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NAVY MANAGER'S GUIDE FOR THE TEST AND EVALUATION SECTIONS OF MI--ETC(U)
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NAVY MANAGER'S GUIDE FOR THE TEST AND EVALUATION SECTIONS OF MIL-H-46855

BOEING Aerospace Company
Logistics Support and Services
Seattle, Washington 98124

June 30, 1977

Prepared for
Naval air Development Center
Warminster, Pennsylvania 18974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Assistance is provided to HFE Navy managers in planning, scheduling, and performing HFE T&E in accordance with the requirements of MIL-H-46855. The emphasis of this guide (as compared to the user's guide) is placed on the planning and scheduling necessary to produce the most cost effective total T&E effort. Both formal and technical T&E program requirements are indicated. Basic T&E considerations such as data inputs, level of detail, timing, and applications are described. Types of HFE T&E techniques are

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20. indicated and a system for choosing or evaluating particular techniques is briefly described. 33 techniques are listed along with brief descriptions of each. A fold-out chart, which integrates much of the guide content into a Navy manager's program planning decision tree, is provided and may be used as a checklist to assist him in his job. A list of personnel surveyed to obtain much of the guide material is included in the appendices.

PREFACE

This guide is the result of work conducted under Naval Air Development Center Contract No. N62269-76-C-0434 between 1 July 1976 and 30 June 1977. Whereas the objective of this Navy Manager's guide is to clarify and expand on the test and evaluation sections of MIL-H-46855, this is only one phase of an effort to develop user's guides for the major portions of MIL-H-46855.

The author is indebted to the following persons for their guidance and contributions:

CDR Paul R. Chatelier, Naval Air Systems Command
Dr. Lloyd Hitchcock, Naval Air Development Center
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1.0 INTRODUCTION

During the course of system development, test and evaluation (T&E) are required to assure that the evolving system meets a myriad of requirements ranging from reduction of technical risks through demonstrating the system's military utility. Generally, two broad categories of test and evaluation are used (Reference 1): Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E), where the former is planned, conducted, and monitored by the Developing Agency (DA) of the system, and the latter is the responsibility of the Operational Test and Evaluation Force (OPTEVFOR). A third category, Production Aceptance Test and Evaluation (PAT&E), is testing conducted on production items to demonstrate that systems meet contract requirements and specifications.

The first two categories of T&E are defined in Reference 1 as follows:

> "DT&E is that test and evaluation conducted to: demonstrate that the engineering design and development process is complete; demonstrate that the design risks have been minimized; demonstrate that the system will meet specifications; and estimate the system's military utility when introduced..."

> "OT&E is that test and evaluation conducted to estimate the prospective system's military utility, operational effectiveness, and operational suitability (including compatibility, interoperability, reliability, maintainability, and logistic and training requirements), and need for modifications. In addition, OT&E provides information on organization, personnel requirements, doctrine, and tactics. Also, it may provide data to support or verify material in operating instructions, publications, and handbooks..."

Human factors engineering (HFE) is an extremely important aspect of the total T&E effort. HFE T&E must be established to:

a) demonstrate conformance of system, equipment and facility design to human engineering design criteria;

b) confirm compliance with performance requirements where man is a performance determinant;

c) secure quantitative measures of system performance which are a function of man-machine interaction; and

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[1] OPNAVINST 3960.10. Department of the Navy. Office of the Chief of Naval Operations, "Test and Evaluation', Washington, D. C., October 1975.

d) determine whether undesirable design or procedural features have been introduced.

1.1 Purpose of the Guide

The objective of this guide is to provide assistance to human factors engineering (HFE) Navy Managers in the planning, scheduling, and performance of human factors engineering T&E in accordance with the requirements of MIL-H-46855 (Reference 2). The requirements of paragraph 3.2.4 through 3.2.4.3 of MIL-H-46855 are interpreted and delineated in terms of the HFE T&E steps and techniques which need to be performed. This guide will help to ensure that the HFE manager includes all appropriate aspects of the total HFE T&E process in system development efforts.

The particular need for this T&E guide has been to select effectively, for a given type of program, just which HFE T&E techniques should be performed, when and how to perform them, how their results will be used, and what their relative cost will be. These technique selection criteria enable the Navy manager to develop realistic, objective planning within the monetary and time constraints of a program. This document provides guidelines for the HFE manager that are based on both Navy and industry surveys of T&E experience and needs. The guide lists and explains the basis criteria for choosing various T&E techniques. It provides the basis for matching particular techniques to particular applications, and it describes in general how to use the various techniques.

This guide may be used at all levels of program design and procurement, including analysis; however, it is designed more specifically for the Navy manager to use during the later design development test and evaluation stages.

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[2] MIL-H-46855, Human Engineering Requirements for Military Systems, Equipment and Facilities, 2 May 1972.

1.2 Scope of the Guide

This document assumes Navy manager knowledge of basic HFE concepts. It presents the significant aspects of HFE T&E alone rather than material on the complete field of human factors engineering. A complete description of human factors engineering as well as its typical applications and value may be found in several HFE textbooks. A detailed description of the analysis sections of MIL-H-46855 is contained in References 3 and 4. These two analysis guides have been prepared as part of a total effort to amplify and interpret the requirements of MIL-H-46855.

This guide contains a description of specific HFE T&E tasks and techniques. It indicates, in general, how to go about implementing or using these tasks and techniques and the best time to use them. Comments are included regarding general technique selection and usefulness.

The guide will be of use in preparing RFP's (Request for Proposals) and in the review of HFE Test and Evaluation Plans and HFE Program Plans in particular. A program planning decision tree checklist for Navy HFE managers is included in Section 2.3 of this guide. This decision tree checklist indicates the decisions to be made and actions to be taken in preparing an RFP or during the monitoring of the MIL-H-46855 T&E effort.

A similar guide to this has been prepared for use by HF engineers (Reference 5). It includes most of the same material; the major difference in that guide is in additional detail presented in the sections on HFE T&E tasks and techniques. The section on program planning in the HF engineer's guide is modified appropriate to the HF engineer's point of view.

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[3]Geer, C. W., Navy Manager's Guide for the Analysis Sections of MIL-H-46855, D180-19476-2, Boeing Aerospace Company, Naval Air Development Center, June 1976.

[4]Geer, C. W., Analyst's Guide for the Analysis Sections of MIL-H-46855, D180-19476-1, Boeing Aerospace Company, Naval Air Development Center, June 1976.

[5]Geer, C. W., User's Guide for the Test and Evaluation Sections of MIL-H-46855, D194-10006-1, Boeing Aerospace Company, Naval Air Development Center, June 1977.

In Appendix A there is a list of all the various organizations that were contacted in order to determine the kind of data which should be contained in the two guides. These individuals were interviewed directly as to their T&E experience, problems, and needs. The appendices also contain information on definitions/acronyms pertaining to this guide, and the T&E sections of MIL-H-46855.

2.0 HFE TEST AND EVALUATION APPROACH

This section of the guide describes a general approach to the HFE T&E effort. It includes both the formal and the practical (or technical) reasons for performing HFE T&E. The approach to this HFE T&E effort is detailed by a program planning decision tree diagram and by a section describing the basic HFE T&E technique considerations of a) data inputs, b) timing, c) level of evaluation detail, and d) evaluation applications.

2.1 Formal Requirements

The formal requirements for performing test and evaluation are found in certain Department of Defense (DoD) directives and SECNAV (Secretary of Navy), NAVMAT (Chief of Navy Material), and OPNAV (Chief of Naval Operations) instructions. The particular formal requirements for HFE and HFE T&E, are found in NAVMATINST 3900.9 (Reference 6). Additional requirements for HFE T&E are also found in MIL-H-46855. Two Data Item Descriptions (DID's) have been developed for use in performing HFE T&E. There are also several guides, handbooks, and general literature sources on the subject of HFE T&E. Some of the most important formal HFE T&E requirements are always to be found in the program contract, including the system specification and statement-of-work. While the military is largely controlled by directives and instructions, contractors are controlled by military specifications/standards and DID's. Guides, handbooks, general literature and the attitudes of both the procurement agency and contractor tie military and contractor HFE T&E efforts together.

2.1.1 T&E Directives and Instructions

In 1971, the Deputy Secretary of Defense promulgated the policy for major defense system acquisition via DoD Directive 5000.1, "Major Systems Acquisition" (Reference 7). Included within this directive is the

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[6] NAVMATINST 3900.9, Department of Navy, Headquarters Naval Material Command, "Human Factors", Washington, D. C. 20360, September 1970.

[7] DoD Directive 5000.1, Department of Defense, "Major Systems Acquisition", Washington, D. C. 20301, January 1977.

requirement to formalize and incorporate T&E into the early program development stages. This directive also required the Navy to upgrade and expand T&E of all weapon systems to include testing in a simulated combat environment as a prerequisite for procurement. SECNAVINST 5000.1 implemented this system acquisition policy within the Navy. Reference 8 presents the Defense System Acquisition Review Council (DSARC) review requirements for weapons systems acquisition, and translates the review checklists (DSARC milestones) into HFE requirements.

DoD Directive 5000.3, "Test and Evaluation" (Reference 9) establishes policy for the conduct of test and evaluation by the Military Departments and Defense Agencies. It directs the developing agency of the DoD component to initiate T&E as early as possible and to continue throughout the system acquisition process as necessary to assist in progressively reducing acquisition risks and in assessing military worth. In addition, DoD Directive 5000.3 requires that the acquisition schedules be based upon accomplished T&E milestones prior to the time key decisions are to be made, which would commit significant additional resources.

NAVMATINST 3960.6, "Planning and Implementation of Tests and Evaluations of New Weapon Systems", (Reference 10) provides guidance for the planning and implementation of tests and evaluations required as a part of the system acquisition process. This instruction provides guidance for preparing the Test and Evaluation Master Plan (TEMP).

OPNAVINST 3960.10, "Test and Evaluation", (Reference 1) establishes policies for T&E in Navy acquisition programs and defines T&E responsibilities

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[8] Holshouser, E. L., Translation of DSARC Milestones into Human Factors Engineering Requirements, Pacific Missile Test Center, Point Mugu, Calif., 93042, TP-75-58, AD-3006927L, September 1975.

[9] DoD Directive 5000.3, Department of Defense, "Test and Evaluation", Washington, D. C. 20301, January 1973.

[10] NAVMATINST 3960.6, Department of Navy, Headquarters Naval Material Command, "Planning and Implementation of Tests and Evaluations of New Weapons Systems", Washington, D. C. 20350, August 1973.

for various organizations. It establishes procedures for planning, conducting, and reporting T&E. It describes the relationship between developmental and operational T&E and it establishes procedures and a format for test and evaluation master plans (TEMP's). It also establishes procedures for obtaining fleet RDT&E (Research Development Test and Evaluation) Research and Development (R&D) that is not part of an acquisition program. Three distinct phases of T&E are defined by this instruction. The relationship between these phases is discussed in Section 3.0.

NAVMATINST 3900.9, "Human Factors", establishes policies and requirements necessary to insure adequate development of human factors aspects of systems and equipment. This includes all development, test and evaluation, and production programs and projects. This instruction states that the human element of the Navy systems shall undergo the same development, test and evaluation steps as equipment elements of the same system.

2.1.2 Military Specifications and Standards

The primary source for contractor HFE T&E requirements is MIL-H-46855. A copy of the sections pertinent to analysis is contained in Appendix C. Figure 2.1-1 shows each of the major MIL-H-46855 sections in functional relation to each other. Section 3.2.4 "Perform HE Test and Evaluation" is the function/section most pertinent to this guide. It is divided into three subsections: planning, implementation, and failure analysis.

Unless otherwise contractually noted, Section 3.2.4 and its subsections are the detailed requirements in MIL-H-46855 necessary to provide an adequate HFE T&E program. Paragraph 3.2.4 indicates most of the tasks which must be performed by contractors. Paragraph 3.2.4.1 (Planning) emphasizes the need for HFE tests integrated along with other system tests in order to save the cost/duplication of completely separate testing. Early testing, in accordance with this paragraph, will also save the cost of unnecessary late system rework. Paragraph 3.2.4.2 (Implementation) contains a list of test tasks to be performed in order to insure a complete HFE T&E program. Paragraph 3.2.4.3 (Failure Analysis) emphasizes the need to investigate human error. HFE T&E techniques listed in later sections of this guide may be used to accomplish this requirement for human failure analysis.

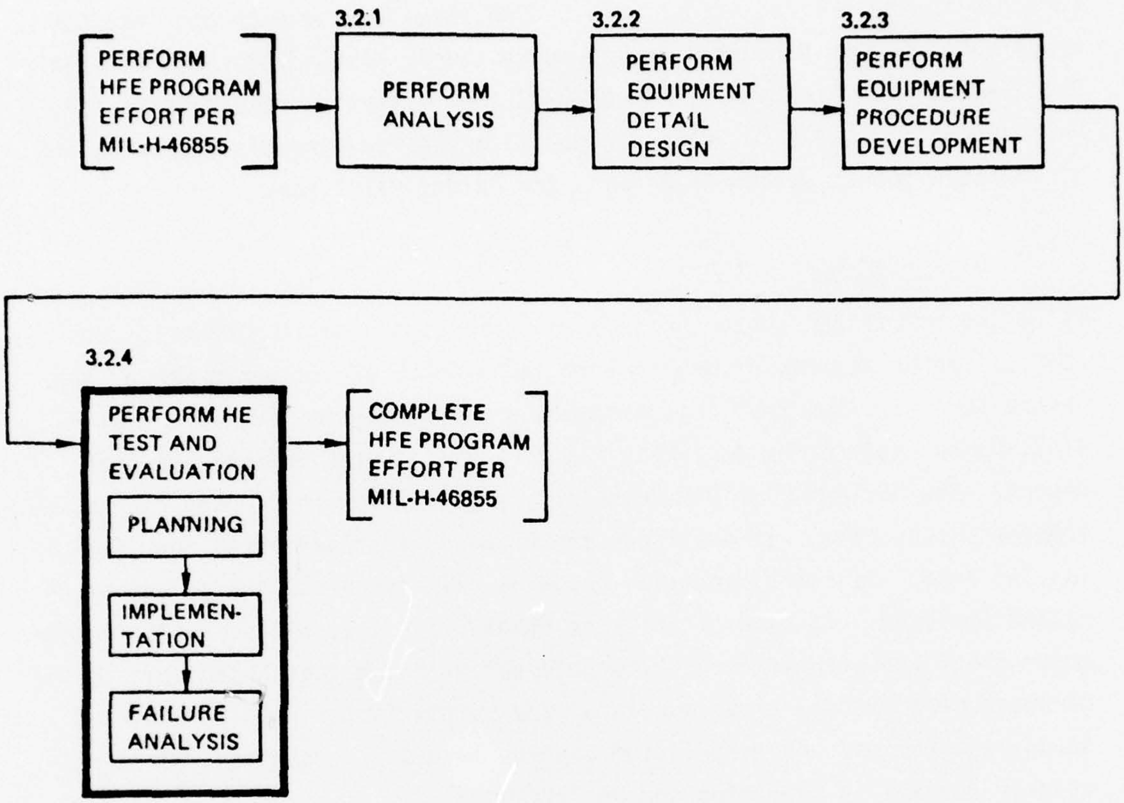

Figure 2.1-1, MIL-H-46855 Section Functional Relationships

The primary source of HFE design criteria to test to is in MIL-STD-1472 (Reference 11). This standard presents HE design criteria, principles, and practices to be applied in the design of systems, equipment and facilities. The purpose of HFE T&E in regard to this standard is to insure: operator/maintainer required performance is achieved; skill, personnel, and training requirements are minimized; required reliability of personnel-equipment combinations is achieved; and the design within and among systems is standardized. There are several other standards that contain design criteria which may need to be verified during HFE T&E. However, they are too numerous to list here.

In addition to MIL-H-46855, the following specifications are of some importance to the HFE T&E effort: MIL-D-8706 (Engineering Data and Test Contract Requirements for Aircraft Weapon Systems); MIL-D-8708 (Demonstration Requirements for Airplanes); MIL-D-23222 (Demonstration Requirements for Helicopters); MIL-M-8650 (General Specification for Aircraft Mockups); and MIL-M-18828 (Construction of Mockups for Guided Missiles).

2.1.3 Data Item Descriptions

If called for in the system program contract, the Data Item Descriptions (DID's) can be extremely important to the HFE T&E effort performed by the contractor. The two most important DID's pertaining to HFE T&E are DI-H-2105, Human Engineering Test Plan and DI-H-2111, Human Engineering Test Report. The HE Test Plan DID describes in detail how to prepare the contractor's test plan. It describes the proposed approach taken for obtaining T&E data. It establishes and explains all standards, tests, and associated analyses. It also establishes other means that will constitute adequate proof upon completion of the development phase that acceptable levels of human performance, time, accuracy, and safety factors can be achieved in operational use under specified manning levels. Reference 12 is particularly helpful in preparing the HE Test Plan.

The HE Test Report DID describes how to prepare the documentation associated with contractor tests. The test report is to be used by the procuring activity to assure that the man-equipment interface requirements for the operation and maintenance of the system conform to the contractual requirements.

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[11] MIL-STD-1472B, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, 31 December 1974.

2.1.4 Guides, Handbooks, and General Literature

This category of HFE T&E requirements is by far the most voluminous, and it includes several data sources of note. The Department of the Navy RDT&E Management Guide (Reference 13) is a good source of general Integrated Logistics Support (ILS) T&E requirements. Reference 14 is an excellent summary of policy and procedures for HFE T&E which can serve as a useful guide for gaining an overview of the scope of the HFE T&E effort. Reference 15, Human Factors Evaluation in System Development, is an excellent textbook source for HFE T&E data. General theory, data collection, and analysis methods are thoroughly presented.

References 16, 17, 18, and 19 are also particularly useful documents.

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[12] Holshouser, E. L., Guide to Human Factors Engineering General Purpose Test Planning (GPTP), Pacific Missile Test Center, Point Mugu, Calif., 93042, 1st Iteration, September 1976.

[13] Department of the Navy Management Guide, NAVSO P-2457 (Rev. 1-75), 1 January 1975.

[14] Holshouser, E. L., Human Factors Engineering Policy and Procedures for Test and Evaluation of Navy Systems, TP-75-15, Pacific Missile Test Center, AD-B006035L, July 1975.

[15] Meister, D., and Rabideau, G. F., Human Factors Evaluation in System Development, John Wiley and Sons, New York, 1965.

[16] Askren, W. B., and Newton, R. R., Review and Analysis of Personnel Subsystem Test and Evaluation Literature, AFHRL-TR-68-7, AFHRL, AFSC, W-PAFB, January 1969.

[17] Keenan, J. J., et. al., Concepts and Practices in the Assessment of Human Performance in Air Force Systems, AMRL-TR-65-168, AD 625 041, Aerospace Medical Research Laboratories, W-PAFB, September 1965.

[18] Myers, L. B., et. al., Guidebook for the Collection of Human Factors Data, Report PTB 66-3, AD 631 023, HRB - Singer, Inc., State College, Pennsylvania, January 1966.

[19] Rabideau, G. F., "Field Measurement of Human Performance in Man-Machine Systems", Human Factors, December 1964.

2.2 Technical Requirements

These are the important "real world" requirements such as design criteria, safety, training, and life support that the HFE observer/evaluator needs to ensure are verified as integral to the system design being evaluated. The system must meet these requirements in order to insure the adequacy of the man/machine interface. Table 2.2-1 lists each of these requirements in a matrix comparison with the techniques presented in Section 5.0. The purpose of this matrix is to show quickly which techniques may be used to test and evaluate the system in order to verify compliance with these technical requirements. Each of these technical requirements is presented in the following subsections along with a brief summary of the reasons for the importance of their test and evaluation.

2.2.1 Human Performance

All systems require a degree of human performance in order to function as specified. In order to meet system performance requirements such as speed, maneuverability, range, or turnaround time, the operators and maintainers must meet certain minimum requirements for performing their assigned tasks. These requirements are most always in terms of time to perform a task or accuracy (or reliability) with which a task must be performed. The planned operator/maintainer task times and error rates must therefore be verified by HFE observation and test.

2.2.2 Design Criteria

Human engineering design criteria are the kinds of requirements contained in MIL-STD-1472 (Reference Section 2.1.2). The incorporation of these criteria into the hardware design insures a relatively high degree of operator/maintainer performance. These criteria are based on several years of experience as to the design features or details that tend to minimize operator errors or slow operator performance. Many of these design requirements are based on lab experiments and quantified comparative data. For each of the basic system functions, there should be certain HE criteria that should be incorporated into the design and should therefore be evaluated to insure its existence. General categories of HE design criteria include: displays, controls, labeling, workspace layout, and maintainability.

Table 2.2-1: HFE T&E Technical Requirements vs. Techniques

SPECIFIC HFE T&E TECHNIQUES/TOOLS	TECHNICAL REQUIREMENTS							
	PAGE REFERENCE	HUMAN PERFORMANCE	DESIGN CRITERIA	SAFETY	TRAINING	PERSONNEL SKILL/QUANTITY	TECHNICAL PUBLICATIONS	LIFE SUPPORT CRITERIA
MANUAL DIRECT:								
CONTINUOUS OBSERVATION	37	•	•	•	•	•	•	•
SAMPLED OBSERVATION	37	•	•	•	•	•	•	•
DESIGN CRITERIA CHECKLIST	37		•	•				•
SPEC COMP SUMMARY SHEET	38	•	•					•
T.O. FUNCT EVALUATION	38						•	
HPR TESTING	38	•						
HFTEMAN	39		•	•				•
G-2/G-5 ANTHROPOMETERS	39		•	•				
TERRAIN VISIBILITY DEF	39		•					
ENV & PERF MEAS. EQUIP.	40	•	•	•				•
MANUAL SYS MEASUREM'TS:								
SYSTEM RECORDS REVIEW	40	•		•	•	•	•	
HUMAN INITIATED FAILURES	40	•	•			•	•	
TEST PART. HISTORY RECORD	41				•	•		
MANUAL INDIRECT:								
INTERVIEWS	41	•	•	•	•	•	•	•
QUESTIONNAIRES	41	•	•	•	•	•	•	•
FUNCT DESC INV(FDI)	42			•	•	•		
PAARS	42	•				•	•	
COOPER-HARPER	43		•	•				
PROBLEM INCIDENT REP	43	•	•	•		•	•	•
AUTOMATIC RECORDING:								
MOTION PICTURES	43	•	•	•	•	•	•	•
SOUND TAPES	44	•	•	•	•	•	•	•
VIDEO TAPES	44	•	•	•	•	•	•	•
PHOTOGRAPHY	44	•	•	•	•	•	•	•
EVENT RECORDING	44	•						
OPREDS	44	•			•	•	•	
SECONDARY TASK MON.	45	•				•		
AUTOMATIC PHYSIOLOGICAL:								
PHYSIOLOGICAL INSTRUMENTAITON	45	•						•
PHYSICAL MEASUREMENT	45	•				•		
SIMULATION:								
CGE	46		•	•				
CAR	46		•	•				
CAPE	46		•					
FOVEA	47		•					
ONLINE INTERACTIVE	47	•			•	•	•	

2.2.3 Safety

This is a special category of design criteria that is listed here and in other documentation separately in order to add emphasis to its importance. As is the case with other design criteria, lab tests and experience have indicated that certain design requirements (e.g., rails on stairs) inherently increase the system safety.

2.2.4 Training

Depending on the organizational setup or "charter" of a particular HFE T&E group, the evaluation of test participant training may or may not be necessary by the HFE group. Certainly training is an important aspect of a total system test. All other HFE aspects may be properly provided for but improper training of participants may be sufficient cause to ruin an otherwise successful test. Training requirements may be evaluated in terms of type duration, and detail.

2.2.5 Personnel Skill/Quantity

Closely associated with training is the test participant skill level. This is a combination of his training on other systems somewhat related to the present system being tested and his aptitude for the type of work he is performing. Quantity simply refers to the number of test participants performing each of the operator/maintainer tasks. The fact that the proper number, too many, or too few operators are assigned to a test task should be observed and reported.

2.2.6 Technical Publications

This technical requirement is similar to the training requirements in that it is often not the job of HFE observers to evaluate. However, technical publications (tech orders or job manuals) are a very important part of the total system under test. In most instances, test participants operate or maintain the system under test in accordance with procedures that have been developed for the particular system function. Just as it is necessary that the prototype hardware be tested and evaluated, so must the "prototype" or preliminary technical publications be tested. This evaluation should include how well the technical data meets the requirement to provide easily understandable and accurate procedural data. Technical narrative, diagrams, illustrations, and photographs should all be evaluated.

2.2.7 Life Support Criteria

Life support criteria is another special category of design criteria. It is listed here separately from design criteria to add emphasis to these requirements. Life support requirements include: atmospheric conditions, noise, vibration, shock, toxicology, radiology, lighting, psychophysiology, fatigue, clothing, and personal equipment. In many man/machine system designs, life support requirements are relatively insignificant. However, in high performance systems and those requiring closed loop environmental control, life support requirements are particularly critical.

2.3 Decision Making Structure

There are a considerable number of decisions that must be made and actions taken by the HFE observer/evaluator during the HFE T&E program effort phase. The decision tree fold-out provided in this section of the guide (Figure 2.3-1) is designed to aid the Navy HFE manager in determining the proper decisions and actions. Its further purpose is to provide the HFE manager with planning assistance and checklist items to ensure inclusion of all necessary tasks and data in the T&E program. This diagram is designed to be an adjunct to the General Purpose Test Planning (GPTP) (Reference 12) diagrams.

The Human Engineering Test Plan is developed as a result of specified program office requirements and Data Item Description (DID's) which are called out in program statements-of-work (SOW's). The GPTP indicates how to prepare this Human Engineering Test Plan which is the documentation of how the HFE effort will be accomplished. The GPTP diagrams are designed to assist the contractor HFE manager and observer/evaluator in preparing the HE test plan. The diagram in this section is intended to assist in the initial phase of an HFE T&E effort.

The pertinent decisions and possible actions have been placed on the flow chart diagram in blocks adjacent to other associated or related decision and action blocks. Arrows are provided between the blocks to indicate the direction of sequence of task action. The placement of several blocks on a single page with connecting arrows allows the Navy manager to see quickly relationships between each of the tasks that he must accomplish. A narrative description of these same HFE T&E tasks and task relationships would undoubtedly be hopelessly complex.

2.4 Basic Considerations

There are several important considerations pertaining to the HFE T&E effort which are in addition to the appropriate sections of MIL-H-46855, the program office manager's guidelines, Navy policy, and the other constraints indicated in Sections 2.1, 2.2, and 2.3. These considerations consist of the type of data required to start an HFE T&E effort, the timing as to when to perform the T&E, the level of T&E detail required, and the type of specific results normally expected from the HFE T&E effort. This section pertains to these basic considerations in relation to the overall HFE T&E effort.

2.4.1 Data Inputs

These consist of criteria or human performance requirements that are to be determined or verified by T&E. They may be system or mission requirements established early in the program. They may be military specifications and standards criteria. Operator/maintainer requirements (and assumptions) developed out of MIL-H-46855 analysis effort should be available for evaluation. Ideally, these data are available from a program data retrieval system (e.g., FLAG). They may be available from a technology other than HFE. In any case, T&E should be conducted against set test criteria (success criteria) and if the data does not exist, it must be generated.

2.4.2 Timing

Without the proper scheduling of the HFE T&E effort, it can turn out to be of little use to the system design. It is not sufficient just to perform

GENERAL REQ'MT

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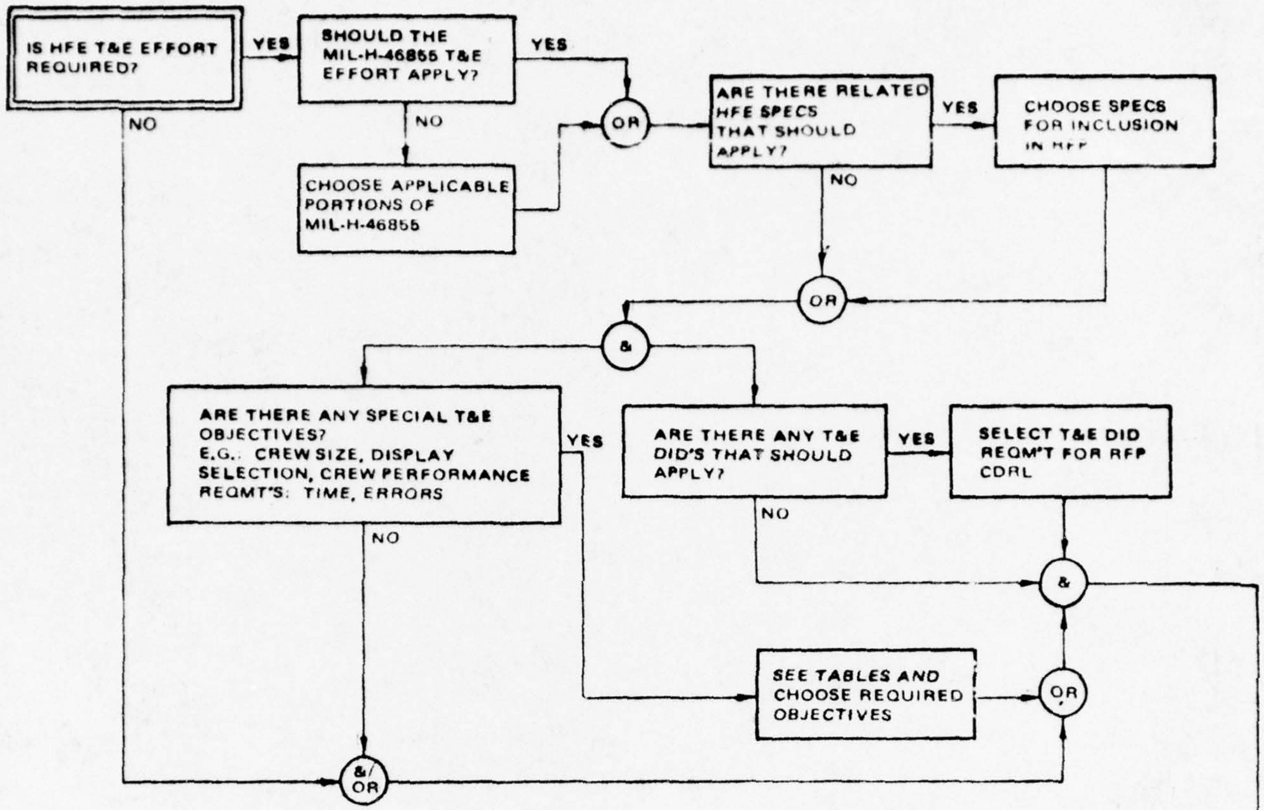

ALLOCATION OF EFFORT

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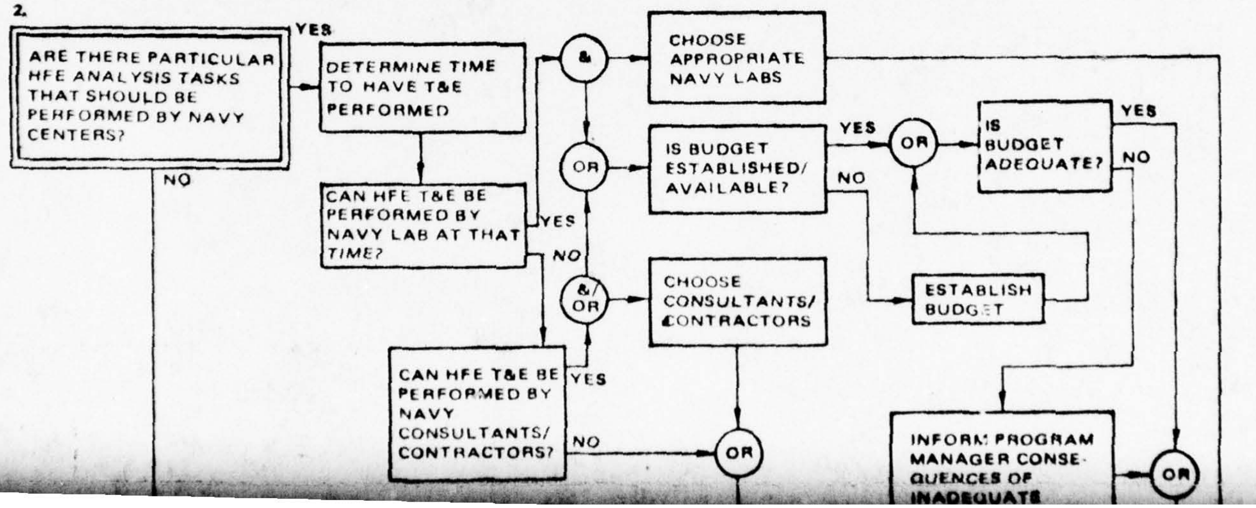

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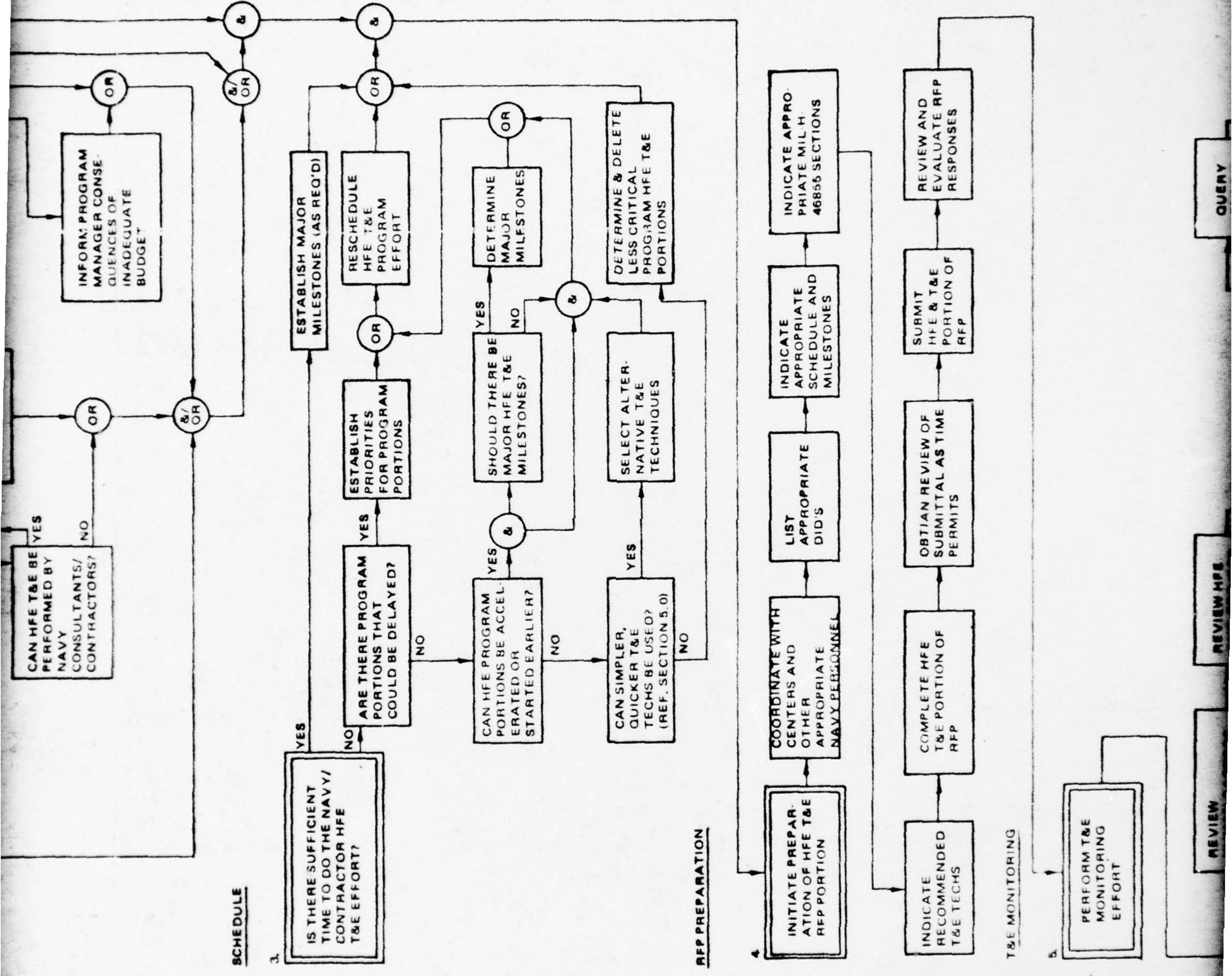

Figure 2.3-1: Navy Manager's Program Pla

3

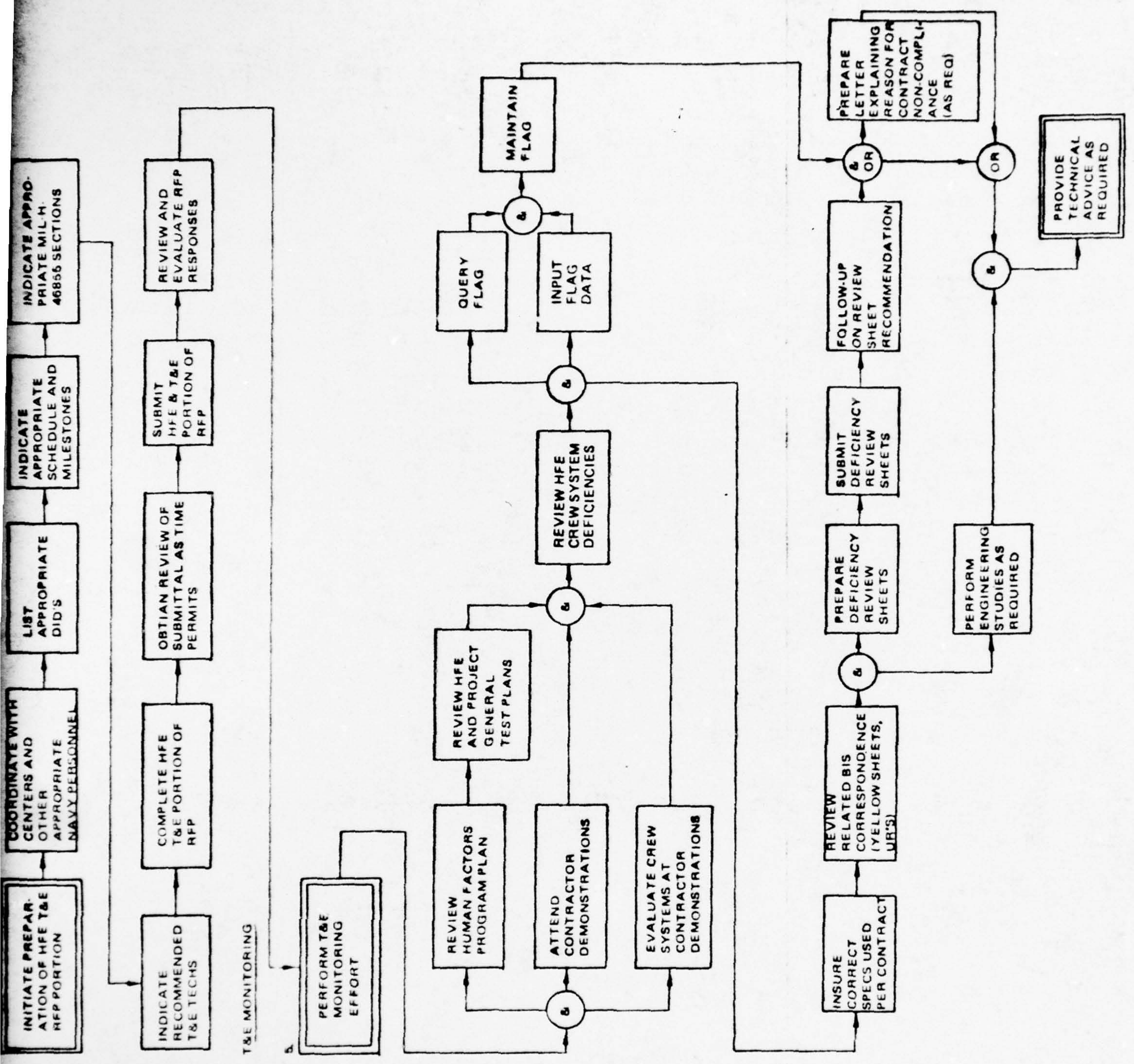

Figure 2.3-1: Navy Manager's Program Planning Decision Tree

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HFE T&E. It is equally important to demonstrate that the results of the effort will be completed or partially completed at a point in the schedule when it can properly impact the system design. All too often, HFE T&E is performed as an after-the-fact documentation exercise or just a workaround procedure that appears in a technical publication. The later the design is tested, the less chance there is to modify the crew station or other man/machine interface. Late findings of serious crew system problems can be extremely expensive, both in accidents and system redesign.

2.4.3 Level of Detail

The level of T&E detail that must be performed is significant to the HFE manpower effort. If the wrong emphasis is given to the amount of detailed data gathering, HFE T&E may be wasted by either obtaining data that has no use or by failing to obtain sufficiently detailed data to be useful. It is the job of the HFE manager/observer to decide what level of T&E will lead to worthwhile data or useful design criteria. For example, new system designs or programs often contain requirements that are identical to previously designed and tested systems. There is probably no point in repeating a detailed HFE T&E of all the system functions and operator tasks that have already been evaluated. It is simply not cost effective, especially when new program schedules and manpower budgets are extremely limited. The old system test and evaluation results should provide all the data that would be needed for that portion of the new system design criteria.

The effort that should be expended during the new program is on the new and potentially critical functions and tasks. These are the kinds of tasks that appear to be marginal in terms of operator reliability, time performance, or safety hazards. The level of test and evaluation detail attempted for such tasks should be as far down as possible to the subtask element (indicator monitoring/button pushing) based on program timing/scheduling.

2.4.4 Applications

The end products of the HFE T&E effort are to verify system design, discover system inadequacies, provide recommendations for design or other system changes, and provide information for a data bank of human performance and crew systems design related data to be used on later programs. These outputs may be left in the form of the T&E technique worksheets. More probably, the outputs should be condensed and otherwise modified to make them more easily understood by the program design personnel and others who have use of them. (See Reference 10 for GPTP guide for standardized formats). Table 2.4-1 shows the applications for data developed from using the various listed T&E techniques.

Table 2.4-1, HFE T&E Techniques Data Applications

SPECIFIC HFE T&E TECHNIQUES/TOOLS / APPLICATIONS	PAGE REFERENCE	CONCEPT FORMULATION IDEAS	DETAILED DESIGN REQUIREMENTS	PERSONNEL REQUIREMENTS INFO	OPERATIONAL PROCEDURES DEVELOPMENT	TRAINING SYSTEM DEVELOPMENT	MAINTENANCE SYSTEM DEVELOPMENT	SYSTEM OPERATIONAL EVALUATION	ADDITIONAL HUMAN FACTORS ANALYSIS	HFE DATA STORE INFO (FLAG)
MANUAL DIRECT:										
CONTINUOUS OBSERVATION	37	●	●	●	●	●	●	●	●	●
SAMPLED OBSERVATION	37	●	●	●	●	●	●	●	●	●
DESIGN CRITERIA CHECKLIST	37		●				●	●		●
SPEC COMP SUMMARY SHEET	38		●				●	●		●
T.O. FUNCT EVALUATION	38				●		●	●	●	●
HPR TESTING	38						●	●	●	●
HFTEMAN	39		●				●	●		●
G-2/G-5 ANTHROPOMETERS	39	●	●					●		●
TERRAIN VISIBILITY DEF	39	●	●					●		●
ENV & PERF MEAS. EQUIP.	40	●	●					●		●
MANUAL SYS MEASUREM'TS:										
SYSTEM RECORDS REVIEW	40			●	●	●	●	●	●	●
HUMAN INITIATED FAILURES	40		●	●	●		●	●	●	●
TEST PART. HISTORY RECORD	41			●		●		●	●	●
MANUAL INDIRECT:										
INTERVIEWS	41	●	●	●	●	●	●	●	●	●
QUESTIONNAIRES	41	●	●	●	●	●	●	●	●	●
FUNCT DESC INV(FDI)	42			●		●		●	●	●
PAARS	42			●	●		●	●	●	●
COOPER-HARPER	43		●					●		●
PROBLEM INCIDENT REP	43		●	●	●		●	●	●	●
AUTOMATIC RECORDING:										
MOTION PICTURES	43	●	●	●	●	●	●	●	●	
SOUND TAPES	44	●	●	●	●	●	●	●	●	
VIDEO TAPES	44	●	●	●	●	●	●	●	●	
PHOTOGRAPHY	44	●	●	●	●	●	●	●		
EVENT RECORDING	44	●					●	●	●	●
OPREDS	44			●	●	●		●	●	●
SECONDARY TASK MON.	45	●		●				●	●	●
AUTOMATIC PHYSIOLOGICAL:										
PHYSIOLOGICAL INSTRUMENTATION	45	●						●		●
PHYSICAL MEASUREMENT	45	●		●				●	●	●
SIMULATION:										
CGE	46	●	●							●
CAR	46	●	●							●
CAPE	46	●	●							●
FOVEA	47	●	●					●		●
ONLINE INTERACTIVE	47	●		●	●	●			●	●

3.0 TYPES OF HFE TEST AND EVALUATION

As indicated in the introductory section of this guide, there are different types of T&E. The definitions provided there are precise since they are based on the Reference 1 instruction. There are additional detailed definitions provided in Reference 1 that are included in this section of the guide. There are also included herein the less formal definitions which are based on either system program schedules or funding sources.

3.1 Informal vs. Formal T&E

In attempting to develop an integrated HFE T&E technology, one needs to recognize that different types of test and evaluation are involved in systems development (both in DT&E and OT&E): One, called HFE "t&e" (lower case) is predominant in design concept feasibility efforts and in selection from design configuration alternatives. Design concept feasibility efforts are exploratory in nature. They are extremely dependent upon paper analysis. The observation, experimentation and testing activities in this category are oriented to the goal of developing new knowledge. The selection of design configuration alternatives is a resolution process in which trade studies are performed and evaluated. The other type of test and evaluation, labeled HFE "T&E", is predominant in system performance verification. System performance verification is performed with mockups and prototype hardware. The objective which characterizes this category is one of determining whether a man-machine system, as designed, meets its performance requirements. Systems performance verification is a much more formal test and evaluation than the lower case "t&e". It is this latter type of T&E (capital letters) which is covered by this guide since the applicable paragraph in MIL-H-46855 carries the heading "Human Engineering in Test and Evaluation". At the same time, HFE "t&e" may be called for (both exploratory and resolution) when system program Engineering Change Proposals (ECP's) are required. The relationship between these differential aspects is illustrated in Figure 3.1-1.

3.2 OPNAVINST 3960.10 Definition

OPNAVINST 3960.10 (Reference 1) makes a formal distinction between three types or phases of T&E. These are Development Test and Evaluation (DT&E),

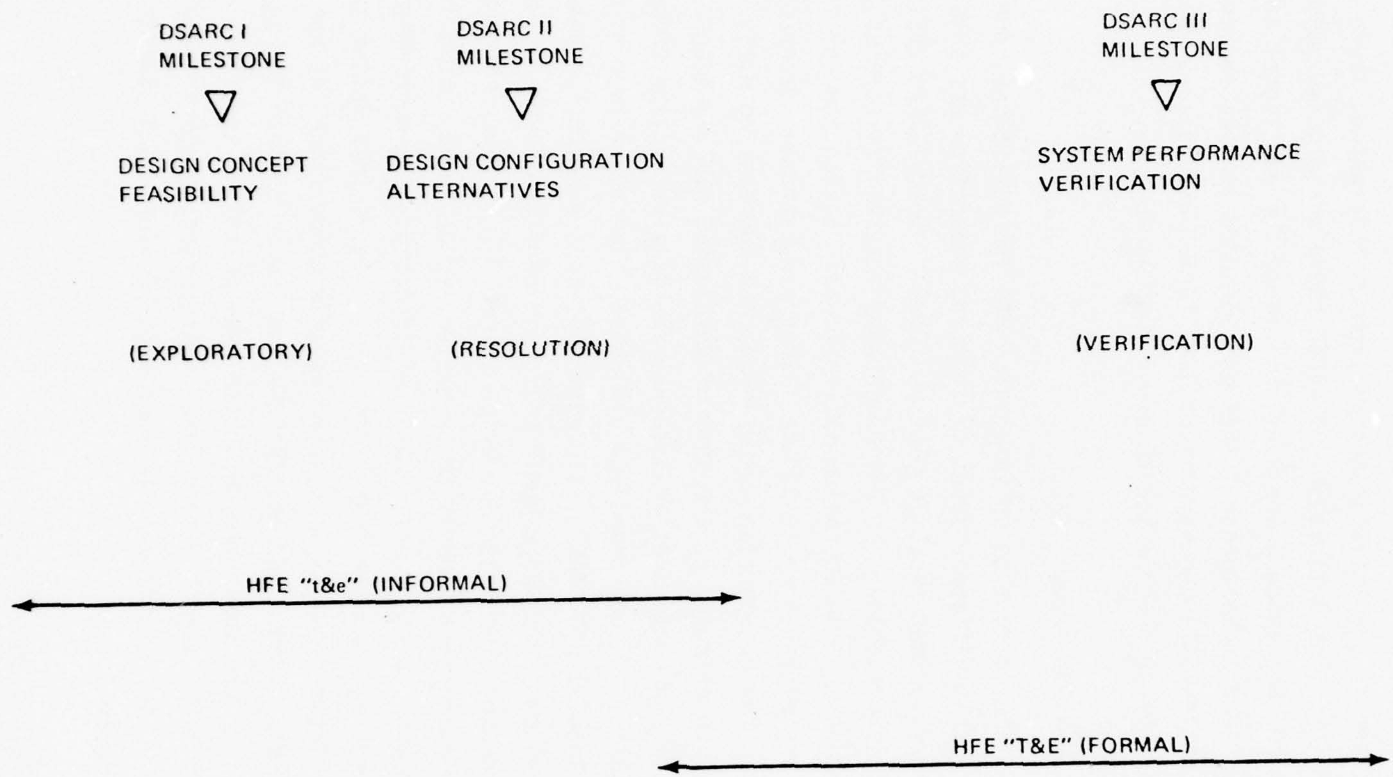

Figure 3.1-1: Informal vs. Formal Aspects of HFE T&E

Operational Test and Evaluation (OT&E), and Production Acceptance Test and Evaluation (PAT&E). These types of T&E are shown in relation to each other, to their subphase elements, and to the program phases and milestones in Figure 3.2-1. It is interesting to compare this figure with the Figure 3.1-1 definition of T&E by phases.

3.2.1 DT&E

DT&E is required for all acquisition programs and is conducted in four major phases:

a) DT-I is DT&E conducted during the conceptual phase to support the program initiation decision. It consists primarily of analysis and studies to derive the human factors/system requirements.

b) DT-II is DT&E conducted during the validation phase to support the full scale development decision. It demonstrates the design risks have been identified and minimized. It consists of verifying the results of the special analysis and studies including modeling and simulation on the critical areas identified earlier. It is normally conducted at the subsystem/component level, up to and including employment of engineering models for final evaluation.

c) DT-III is DT&E conducted during the full scale development phase to support the first major production decision. It demonstrates that the design meets its specifications in performance, reliability, maintainability, supportability, survivability, system safety, and electromagnetic vulnerability. This phase may be further subdivided into additional phases, such as contractor technical evaluation (CTE) and formal Navy technical evaluation (NTES). The final subphase of DT-III is TECHEVAL, the purpose of which is to certify that the design meets specified requirements and is ready for OPEVAL (operational evaluation).

d) DT-IV is DT&E conducted after the first major production decision to verify that product improvements, or correction of design deficiencies discovered during OPEVAL, FOT&E (follow-on test and evaluation), or fleet employment, are effective.

3.2.2 OT&E

OT&E is required for all acquisition programs except for those programs designated by Chief of Navy Material. OT&E is subdivided into two major categories: initial OT&E (IOT&E), which is all OT&E accomplished prior to

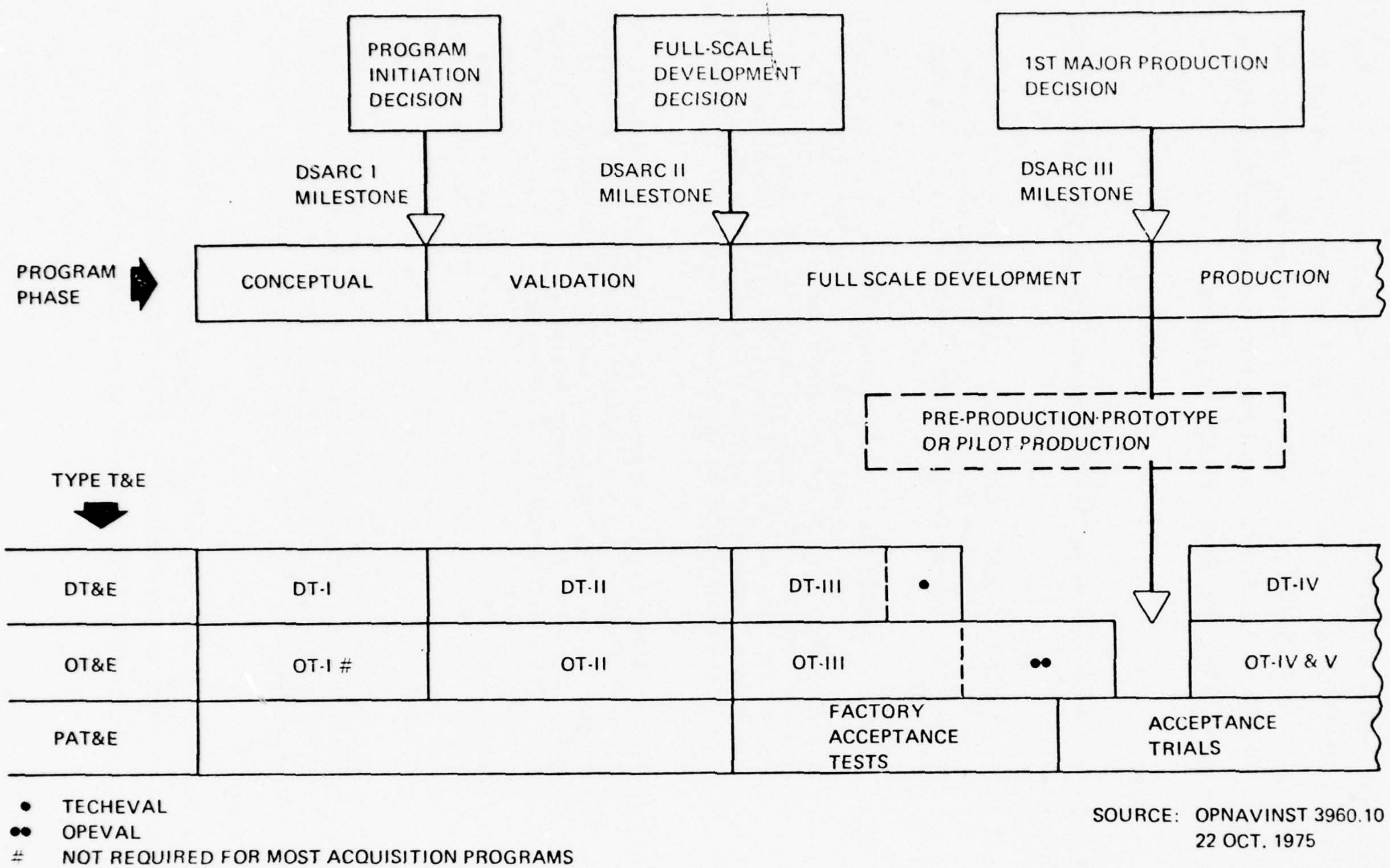

Figure 3.2-1: Test & Evaluation Phases

the first major production decision; and follow-on OT&E (FOT&E), which is all OT&E after the first major production decision. OT&E is further divided into five major phases (3 IOT&E, and 2 FOT&E):

a) <u>OT-I</u> is any IOT&E that may be conducted during the conceptual phase to support the program initiation decision. Most acquisition programs do not require OT-I. However, when an OT-I is conducted, existing systems or modifications thereto will normally be used to help estimate the military utility of the proposed new system.

b) <u>OT-II</u> is IOT&E conducted during the validation phase to support the full-scale development decision. It provides an early estimate of projected operational effectiveness and operational suitability of the system; initiates tactics development; estimates program progress, and identifies operational issues for OT-III.

c) <u>OT-III</u> is IOT&E conducted during the full-scale development phase to support the first major production decision. OPEVAL (Operational Evaluation) is the final subphase of the OT-III. It consists of a demonstration of achievement of program objectives for operational effectiveness and operational suitability, and continuing tactics development. OPEVAL normally uses pilot production hardware, and begins about one month after completion of TECHEVAL (Technical Evaluation) testing.

d) <u>OT-IV</u> is FOT&E conducted after the first major production decision, but before production systems are available for testing. Normally, OT-IV is conducted with the same pre-production prototype or pilot production systems used in OPEVAL. OT-IV consists of testing of fixes to be incorporated in production systems, completion of any deferred or incomplete IOT&E, and continuing tactics development.

e) <u>OT-V</u> if FOT&E conducted on production systems as soon as they are available. OT-V provides for a demonstration of the achievement of program objectives for production system operational effectiveness and operational suitability. In addition, OT-V includes OT&E of the system in new environments, or in new applications, or against new threats.

3.2.3 <u>PAT&E</u>

As previously indicated, PAT&E is testing conducted on production items to demonstrate that systems meet contract requirements and specifications. There are no subphases to PAT&E.

3.3 General Definitions

Further definition of HFE T&E may be made from the standpoint of the money source to pay for the T&E job, e.g., if design engineering money pays for an evaluation of some item of hardware, then the evaluation process is considered "design". In a similar manner, the program schedule helps define the terms, e.g., a paper analysis of a system concept may be considered as an on-paper "evaluation". However, since it may occur early in the program during the concept definition phase, it will most probably be considered "analysis" at that time period.

The total spectrum of how to categorize and differentiate among the divergent objectives, criteria and applications of test and evaluation need to have a definition agreed upon between customer and contractor and between customer agencies before significant HFE T&E program work may occur. A good starting point for establishing a baseline for this would be Meister's Human Factors: Theory and Practice (Reference 20), and the somewhat earlier Meister & Rabideau Human Factors Evaluation in System Development (Reference 15).

[20] Meister, D., Human Factors: Theory and Practice, Wiley, New York, 1971.

4.0 T&E METHODS

Numerous HFE T&E techniques have been developed in response to different needs or characteristics that have been required of each. It is the intent of this section of the guide to describe both the basic HFE T&E methods, or general techniques, and the basic characteristics that should be used to evaluate them. The methods are described and evaluated in general in relation to the different qualities or characteristics that each typifies. Also, the use of mockups, models, and prototype hardware are discussed briefly in this section.

4.1 Technique Evaluation Characteristics

The choice of the most efficient technique for performing an HFE T&E is a critical step in the total evaluation process. The general technique or method chosen will influence the entire conduct of HFE T&E. Several general technique characteristics should be selected for use in evaluation of the different T&E methods/techniques. The techniques may be compared to each other by use of narrative comments for each evaluation characteristic or by use of evaluation worksheets. The basic evaluation factors used to choose the techniques should be "program use", "inherent features", "best use", "relative performance", and "program interface requirements".

The "program use" factor includes a list of the previous systems/programs that have successfully used that method and the applicable stage or phase of a program that the technique is best suited for.

The "inherent features" factor includes all of the advantages and disadvantages of that particular technique. The inherent validity or repeatability of the technique should be considered along with the advantages and disadvantages. The implications of not using the technique should also be included.

The "best use" factor includes suitability for qualitative or quantitative data, testing as opposed to evaluation, total system versus subsystem or component evaluation, and single task testing versus several simultaneous tasks. The "relative performance" factors include time to perform, complexity, personnel required, and cost.

The "program interface" requirements are the input and outputs to/from the techniques and the coordination required in order to use the technique.

4.2 General Technique Categories

The various HFE T&E techniques are categorized for the purpose of reference and comparison with the previously indicated technique evaluation characteristics. Examination of the various technique types leads to the realization that two major categories are automatic and manual. The automatic techniques rely primarily on test instrumentation or computer simulations. The manual techniques rely to a large extent on the observer as the data collection device.

4.2.1 Manual Techniques

A further distinction in the manual category is that of direct versus indirect observation. System measurement is considered a third category of manual technique; although it could also be classified as a form of indirect observation. Direct manual techniques may be further categorized as being continuous or sampled. System measurement techniques are those in which the test evaluator gathers HFE T&E data through a review of test logs, maintenance records, or debriefing records to obtain necessary HFE T&E data. Indirect techniques include interviews and general questionnaires. The technique descriptions in Section 5.0 provide a limited amount of information in the way of individual technique comparisons. The Reference 5 User's Guide provides considerable more detail on each of the techniques.

4.2.2 Automatic Techniques

Automatic techniques are categorized as to those that are primarily measurement devices of external data and those that measure and create new data based on specified inputs. This later category consists of the computer program techniques or computer simulations. These may be further divided into on-line interactive techniques and off-line (e.g., batch mode) techniques.

The measurement devices include all of the recording techniques/tools such as video tapes, sound tapes, event recorders, and photography. Measurement devices also include physiological instrumentation of parameters such as heart rate and EEG. Also included under measurement devices are the psysical anthropological techniques/tools such as the tape measure and goniometer.

4.3 Inherent Technique/Characteristic Relationships

Many of the particular relationships between techniques and evaluation characteristics may be found in Section 5.0. There are, however, some general relationships that may be stated. One general relationship is somewhat similar to the relationship noted between man (manual) and machines (automatic) in the notable Fitts list (Reference 4).

Manual techniques tend to be more subjective and qualitative than automatic techniques. Their cost tends to be lower than automatic techniques. Automatic techniques are better used for objective and quantitative data. The validity or reliability of automatic techniques tends to be higher than manual techniques. This is because manual techniques are often based on the opinion of the test participant or observer. Automatic techniques are based on actual measured or precisely calculated data. Automatic techniques tend to be more costly and more complex than manual techniques. Automatic techniques require more time to initiate but once set up, they are more efficient than manual techniques. Computer simulations (automatic) are best used early in a program.

Another general relationship between techniques is the inverse relationship between their fidelity (or accuracy) and their ease of use. The end product of any T&E effort is to make valid judgments in regard to the real world situation. Some techniques are inherently more precise than others in terms of their fidelity to the proposed actual operating system situation. Unfortunately, the reason for their fidelity is largely due to the effort required by the use of the technique. This inverse relationship between technique accuracy and ease of use is illustrated in Figure 4.3-1. The real world situation is represented at the left of the figure. The most accuracy would be obtained by measuring always the real world situation. However, as always, the process of making observations or measurements tends to distort the test results and a degree of test fidelity is lost.

Field studies have less fidelity than real world observations because such studies are set up as artificial situations. Simulations with the use of

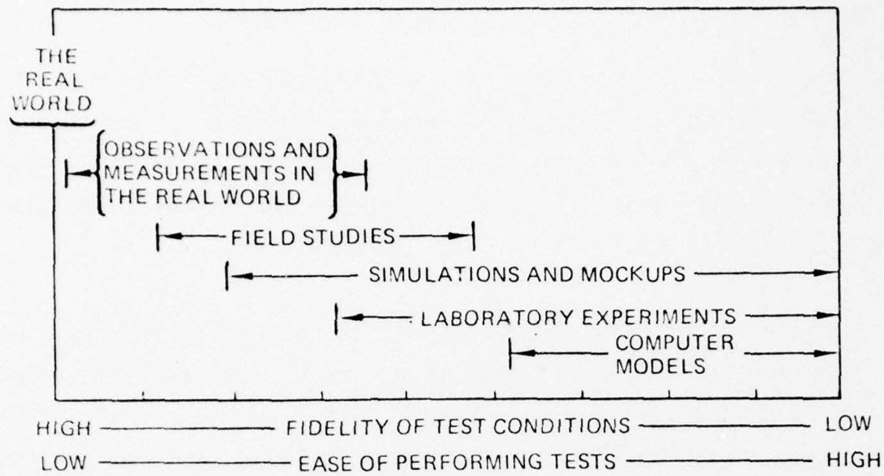

Figure 4.3-1, Technique Fidelity Vs. Ease of Use

mockups cover a wide range on the fidelity scale. Laboratory experiments also have a wide range of fidelity variability. Some laboratory experiments may be quite realistic while others may be highly abstract. Computer or mathematical models are the easiest to develop, manipulate, and use, but they are the least accurate in their representation of real world situations. Considerable advancement is now being made in the area of developing computer models to simulate more accurately real world situations.

4.4 Drawings, Mockups and Prototypes

There are a number of different tools or media that engineers, in general, and HF engineers, in particular, work with throughout the life of a program. These range from engineering sketches during the exploratory or concept formulation phase of a program to the prototype hardware which would result from a full scale development effort. The techniques that the HFE observer/evaluator uses depend to some extent upon the media or engineering tools available.

The first tools with which the HFE has to work during the "t&e", or exploratory, phase of the program are engineering sketches. These sketches may be well crafted engineering drawings but are referred to as sketches only because of their intended lack of contractor or customer sign-off approval.

Engineering drawings are prepared in anticipation of such management approval. Interface control drawings are another type of drawing that should require HFE review. As the name implies, these drawings are used to describe and to control eventually proposed interfaces between components, subsystems, or different contractor's equipment items. Most of these types of drawings may be used to perform a rough HFE evaluation, particularly by use of the design criteria checklist. Software and equipment item specification are prepared to document required system component performance and design criteria. To a limited extent, these may be used to verify compliance with contractual specifications. HFE T&E computer simulation techniques may be used to test system design concepts as indicated in the drawings and equipment item specifications.

As the system design progresses, full-scale mockups should be constructed to evaluate workspace and accessibility provisions. Wiring, cabling, piping, and ducting may be designed and evaluated much more easily with mockups. It is difficult to visualize three-dimensional problems from scaled down, two-dimensional drawings. The mockups should be made initially with the easiest to use and cheapest material possible. Various thicknesses of plastic foam core-filled cardboard sheets may be used quite easily with a hot glue gun and a sharp matte knife to build consoles, racks, and even complete cockpits. Console panel layout drawings may be simply glued to the foam core cardboard to simulate the appropriately located displays and controls. Test participants or evaluators may simulate the observation of displays or actuation of controls by simply touching the drawing and performing the appropriate hand (foot) motion. As the system design progresses and mockup tolerances become more critical, plywood material should be used. Plywood is both more rigid and durable, although considerably more costly in terms of construction costs. The plywood mockups may be converted from a static representation of the system to a dynamic or hot mockup. These mockups are also referred to as functional mockups. The console panel drawings which were glued to the plywood may be replaced by the actual displays and controls. It is cheaper to develop a hot mockup, which includes the proposed electrical wiring, than it is to build a prototype with numberous design errors. A functional mockup makes it possible to study the performance of personnel in simulated operational situations. The HF engineer can thereby evaluate operating characteristics of equipment in terms of human performance. More realistic lighting and sound measurements may be taken. Procedures may be verified. Test participants may be observed and interviewed with a much greater degree of confidence as to the validity of their responses. In addition to all of the above, mockups along with photographs and movies provide a means of design documentation to show the evolution of the system configuration.

The last major engineering tool short of the production hardware is the prototype. This is the first item of hardware produced. Whereas it is the most valid representation of the proposed system end item, it does not necessarily comply with all system requirements. Depending on the objective of the system design, the prototype hardware may be the first opportunity to evaluate the design in a mobile state. With the exception of the computer simulation techniques, virtually all of the HFE T&E techniques may be used for prototype hardware man/machine evaluation.

5.0 T&E TECHNIQUES

This section contains a brief summary of descriptions of 33 significant HFE T&E techniques. They are listed according to the general categorization presented in Section 4.2. Additional details, including use, validity, numerous references and, in some cases, examples of these techniques are contained in Reference 5, which is the user's guide for the HFE observer/evaluator.

5.1 Direct Manual

5.1.1 Direct Continuous Observation

This technique is simply the process of taking a relatively continuous record of the task or work activity or some aspect of the test performance. The operation may consist of an observer keeping a running log or description of the test activity as he understands it. The data may be recorded by hand on a clip board, or some of the more sophisticated techniques/tools (Section 5.4.5) may be used for recording events and times.

5.1.2 Direct Sampled Observation

This technique is identical to the previously listed one with the exception of the amount of time spent by the observer observing the test. The particular times chosen to perform test observation should, if possible, be those which coincide with the performance of critical tasks.

5.1.3 Design Criteria Checklist

The checklist is a series of equipment and facilities design requirements or criteria taken from human engineering standards, e.g., MIL-STD-1472, handbooks and guides. Often, during the early stages of a program, a checklist is developed by HF engineers for that particular program. Design criteria which would be applicable to the particular program are extracted from the various standards and handbooks and listed in a program unique checklist. The checklists generally have a space to the right of each listed item of design criteria. This space is divided into three columns: compliance, non-compliance, and not applicable. The HFE evaluator reads the item of criteria, observes the item of hardware (or mockup or drawing), and checks the appropriate space for applicability and compliance.

5.1.4 Specification Compliance Summary Sheet

This is a form that is used to verify that system performance is in accordance with specified HFE requirements. Briefly, the total process of verifying HFE specification compliance is: first, to decide the best method to verify the specification requirement (i.e., analysis, demonstration, or quantitative data), second, to perform the analysis/test and, third, to document the results. In any case, reports are written as to the analysis or test results. The Specification Compliance Summary Sheet is a way of summarizing this compliance or lack of compliance.

5.1.5 Technical Order Functional Evaluation

As its title would indicate, this technique is designed to evaluate technical orders or publications pertaining to the test. The technique is based on the use of a form to be completed by the test observers while they are performing their other direct observations of the test. The technical publications must be evaluated as to their usefulness and adequacy in three areas:

a) Job Instructions
b) Training
c) Job Performance Aids

5.1.6 Human Performance Reliability Testing

The method or approach employed in the use of this technique is simply direct observation; the purpose is to record test participant errors. This testing may occur at any time during direct observation testing.

As in the case of the direct observation technique (Section 5.1.1) the observer must first become familiar with the anticipated man/machine performance.

5.1.7 Human Factors Test and Evaluation Manual (HFTEMAN)

HFTEMAN must be considered as more than an HFE T&E technique. It is a human factors test and evaluation manual that is designed to assist the HFE in the areas of test plan preparation, test conduct, test data evaluation and analysis, and test report preparation. The HFTEMAN consists of two documents: the first contains detailed HFE test data and the second is a guide book supplement that contains specific HFE design criteria.

5.1.8 G-2/G-5 Anthropometers

These are two anthropometric devices which may be used as models of various size or percentile crewmen in order to check the adequacy of workstation geometry. They may be regarded as adjustable representations of the more critical crew dimensions. Each device is more analogous to a stick figure than to an anthropometric dummy. They may be adjusted to the 95th, 98th or any desired percentile dimensions for several of the more important crew size parameters.

The G-2 anthropometer may be used at any crew station. The G-5 is designed primarily for use as an escape envelope measuring device.

5.1.9 Terrain Visibility Definition

With the participant (pilot) seated in the aircraft (or mockup) cockpit and the aircraft in a horizontal flight attitude, direct measurements of the canopy sill vertical and horizontal visual angles are made with a surveyor's transit. The total procedure establishes the following four parameters:

a) horizontal angle
b) horizontal distance from pilot's eye to a marked point
c) vertical distance from pilot's eye to a marked point

d) slant range from pilot's eye to marked point

The outside visual field may then be calculated from these data.

5.1.10 Environment and Performance Measuring Equipment

There are several different items of test or measuring equipment that are extremely useful to the HFE test observer. A few of these T&E tools are included in separate sections, but most are listed here:

a) Photometer.
b) Spot Brightness Meter.
c) Sound Level Meter and Analyzer.
d) Vibration Meter and Analyzer.
e) Thermometer.
f) Anemometer.
g) Hygrometer or Psychrometer.
h) Gas Tester.
i) Forces, Torque and Dimension
j) Anthropometry Instrument Kit.

5.2 System Measurement

5.2.1 System Records Review

There are a number of typical test and evaluation program records that may be useful for review by the HFE personnel. This technique, the review of system T&E records, is unique in that there is no direct contact between the test evaluator and the test participants. All that is required on the part of the HF engineer is to obtain permission to review the existing test records and to go ahead with the tedious task of looking through them. Typically, system records will contain test logs, maintenance records, and debriefing records. The HF engineer may find data on equipment operation problems, technical publication inadequacies, human initiated errors, and training inadequacies.

5.2.2 Human Initiated Failures

A special form or forms may be provided to record only test participant errors. In order to do this properly, the test observer must be knowledgeable of the system procedures to the extent that he will notice operator or participant errors. The form requires the following information: where and when the error occurred, a description of exactly what the error was; and estimates as to the cause of the error, both by the observer and the participant. Possible causes may be presented in a short check list format (e.g., fatigue, environment, equipment design, etc.).

5.2.3 Test Participant History Record

This is not a direct test technique but rather a method of improving the test evaluation process. The Test Participant History Record form is used to collect data on personnel participating in HFE tests. This form should be completed before participation in the tests, is possible. Otherwise, the form may be completed as part of the post-test interview. The form emphasizes participant training, experience in systems similar to the one being tested, and participation in previous testing related to the same overall system presently being tested.

5.3 Indirect Manual

5.3.1 Interviews

The interview technique is simply the process of the HFE test evaluator discussing the test events with the test participants. This discussion should be structured in order to insure that the most information is obtained in the least amount of time.

The product of the interview is a quantity of test data (facts and opinions) to review and evaluate for the purpose of presenting system problems and recommendations, and in many cases system verification.

5.3.2 Questionnaires

The basic tool for obtaining subjective data is the questionnaire. It is the most frequently used and most difficult to construct of the subjective techniques. The questionnaire provides a structured method for asking a series of predetermined questions in order to obtain measurable expressions of attitudes, preferences, and opinions.

There are four basic question forms that may be used in a questionnaire:

a) The open-end or free-answer,
b) The dichotomous or two-way,
c) The multiple choice, and
d) The rating scale.

5.3.3 Functional Description Inventory (FDI)

The FDI is a new HFE T&E assessment methodology or special case questionnaire. The FDI requires a series of investigations analyzing the operational functions of crewmembers, with an essential part involving the determination of roles, duties, and tasks performed by each crewmember. Subsequent to this, analysis time is provided in order that the crewmembers can judge how important these roles, duties, and tasks were for mission success. They also judge how frequent they are performed on a typical mission, how adequate the training has been to insure effective performance of the task, and finally, how effective the particular system has been in accomplishing these operational functions.

5.3.4 Personnel Activity Analysis Radio System (PAARS)

The Personnel Activity Analysis Radio System is essentially a direct observation questionnaire technique. It is based on the use of 2-way radios between one HF engineer and several maintenance technicians or crews. It is not intended to be used as an observation technique for formal HFE test and evaluation. It is intended for quick and efficient gathering of human factors data from maintenance operations being performed on certain systems in the operational inventory. Technicians are required to report in from the location of their work. They are asked questions in regard to equipment problems, procedural problems, delays, and potential hazards.

5.3.5 Cooper-Harper Scale

The Cooper-Harper Scale is a well known technique used to evaluate aircraft handling qualities through the use of pilot ratings. The pilot participants are requested to provide their evaluation of given flight tasks, sub-phases, phases, or even the total flight (or mission). The technique is basically dichotomous. The pilot decides if the aircraft is controllable for a given task, sub-phase, etc. If the aircraft is controllable, he decides if the mission, phase, etc., performance is adequate with a tolerable workload. If not adequate, he choses (on a scale of three) how bad the major deficiencies are. If adequate, he determines if the performance is satisfactory without the need for improvement. If not satisfactory, he determines (on a scale of three) how bad the deficiencies are. If satisfactory, he determines (on a scale of three) how satisfactory the performance is.

5.3.6 Problem Incident Report

This form is used whenever the data source indicates an unsatisfactory condition relating to the operator/maintainer element of the system being tested. The terminology for this technique or form varies. It is often called an "Unplanned Event Record", "Crew Interface Data", or just a "Squawk Sheet". The report is completed by HFE personnel or anyone observing HFE related problems. Records are kept on each report as they are acted upon by HFE personnel to achieve problem resolution.

5.4 Automatic Recording

5.4.1 Motion Pictures

This technique is simply the process of filming participant performance as a part of a system test. Actual prototype hardware or sophisticated mockups should be available to justify the use of this technique. Less sophisticated mockups imply more uncertainty in design, and therefore a greater risk in expending a motion picture effort on unsuccessful concepts.

5.4.2 Sound Tapes

Sound tape recorders are commonly used to maintain a complete record of test conversation and events. Test notes may be verbally entered by the observers themselves or they may be used to record participant interview comments. The use of both sound tapes and video tapes together is frequently valuable.

5.4.3 Video Tapes

This technique is the use of video cameras and related equipment to make video tape recordings for detailed review and evaluation of operator and maintenance personnel tasks. As with motion pictures, actual prototype hardware or extremely sophisticated mockups should be available to justify the use of this technique.

5.4.4 Photography

This technique is perhaps too simple to be considered as such and should be described rather as a HFE test and evaluation tool. It is, very simply, the process of taking photographs of whatever tasks, objects or events that are pertinent to the HFE effort.

5.4.5 Event Recording

This is a technique for recording test situation or event times. The equipment involved in the use of this technique varies in complexity from the stopwatch to complete systems. Recently available recording equipment is designed such that the test observer simply presses combinations of keys to note task functions as they occur. Data entries record in a solid-state memory in a computer program format. The data is later transmitted to the computer by connecting the device via a simple connecting cable.

5.4.6 Operational Performance Recording and Evaluation Data System (OPREDS)

OPREDS is a real time data acquisition system which presently is being used to evaluate the Naval Tactical Data System (NTDS) and related command and control system performance. OPREDS performs analyses and evaluations of ship systems in two phases:

a) Onboard data recording and preliminary analysis.
b) Data reduction, analysis, storage, and retrieval.

5.4.7 Secondary Task Monitoring

For the purpose of determining crew workload, test participants are given both operational tasks and secondary tasks to perform. The secondary tasks are performed with prototype hardware or hot mockups on special equipment that is instrumented through hardwire or telemetry to record crew performance. The participant is instructed to perform the secondary tasks when not required to perform the operational tasks. The crew workload required to perform the operational tasks is implied on the basis of the measured time (or effort) not spent doing the operational tasks.

5.5 Physiological

5.5.1 Physiological Instrumentation

This instrumentation may be performed to monitor physiological parameters which will insure that the test participant remains in a safe range of performance. The process of measuring test participant physiological data is generally quite rigorous. In addition to all of the set up procedures required for the test itself, it requires several important tasks that must be performed just for the physiological instrumentation.

5.5.2 Physical Measurement

This technique is the process of measuring what the test participants can do in terms of their physical performance or what they are doing in terms of physical and cognitive performance. Three different types of physical measurement may be used. The first, anthropometry, deals with potential test participant physical performance. The other two, oculometry and voice monitoring, pertain to measurement of the participants' physical and cognitive processes.

5.6 Simulation

5.6.1 Cockpit Geometry Evaluation (CGE)

The CGE Program is an experimental development partially funded by the Joint Army - Navy Aircraft Instrumentation Research (JANAIR) Program Working Group to develop an improved method of evaluating the physical compatibility of crewmen with specified crew stations. The heart of the program is a computerized mathematical man-model (BOEMAN). The CGE Computer Program System (CGECPS) serves as the basic integrated tool to store required anthropological and geometric data, make computations to simulate typical crew movements during the performance of tasks, check and correct for visual and physical interference, and output related information. Crew station compliance with selected military standards and specifications is also performed.

5.6.2 Crewstation Assessment of Reach (CAR)

The CAR Model establishes the actual percentage of pilots that can be accommodated in the critical areas of a given crewstation geometric configuration. The model examines hand and leg control positions, seat movement to establish over the nose vision, and head clearance for a representative sample of the Navy pilot population. The model is designed for interactive use; it coaches and prompts the user in the use of the model.

5.6.3 Computer Accommodated Percentage Evaluation (CAPE)

CAPE is a Monte Carlo computer model for generating representative pilot anthropometric features (including links) and comparing these data with an adjustable workspace model so that the population accommodated by the workspace can be estimated and maximized. The computerized accommodated percentage evaluation (CAPE) model has two options: exclusion demonstration and cockpit analysis.

An exclusion demonstration determines what percentage of a potential population is excluded from a workspace design with respect to each anthropometric feature entered into the program. The cockpit analysis determines the percentage of a population that will be excluded from a cockpit design based on the geometric parameters of the workspace.

5.6.4 Field of View Evaluation Apparatus (FOVEA)

FOVEA is a technique used to test and evaluate the pilot's field of view from the cockpit eye reference point. It is designed to plot the actual field of view rather than the field of view as represented by photographs and distorted reference grids. The technique requires the procurement of certain test equipment such as a video camera, video recorder, a small computer, and plotter (or high quality graphics prints). Remote maneuvering equipment is also required to move the camera.

5.6.5 Online Interactive Simulation

The general technique described in this section pertains to the use of real time computer program simulations and actual test participant operators. Like other simulations, online interactive programs are used to evaluate and demonstrate the application of specific procedures and equipment to specific operations. The most important requirement of an online interactive simulation is that it be an accurate representation of some portion of the proposed system. Critical variables in the proposed system should be properly duplicated in the simulation.

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APPENDIX A: LIST OF PERSONNEL SURVEYED

One of the first tasks in the preparation of this guide was to visit various Navy labs and centers. Knowledgeable personnel were questioned in regard to their HFE T&E experience, problems, and needs. The following is a list of those contacted during the survey visits.

NADC - Warminster
- Dr. L. Hitchcock
- LCDR N. Lane
- D. E. Murry

TECOM/HEL - Aberdeen
- J. Perkins
- J. Miles
- Dr. J. Getty

NATC - Patuxent River
- A. Weaver
- Dr. S. G. Schiflett
- R. M. Walchli

NAVAIR - Jefferson Plaza
- J. C. Hemingway
- S. Miller

CNO - Pentagon
- Dr. R. Smith

ONR - Arlington
- Dr. M. Tolcott
- G. S. Malecki

OPTEVFOR - Norfolk
- T. P. Enderwick

NTEC - Orlando
- LCDR J. Funaro
- Lt. R. E. Perryman
- W. B. Boney
- R. G. Bird

OPTEVFOR - North Island
- Dr. R. Rhea
- LCDR W. F. Moroney
- Lt. W. R. Helm

NELC - San Diego
- R. Coburn
- LCDR W. F. Moroney
- Lt. W. Helm

NPRDC - San Diego
- Dr. D. Meister
- R. Harris
- LCDR W. F. Moroney
- Lt. W. Helm

APPENDIX B: DEFINITIONS/ACRONYMS

AFHRL	Air Force Human Resources Laboratory
AWACS	Airborne Warning and Control System
BOEMAN	Computerized Math Man-Model
CAPE	Computer Accommodated Percentage Evaluation
CAR	Crewstation Assessment of Reach
CGE	Cockpit Geometry Evaluation
CIC	Combat Information Center
CPS	Computer Program System
CTE	Contractor Technical Evaluation
DA	Developing Agency
DACOLS	Data Collection System
DoD	Department of Defense
DSARC	Defense System Acquisition Review Council
DT&E	Development Test and Evaluation
EEG	Electroencephholograph
FLAG	Feedback Loop Action Generation
FOT&E	Follow-on Operational Test and Evaluation
FDI	Functional Description Inventory
FOVEA	Field of View Evaluation Apparatus
GPTP	General Purpose Test Planning
HE	Human Engineering
HF	Human Factors
HFE	Human Factors Engineering
HFTEMAN	Human Factors Test and Evaluation Manual
HPR	Human Performance Reliability
ILS	Integrated Logistics Support
IOT&E	Initial Operational Test and Evaluation
JANAIR	Joint Army-Navy Aircraft Instrumentation Research
LED	Light Emitting Diodes

APPENDIX B: DEFINITIONS/ACRONYMS (cont.)

NAVMAT	Chief of Navy Material
NTDS	Naval Tactical Data System
NTE	Navy Technical Evaluation
OPEVAL	Operational Evaluation
OPNAV	Chief of Naval Operations
OPREDS	Operational Performance Recording and Evaluation Data System
OT&E	Operational Test and Evaluation
PAARS	Personnel Activity Analysis Radio System
PAT&E	Production Acceptance Test and Evaluation
PSTE	Personnel Subsystem Test and Evaluation
RFP	Request for Proposal
RID	Remote Input Devices
SOW	Statement of Work
SECNAV	Secretary of Navy
T&E	Test and Evaluation
TECHEVAL	Technical Evaluation
TEMP	Test and Evaluation Master Plan

APPENDIX C: T&E SECTIONS OF MIL-H-46855

3.2.4 Human Engineering in Test and Evaluation - The contractor shall establish and conduct a test and evaluation program to: (1) assure fulfillment of applicable requirements herein; (2) demonstrate conformance of system, equipment and facility design to human engineering design criteria; (3) confirm compliance with performance reqirements where man is a performance determinant; (4) secure quantitative measures of system performance which are a function of man-machine interaction; and (5) determine whether undesirable design or procedural features have been introduced. (The fact that these functions may occur at various stages in system or equipment development shall not preclude final human engineering verification of the complete system. Both operator and maintenance tasks shall be performed as described in approved test plans during the final system test.)

3.2.4.1 Planning - Human engineering testing shall be incorporated into the test and evaluation program and shall be integrated into engineering design tests, contractor demonstrations, R&E acceptance tests and other major development tests. Compliance with human engineering requirements shall be tested as early as possible. Human engineering findings from early testing shall be used in planning and conducting later tests.

3.2.4.2 Implementation - The human engineering test and evaluation program, contained in approved test plans, shall be implemented by the contractor. Test documentation (e.g., checklists, data sheets, questionnaires, schedules, operating procedures, test procedures) shall be available at the test site. Human engineering portions of all tests shall include, where applicable, the following:

a. A simulation (or actual conduct where possible) of mission or work cycle.

b. Tests in which human participation is critical with respect to speed, accuracy, reliability or cost.

c. A representative sample of non-critical scheduled and unscheduled maintenance tasks.

d. Proposed job aids.

e. Utilization of personnel who are representative of the range of the intended military user population in terms of skills, size and strength and wearing suitable military garments and equipment which are appropriate to the tasks, and approved by the procuring activity.

f. Collection of task performance data.

g. Identification of discrepancies between required and obtained task performance.

h. Criteria for the acceptable performance of the test.

3.2.4.3 Failure Analysis - All failures occuring during, or as a result of, test and evaluation shall be subjected to a human engineering review to differentiate between failures due to equipment alone, man-equipment incompatibilities and those due to human error. The procuring activity shall be notified of design deficiencies which contribute to human error.