d_e)$, is less than $W_R(d_s)$, the logical process loops to check again for a detected signal. When $w(d_e)$ is equal to or greater than $W_R(d_s)$, "time-out" without detection has occurred. Nonperformance for that detection "opportunity" is the outcome, and the nondetection outcome counter, D_n, is incremented by one. The data reduction procedure for that trial is ended, and the procedure re-starts with the procedure for estimating detection function parameter values for the next trial.

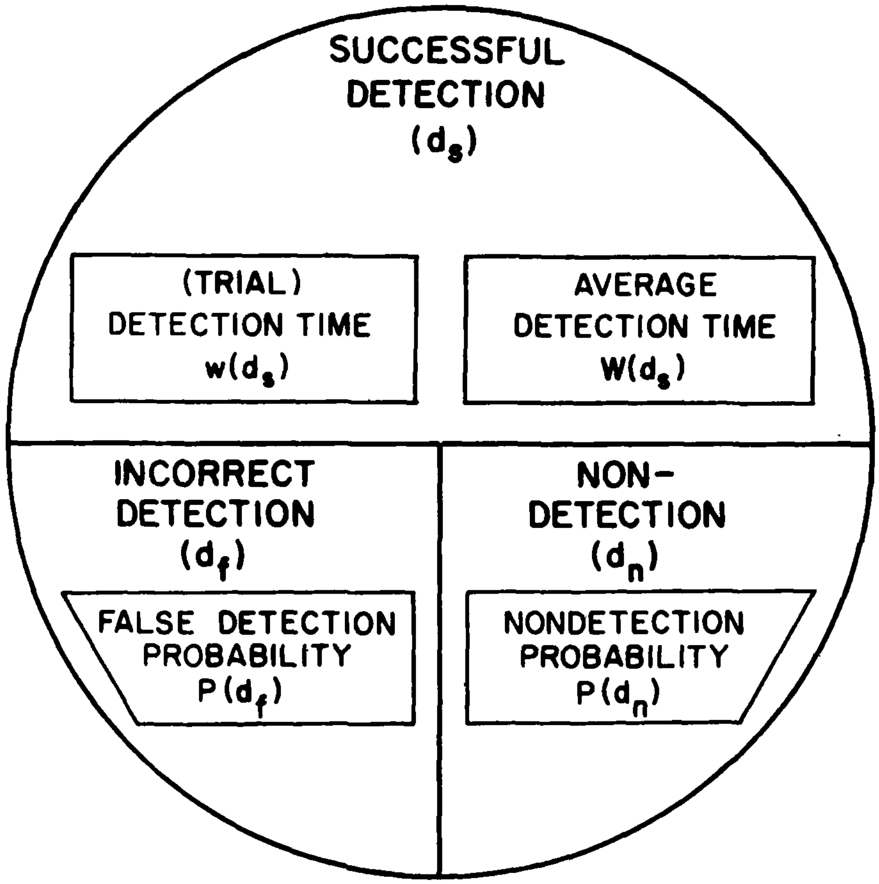
If there is an indication of a detected signal, the procedure checks some characteristic (e.g., the carrier frequency) of the detected signal for a "match" with the known value of the signal characteristic. When this "match" check is negative, the logical conclusion is false detection, and the incorrect performance counter, D_f, is incremented by one. The data reduction procedure for that trial is ended, and the procedure re-starts with the procedure for estimating detection function parameter values for the next trial. Desired performance has occurred when the "match" check is positive, and the successful detection outcome counter, D_s, is incremented by one. The end of the detection time, $t(d_s)$, also is recorded.

The next step in the procedure is to calculate the measured values of the detection performance parameters, $w(d_s)$, $P(d_f)$, and $P(d_n)$, and to update the estimate of average detection time, $W(d_s)$. The detection function performance outcomes and equations for calculating the estimates of parameter values are illustrated in Figure 39. The procedure for estimating detection function performance parameter values now is complete, and the data reduction procedure advances to the procedure for estimating the performance parameter values for the signal characterization function.

The procedure for estimating parameter values for the signal characterization function is shown in Figure 40. The procedure assumes as its input a sequence of recorded primary reference events that represent the source/system and user/system interface interactions and that successful detection has occurred for the trial being considered. (The total number of consecutive trials constitute the test.) The procedure produces as its output an estimated value for each of the three signal characterization performance parameters, $w(c_s)$, $P(c_f)$, and $P(c_n)$, and the updated average signal characterization time, $W(c_s)$.

The first step in the data reduction procedure for the signal characterization function is to initialize the variables used in recording the signal characterization outcomes. Each signal characterization "opportunity" (or attempt) is the result of a characterization command that is issued, either manually, automatically by the SLF, or automatically by the SUT, but it must follow a successful detection function outcome for that trial. The characterization command will increment the characterization "opportunity" counter, C, and mark the start of the signal characterization time, t(c).

There is a conceptually logical and recurring check for indication of the measured signal characteristics (frequency, PW, and PRF/PRI) following issuance of the characterization command. If there is no indication of a complete set of measured signal characteristics, the elapsed time in attempting to characterize the signal is checked to determine if the specified (required) performance time for signal characterization, $W_R(c_s)$, has elapsed. When the elapsed time, $w(c_e)$, is less than $W_R(c_s)$, the logical process loops to check again for complete measured signal characteristics. When $w(c_e)$ is equal to or greater than $W_R(c_s)$, "time-out" without complete signal characterization has occurred. Nonperformance for that signal characterization "opportunity" is the outcome, and noncharacterization outcome counter, C_n, is incremented by one. The data reduction procedure for that trial is ended, and the procedure



DETECTION PARAMETER EQUATIONS

1. Detection time (trial)

$$= w(d_s) = t(d_s) - t(d)$$

2. Average detection time

$$= W(d_s) = \frac{1}{D_s} \sum_{d_s=1}^{D_s} w(d_s)$$

3. False detection probability

$$= P(d_f) = \frac{D_f}{D}$$

4. Nondetection probability

$$= P(d_n) = \frac{D_n}{D}$$

DEFINITIONS

d_s = Successful detection.

D = Total number of detection "opportunities" during the test.

D_f = Total number of false dectections during the test.

D_n = Total number of nondetections during the test.

D_s = Total number of successful detections during the test.

$t(d)$ = Start time for the detection function.

$t(d_s)$ = Stop time for successful detection.

Figure 39. Detection function performance outcomes and equations for calculating estimates of the parameter values.

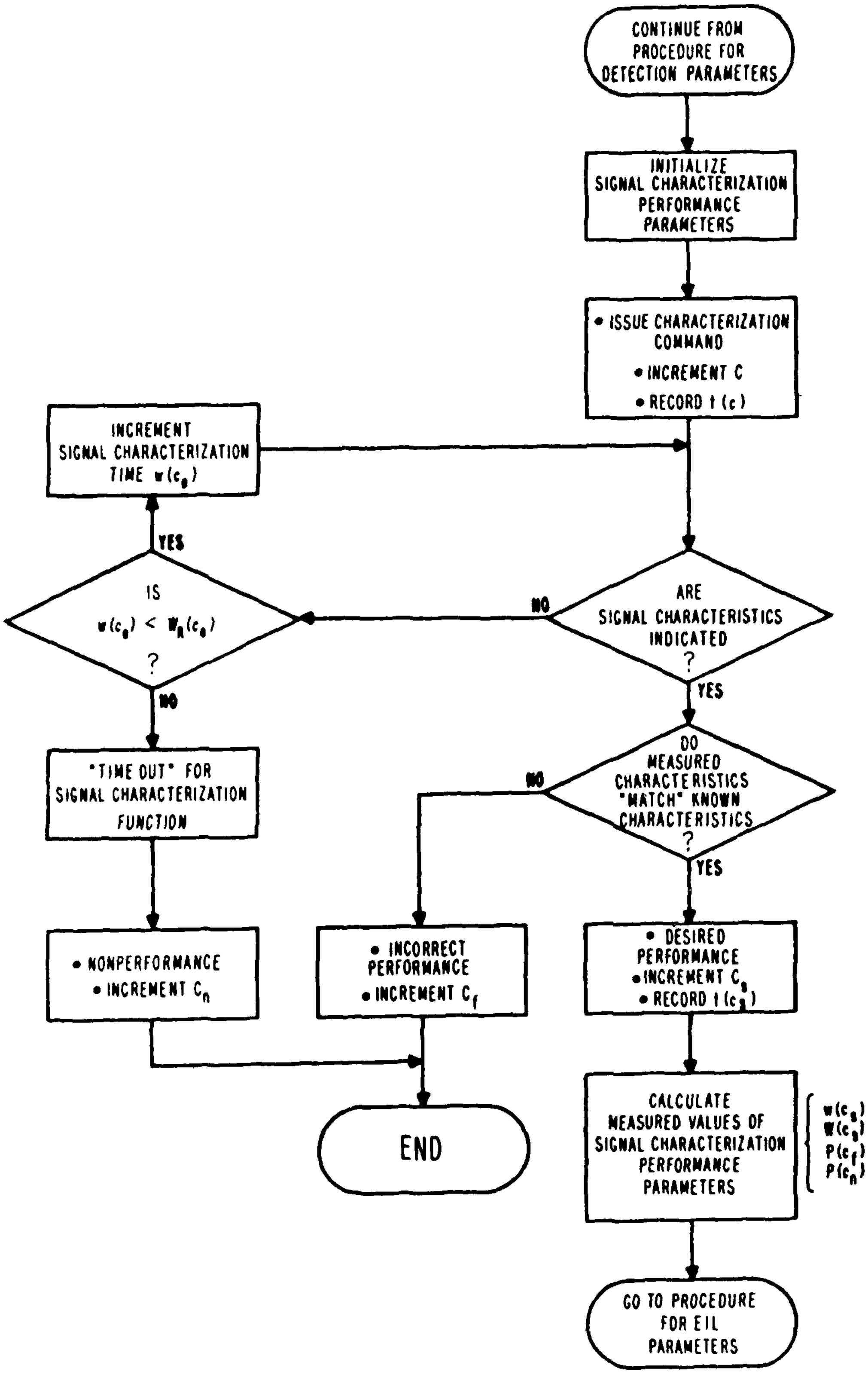


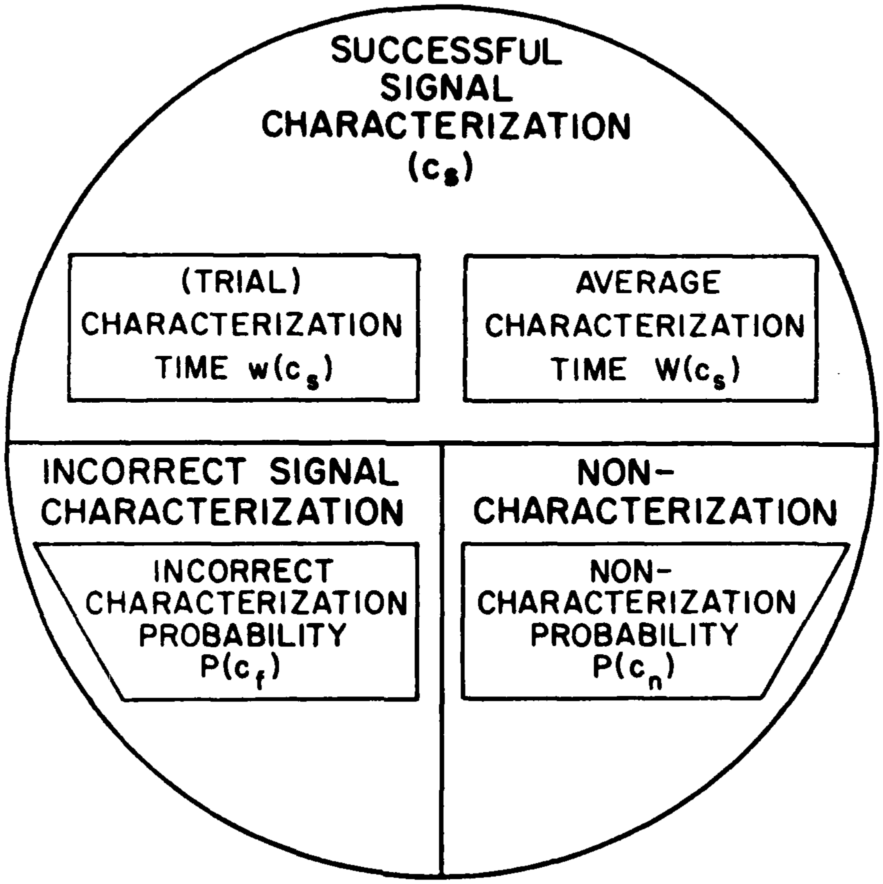
Figure 40. Procedure for estimating signal characterization function parameter values.

restarts with the procedure for estimating detection function parameter values for the next trial.

If measured signal characteristics are indicated, the procedure checks the measured characteristics for a "match" with the known characteristics of the test signal. When this "match" check is negative, the logical conclusion is incorrect signal characterization, and the incorrect performance counter, C_f, is incremented by one. The data reduction procedure for that trial is ended, and the procedure re-starts with the procedure for estimating detection function parameter values for the next trial. Desired performance has occurred when the "match" check is positive, and the successful signal characterization outcome counter, C_s, is incremented by one. The end of the signal characterization time, $t(c_s)$, also is recorded. (This part of the data reduction procedure for the signal characterization function could be expanded, if desired, to account for partial completion of function. We have assumed that the function is either completed or not completed.)

The next step in the procedure is to calculate the measured values of the signal characterization performance parameters, $w(c_s)$, $P(c_f)$, and $P(c_n)$, and to update the estimate of average signal characterization time, $W(c_s)$. The signal characterization function performance outcomes and equations for calculating the estimates of parameter values are illustrated in Figure 41. The procedure for estimating signal characterization function performance parameter values now is complete, and the data reduction procedure advances to the procedure for estimating the performance parameter values for the emitter identification and location function.

The procedure for estimating parameter values for the EIL function is shown in Figure 42. The procedure assumes as its input a sequence of recorded primary reference events that represent the source/system and user/system interface interactions and that successful signal characterization has occurred for the trial being considered. (The total number of consecutive trials constitute the test, but it is unlikely that all functions of every trial will be completed since the signal characterization and EIL functions will not be attempted if the preceding function has not been completed successfully.) This procedure provides as its output an estimated value for each of the three EIL performance parameters, $w(l_s)$, $P(l_f)$, and $P(l_n)$, and the updated average EIL time, $W(l_s)$.



SIGNAL CHARACTERIZATION PARAMETER EQUATIONS

1. Characterization time (trial) $= w(c_s) = t(c_s) - t(c)$

2. Average characterization time $= W(c_s) = \dfrac{1}{C_s} \sum_{c_s=1}^{C_s} w(c_s)$

3. Incorrect characterization probability $= P(c_f) = \dfrac{C_f}{C}$

4. Noncharacterization probability $= P(c_n) = \dfrac{C_n}{C}$

DEFINITIONS

c_s = Successful signal characterization.

C = Total number of signal characterization "opportunities" during the test.

C_f = Total number of incorrect signal characterizations during the test.

C_n = Total number of noncharacterizations during the test.

C_s = Total number of successful signal characterizations during the test.

$t(c)$ = Start time for the signal characterization function.

$t(c_s)$ = Stop time for successful signal characterization.

Figure 41. Signal characterization function performance outcomes and equations for calculating estimates of the parameter values.

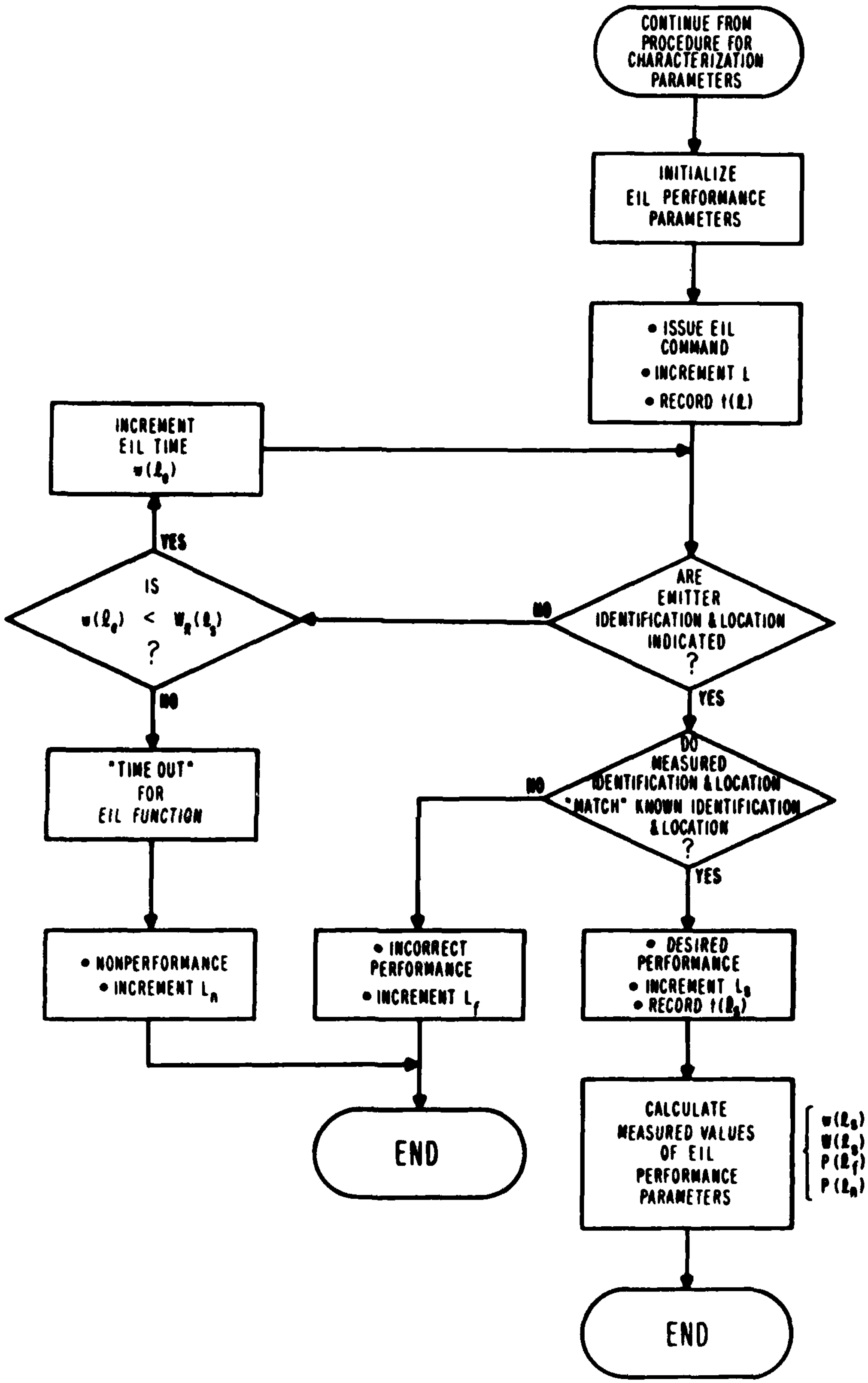


Figure 42. Procedure for estimating emitter identification and location function parameter values.

The first step in the data reduction procedure for the emitter identification and location function is to initialize the variables used to record the EIL outcomes. Each EIL "opportunity" (or attempt) is the result of an EIL command that is issued, manually by the test operator, automatically by the SLF, or automatically by the SUT; but, it must follow a successful signal characterization function outcome for that trial. The EIL command will increment the EIL "opportunity" counter, L, and mark the start of the emitter identification and location time, $t(_1)$.

There is a conceptually logical and recurring check for indication of an emitter's identification and location from the measured data (frequency, PW, PRF/PRI, and LOB from a reference location or the location coordinates) that follows the issuance of the EIL command. If there is no indication of the determination of emitter identification and location from the measured data, the elapsed time in attempting to determine emitter identification and location is checked to determine if the specified (required) performance time for emitter identification and location, $W_R(l_s)$, has elapsed. When the elapsed time, $W(l_s)$, is less than $W_R(l_s)$, the logical process loops to check again for emitter identification and location determination from the measured data. When $W(l_s)$ is equal to or greater than $W_R(l_s)$, "time-out" without determining emitter identification and location has occurred. Nonperformance for the EIL "opportunity" is the outcome, and the EIL nonperformance outcome counter, L_n, is incremented by one. The data reduction procedure for that trial is ended, and the procedure re-starts with the procedure for estimating detection function parameter values for the next trial.

If emitter identification and location are indicated from the measured data, the procedure checks the "measured" identification and location for a "match" with the known emitter identification and location for the test signal. When the "match" check is negative, the logical conclusion is incorrect performance for the function, and the incorrect performance counter, L_f, is incremented by one. The data reduction procedure for that trial is ended, and [illegible] re-starts with the procedure for estimating detection function [illegible] for the next trial. Desired performance has occurred when the [illegible], and the successful emitter identification and [illegible], is incremented by one. The end of the emitter [illegible] time, $t(l_s)$, also is recorded. (This part of the [illegible] emitter identification and location function could be expanded, if desired, to develop unique procedures for systems that determine only line of bearing as opposed to systems that fully determine location as the intersection of at least two lines of bearing from different reference locations.)

The next step in the procedure is to calculate the measured values of the emitter identification and location performance parameters, $w(1_S)$, $P(1_F)$, and $P(1_M)$, and to update the estimate of average emitter identification and location time, $W(1_S)$. The emitter identification and location function performance outcomes and equations for calculating the estimates of parameter values are illustrated in Figure 43. The procedure for estimating emitter identification and location function performance parameter values now is complete and the trial is ended. The data reduction procedure advances to the next trial and starts the procedure for estimating the performance parameter values for the detection function.

The procedures discussed so far provide estimates of values for the primary performance parameters. Values for the secondary performance parameters are estimated following similar procedures. Consider now the availability function that maps primary performance outcomes over performance periods into system operability states. In general, this process requires selection of the primary parameters to be used, definition of the performance thresholds for these parameters, and specification of the performance period to be considered in making the logical decision concerning system operability states.

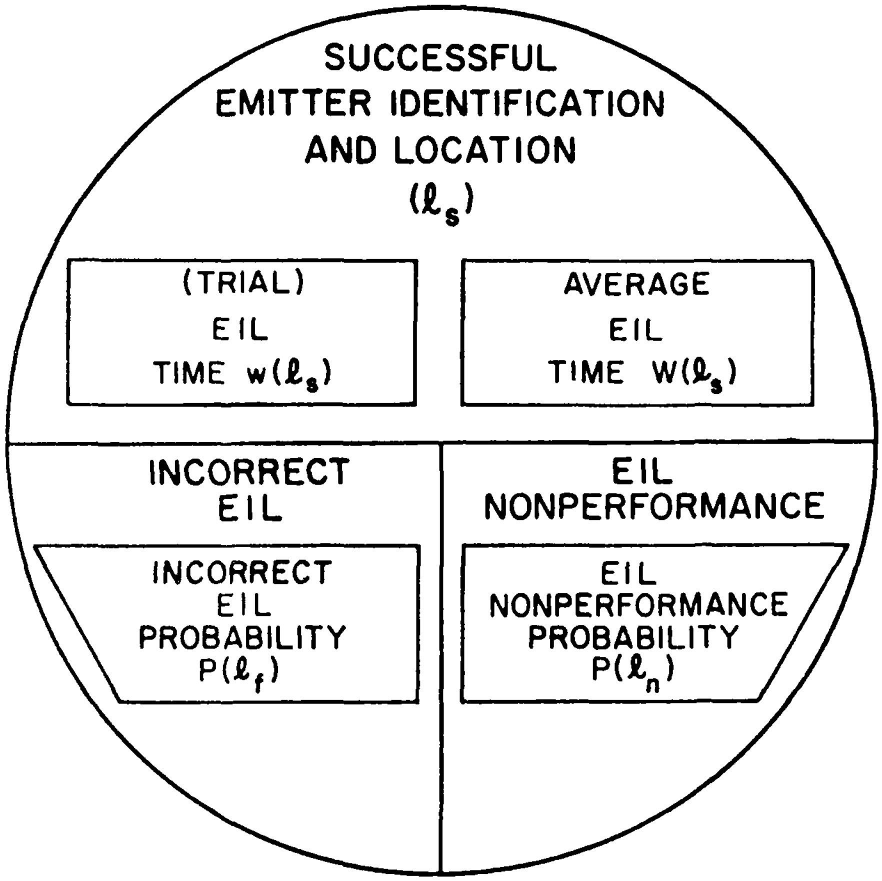
We define the following parameters to facilitate discussion of the secondary function and performance parameters. These parameters provide the necessary notation to discuss a test that spans T performance periods, with B trials during each performance period.

[illegible] denotes the ith trial during the jth performance period, i = 1, 2, ••• B and j = 1, 2, ••• T,

[illegible] denotes a successful trial,

[illegible] denotes the required fraction of successful trials during a performance period,

[illegible] denotes the total number of trials in the jth performance period,



EIL PARAMETER EQUATIONS

1. EIL time (trial)
$$= w(\ell_s) = t(\ell_s) - t(\ell)$$

2. Average EIL time
$$= W(\ell_s) = \frac{1}{L_s} \sum_{\ell_s = 1}^{L_s} w(\ell_s)$$

3. Incorrect EIL probability
$$= P(\ell_f) = \frac{L_f}{L}$$

4. EIL nonperformance probability $= P(\ell_n) = \dfrac{L_n}{L}$

DEFINITIONS

ℓ_s = Successful emitter identification and location.

L = Total number of EIL "opportunities" during the test.

L_f = Total number of incorrect EIL's during the test.

L_n = Total number of EIL non-performances during the test.

L_s = Total number of successful EIL's during the test.

$t(\ell)$ = Start time for the EIL function.

$t(\ell_s)$ = Stop time for successful EIL.

Figure [illegible]. Emitter identification and location function performance outcomes and equations for calculating estimates of the parameter values.

B_s denotes the total number of successful trials in a performance period,

τ_j denotes the jth performance period of the test,

τ_s denotes a successful performance period,

τ_{Rs} denotes the minimum fraction of successful performance periods required for successful (satisfactory) system operation,

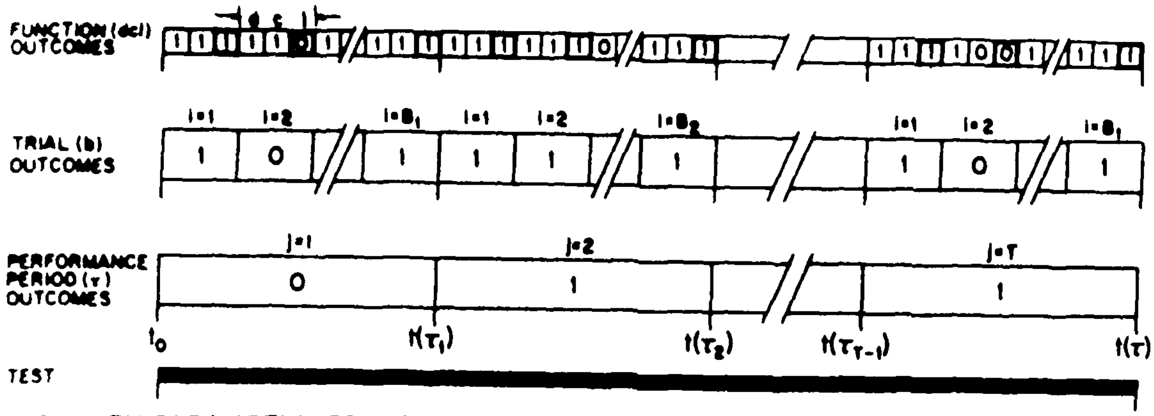
T denotes the total number of performance periods in a test,

T_s denotes the total number of successful performance periods in a test,

$P(b_s)$ denotes the probability of a successful trial during a performance period, and

$P(\tau_s)$ denotes the probability of a successful performance period during a test.

The basic element of a test is the trial, b. Three primary functions (detection (d), signal characterization (c), and emitter identification and location (l)) will be performed during each trial when the system operates satisfactorily. If a primary function is not performed successfully, however, the trial is ended, the remaining functions are not attempted, and a new trial begins. Some number of trials, B, based on achieving statistical significance in the test results, will constitute a performance period, τ, for the purpose of deciding the system operability state. A threshold, b_{Rs}, will be defined by the test planner for the fraction of successful trials that are required during a successful performance period, that is, $B_s/B \geq b_{Rs}$. (We require all functions to be completed successfully for a successful trial. Logically, this requirement means that only the emitter identification and location function need be checked for successful completion, since each function of the trial is attempted only if the preceding function is completed successfully. In other words, any function completed incorrectly or not completed causes an unsuccessful trial.) The relationships of these events (not to be confused with the interface events that are discussed in other sections of this report) and the elapsed testing time associated with these events are illustrated in Figure 44. (Figure 21 illustrates the concept of successful and unsuccessful outcomes, denoted by "1" or "0" respectively, during successive performance periods.



SECONDARY PARAMETER EQUATIONS

1. $TTT = t(\tau_T) - t_0$

2. $SPPT = \left[t(\tau_j) - t(\tau_{j-1})\right]\Big|_{B_s/B \geq b_{Rs}}$

3. $TSPT = \sum_{j=1}^{T}\left[t(\tau_j) - t(\tau_{j-1})\right]\Big|_{B_s/B \geq b_{Rs}}$

4. Availability, $A = (TSPT)/(TTT)$

5. $\overline{OTBF} = \frac{1}{T_f + 1}(TSPT)$

6. $FPPT = \left[t(\tau_j) - t(\tau_{j-1})\right]\Big|_{B_s/B < b_{Rs}}$

7. $\overline{FPPT} = \frac{1}{T_f}\sum_{k=1}^{T_f}\left[t(\tau_j) - t(\tau_{j-1})\right]\Big|_{B_s/B < b_{Rs}}$

DEFINITIONS

b = A test trial.

b_{Rs} = The required fraction of successful trials during a performance period.

B = The total number of trials during a performance period.

B_s = The total number of successful trials during a performance period.

FPPT = A Failed Performance Period (elapsed) Time.

$\overline{FPPT}$ = The average Failed Performance Period (elapsed) Time (typical MTTR).

k = The counting index for failed performance periods; i.e. $k=1,2\ldots T_f$

$\overline{OTBF}$ = The average Operating Time Between Failures (typical MTBF)

SPPT = A Successful Performance Period (elapsed) Time.

t = Test time.

t_0 = Test start time.

$t(\tau_j)$ = Time that the j th performance period is ended; $j=1,2\ldots T$.

T = The total number of performance periods comprising a test.

T_f = The total number of failed performance periods during a test.

TSPT = The Total Successful Performance (elapsed) Time.

TTT = Total Test (elapsed) Time.

τ = A performance period.

Figure 44. System operability state (secondary) function performance outcomes and equations for calculating estimates of the parameter values.

With the basis above for describing system performance, it is straightforward to define the probability of a successful trial, b_S, during a performance period, τ, to be

$$P(b_S) = B_S/B, \text{ and}$$

the probability of a successful performance period, τ_S, during a test to be

$$P(\tau_S) = T_S/T.$$

"Satisfactory" system performance, then, can be defined as the condition when

$$P(\tau_S) = T_S/T \geq \tau_{RS}.$$

It is important to note that these definitions deal with the probabilities of events occurring and that time is only an implicit parameter. Equal numbers of trials (or performance periods) do not necessarily represent equal periods of test (or system operation) time.

Though the event probabilities as descriptions of system performance for the secondary function are conceptually straightforward, it is not convenient with these definitions to define operability states for the system, that is, time when the system is available and time when the system is unavailable and the times for transitions between these states.

The concepts of reliability and availability frequently are used to develop a more general, more macroscopic description of system performance than is provided by the definitions of the primary performance parameters. A common definition of reliability is the probability that a system will operate without failure for a specified function (or above some thresholds) for a specified period of time. As noted earlier in this discussion of secondary performance parameters, this definition of reliability does not distinguish between incorrect performance and nonperformance, but combines these two outcome categories into the single, more general category of performance failure. Availability often is defined as the probability that a system will be in an operational state at any arbitrary time during some much longer test (or field operation) time period.

The commonly used exponential model for characterizing system operability states is discussed briefly in Section 4. The key issues are to choose the primary parameter (function(s)) to be used to measure availability performance, to determine the minimum measurement time over which the selected function performance values will be measured, and to specify the threshold values to be used in defining system failures. We consider a successful trial to occur when the emitter identification and location function is completed successfully (which means that detection and signal characterization functions also have been completed successfully). Minimum measurement time will be defined by the test planner consistent with the statistical quality desired from the test results. Section 7 of this report contains guidance for making that decision. Equations for calculating estimates of the secondary function, system performance parameter values, with time as an explicit parameter, are given in Figure 44, along with the illustrations of performance outcomes.

6.4 Data Analysis

This section discusses methods for analyzing the measured system performance data and describes statistical information that should be prepared and reported with the measurement results. Analysis methodology and statistical information that correspond to each of the three general types of tests that are identified in Section 6.1 (and for which the approach followed in this report is useful), namely, absolute performance characterization tests, hypothesis tests, and analysis of factor-effects tests, are presented. The data analysis methods are described only to the extent necessary to define the minimum requirements for reporting measurement precision. The subject of statistical data analysis is addressed comprehensively in other reports and books (e.g., Fisz, 1963, or Hoel, 1962). The application of statistical data analysis techniques to digital communication systems is developed thoroughly in the report by Miles (1984).

Absolute performance characterization tests are performed to characterize the performance of an electronic surveillance system under a single specified set of conditions (a particular factor combination) without concern about factor effects or previously stated performance values. Such tests are intended to be used in estimating population parameters from sample data; they provide no basis for decisions based on performance comparisons. A parameter estimate calculated from measured data cannot be expected to equal exactly the true population value because of sampling error. Therefore, it is important for such an estimate to be accompanied by an explicit specification of measurement precision. The primary purpose of the data analysis in absolute performance characterization tests is to develop this specification.

The precision of a population parameter estimate calculated from a finite sample is expressed in terms of a confidence interval and an associated confidence level. A confidence interval is a range of values about a measured parameter estimate within which the "true" (population) value of the parameter can be expected to be, with a stated confidence (in percent). The end points of a confidence interval are called confidence limits. These limits may be expressed either in absolute terms (e.g., ±1.0 min) or in relative terms (e.g., half-length of the confidence interval divided by the estimate).

Confidence level is defined in Section 6.1 as a numerical value, typically expressed as a percentage, that defines the likelihood that a confidence interval calculated from the sample data will contain the true value of the estimated parameter. If, for example, a 95 percent confidence level is specified, confidence intervals calculated from individual samples will contain the "true" parameter value in about 95 out of 100 samples. Figure 45 illustrates a set of 20 (hypothetical) calculated confidence intervals, 95 percent confidence assumed, with one interval that does not include the true parameter mean.

Methods for calculating 90 and 95 percent confidence intervals for digital communication system parameters are described in detail in the report by Miles (1984). *These or equivalent methods should be used in calculating confidence* intervals for all absolute performance characterization tests that are conducted on electronic surveillance systems following the test approach developed in this report.

Hypothesis testing is testing from which the validity of a particular statistical hypothesis[12] is examined and ultimately accepted or rejected. A statistical hypothesis is an assumption about the distribution of a population, expressed in terms of specified values for one or more population parameters. Very simple hypothesis testing is described here in which a performance value measured under a single factor combination is compared with a previously specified (hypothetical) value to determine if a "significant" difference exists. The decision to accept or reject a hypothesis normally is made with some uncertainty, since the parameter estimate based on a finite sample can

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[12] The tested hypothesis traditionally is called the null hypothesis, because the truth of the hypothesis implies that no difference exists between the hypothetical and true population values.

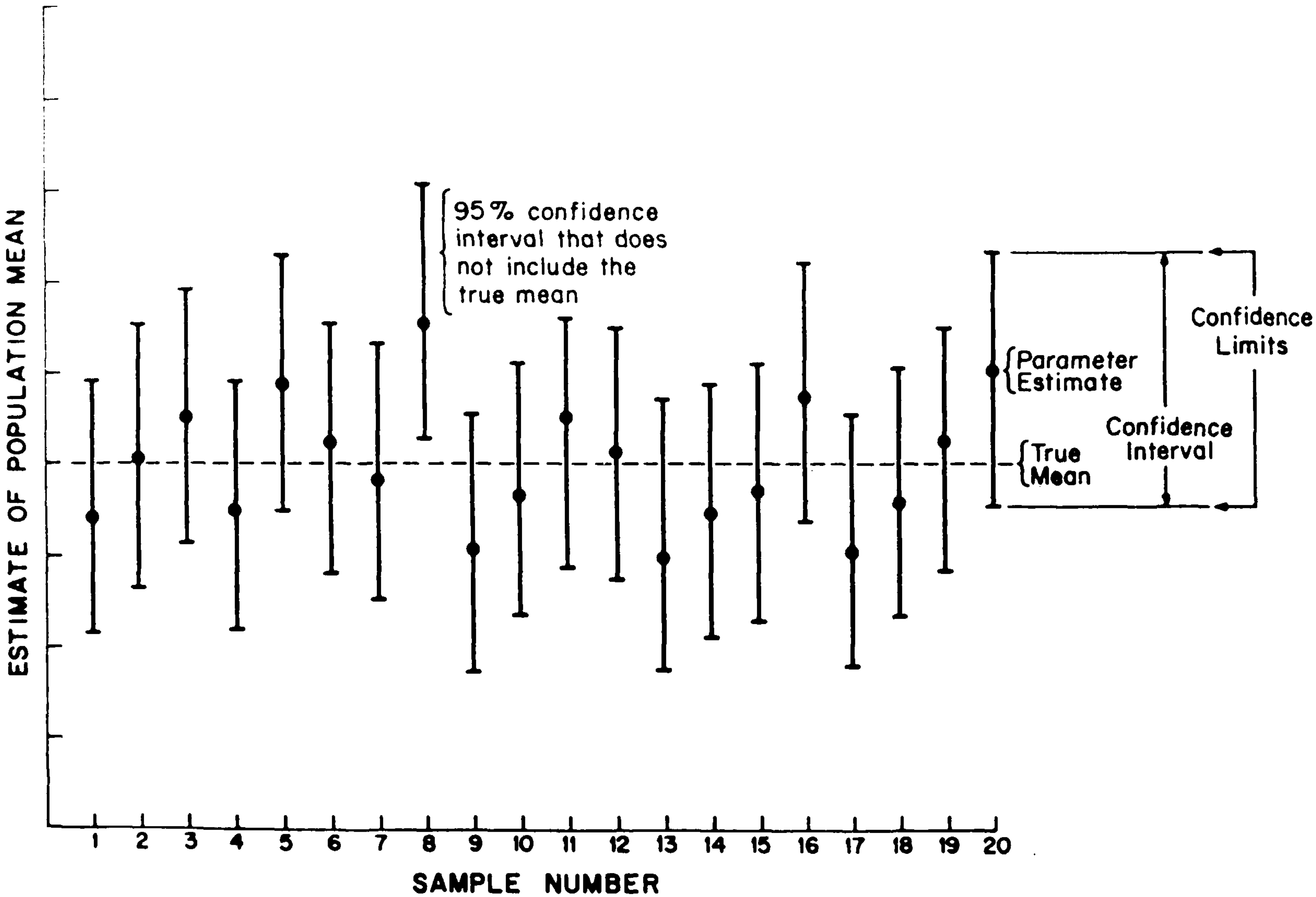

Figure 45. Illustration of 20 calculated confidence intervals (95% hypothetical) and the true mean for a parameter.

deviate, sometimes substantially, from the true parameter value. The uncertainty of a hypothesis test is expressed by its <u>significance level</u>, α, which is the probability of rejecting the tested hypothesis when, in fact, it is true.[13]

The hypothesis to be tested and a desired significance level must be specified during test design. The data extraction and data reduction processes produce an estimate of the measured parameter. With these inputs, an analysis to test the hypothesis that a specified value equals the true population mean is accomplished as follows:

1. Calculate a confidence interval from the measured data following the methods that have been described above. If the null hypothesis is true, the calculated confidence interval will include the specified value with probability equal to $(1 - \alpha)$.

2. Compare the specified value with the confidence interval. If the specified value lies within the confidence interval, the null hypothesis can be accepted with a significance level (probability of error) equal to α. If the specified value lies outside the confidence interval, the null hypothesis is rejected.

In some hypothesis tests, the purpose may be to determine if the actual performance is <u>equal to or better than</u> (rather than exactly equal to) a specified value. The approach described above can be applied to such tests by simply using half of the significance level. The resultant value expresses the probability that a measured value lies within that part of the confidence interval that represents performance equal to or better than the specified value. The same approach can be used to test a negative hypothesis (actual performance is not as good as a specified value).

In some hypothesis tests, it may be necessary to consider another type of error--the error of accepting a stated hypothesis when it actually is false.[14] The likelihood of such an error is determined by three variables:

1. the significance level, α, of the test

2. the test sample size

3. the actual difference between the hypothetical and "true" values.

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[13] The error of rejecting a true hypothesis is called a <u>type I error</u>.

[14] The error of accepting (failing to reject) a false hypothesis is called a <u>type II error</u>. The probability of a type II error commonly is represented by the symbol β.

Specific relationships between these variables may be determined using "power curves," such as the operating-characteristic curves described in the manual by Crow, Davis, and Maxfield (1960).

Analysis of factor effects tests are tests conducted using several factor combinations, and the results are compared in the analysis to identify and quantify postulated factor effects. The analysis typically consists of two steps:

1. an analysis of variance or an equivalent category of data analysis to identify the significant factor effects and

2. individual performance comparisons to examine and quantify such effects.

Analysis of variance is a statistical technique by which the observed [illegible] of a sample is separated into several components, each of which [illegible] the variability attributable to a particular factor. The variance attributed to each factor is compared with a residual variance, attributed to testing error, and the factor effect is deemed significant (at a particular significance level, α) if the variances differ more than predicted by the tabulated F statistic. The procedure is described in the Statistics Manual (Crow, Davis, and Maxfield, 1960).

Analysis of variance is recommended for use in evaluating the effects of performance factors on all time and rate parameters specified in this approach for testing electronic surveillance systems using the SLF. An equivalent category of data analysis that uses the χ^2 (chi-squared) statistic should be used for the analysis of failure probabilities. This analysis procedure also is described in the Statistics Manual. Formulas for calculating the χ^2 and F statistics are included in the application of statistical analysis techniques to digital communication systems by Miles (1984).

When an analysis of variance (or an equivalent category of data analysis) indicates that a postulated factor has no significant effect on performance, [illegible] under all levels of the factor may be combined. This combining [illegible] the overall performance specification by eliminating unnecessary [illegible] of the data. When significant factor effects are identified, [illegible] performance comparisons normally are undertaken to examine those [illegible]. [illegible] comparisons may serve two objectives:

1. to simplify the specification as described above by identifying particular levels of a performance factor that need not be distinguished and

2. to provide a basis for defining quantitative relationships between factor levels and performance values.

Performance data for different factor levels may be combined whenever one measured value lies within the confidence interval of another.

The most direct way to summarize quantitative relationships between factor levels and performance values is simply to list the calculated values (sample means and confidence limits for each level. These data also may be graphed in various ways to present possible models of relationship.

There are three additional, more formal data analysis and presentation methods that may be used to provide more detailed information about a measured population. These methods are:

1. graphical presentation of frequency distributions

2. control charts

3. regression analysis.

These three methods apply, respectively, to the three general types of performance tests that we have been discussing.

Graphical presentations of frequency distributions include diagrams such as histograms and cumulative distributions. Control charts are graphical presentations of systematic variations in a monitored process. Regression analysis is a mathematical method for expressing relationships between random variables, i.e., performance factors and parameters. Each of these techniques is described in the references for statistical methods that have been cited earlier.

[illegible]. MEASUREMENT METHODS FOR TYPICAL ELECTRONIC SURVEILLANCE SYSTEMS

Section [illegible] presents a structured approach to the description of system performance. Applying the structured approach in Section 5 to two typical electronic surveillance systems leads to the definitions of 11 measures of functional performance that relate to 3 primary functions and 1 secondary function for electronic surveillance systems. (The structured approach applied to other types of systems would follow the same process, but other functions and measures of functional performance would be defined.) The performance measurement approach that encompasses a four-phase testing process is defined in Section 6. Now, in Section 7 specific measurement methods are discussed for testing electronic surveillance systems using the SLF and other testing capabilities of the Electromagnetic Environment Test Facility. First, an outline for a Detailed Test Plan for electronic surveillance systems is presented. Then, specific test modes (SLF tests, computer simulation, bench tests, field facility tests, etc.) and the interrelationships of these various test modes are discussed.

7.1 Outline for a Detailed Test Plan

. . Army regulations that define the life cycle (development, [illegible], and operational use) of Army C-E equipments and systems identify a [illegible] specific tests (e.g., Development Tests at various phases of development, [illegible] Tests at various phases of development, First Article Tests, [illegible] must be conducted before the equipment/system can be certified for [illegible] procurement and operational use. The Detailed Test Plan (DTP) [illegible] presented in Table 8 is intended for general applicability; [illegible] it may be necessary to tailor, slightly, this outline before using [illegible] a Detailed Test Plan for a particular type/phase test. It will [illegible] the detailed test plan outline covers SLF tests, bench tests (in [illegible] and/or the antenna test range), computer simulation [illegible] data obtained during bench tests), and Field Facility tests, [illegible] pretest check-outs of the system, subsystem, or compon-[illegible]. An expanded outline for The Detailed Test Plan is presented [illegible].

7.2 Test Mode Interrelationships

[illegible] the use of user-oriented (system independent) [illegible] parameters to evaluate and describe the performance of sophisti-[illegible] C-E systems that would be tested using the SLF. In developing and [illegible] methodology for these user-oriented performance measurements, [illegible] is given to the testing of electronic surveillance systems [illegible] of the sponsor's technical representative for this study). [illegible] in accordance with the methodology developed in this report [illegible] of other tests that may involve the measurement of [illegible] (system dependent) performance parameters, except as it

Table 8. Detailed Test Plan Outline, (Type/Phase) Test of (Nomenclature of Test Item)

1. INTRODUCTION

2. DETAILS OF SLF TESTS

   2.1 Pretest System Check-out
      2.1.1 Objectives
      2.1.2 Criteria (Appropriate Regulation)
      2.1.3 Data Required
      2.1.4 Data Acquisition Procedure
      2.1.5 Analytical Procedure

   2.2 Detection Function
      2.2.1 Objectives
      2.2.2 Criteria (Appropriate Regulation)
      2.2.3 Data Required
      2.2.4 Data Acquisition Procedure
      2.2.5 Analytical Procedure

   2.3 Signal Characterization Function
      2.3.1 Objectives
      2.3.2 Criteria (Appropriate Regulation)
      2.3.3 Data Required
      2.3.4 Data Acquisition Procedure
      2.3.5 Analytical Procedure

   2.4 Emitter Identification and Location (EIL) Function
      2.4.1 Objectives
      2.4.2 Criteria (Appropriate Regulation)
      2.4.3 Data Required
      2.4.4 Data Acquisition Procedure
      2.4.5 Analytical Procedure

   2.5 System Operability State Function (Secondary)
      2.5.1 Objectives
      2.5.2 Criteria (Appropriate Regulation)
      2.5.3 Data Required
      2.5.4 Data Acquisition Procedure
      2.5.5 Analytical Procedure

3. DETAILS OF INSTRUMENTED WORKSHOP TESTS (BENCH TESTS)

   3.1 Pretest System, Subsystem, or Component Check-out
      3.1.1 Objectives
      3.1.2 Criteria (Appropriate Regulation)
      3.1.3 Data Required
      3.1.4 Data Acquisition Procedure
      3.1.5 Analytical Procedure

Table 9. (Continued)

- 3.2 Receiver Characteristics Tests
  - 3.2.1 Objectives
  - 3.2.2 Criteria (Appropriate Regulation)
  - 3.2.3 Data Required
  - 3.2.4 Data Acquisition Procedure
  - 3.2.5 Analytical Procedure

- 3.3 Antenna Subsystem Characteristics Tests
  - 3.3.1 Objectives
  - 3.3.2 Criteria (Appropriate Regulation)
  - 3.3.3 Data Required
  - 3.3.4 Data Acquisition Procedure
  - 3.3.5 Analytical Procedure

- 3.4 System Characteristics Tests
  - 3.4.1 Objectives
  - 3.4.2 Criteria (Appropriate Regulation)
  - 3.4.3 Data Required
  - 3.4.4 Data Acquisition Procedure
  - 3.4.5 Analytical Procedure

4. DETAILS OF COMPUTER SIMULATION

- 4.1 Preparation of Input Data
  - 4.1.1 Objectives
  - 4.1.2 Criteria (Appropriate Regulation)
  - 4.1.3 Data Required
  - 4.1.4 Data Acquisition Procedure
  - 4.1.5 Analytical Procedures

- 4.2 Execution of the Computer Simulation
  - 4.2.1 Objectives
  - 4.2.2 Criteria (Appropriate Regulation)
  - 4.2.3 Data Required
  - 4.2.4 Data Acquisition Procedure
  - 4.2.5 Analytical Procedures

5. DETAILS OF FIELD FACILITY TESTS

- 5.1 Pretest System, Subsystem, and/or Component Check-outs
  - 5.1.1 Objectives
  - 5.1.2 Criteria (Appropriate Regulation)
  - 5.1.3 Data Required
  - 5.1.4 Data Acquisition Procedure
  - 5.1.5 Analytical Procedures

- 5.2 Execution of the Field Facility Tests
  - 5.2.1 Objectives
  - 5.2.2 Criteria (Appropriate Regulation)
  - 5.2.3 Data Required
  - 5.2.4 Data Acquisition Procedure
  - 5.2.5 Analytical Procedures

will be necessary to verify that a system is in "normal operating condition" prior to the start of any SLF testing.

Bench testing will continue to be an important component of performance testing of Army C-E systems, subsystems, and discrete equipment components. There are at least two important reasons for the importance of bench tests:

-- SLF testing may produce user-oriented performance results that cannot be understood without the results of some bench testing.

-- System/subsystem/component performance requirements often will be described in terms of engineering-oriented performance parameters that will have to be measured using bench tests. Many of these engineering-oriented parameter values will be required as input data for computer simulation.

Computer simulation also will continue as an important component of performance evaluation of Army C-E systems, subsystems, and discrete equipment components. There are at least two situations under which computer simulation may be particularly important. These are:

-- The complexity that is required for adequate evaluation of some systems may exceed the capabilities of the SLF.

-- Somewhat simplified computer simulation can serve as a good mechanism for defining the environment that should be specified for SLF tests.

Field facility testing can be the most realistic evaluation of the performance of a system under known and controlled test conditions. However, such tests are subject to the uncertainties of variations in propagation conditions. More important, however, is the fact that good field tests can require an enormous amount of equipment in addition to the system to be tested, the test time can be very long, and the test costs can be very high. Field facility tests, therefore, should be considered as the tests of "last resort." That is, field tests should be considered only when

-- other test modes and/or computer simulation fail to answer sufficiently the questions being asked concerning performance of the system being tested or

-- it is clear that these other test/analysis modes are inadequate to perform the evaluation of system performance that is required.

5. CONCLUSIONS AND RECOMMENDATIONS

The U.S. Army Electronic Proving Ground has extensive test capabilities known as the Electromagnetic Environmental Test Facility that are used to determine the EMC/EMV of U.S. Department of Defense C-E systems and equipment. As increasingly sophisticated C-E systems and equipment are being developed, however, these test capabilities need to be upgraded substantially to ensure [illegible] sufficient testing is performed to assure satisfactory operation of the [illegible] equipment and that this testing is performed as economically as [illegible] Stress Loading Facility is envisioned as a capability that will [illegible] requirements.

[illegible] directed to the development of methodology to utilize the [illegible] that have been addressed in performing the study. [illegible] review of existing SLF-type test capabilities, (2) the [illegible] functional performance as the basis for evaluating [illegible] surveillance systems, and (3) the development of [illegible] methodology for SLF utilization.

[illegible] SLF-type capabilities considers capabilities that [illegible] within and outside of USAEPG. Capabilities that exist within USAEPG [illegible] extensive "bench test" capabilities (which are identified and discussed [illegible], field test capabilities (which are discussed in [illegible], and extensive computer simulation capabilities (which are [illegible] Section [illegible]). Many of these capabilities will [illegible] SLF, as discussed in Section 3. For example, the [illegible] deployment and integrated scenarios; the identification and [illegible] from the deployment and integrated scenario that realisti[illegible] detected by the SUT; the development, updating, and [illegible] location and parameter files; and the determination of [illegible] the deployed emitters are functions that the EMETF [illegible]. The parameter data required for the emitter and [illegible] be obtained using the current EMETF "bench test" [illegible] EMETF capability known as the Test Item Stimulator [illegible] capabilities that will reside in the control [illegible] Signal Systems Simulator.

[illegible] that have been developed outside of USAEPG include the [illegible] Simulator and the Central Target Simulator, [illegible] Laboratory and some near-field, of [illegible] coupling techniques, developed for testing avionics systems on military aircraft. USAEPG is planning to purchase an Advanced Tactical Electronic Warfare Simulator that functionally, at least, will become the major portion of the SLF Non-COMM Threat Simulator. The Central Target Simulator (at NRL) is a large, state-of-the-art laboratory facility (anechoic chamber) that effectively includes a TEWES. The NRL facility is designed to operate only over the frequency range of 8 to 18 GHz. The USAEPG SLF will require a facility of this type, but with substantially expanded capabilities to accommodate the COMM Threat Simulator, as well as the expanded frequency range of the Non-COMM Threat Simulator. The expanded frequency coverage at lower frequencies will require appropriate physical expansion of the facility, which may be quite unreasonable unless some direct or radiated near-field coupling techniques can be developed and implemented at the lower test frequencies. Techniques for near-field coupling of rf energy have been developed and are used for testing (verifying operability) avionics systems on military aircraft. These techniques have a number of limitations that will be very difficult to overcome for SLF testing. For example, the alignment of one antenna with respect to the other is very critical to obtaining repeatable results. These alignment requirements are met through the development and use of elaborate and expensive devices for exact positioning of the antenna (surface conforming for the SUT) to insure repeatable test results. Another important consideration in using near-field coupling techniques is the translation of test results observed when using near-field coupling to system behavior under normal operating conditions (far-field coupling would be expected).

The major areas of development required for implementation of the SLF test concept seem to be

-- Development of the Non-COMM Threat Simulator

-- Development of suitable rf energy coupling techniques for the full frequency operating range of the SLF

-- Definition of the physical enclosure (anechoic chamber), consistent with the two items above, for the SLF

-- Definition/development of the central computer and test control system

-- Definition/development of the test data monitoring subsystem(s)

-- definition/development of interface units for the SUTs, which would include the source/system and user/system interfaces for identifying and recording interface events in accordance with the test methodology developed in these studies

-- further refinement of the test methodology that is developed in the report following the structured approach that is system independent.

The development of measures of functional performance has followed a structured approach to the problem of defining system functions and selecting parameters to describe the performance of the system. The approach follows step-by-step procedures to ensure that the selected set of performance parameters is complete, efficient, and measurable. The parameter development is approached from the point of view of the user who produces parameters that are measures of user-perceived performance rather than measures of the causes (of user-perceived performance) within the system. Such parameters are system independent and, thus, very useful for specifying the performance requirements for systems not yet specified or designed and for comparing performance among systems. The parameter development process involves:

-- defining system interfaces for inputs and outputs

-- defining primary functions performed by the system in terms of the inputs and outputs

-- defining outcomes for the primary functions (intended performance, incorrect performance, or nonperformance)

-- selecting the parameters of interest from the matrix of all possible primary function and outcome pair possibilities.

([illegible]-oriented parameters, though system dependent, certainly are important and often are essential for identifying and understanding the causes of user-perceived performance effects.)

Primary parameters provide descriptions of system performance during periods of normal operation, but a complete characterization of performance [illegible] quantitative description of the frequency and duration of [illegible], "secondary" parameters are defined, using [illegible] primary parameters, to describe system performance [illegible] point of view often associated with the concept of [illegible] primary functions are illustrated for several types of

C-E systems that include communications systems, navigation/timing systems, remote sensing systems, and electronic surveillance systems.

At the request of the sponsor, emphasis is given to electronic surveillance systems in the test methodology development. Two systems, considered typical of EWI systems, are described. One system is the AN/MSQ-103 Special-Purpose Receiver Set (commonly known as TEAMPACK), which is a ground-based (small vehicle-mounted) intercept and direction of arrival system for identifying and locating unfriendly Non-COMM systems. The other system is the Advanced QUICK LOOK System, which can include up to three airborne Non-COMM emitter identification and location subsystems that are connected to a ground data analysis subsystem via wideband data links.

The structured approach to describing system performance parameters from a user's perspective is applied to the development of performance parameters for the two systems identified above. Source/system and user/system interfaces are defined and illustrated (using functional block diagrams) for each system. Three generic functions, for the general class of electronic surveillance systems, that include signal detection, signal characterization, and emitter identification and location are used and the possible outcomes (desired performance, incorrect performance, and nonperformance) are discussed and illustrated for each function. This process leads to *nine primary parameters* and two secondary parameters that are defined as the recommended measures of functional performance for these EWI systems. These parameters would be applicable to any electronic surveillance system for which the primary functions are signal detection, signal characterization, and emitter identification and location.

The complete process for using the SLF to test systems that would be evaluated using the set of measures of functional performance developed for the two candidate systems then is described. This process includes:

-- the procedures for and steps to be followed in developing a good test design

-- the concept of and methodology for developing interface monitors to collect interface events, process these events, and record reference events that are the data required to determine system performance

-- the requirements and procedures for reducing the reference event data into estimated values for the primary and secondary parameters (estimates of the measures of functional performance)

-- procedures for analyzing the measured system performance data to determine (or assure) the statistical significance of the data.

Finally, specific measurement methods are discussed for testing electronic surveillance systems using the SLF and other testing (and analysis) capabilities of the EMETF. First, an outline for a Detailed Test Plan is presented. Secondly, the interrelationships of specific test and simulation (analysis) modes are discussed.

Several recommendations, based on the results of this test methodology development, are offered.

1. The structured approach to the development of measures of functional performance using functions and parameters that are user-oriented and system independent offers wide opportunity for specifying desired system performance in terms that are meaningful to users and for comparing system performance results using a common basis; we strongly recommend the use of these measures of functional performance for SLF testing.

2. Further study is needed to understand the relationships between overall SLF test frequency capabilities, physical size required for the enclosure, and methods for coupling rf energy at all test frequencies and evaluate the impact of these factors on continued SLF development.

3. If testing is planned that will employ antenna-to-antenna coupling of rf energy in the near field, further study is needed to extend system performance results observed under these near-field conditions to expected performance under normal operating conditions (presumed to be far-field conditions).

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APPENDIX A: DEFINITIONS OF TERMS AND ACRONYMS

The field of electronic warfare (EW), like many other fields, has produced its own lexicon. In addition, the U.S. Department of Defense uses many acronyms in their documents. This appendix is included to assist readers in understanding better the purpose of this report by familiarizing them with terms used in the report. Some of the terms defined are peculiar to EW, while others are defined in a way that is unique to the SLF and this report, e.g., [illegible] has not been previously defined. In all cases, an attempt has been made to keep definitions consistent with other documents and as concise as possible without loss of substance.

Availability Function, **A(t)** - The probability that a system will be in an operating state at time t, during the total mission time.

Communications **Systems (COMM)** - In addition to the normal definition of this word, the following definition shall apply to this report: systems that operate at or below 500 MHz.

Communications **Intelligence (COMINT)** - Technical and intelligence information derived from foreign communications by other than the intended recipients (Department of the Army, 1983).

Development **Testing (DT)** - Testing of materiel systems conducted by the materiel developer using the principle of a single, integrated development test cycle to demonstrate that the design risks have been minimized, that the engineering development process is complete, and that the system will meet specifications and to **estimate the system's military utility** when it is fielded. Development testing is conducted in factory, laboratory, and proving ground environments, (Department of the Army, 1976).

Direction Finding **(DF)** - A procedure for obtaining bearings of radio frequency emitters by using a highly directional antenna and a display unit on an intercept receiver or ancillary equipment (GSA, 1986).

Electromagnetic **Environmental Test Facility (EMETF)** - A facility operated by the U.S. Army Electronic Proving Ground, Fort Huachuca, Arizona, with capabilities for performing laboratory and field measurements, data base development, and analyses to evaluate the EMC/EMV of U.S. Army C-E systems and equipment.

Electronic Counter-**Countermeasures** (ECCM) - That division of electronic warfare involving actions taken to ensure friendly use of the electromagnetic spectrum despite the enemy's use of electronic warfare (GSA, 1986).

Electronic **Countermeasures** (ECM) - That division of electronic warfare involving actions taken to prevent or reduce an enemy's effective use of the electromagnetic spectrum (GSA, 1986).

Electronic Order of Battle (EOB) - A listing of all the electronic radiating equipment of a military force giving location, type, function, and other pertinent data.

Electronic Warfare (EW) - Military action involving the use of electromagnetic energy to determine, exploit, reduce, or prevent hostile use of the electromagnetic spectrum and action to retain its effective use by friendly forces (GSA, 1986).

Electronic Warfare and Intelligence (EWI) - Electronic warfare is defined immediately above; electronics intelligence is the second definition below.

Electronic Warfare Support Measures (ESM) - That division of electronic warfare involving actions taken under direct control of an operational commander to search for, intercept, identify, and locate sources of radiated electromagnetic energy for the purpose of immediate threat recognition. Thus, electronic warfare support measures provide a source of information required for immediate decisions involving electronic countermeasures (ECM), electronic counter-countermeasures (ECCM), avoidance, targeting, and other tactical employment of forces. Electronic warfare support measures data can be used to produce signal intelligence (SIGINT), both communications intelligence (COMINT) and electronics intelligence (ELINT) (GSA, 1986).

Electronics Intelligence (ELINT) - Technical and intelligence information derived from foreign noncommunications electromagnetic radiations emanating from other than nuclear detonations or radioactive sources (GSA, 1986).

Intercept - 1. To gain possession of communications intended for others without their consent, and, ordinarily, without delaying or preventing the transmission; 2. Acquisition of a transmitted signal with the intent of delaying or eliminating receipt of that signal by the intended user (GSA, 1986).

Measures of Functional Performance (MOFP's) - The set of bounds or parameters within which a system is expected to normally operate. A measure of performance is an essential element of a test criterion.

Non-Communications Systems (Non-COMM) - In addition to the normal definition of this word (e.g., radar, navigation aids), the following definition shall apply to this report: systems that operate above 500 MHz.

Reliability Function, R(t) - The probability that a system will operate throughout the total mission time.

Signals Intelligence (SIGINT) - 1. A category of intelligence information comprising all communications intelligence (COMINT), electronics intelligence (ELINT), and telemetry intelligence; 2. Intelligence information comprising, either individually or in combination, all communications intelligence (COMINT), electronics intelligence (ELINT), and foreign instrumentation signals intelligence, however transmitted (GSA, 1986).

Stress Loading Facility (SLF) - An (envisioned) integrated and automated test facility that will be capable of generating a dense electromagnetic threat test environment, containing both COMM and Non-COMM systems and equipments, and [illegible] monitoring key performance parameters of a SUT.

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Department of the Army (1976), Test and Evaluation During Development and Acquisition of Material, Army Regulation (AR) 70-10, January 1 (available from U.S. Army Material Command, Washington, D.C.).

Department of the Army (1983), Force Development Independent Evaluation Methodology and Procedures, Training and Doctrine Pamphlet 71-13 (TRADOC Pam) available from U.S. Army Training and Doctrine Command, Ft. Monroe, VA).

[illegible], Federal Standard 1037A, Glossary of Telecommunication Terms, [illegible].

[illegible] SUMMARY--STRUCTURED APPROACH APPLIED TO THE DEVELOPMENT OF PERFORMANCE PARAMETERS FOR DIGITAL COMMUNICATION SYSTEMS

[illegible] National Standards Institute (ANSI) approved American National [illegible] X3.102-1983, "American National Standard for information systems--data [illegible] systems and services--user-oriented performance parameters" on [illegible] (ANSI, 1983). The purpose of the standard is "to establish a [illegible] specifying, assessing, and comparing the performance of data [illegible] systems and services from the point of view of the data [illegible] user." This standard subsequently was adopted as Federal [illegible] 1985 (GSA, 1985).

[illegible] taken in Standard X3.102 is the focus on user [illegible] performance rather than on engineering design considera- [illegible], it is possible to describe these user-oriented [illegible] that are system independent; i.e., the parameters may [illegible] communication system or service, irrespective of [illegible] topology, or control protocol.

[illegible] for digital communication systems consists of [illegible] illustrated in Figure B-1:

[illegible] Communication Process Model). The digital [illegible] and users must be defined using a user-oriented [illegible] process. This definition must identify the [illegible] between the user(s) and the system, the information [illegible] the user/system interface, and how the information [illegible] user/system interface. All user/system [illegible] telecommunication processes--may be defined as [illegible] may be counted, timed, or compared. Key interface [illegible] "reference events" to be used to calculate performance [illegible], these reference events specify all information [illegible] in a comprehensive, user-oriented way. It [illegible] "user" may be either a human or a computer application [illegible] communicated information. For a human user, the [illegible] corresponds to the physical interface between the human [illegible] terminal. For a computer-application-program user, the [illegible] is the functional interface between the application [illegible] operating system. Either a (human) terminal operator or an [illegible] may use data recording media in transferring information to [illegible] information from a system. Typical media used by terminal [illegible] cards, magnetic stripe cards, punched paper tape, and [illegible]. Typical media used by application programs are [illegible] disks. In either case, these data media are [illegible] rather than with the system. Information can be [illegible] system interface in a variety of ways. Typical [illegible] terminal interface are manual keystrokes on the [illegible] printing or displaying of received characters. [illegible] application program/operating system interface are [illegible] the exchange of application program data. Typical [illegible] interface are the reading and writing of [illegible], magnetic tape, or magnetic disks.

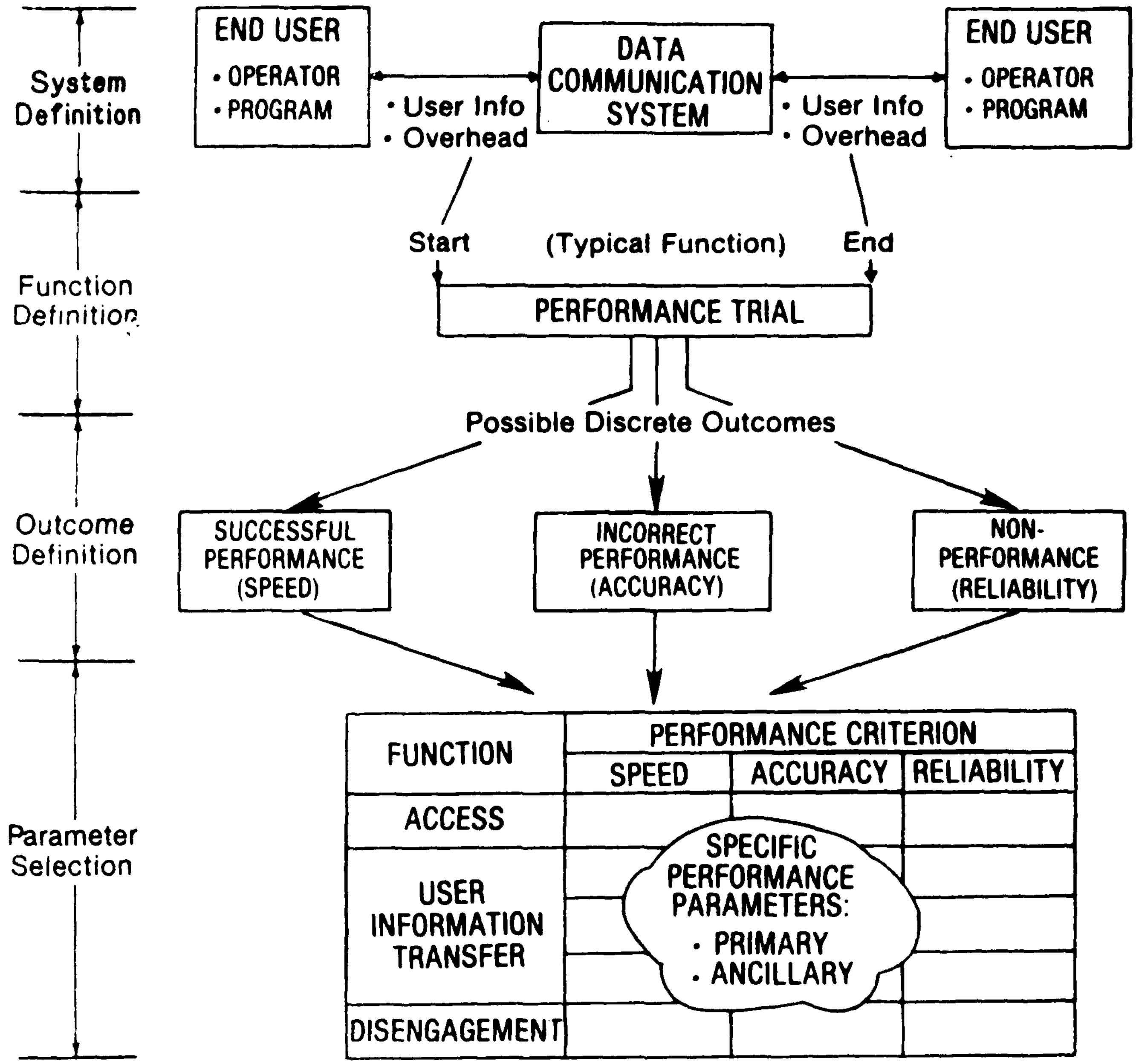


Figure [illegible]-1. The steps followed in ANS X3.102-1983 to develop performance parameters for digital communication systems and services (ANSI, 1983).

[illegible]. Function Definition. Any description of performance must relate to some function(s) that the system is expected to perform. The second step, then, in defining performance parameters (and MOFPs) for digital communication systems is the definition of a set of specific communication functions. The Standard defines three primary functions (in terms of reference events) as follows:

The access function describes a user's "access request." An access request begins when any signal is applied to the user/system interface for the purpose of initiating a digital communication session and ends when the first bit of user information is input to the system. The access request includes dialing, switching, and ringing traditionally associated with establishing physical circuits and higher protocol level activities such as are associated with establishing X.25 virtual circuits.

The information transfer function describes user exchanges of information through the system. In general, information transfer begins when access is completed and ends when the last disengagement request is issued. Information transfer includes all formatting, transmission, storage, error control, and media conversion activities performed between start of transfer and completion of delivery. Two specific information transfer functions are the bit transfer function and the block transfer function. The bit transfer function provides a common basis for comparing systems/services that use different characteristic block lengths; the block transfer function describes performance relative to an information unit that is more relevant to [illegible].

The disengagement function describes the user's "disengagement request." The disengagement request begins when any signal is applied to a user/system interface for the purpose of terminating a user's participation in a digital communication session and ends, for that user, when disengagement has been requested for that user and that user is able to initiate a new access request. Disengagement includes physical circuit disconnection, where required, and higher-level protocol termination activities such as X.25 virtual circuit clearing, as appropriate.

An important characteristic of these primary communication functions is that [illegible] user dependent. This characteristic means that successful performance [illegible], in general, on events that are user-controlled. Using these [illegible] to describe required system performance creates a problem in that the system developer or vendor has no control over user practices in using the [illegible]. This problem is overcome by explicitly describing the influence of [illegible] the primary parameter values by defining separate "ancillary" [illegible] discussed later in this Appendix.

[illegible]. [illegible] Definition. The third step in defining performance parameters (and [illegible] digital communication systems is to define a set of possible [illegible] each of the primary parameters. Three general categories of [illegible] are:

Successful Performance. The function is completed within a specified maximum performance time, and the result or output is exactly as intended. A familiar example is successful connection to the correct called party in a voice telephone call.

Incorrect Performance. The function is completed within the specified maximum performance time, but the result or output is not as intended. A familiar example is connection to a wrong number in a voice telephone call (as a result of a system switching error).

Nonperformance. The function is not completed within a specified maximum performance time. A familiar example is the blocking of a voice telephone call attempt by the system (as indicated by a circuit-busy signal).

These outcomes are significant because they correspond with three basic performance concerns of digital communication users. Successful performance is associated with a user's concern for speed (delay or rate), incorrect performance is associated with a user's concern for accuracy, and nonperformance is associated with a user's concern for reliability. These general performance criteria are used as a framework for organizing the primary parameters. The incorrect performance and nonperformance outcome categories are divided, however, to define more detailed outcomes and a more comprehensive outcome sample space. The more detailed possible outcomes of a primary function, for an individual performance trial, are:

Successful Performance. The expected result/output occurs and is correct in both location and content.

Content Error. The expected result/output occurs at the correct location but is incorrect in content.

Location Error. The expected result/output occurs at an incorrect location.

Extra Event. An unexpected result/output occurs in addition to that expected.

System Nonperformance. The expected result/output does not occur within the maximum performance time either as a result of the system issuing a blocking (busy) signal or due to excessive delay by the system.

User Nonperformance. The expected result/output does not occur within the maximum performance time either as a result of the user issuing a blocking (busy) signal or due to excessive delay by the user.

The possible outcomes defined by the Standard for each of the primary functions are shown in the outcome sample space matrix shown in Figure B-2. Note that some outcomes do not make sense and are not defined for the access and [illegible] functions.

PRIMARY FUNCTIONS	OUTCOMES INCLUDED IN SAMPLE SPACE					
	SUCCESSFUL PERFORMANCE	CONTENT ERROR	LOCATION ERROR	SYSTEM NON-PERFORMANCE	USER NON-PERFORMANCE	EXTRA EVENT
ACCESS	✓		✓	(DENIAL) (OUTAGE)	✓	
BIT TRANSFER	✓	✓	✓	✓	✓	✓
BLOCK TRANSFER	✓	✓	✓	✓	✓	✓
DISENGAGEMENT	✓			✓	✓	

Figure [illegible]. A sample-space matrix showing outcomes for the digital communication systems/services functions used in ANS X3.102-1983 (ANSI, 1983).

4. Parameter Selection. The final step in defining performance parameters (and MTFPs) for digital communication systems is to select and define a minimum set of parameters to describe performance relative to each function and outcome. As noted earlier, this process results in primary (user dependent) parameters and ancillary parameters that express the user's contribution(s) to observed delays. In performing this step, the Standard defines 21 parameters of which 17 are primary parameters and 4 are ancillary parameters. Each of these parameters is defined in mathematical form in the Standard (ANSI, 1983) and a User Reference Manual (Seitz and Grubb, 1983) for the Standard. Of the primary parameters, 4 relate to the access function, 11 relate to the information transfer function, and 2 relate to the disengagement function. The parameters are listed below and summarized in Figure B-3, organized by function and performance criterion and by function and performance parameter type for ease of understanding.

Primary Parameters

1. Access Time
2. Incorrect Access Probability
3. Access Denial Probability
4. Access Outage Probability
5. Bit Error Probability
6. Bit Misdelivery Probability
7. Extra Bit Probability
8. Bit Loss Probability
9. Block Transfer Time
10. Block Error Probability
11. Block Misdelivery Probability
12. Extra Block Probability
13. Block Loss Probability
14. User Information Bit Transfer Rate
15. Transfer Denial Probability
16. Disengagement Time
17. Disengagement Denial Probability

Ancillary Parameters

18. User Fraction of Access Time
19. User Fraction of Block Transfer Time
20. User Fraction of Input/Output Time
21. User Fraction of Disengagement Time

Three additional secondary (or availability) parameters, so termed to emphasize the fact that they are defined on the basis of measured primary parameter values rather than on the basis of direct observations of interface events, but are closely related to the Standard have been defined in a paper by Seitz and Hanson (1980). These parameters provide a macroscopic, long-term performance description in terms traditionally associated with the concept of availability. These secondary performance parameters are:

Service Time Between Outages. The average value of elapsed time between entering and next leaving the Operational Service state (sometimes known as the mean time between failure, MTBF).

FUNCTION	PERFORMANCE CRITERION: SPEED	PERFORMANCE CRITERION: ACCURACY	PERFORMANCE CRITERION: RELIABILITY	PERFORMANCE TIME ALLOCATION
ACCESS	ACCESS TIME	INCORRECT ACCESS PROBABILITY	ACCESS DENIAL PROBABILITY ACCESS OUTAGE PROBABILITY	USER FRACTION OF ACCESS TIME
USER INFORMATION TRANSFER	BLOCK TRANSFER TIME	BIT ERROR PROBABILITY BIT MISDELIVERY PROBABILITY EXTRA BIT PROBABILITY BLOCK ERROR PROBABILITY BLOCK MISDELIVERY PROBABILITY EXTRA BLOCK PROBABILITY	BIT LOSS PROBABILITY BLOCK LOSS PROBABILITY	USER FRACTION OF BLOCK TRANSFER TIME
	USER INFORMATION BIT TRANSFER RATE	TRANSFER DENIAL PROBABILITY		USER FRACTION OF INPUT/OUTPUT TIME
DISENGAGEMENT	DISENGAGEMENT TIME	DISENGAGEMENT DENIAL PROBABILITY		USER FRACTION OF DISENGAGEMENT TIME

Legend: Primary Parameters (plain box); Ancillary Parameters (hatched box)

a. Organization by function and performance criterion.

FUNCTION	PERFORMANCE PARAMETER TYPE: DELAY (IF COMPLETED)	RATE (IF COMPLETED)	FAILURE PROBABILITY
ACCESS	• ACCESS TIME • USER FRACTION OF ACCESS TIME		• INCORRECT ACCESS • ACCESS OUTAGE • ACCESS DENIAL
USER INFORMATION TRANSFER	• BLOCK TRANSFER TIME • USER FRACTION OF BLOCK TRANSFER TIME • USER FRACTION OF INPUT/OUTPUT TIME	• USER INFORMATION BIT TRANSFER RATE	• BIT ERROR • BIT MISDELIVERY • EXTRA BIT • BIT LOSS • BLOCK ERROR • BLOCK MISDELIVERY • EXTRA BLOCK • BLOCK LOSS • TRANSFER DENIAL
DISENGAGEMENT	• DISENGAGEMENT TIME • USER FRACTION OF DISENGAGEMENT TIME		• DISENGAGEMENT DENIAL

b. Organization by function and performance parameter type.

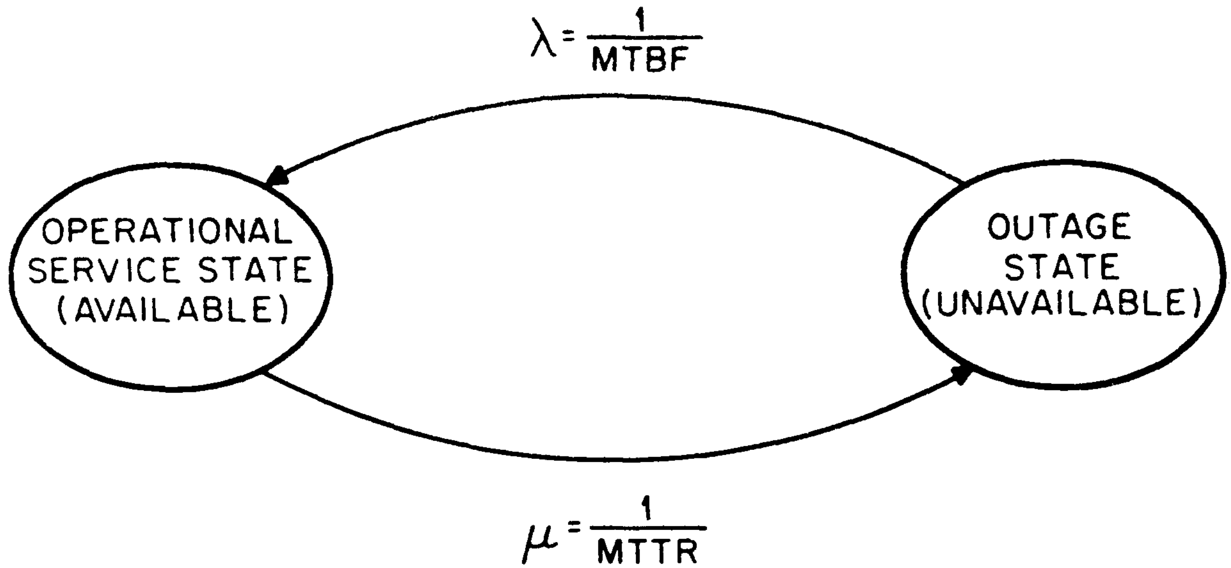
[illegible] the user-oriented parameters defined in [illegible] to describe performance of digital [illegible] services ([illegible], 198[illegible]).

Outage Duration. The average value of elapsed time between entering and next leaving the Outage state (sometimes known as the mean time to repair, MTTR).

Outage Probability. The ratio of total message transfer attempts resulting in the Outage state to total message transfer attempts included in the measurement sample.

These secondary parameters as used to define the concepts of availability and unavailability are illustrated in Figure B-4.

Much additional definition and explanation of the Standard are given in the references that have been cited and material referenced in those documents. One additional source of considerable use in applying the Standard to system performance measurements is a report that defines and describes measurement methods for user-oriented performance evaluation (ANSI, 1986).



$$\text{AVAILABILITY} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}} = \frac{\mu}{\mu + \lambda}$$

$$\text{UNAVAILABILITY} = \frac{\text{MTTR}}{\text{MTBF} + \text{MTTR}} = \frac{\lambda}{\mu + \lambda}$$

Figure B-4. Illustration of secondary performance parameters used to define the concepts of availability and unavailability.

REFERENCES

ANSI (1983), American National Standard for information systems--data communication systems and services--user-oriented performance parameters, X3.102-1983, February 22.

ANSI (1986), DRAFT American National Standard for data communication systems and services--measurement methods for user-oriented performance evaluation, Rev.7, X3S3/135, August.

Miles, M. J. (1984), Sample size and precision in communication performance measurements, NTIA Report 84-153, August (NTIS Order No. PB 85-114270).

Seitz, N. B., and D. Bodson (1980), Data communication performance assessment, Telecommunications, February.

Seitz, N. B., and D. S. Grubb (1983), American National Standard X3.102 user reference manual, NTIA Report 83-125, October (NTIS Order No. PB 84-155571).

APPENDIX C: EXPANDED OUTLINE OF A DETAILED TEST PLAN FOR (TYPE/PHASE) TEST OF (NOMENCLATURE OF TEST ITEM)

1. INTRODUCTION

This section, with the use of subsections as appropriate, will present background to the development of the equipment/system, a brief description of the equipment/system, clear statement(s) of test objective(s), and a description of the scope of the test.

[illegible] OF THE TESTS

[illegible] section, with the use of subsections, will define and describe the tests [illegible] to be conducted, using the SLF to create the desired test [illegible](s), so as to produce and collect the interface events that must be [illegible] or counted for reduction and analysis (as described in Section 6) [illegible] performance in accordance with the user-oriented functions and [illegible] parameters that have been selected for use in the test. Such [illegible] characterized as system independent.

[illegible] System Check-out

[illegible] [illegible]tives

[illegible] are to determine that the system to be tested is complete and in [illegible] condition and that any required support equipment is [illegible], complete, and in normal operating condition prior to start of the [illegible].

[illegible] [illegible] Appropriate Regulation)

[illegible]. [illegible] to be tested shall be complete and in normal operating condition prior to start of the test(s).

[illegible]. Any support equipment required for the system to be tested shall be available, complete, and in normal operating condition prior to start of the test(s).

[illegible] [illegible] Required

[illegible] of discrepancies existent for the system to be tested

[illegible] discrepancies existent for required support equipment [illegible] system to be tested

[illegible] documentation of any physical damage existent for [illegible] tested and/or the support equipment required for [illegible] tested

[illegible] adjustments and repairs performed and all [illegible] met.

2.1.4 Data Acquisition Procedure

The test officer and other technical and maintenance personnel, as required, will conduct the pretest system check-out. This check-out will include:

a. Unpack and inventory the system to be tested and all required support equipment and compare the contents with packing list to determine if any discrepancies exist.

b. Inspect the system to be tested and all required support equipment evidence of physical damage.

c. Perform a pretest operational performance verification check on the system to be tested and all required support equipment, as appropriate.

d. Adjust and/or repair each discrepant condition, if possible.

e. Record all discrepant conditions, including those removed by adjustment and/or repair as well as those not removed.

2.1.5 Analytical Procedure

The data will be used to assist the test officer in determining if the system to be tested and all required support equipment are complete, undamaged, in operating condition, and ready for testing.

2.2 Detection Function

2.2.1 Objective(s)

The objective(s) of detection function testing must be defined in a short, clear statement.

2.2.2 Criteria (Appropriate Regulation)

The criteria for successful detection function outcomes must be defined along with the basis for the criteria. At least two criteria are applicable to each test; these criteria are the time for successful detection for each trial which is the basis for calculating the detection rate, and the percentage of successful (trial) detections that are required for a successful performance period.

2.2.3 Data Required

a. the start time for each detection attempt

b. the function stop time for each successful detection

c. the total number of detection opportunities (trials)

d. the total number of successful detections

e. the total number of incorrect detections

f. the total number of nondetections.

..... Data Acquisition Procedure

The data will be acquired using the SLF and interface monitors as described in Section 6.1.

..... Analytical Procedures

The data will be reduced and analyzed as described in Sections 6.3 and 6.4. ... values that will be calculated include:

a. ... time (for each trial)

b. average detection time (calculated for each performance period ... for each factor combination of the test)

c. ... detection probability (calculated for each factor ... of the test)

d. ... detection probability (calculated for each factor combination ... test).

..... Characterization Function

..... s.

... of signal characterization function testing must be defined in ... statement.

..... (Appropriate Regulation)

... for successful signal characterization function outcomes must be ... with the basis for the criteria. Several criteria that apply ...:

a. the time for successful signal characterization for each trial

b. ... allowable tolerance in measuring signal frequency (may be ... pulsed or CW carrier)

c. ... allowable tolerance in measuring PW, if carrier is pulsed

d. ... allowable tolerance in measuring PRF/PRI, if carrier is ...

e. ... of successful signal characterizations that are required for a successful performance period.

2.3.3 Data Required

a. the start time for each signal characterization attempt

b. the function stop time for each successful signal characterization

c. the total number of signal characterization opportunities (usually not the total number of trials, because signal characterizations are attempted only when the detection function outcome has been successful)

d. the total number of successful signal characterizations

e. the total number of incorrect signal characterizations

f. the total number of signal noncharacterizations.

2.3.4 Data Acquisition Procedure

The data will be acquired using the SLF and interface monitors as described in Section 6.2.

2.3.5 Analytical Procedures

The data will be reduced and analyzed as described in Sections 6.3 and 6.4. The parameter values that will be calculated include:

a. signal characterization time (for each trial)

b. average signal characterization time (this parameter may be calculated for each performance period and/or for each factor combination of the test)

c. incorrect signal characterization probability (this parameter would be calculated for each factor combination of the test)

d. signal noncharacterization probability (this parameter would be calculated for each factor combination of the test).

2.4 Emitter Identification and Location (EIL) Function

2.4.1 Objective(s)

The objective(s) of EIL function testing must be defined in a short, clear statement.

2.4.2 Criteria (Appropriate Regulation)

The criteria for successful EIL function outcomes must be defined along with the basis for the criteria. Several criteria that apply include:

a. the time for successful emitter identification and location for each trial

b. the allowable tolerance in measuring a line of bearing

c. the allowable tolerance in elliptical error probability when calculating a position from two or more lines of bearing that have been measured from different locations

d. the percentage of successful EIL trials that are required for a successful performance period.

This function may be the function of primary interest, since successful completion of this function is dependent upon successful completion of the preceding functions.

[illegible] Data Required

a. the start time for each EIL attempt

b. the function stop time for each successful EIL

c. the total number of successful opportunities (usually not the total number of trials nor the total number of successful signal characterizations, because the EIL function is attempted only when the signal characterization function outcome has been successful)

d. the total number of successful EIL functions

e. the total number of incorrect EIL functions

f. the total number of EIL function nonperformances.

[illegible] Data Acquisition Procedure

The data will be acquired using the SLF and interface monitors as described in Section 6.[illegible].

[illegible] Analytical Procedures

The data will be reduced and analyzed as described in Sections 6.3 and 6.4. The parameter values that will be calculated include:

a. emitter identification and location time (for each trial)

b. average EIL time (this parameter may be calculated for each performance period and/or for each factor combination of the test)

c. incorrect EIL probability (this parameter would be calculated for each factor combination of the test)

d. EIL nonperformance probability (this parameter would be calculated for each factor combination of the test).

2.5 System Operability State Function (Secondary)

2.5.1 Objective(s)

The objective(s) for the system operability function must be defined in a short, clear statement.

2.5.2 Criteria (Appropriate Regulation)

The criteria for the system to be in an "Available" (operational) state and the acceptable frequency and duration of "Unavailable" (nonoperational) states must be defined along with the basis for the criteria:

a. the required successful function outcomes in order for the trial outcome to be successful

b. the percentage of successful trial outcomes that are required for a successful performance period

c. the fraction of total test time that the system must be in an operational state (Available)

d. the requirement for minimum time that the system must be in an operating state between failures

e. the requirement for maximum time that the system may be in a nonoperating state (failed).

2.5.3 Data Required

All data required for the (secondary) system operability state function are recorded as data required for the primary functions. Those data are:

a. the start time for the test

b. the time that each performance period starts (if different from the test start time for the first performance period or the end of the preceding performance period for subsequent performance periods)

c. the time that each performance period ends

d. the time that the test ends (if different from the end of the last performance period of the test)

e. the outcome for each function attempted

f. the outcome for each trial

g. the outcome for each performance period

h. the total number of trials during each performance period

i. the total number of successful trials during each performance period

j. the total number of performance periods during the test

k. the total number of successful performance periods during the test.

[illegible] Data Acquisition Procedure

The basic data will be acquired to describe the primary function outcomes using the CLF and interface monitors as described in Section 6.2. Additional calculations using the primary data and the results of primary function outcomes are required to determine the system operability state.

[illegible] Analytical Procedures

The data will be reduced and analyzed as described in Sections 6.3 and 6.4. As noted above, the data used to calculate the secondary parameters are primary-function data and primary-function outcome data. The secondary-parameter values that will be calculated include:

a. total test time

b. the elapsed time for each successful performance period

c. the aggregate elapsed time for all successful performance periods

d. the elapsed time for each failed performance period

e. the aggregate elapsed time for failed performance periods

f. availability, as the ratio of aggregate successful performance time to total test time

g. the average system operating time between failures

h. the average system failure time.

[illegible]. DETAILS OF INSTRUMENTED WORKSHOP TESTS (BENCH TESTS)

This section, with the use of subsections, will define and describe the bench tests that will be required to verify most system and component specifications that have been used to define required performance in terms of system specific (or engineering-oriented) parameters. Bench tests to determine values for these engineering-oriented parameters often will help the test officer understand some of the user-oriented (system independent) performance results. Additionally, it will be necessary to perform bench tests to obtain engineering-oriented performance data that are required to describe system performance when computer simulations are to be conducted. These bench tests will consist of a series of tests that begin with the Pretest System, Subsystem, or Component Check-out and span all the tests required to be performed, numbered 3.1 through 3.N (where N = the maximum number required). Very often these bench tests will include Receiver Characteristics Tests (3.2), Antenna Characteristics Tests (3.3), and System Characteristics Tests (3.4), but other tests may be identified as required.

3.1 Pretest System, Subsystem, or Component Check-out

3.1.1 Objective(s)

The objectives are to determine that the system, subsystem, or component to be tested is complete and in normal operating condition and that any required support equipment is available, complete, and in normal operating condition prior to start of the test(s).

3.1.2 Criteria (Appropriate Regulation)

a. The system, subsystem, or component to be tested shall be complete and in normal operating condition prior to start of the test(s).

b. Any support equipment required for the system, subsystem, or component to be tested shall be available, complete, and in normal operating condition prior to start of the test(s).

3.1.3 Data Required

a. record of discrepancies existent for the system, subsystem, or component to be tested

b. record of discrepancies existent for required support equipment for the system, subsystem, or component to be tested

c. photographic documentation of any physical damage existent for the system, subsystem, or component to be tested and/or the support equipment required for the system, subsystem, or component to be tested

d. record of all pretest adjustments and repairs performed and all performance checks not met.

3.1.4 Data Acquisition Procedure

The test officer and other technical and maintenance personnel, as required, will conduct the pretest system, subsystem, or component check-out. This check-out will include:

a. Unpack and inventory the system, subsystem, or component to be tested and all required support equipment and compare the contents with packing list to determine if any discrepancies exist.

b. Inspect the system, subsystem, or component to be tested and all required support equipment for evidence of physical damage.

c. Perform a pretest operational performance verification check on the system, subsystem, or component to be tested and all required support equipment, as appropriate.

d. Adjust and/or repair each discrepant condition, if possible.

e. Record all discrepant conditions, including those removed by adjustment and/or repair as well as those not removed.

3.1.5 Analytical Procedure

The data will be used to assist the test officer in determining if the system, subsystem, or component to be tested and all required support equipment are complete, undamaged, in operating condition, and ready for testing.

3.2 Receiver Characteristics Tests

3.2.1 Objective(s)

The objective(s) of receiver characteristics testing must be defined in one or more short, clear statement(s). Different objectives may be necessary for different characteristics tests of the receiver.

3.2.2 Criteria (Appropriate Regulation)

The criterion for performance of the receiver(s) relative to each of the characteristics that is tested must be defined along with the basis for each criterion.

3.2.3 Data Required

Data normally required to define characteristics of a receiver are defined by MIL-STD-449C (Department of Defense, 1963 and 1965) and include the items listed below, as applicable. Items that are important to the characterization of a particular electronic surveillance system receiver may not be included in this standard and should be added, such as items k, l, and m.

a. the types of signals (modulations) to which the receiver will respond

b. sensitivity as a function of frequency for each of the types of signals to which the receiver is intended to respond

c. selectivity as a function of frequency for each of the types of signals to which the receiver is intended to respond

d. spurious responses

e. overall susceptibility at spurious response frequencies

f. intermodulation characteristics

g. pulse desensitization

h. CW desensitization and adjacent signal interference, as appropriate

i. dynamic range

j. oscillator radiation test

k. signal detection bandwidth

l. sweep time for frequency tuning

m. resolution and accuracy in measuring the carrier frequency of a received signal (for each type of signal to which the receiver is intended to respond) when operated in the discrete tuning and scanning modes, as appropriate.

3.2.4 Data Acquisition Procedure

The data will be acquired using the Instrumented Workshop in accordance with the measurement setups and procedures outlined in MIL-STD-449C (Department of Defense, 1963 and 1965).

3.2.5 Analytical Procedures

The data will be reduced, analyzed, and presented in formats consistent with the instructions for presentation of the data given in MIL-STD-449C.

3.3 Antenna Subsystem Characteristics Tests

3.3.1 Objective(s)

The objective(s) of antenna performance testing must be defined in one or more short, clear statement(s). Different objectives may be necessary for different characteristics tests of the antenna subsystem.

3.3.2 Criteria (Appropriate Regulation)

The criteria for performance of the antenna subsystem relative to each of the characteristics that is tested must be defined along with the basis for each criterion.

3.3.3 Data Required

Data normally required to define characteristics of a surface-based antenna are defined by MIL-STD-449C (Department of Defense, 1963 and 1965). Data normally required to define characteristics of an airborne antenna are defined in MIL-A-37136 (U.S. Air Force, 1979). Measurements of the properties that characterize antennas also are comprehensively defined in the IEEE Test Procedure for Antennas, Number 149 (1965). Items that are important to the characterization of an antenna subsystem for a particular electronic surveillance system may not be included in these standards and should be added, as required. Items that normally are important to defining the characteristics of an antenna include:

a. environmental conditions that affect antenna performance

b. radiation patterns as a function of space coordinates and frequency that represent amplitude, phase, and polarization properties of the antenna

c. maximum power gain and directivity of the antenna as a function of frequency

d. radiation efficiency of the antenna as a function of frequency

e. input and mutual impedance characteristics of the antenna as a function of frequency

f. noise temperature of the antenna as a function of frequency.

3.3.4 Data Acquisition Procedure

The data will be acquired using the Instrumented Workshop and the antenna test range in accordance with the measurement setups and procedures outlined in MIL-STD-449C (Department of Defense, 1963 and 1965), MIL-A-87136 (U.S. Air Force, 1979), and/or the IEEE Test Procedure for Antennas (1965), as appropriate.

3.3.5 Analytical Procedures

The data will be reduced, analyzed, and presented in formats consistent with the instructions for presentation of the data given in MIL-STD-449C, MIL-A-87136, and/or the IEEE Test Procedure for Antennas, as appropriate.

3.4 System Characteristics Tests

3.4.1 Objective(s)

The objective(s) of any system performance testing that may be required, to supplement SLF and/or Field Facility testing and/or Computer Simulation, must be defined in one or more short, clear statement(s). Different objectives may be necessary for different characteristics tests of the electronic surveillance system. (System characteristics tests will not be routinely performed, but conducted only as required to understand performance that cannot be understood after completing SLF and/or Field Facility testing as deemed necessary and/or Computer Simulation.)

3.4.2 Criteria (Appropriate Regulation)

The criteria for performance of the system relative to each of the characteristics that is selected for IWS testing must be defined very carefully, along with the basis for each criterion, so as to provide sharp focus to the IWS system characteristics tests.

3.4.3 Data Required

Data required to define system characteristics (engineering-oriented specifications) normally will be system specific, i.e., different sets of data for different systems. It will not be normal procedure to perform system characteristics tests of this type, but such tests may be necessary under unusual situations to understand performance that has been observed for the user-oriented tests. The types of data that may be of interest for electronic surveillance systems include the following:

a. system accuracy in measuring carrier frequency and modulation characteristics, e.g., pulse width, pulse repetition frequency, or pulse repetition interval, etc.

b. bearing accuracy

c. elliptical error accuracy (intersections of multiple bearings from multiple locations

d. signal processing times

e. signal sorting capabilities

f. system clock accuracies

g. speed in recording and/or printing output information

h. self-calibration capabilities

i. self-test capabilities

j. data link capabilities.

3.4.4 Data Acquisition Procedure

The data will be acquired using the Instrumented Workshop and other "bench test" testing capabilities as may be required and appropriate. Data acquisition will be in accordance with measurement setups and procedures outlined in appropriate and applicable standards and good engineering practices.

3.4.5 Analytical Procedures

The data will be reduced, analyzed, and presented in formats consistent with the instructions for presentation of the data given in appropriate and applicable standards and in accordance with good engineering practices.

4. DETAILS OF COMPUTER SIMULATION

This section, with the use of subsections, will define and describe computer simulation that may be required to estimate system performance under normal operating conditions and conditions of intentional and/or unintentional interference. Computer simulation, though it may be much less expensive than testing, usually will require extensive effort to prepare the required input data. These data must describe the technical and operational characteristics of every C-E system and item of equipment that will comprise the environment. Such data to describe the technical characteristics of receivers, transmitters, and antennas must either be estimated or obtained from measurements performed in the IWS (bench tests). There also must be criteria and data for evaluating the performance of systems, both intended performance and performance in response to interfering signals. Data to describe the operational characteristics of the environment must be developed by military scientists through a process that can become very tedious. Furthermore, computer simulation can provide only "snapshots" of system performance in a modeling of the operational situation (scenario) that may be of interest.

4.1 Preparation of Input Data

4.1.1 Objectives

The objective(s) to be met in preparing the input data for computer simulation (analysis) must be clearly and concisely stated. Different objectives will be necessary to satisfy different objectives for the computer simulation.

4.1.2 Criteria (Appropriate Regulation)

The criteria to be followed in preparing the input data for computer simulation must be defined along with the basis for each criterion.

4.1.3 Data Required

Data required to perform computer simulation normally include technical characterizations of all C-E systems and equipments to be included in the scenario deployment along with specification of the operational plan that is to be modeled. This composite of information, known as the electronic order of battle (EOB), will include:

a. a listing of all radiating and receiving (C-E) equipment of the military forces that are represented in the scenario

b. technical characteristics (e.g., modulation, radiated power, emission spectrum, receiver bandwidth, receiver sensitivity, antenna pattern, etc.) for each item of C-E equipment that is represented in the scenario

c. the geometry of the scenario deployment (location of each item of C-E equipment)

d. the operational function of each item of C-E equipment, i.e., all linking of transmitter/receiver pairs that the simulation will consider.

4.1.4 Data Acquisition Procedure

a. Listings of C-E equipment to be included are developed from appropriate Field Manuals.

b. Technical characteristics for C-E equipment to be included are obtained from bench measurements or estimated (e.g., spectrum synthesis, receiver passband synthesis, antenna pattern synthesis and maximum gain calculation, etc.).

c. Scenario deployments and the linking of C-E equipments to simulate communications during combat situations are developed by military scientists who study present and future concepts to develop data that define the deployment of the military units in expected combat situations.

4.1.5 Analytical Procedures

The procedures used to develop the input data for computer simulation are a combination of manual and computer assisted (automated) operations. The product of these operations is a magnetic tape that is suitable for use with the analysis "model."

4.2 Execution of the Computer Simulation

4.2.1 Objective(s)

The objective(s) to be met in performing the computer simulation (analysis) must be stated clearly and concisely. The objective(s) usually will pertain to understanding or verifying some SLF test results or developing an initial understanding of some very complex problem that may subsequently require SLF testing.

4.2.2 Criteria (Appropriate Regulation)

The criteria to be met in performing the computer simulation (analysis) must be defined along with the basis for each criterion.

4.2.3 Data Required

The computer simulation will produce output data from the "model" that describe equipment/system performances for each of the equipments/systems that are represented in the scenario, if desired. These descriptions of performance will be statistical estimates of equipment/system performance, according to the "instructions" for output data given by the "model." Typical information may include:

a. calculated estimates of probabilities of correct performance for equipments/systems of interest or all equipments/systems in the scenario

b. calculated aggregations of the estimates of probabilities of correct performance for equipments/systems of interest in the scenario

c. calculated estimates of received signal level (RSL) for individual equipments/systems of interest in the scenario.

4.2.4 Data Acquisition Procedure

The output data for the computer simulation will be presented as printed and/or plotted information that is formatted to provide the required information about the scenario "snapshot."

4.2.5 Analytical Procedures

The analytical procedures are the assembly of computer subroutines that constitute the "model" which is an implementation of the algorithms developed to perform the required analyses of equipment/system performances.

5. DETAILS OF FIELD FACILITY TESTS

This section, with the use of subsections, will define and describe the tests that may be conducted to verify or supplement understanding of system performance observed during SLF tests and/or from computer simulation. Field facility tests usually will be the tests of "last resort." That is, field tests should be considered only (1) when other test modes and/or computer simulation fail to answer sufficiently the questions being asked concerning performance of the system being tested or (2) when it is clear that these other test/analysis modes are inadequate to perform the evaluation of system performance that is required. Field facility tests may become very involved and expensive. Therefore, it always will be important to carefully plan any field tests that are determined to be necessary, so that only the minimum amount of testing is conducted sufficient to respond to the objectives and criteria of the test(s).

5.1 Pretest System, Subsystem, and/or Component Check-outs

5.1.1 Objectives

The objectives are to determine that the system, subsystem, and/or components to be tested as well as the systems, subsystems, and/or components that will comprise the environment for the test(s) are complete and in normal operating condition and that any and all required support equipments are available, complete, and in normal operating condition prior to start of the test(s).

5.1.2 Criteria (Appropriate Regulation)

a. The system, subsystem, or component to be tested shall be complete and in normal operating condition prior to start of the test(s).

b. Any support equipment required for the system, subsystem, or component to be tested shall be available, complete, and in normal operating condition prior to start of the test(s).

c. The systems, subsystems, and/or components that will comprise the environment for the test(s) shall be complete and in normal operating condition prior to start of the test(s).

d. Any and all support equipment required for the systems, subsystems, and/or components that will comprise the environment for the test(s) shall be available, complete, and in normal operating condition prior to start of the test(s).

5.1.3 Data Required

a. record of discrepancies existent for the system, subsystem, or component to be tested

b. record of discrepancies existent for required support equipment for the system, subsystem, or component to be tested

c. photographic documentation of any physical damage existent for the system, subsystem, or component to be tested and/or the support equipment required for the system, subsystem, or component to be tested

d. record of all pretest adjustments and repairs performed and all performance checks not met for the system to be tested and any required support equipment

e. record of discrepancies existent for the systems, subsystems, and/or components that will comprise the environment for the test(s)

f. record of discrepancies existent for required support equipment for the systems, subsystems, and/or components that will comprise the environment for the test(s).

5.1.4 Data Acquisition Procedure

The test officer and other technical and maintenance personnel, as required, will conduct the pretest system, subsystem, and/or component check-outs. These check-outs will include:

a. Unpack and inventory the system, subsystem, or component to be tested and all required support equipment, and compare the contents with packing list to determine if any discrepancies exist.

b. Inspect the system, subsystem, or component to be tested and all required support equipment for evidence of physical damage.

c. Perform a pretest operational performance verification check on the system, subsystem, or component to be tested and all required support equipment, as appropriate.

d. Adjust and/or repair each discrepant condition, if possible.

e. Record all discrepant conditions, including those removed by adjustment and/or repair as well as those not removed, for the system, subsystem, or component to be tested.

f. Unpack and inventory the systems, subsystems, and/or components that will comprise the environment for the test(s) and all required support equipment, and compare the contents with packing lists to determine if any discrepancies exist.

g. Inspect the systems, subsystems, and/or components that will comprise the environment for the test(s) and all required support equipment for evidence of physical damage.

h. Perform a pretest operational performance verification check on each system, subsystem, and/or component that will comprise the environment for the test(s) and all required support equipment, as appropriate.

i. Adjust and/or repair each discrepant condition, if possible.

j. Record all discrepant conditions that remain uncorrected for the systems, subsystems, and/or components that will comprise the environment for the test(s).

5.1.5 Analytical Procedure

The data will be used to assist the test officer in determining if the system, subsystem, or component to be tested and all associated, required support equipment, as well as all systems, subsystems, and/or components that will comprise the environment for the test along with all required support equipment, are complete, undamaged, in operating condition, and ready for testing.

5.2 Execution of the Field Facility Test(s)

5.2.1 Objective(s)

The objective(s) of field facility testing must be defined in one or more short, clear statement(s). One might wish to measure user-oriented performance, however, the implementation of interface monitors in field testing will be challenging. Or one might wish to measure only some of the many possible engineering-oriented parameters. In other words, different objectives may be necessary for different emphases in the field facility testing.

5.2.2 Criteria (Appropriate Regulation)

The criteria to be met in performing the field facility test(s) must be defined along with the basis for each criterion.

5.2.3 Data Required

Data required to define system performance (engineering-oriented specifications) normally will be system specific, i.e., different sets of data for different systems. The types of data that may be of interest for electronic surveillance systems include the following:

a. system accuracy in measuring carrier frequency and modulation characteristics, e.g., pulse width, pulse repetition frequency, or pulse repetition interval, etc., in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

b. bearing accuracy while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

c. elliptical error accuracy (intersections of multiple bearings from multiple locations) while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

d. signal processing times while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

e. signal sorting capabilities while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

f. speed in recording and/or printing output information while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

g. self-calibration capabilities while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

h. self-test capabilities while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s)

i. data link capabilities while operating in a benign environment as well as in the operational or stressed environment created by the many other systems, subsystems, and/or components deployed for the field test(s).

5.2.4 Data Acquisition Procedure

The data will be acquired using field facility instrumentation that is installed and operated in accordance with good engineering practices.

5.2.5 Analytical Procedures

The data will be reduced, analyzed, and presented in formats that allow for easy comparison with the data taken during other modes of testing (e.g., bench tests, SLF tests, and/or computer simulation). These formats also will be consistent with appropriate and applicable standards and good engineering practices.

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15. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The U.S. Army Electronic Proving Ground (USAEPG) is planning the development of a new test facility to be known as the Stress Loading Facility (SLF). This facility is envisioned as an integrated and automated test capability that will generate a dense electromagnetic threat test environment and simultaneously monitor key performance parameters of a system being tested. This capability is expected to become a part of the Electromagnetic Environmental Test Facility (EMETF), both physically and functionally. However, the SLF will be designed to provide self-contained operation that will be independent of the EMETF, if required. This report reviews current test capabilities that are relevant to the SLF, both within and outside of USAEPG, and develops test methodology for the SLF. The test methodology development follows a structured approach in the selection of parameters that are system independent and, therefore, may be used to describe the performance of various systems that may be tested using the SLF. The study then applies the structured approach to the development of performance descriptions for two typical electronic surveillance systems and develops the associated performance measurement methodology. This methodology covers test design, data collection, data reduction, and data analysis.

16. Key Words *(Alphabetical order, separated by semicolons)*

Automated tests; electromagnetic compatibility; electromagnetic vulnerability; development tests; EMC; EMV; field tests; interference analysis; laboratory tests; simulation; SLF; Stress Loading Facility; system-independent performance parameters; test design; test facility; test methodology

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