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MILITARY HANDBOOK

HUMAN ENGINEERING PROCEDURES GUIDE

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DEPARTMENT OF DEFENSE
WASHINGTON, D.C. 20301

Human Engineering Procedures Guide

1. This standardization handbook was developed by the Department of Defense with the assistance of the military departments, federal agencies, and industry.

2. This document supplements the material in MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, and provides basic information on human engineering techniques and procedures that may be used by requiring organizations when imposing that specification and its related data item descriptions and by performing organizations when complying with that specification and its related data item descriptions.

3. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, U.S. Army Missile Command, ATTN: AMSMI-RD-SE-TD-ST, Redstone Arsenal, Alabama 35898-5270, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FOREWORD

Acquisition of weapon systems, large or small, can be an extremely complex process. As a part of this process, the individual services require the application of human engineering (HE) to system design in order to achieve required performance by operator and maintenance personnel and to minimize personnel skills and training requirements. The various service policies require the application of HE within the limits of time, cost, and performance tradeoffs. Although such service policies and regulations may change, the need for human engineering in systems, equipment and facility development or product improvement and modification will continue.

The primary tasking document used by the services to specify human engineering efforts during system acquisition is MIL-H-46855, "Human Engineering Requirements for Military Systems, Equipment and Facilities." MIL-H-46855 is written to accommodate a wide range of products, including development of small equipment items as well as major acquisitions. This specification provides reasonable latitude for contractors to apply technical/program judgment and innovation consistent with specific procurements. As a result, the specification provides somewhat general tasking provisions for analysis, design and test. A collateral result, however, is a lack of detail. Accordingly, a need exists to provide procedures, task options, background and rationale to assist (1) relatively inexperienced military customer and contracted persons who may be assigned responsibility for HE in the system acquisition process and (2) the military customer and contracted management to understand and utilize HE in the system acquisition process through a medium which will not encumber contractually-cited documents such as MIL-H-46855 and its Data Item Descriptions (DIDs). The objective of this Human Engineering Procedures Guide, therefore, is to meet these needs.

This guide provides assistance to both the customer (or requiring organization) personnel and the contractor (or performing organization) personnel in the following areas:

a. Human engineering, documentation and requirements that should apply to the program.

b. Source data to find out what HE effort is needed.

c. Necessary planning and scheduling to accomplish the program.

d. Necessary coordination between HE and other disciplines and with the program manager as well.

e. Possible allocation of effort to laboratories, consultants, or subcontractors.

f. Tailoring capabilities and limitations.

g. Preparation of HE portion of the request for proposal.

h. Contract Data Requirements List (CDRL) selection rationale and preparation recommendations.

i. Contractor proposal preparation.

j. Proposal evaluation.

k. Performing organization task accomplishment, including the details of several analyses, design, and test and evaluation techniques.

l. Requiring organization monitoring of contractor.

The wording in this handbook should not be construed to discriminate between the sexes. In order to avoid the repetitious use of the terminology "he/she", the terms he, him, his, and man are intended to include both masculine and feminine gender. Any exceptions to this will be noted.

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1. SCOPE

1.1 Purpose and scope. The purpose of this guide is to assist human engineers and managers in application of MIL-H-46855 to the system/equipment acquisition process. The handbook also addresses the long-standing need to (a) assist relatively inexperienced military or industry personnel assigned responsibility for Human Engineering (HE) and (b) help in both military and industry management understand and utilize HE in the acquisition process. The relatively inexperienced person assigned responsibility for HE may start an HE effort with requirements for unneeded effort or data. HE must be considered, along with all other disciplines, for the contribution it can make to the system/equipment acquisition, with each requirement justified, and all unnecessary requirements tailored out. No documentation can completely describe all HE tasks which should take place during the system/equipment acquisition program; however, a common, unified approach as to what HE is and how it relates to other areas should be available. It is the purpose of this guide to provide a better understanding and appreciation of HE to help both managers and the personnel assigned the HE responsibility in the system/equipment acquisition process in the government and in industry.

1.2 Organization. This document is organized into seven sections. The first three sections, 1. Introduction, 2. Referenced Documents, and 3. Definitions, are all intended to support the last four sections. Section 4., HE Significance for Program Acquisition, is intended to be used by both requiring organization and performing organization managers to show current management aspects of the HE process in system acquisition. Section 4. may be used independently from 5. HE Procedures for Requiring Organizations, and 6. HE Procedures for Performing Organizations; however, Sections 5. and 6. are dependent on data in sections 1., 2., 3., and 4.. Section 7. HE techniques is intended for use by both customer and contractor personnel to show current HE analysis, design, and T&E techniques. A cross referenced table of the paragraphs in this handbook with the MIL-H-46855 paragraphs is included in appendix A. Also provided, in appendix B, is a cross reference table of this handbook's major paragraphs with significant references many of which are cited in the text. Appendix C provides a sample generic Human Engineering Program Plan (HEPP) for new ship and other major naval hardware acquisition programs.

1.2.1 HE procedures for requiring organizations. Section 5., HE Procedures for the requiring organization,is intended to present and develop HE procedures throughout the system/equipment acquisition process. This section is intended for use by customer personnel directly assigned to the HE function. These include both HE managers and analysts. A requiring organization can be either a government procuring agency, a prime contractor hiring subcontractors, or an integration contractor.

1.2.2 HE procedures for performing organizations. Section 6., HE procedures for the performing organizations, is intended to present and develop HE procedures for use throughout the system/equipment acquisition process. This section is intended for use by performing organization personnel assigned the HE function. These include both HE managers and analysts. A performing organization can be a government agency (i.e., lab), a contractor (large or small), a prime contractor with any number of subcontractors, a subcontractor (large or small), integration contractor or associate contractor.

1.2.3 HE techniques. Section 7. HE techniques for customer and contractors, presents techniques for use throughout the system/equipment acquisition process. This section is intended for use by both customer and contractor personnel assigned the HE function.

1.3 Relationship to other disciplines. The total guide is directly applicable to HE and HE Test and Evaluation (T&E) rather than the total field of Human Factors Engineering (HFE). However, this guide presents the relationship of HE to other HFE elements, such as Biomedical, Manpower, Personnel, and Training (MPT) considerations. The procedures for integrating MPT into system acquisition are not included in this guide. The relationship of HE to other HFE elements and to other disciplines or technologies such as Maintainability, Safety, Reliability, and Survivability, is indicated throughout the guide.

2. REFERENCED DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this handbook to the extent specified herein.

SPECIFICATIONS

MILITARY

MIL-H-46855 - Human Engineering Requirements for Military Systems, Equipment and Facilities.

STANDARDS

MILITARY

MIL-STD-490 - Specification Practices.
MIL-STD-881 - Work Breakdown Structure for Defense Material Items
MIL-STD-1472 - Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

HANDBOOKS

MILITARY

MIL-HDBK-759 - Human Factors Engineering Design for Army Materiel

2.1.2 Other Government documents, drawings, and publications. The following other Government documents, drawings, and publications form a part of this handbook to the extent specified herein.

DODD 5000.1 - Major Systems Acquisitions
DODD 5000.3 - Test and Evaluation
DODD 5000.19L - Acquisition Management Systems and Data Requirements Control List

AR 602-1 - Human Factors Engineering Program
AR 1000-1 - Basic Policies for Systems Acquisition

NAVSEAINST 3900.8 - Human Factors in the Naval Sea Systems Command

AFR 800-3	- Engineering for Defense Systems
AFR 800-15	- Human Factors Engineering and Management
DI-H-7051	- Human Engineering Program Plan
DI-H-7052	- Human Engineering Dynamic Simulation Plan
DI-H-7053	- Human Engineering Test Plan
DI-H-7054	- Human Engineering System Analysis Report
DI-H-7055	- Critical Task Analysis Report
DI-H-7056	- Human Engineering Design Approach Document-Operator
DI-H-7057	- Human Engineering Design Approach Document-Maintainer
DI-H-7058	- Human Engineering Test Report
DI-H-7059	- Human Engineering Progress Report
TOP 1-2-610	- Part II US Army Test and Evaluation Command Test Operations Procedures, Human Factors Engineering Data Guide for Evaluation (HEDGE) ADA 140391
TP-76-11A	- HFTEMAN VOL. I Data, VOL.II Support, VOL. III Methods & Procedures

2.2 Source of documents. Copies of listed military specifications, standards, and associated documents listed in the Department of Defense Index of Specifications and Standards (DoDISS), are available from the Department of Defense Single Stock Point, Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Ave, Philadelphia, PA 19120. Copies of industry association documents should be obtained from the sponsoring industry association. Copies of all other listed documents should be obtained from the contracting activity or as directed by the contracting officer.

3. DEFINITIONS

3.1 General. Terms used in this handbook are consistent with the explanations in paragraph 6.2 of MIL-H-46855.

3.2 Acronyms. - The acronyms listed in this Handbook are defined as follows:

3D	3 Dimension
AF	Air Force
AFSC	Air Force Systems Command
AMSDL	Acquisition Management System and Data Requirements Control List
ASME	American Society of Mechanical Engineers
ASMS	Advanced Surface Missile Ship
AWACS	Aioborne Warning and Control System
CADET	Computer Aided Design and Evaluation Techniques
CAPE	Computerized Accommodated Percentage Evaluation
CAR	Crewstation Assessment of Reach
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CIC	Combat Information Center
CL	Control List
COMBIMAN	Computerized Biomechanical Man-Model
CRT	Cathode Ray Tube
CTAR	Critical Task Analysis Report
CUBITS	Criticality/Utilization/Bits of Information
DCL	Digital Control Language
DCP	Decision Coordinating Paper
DCS	Data Collection System
DEP	Design Eye Point
DID	Data Item Description
DOD	Department of Defense
DODD	Department of Defense Document
DODISS	Department of Defense Index of Specifications and Standards
DRS	Data Reduction System
DSARC	Defense System Acquisition Review Council
ECP	Engineering Change Proposal
EEG	Electroencephalogram
EKG	Electrocardiogram
ERP	Eye Reference Point
FAA	Federal Aviation Administration
FPC	Flow Process Chart
FSD	Functional Sequence Diagram
FSED	Full-Scale Engineering Development
GSR	Galvanic Skin Response
HDBK	Handbook
HE	Human Engineering
HEDAD-O	Human Engineering Design Approach Document-Operator
HEDAD-M	Human Engineering Design Approach Document-Maintainer
HEDGE	Human Factors Engineering Data Guide for Evaluation

HEDSP	Human Engineering Dynamic Simulation Plan
HEPP	Human Engineering Program Plan
HEPR	Human Engineering Progress Report
HESAR	Human Engineering System Analysis Report
HETP	Human Engineering Test Plan
HETR	Human Engineering Test Report
HF	Human Factors
HFE	Human Factors Engineering
HFTEMAN	Human Factors Test and Evaluation Manual
HODAC	Human Operator Data Analyzer/Collector
HOS	Human Operator Simulator
HP	Human Performance
HQ	Headquarters
ICD	Interface Control Drawing
IDEF	Integrated computer-aided manufacturing DEFinition
ILS	Integrated Logistics Support
ISD	Instructional systems development
LCC	Life Cycle Costs
LED	Light Emitting Diode
LOS	Line-of-Sight
MANPRINT	MANpower and PeRsonnel INTegration
MENS	Mission Element Needs Statement
MTM	Methods Time Measurement
NAVSEA	Naval Sea Systems Command
NDI	Nondevelopment Items
OMB	Office of Management and Budget
OPR	Office of Primary Responsibility
OSD	Operational Sequence Diagram
OWLES	Operator Workload System
PDR	Preliminary Design Review
PLSS	Precision Location and Strike System
PMD	Program Management Directive
PMP	Program Management Plan
PTS	Predetermined Time Standard
RD&E	Research, Development and Engineering
RFP	Request For Proposal
R&D	Research and Development
SAINT	Systems Analysis of Integrated Networks of Tasks
SDR	System Design Review
SECNAV	Secretary of the Navy
SIMWAM	Simulated Interactive Microcomputer Workload
SON	Statement Of Need
SOSD	Spatial Operational Sequence Diagram
SOW	Statement Of Work
SPO	System Program Office
SRP	Seat Reference Point
STS	Space Transportation System
SWAT	Subjective Workload Assessment Technique
T&E	Test and Evaluation
TI	Technical Interchange

TLA-1	Time Line Analysis program model 1
TM	Technical Manual
TMU	Time Measurement Units
VCR	Video Cassette Recorder
WBS	Work Breakdown Structure
WOSTAS	WOrkSTation ASsessor

4. HE SIGNIFICANCE FOR PROGRAM ACQUISITION

This section is prepared primarily for program and HE managers. Data summarizing HE requirements as contained in applicable directives, regulations, and specifications are included in this section. HE activities are described in general terms of both what should be done and when it should be accomplished. The practical value of HE is discussed. Various HE program management relationships are suggested and the procedure for including HE in the total system effort is presented.

4.1 HE support in system acquisition. HE is required during analysis, design and development, and T&E phases of system acquisition, as identified in MIL-H-46855. As a part of the design and development area, technical data procedures are often developed. All of these areas or activities are performed in combination with considerable inter- and intra-coordination. The coordination includes planning and scheduling of these basic efforts to insure that the proper source data are available to do the necessary work, the proper work is performed at the proper time, and that the results of the work improve the design. Frequently, as a result of the work performed, an interactive effort is made to refine the HE design requirements. For example, as a result of test and evaluation, more analysis and eventual redesign may be necessary. Typical interaction relationships between HE areas and other technology areas of system/equipment development are shown in table I. Consistent with paragraph 6.2 of MIL-H-46855, HE applies human factors (HF) and other data to design to achieve effective user-system integration. Figure 1 illustrates this relationship. Finally, realistic HE efforts--whether analytic, design or test and evaluation--should emphasize close interaction between HE specialists and operational personnel.

4.1.1 Analysis area. HE areas of work are like other technology areas or activities in that there are problems brought about by the new system acquisition. These problems can frequently be resolved by analyzing, i.e., breaking them down into smaller elements and applying one or several of the techniques described in section 7.1. The results of these analyses are specific hardware design criteria. When applied, these design criteria will insure hardware compatibility with human performance capabilities and limitations. For example, technical publications may be initiated, based on the task analysis procedures data. Personnel manning and skill level documentation may be established based on the analyses data. Training data and equipment may be initiated from the analysis effort. Figure 1 shows the several technologies from which HE analysis receives input or to which applications data are provided. In addition to those already indicated,

Table I

Human engineering relationship to other technologies

	Interface Matrix	Areas of system development (per MIL-H-46855)		
	Technologies	Analysis	Detailed Design	Test and Evaluation
1	Biomedical		X	X
2	Personnel requirements	X	X	X
3	Training/ISD	X	X	X
4	Test and Evaluation	X	X	X
5	Publications	X		X
6	System Engineering	X		
7	Operations Analysis	X		
8	Reliability	X	X	X
9	Maintainability	X	X	X
10	Survivability/Vulnerability		X	
11	System Safety	X	X	X
12	Integrated Logistics Support		X	X
13	Software	X	X	X
14	Life Cycle Costs	X	X	X
15	Support Equipment	X	X	X

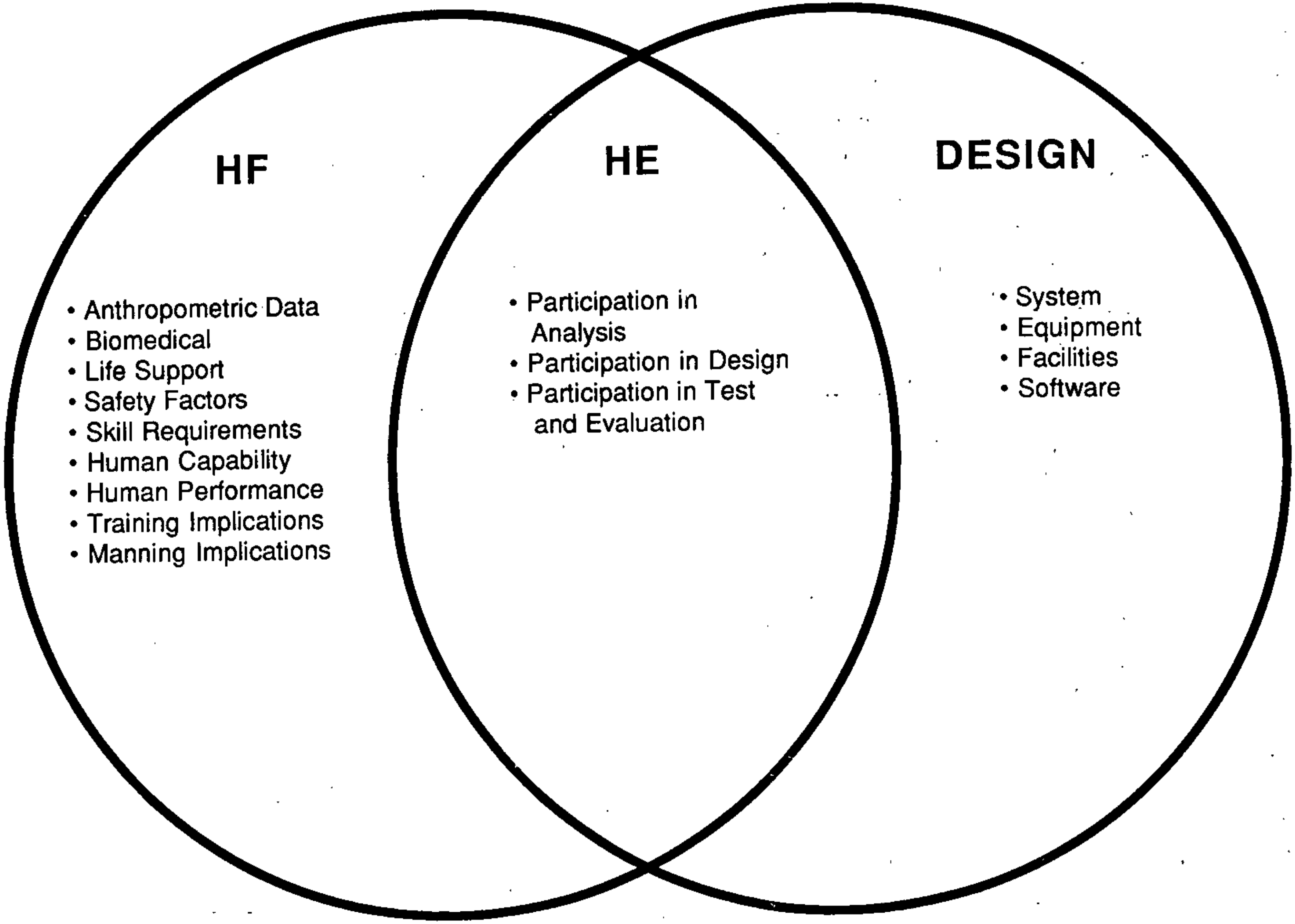


FIGURE 1. Human Engineering relation to Human Factors and Design.

System Engineering and Operations Analysis frequently provide data from which the HE effort may be initiated. Crew Station Design receives the results of HE workload analysis in order to determine proper flight or mission crew size. Figure 2 illustrates the time period during a system acquisition in which the analysis and other areas of system development efforts may occur most usefully.

4.1.2 Design and development area. The purpose of this area of work is to provide the man-machine system design which incorporates all necessary HE design criteria. If the man-machine interface design activity is not performed directly by HE, then it is the job of HE to supply appropriate design data to support the project design organization. Approval of drawings indicates the drawings have been reviewed for compliance with appropriate HE design criteria. The man-machine interface design is not limited to portions of system equipment, but includes software design, procedures, work environments, and facilities associated with the system functions requiring personnel interaction. This area of work is accomplished by converting the results of the analysis activity into HE and biomedical design criteria. This effort is heavily dependent on the selection of applicable MIL-STD-1472 design criteria. Several HE techniques and tools are used. These may include the use of drawings, checklists, vision plots, reach envelopes, mock-ups, specifications, and various computer workstation modeling programs. The final design should provide man-machine interface that will operate within human performance capabilities, will meet system functional requirements, and will accomplish mission objectives while minimizing demands on manpower, skills, and training. Where appropriate, the final design should include man-machine interface considerations and space claims associated with any pre-planned product improvements. HE interfaces with several disciplines during the detailed design effort (see table I). System Engineering and maintainability are two of the most important of these. HE is frequently a part of the System Engineering organization. Most maintainability design criteria are, in fact, HE design criteria. The most appropriate time during a system acquisition program in which the HE design effort may usefully occur is shown in figure 2.

4.1.3 Test and Evaluation (T&E) area. The HE T&E effort is important to verify that the man-machine interface and procedures are properly designed so that the system can be operated, maintained, supported, and controlled by user personnel in its intended operational environment. HE specialists must work closely with operational, maintenance, system engineering, logistics, and training personnel during technical T&E and operational T&E. HE T&E also provides HE performance data and design criteria for

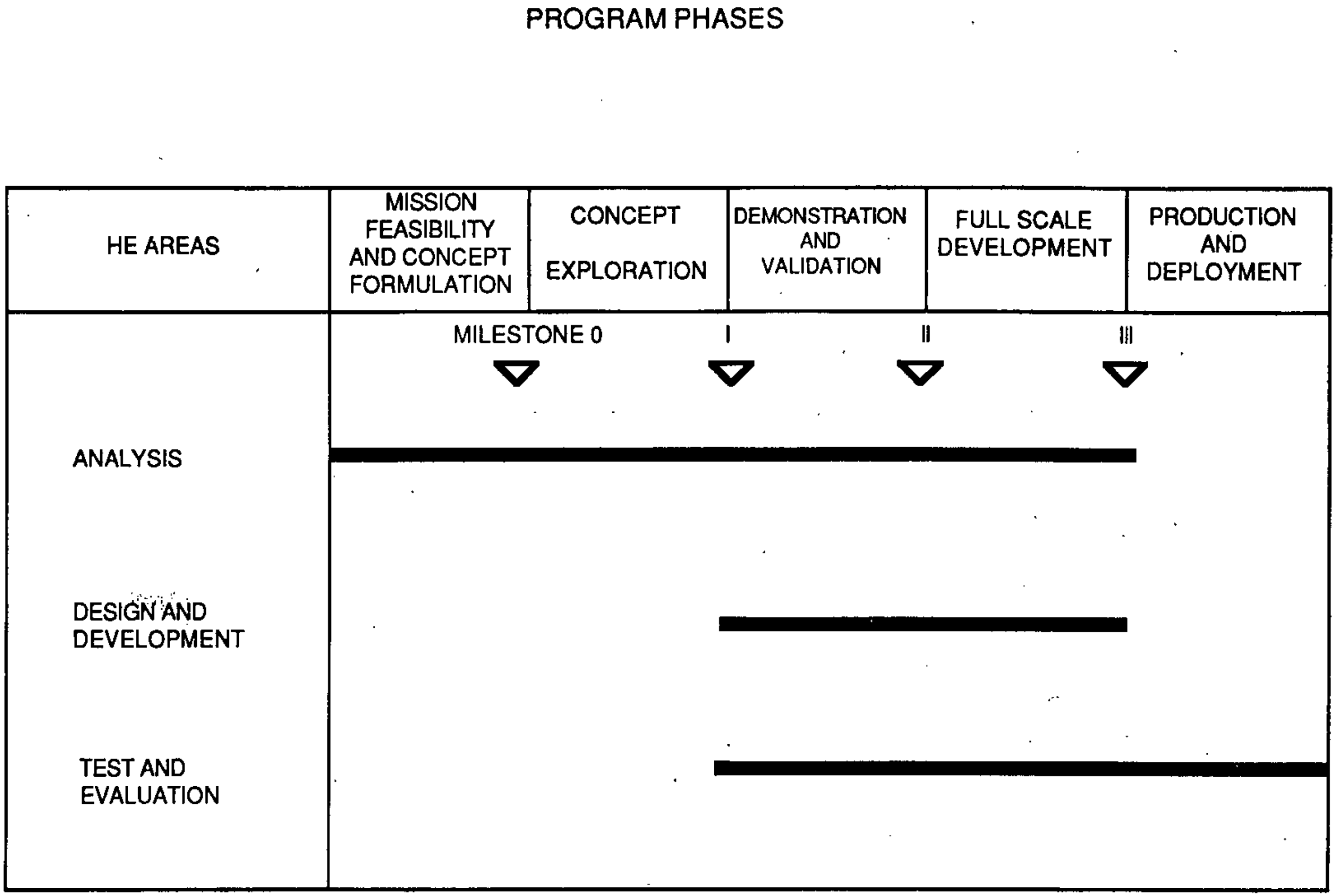


FIGURE 2. Applicable program stages for human engineering areas of system development.

use in the development of later follow-on acquisitions or improvements. There are at least 20 well-known tools and techniques that are used to perform HE T&E. These include environmental measurements (e.g., lighting, sound, workspace), task performance measurements (e.g., time, error), subjective measurements (e.g., questionnaires, interviews, along with various inspection, demonstration, and analytical techniques. Figure 2 illustrates the proper time in which the HE T&E effort may usefully occur during a system acquisition.

4.2 HE value. There are two ways to prove the value of a sound HE effort. One is to show positive results of HE activities, and the other is to show the negative results from the lack of HE. The following material examines the values of the HE effort from both viewpoints.

4.2.1 Benefit from HE. As with most worthwhile efforts, an investment of money and time is needed to gain eventual savings, increased performance, safety, and user satisfaction. The investment in HE is relatively small compared to other areas. The return on the investment can be relatively high. The system: (1) is designed to permit operator, control, and maintenance personnel to achieve required performance; (2) minimizes skill and personnel requirements and training time; (3) achieves required reliability of personnel equipment combinations; and (4) emphasizes safe operations, maintenance, and control. Some of these benefits can be seen from Human Factors Test and Evaluation Reports. Some typical examples of problems found are as follows:

a. HE design changes were developed and implemented to solve a maintenance access problem. A savings of up to 8 hours to remove one cotter pin from the flaperon actuator of the F-16 was made by a simple design change. This was an extreme case of poor accessibility (ref. 1).

b. Ejection seat failure to deploy design changes were developed and implemented to correct the following problem. The pilot of an A-7 reported that he had pulled the ejection handle but the seat failed to fire. Since the same ejection seat was in the F-15, test personnel speculated that an incorrect maintenance procedure could have accounted for the failure. The ejection seat personnel did identify a design deficiency that would allow a maintenance man to misrig the cable to the initiator. A video tape was made of a seat being misrigged and copies sent to the F-15 System Program Office (SPO) prime seat contractor and Life Support SPO (ref. 1).

c. An excellent source of HE benefits in ship design is documented in a report which details all of the HE design improvements incorporated into the AOE-6 as a result of a thorough review of the AOE-1 class fast combat support ships. This report (ref. 2) includes numerous improvements in the following areas: system/equipment arrangement and configuration, workstation lighting, display color coding, maintenance access, stowage space, labeling, and work space layout. The benefits can be considered of two types: a) those which directly affect the ship operations by improved efficiency and safety and b) those which indirectly affect the ship operations by improved crew morale.

d. Although HE cannot take sole credit, military safety statistics have improved greatly during the past 25 years. This is because of the concerted application of HE principles to equipment design, as well as other areas of equipment operation and maintenance. Operator performance has been shown to improve to the point of significantly affecting overall system performance. The difference between a well-designed versus a poorly-designed console layout may be an increase in overall operator reliability by an order of magnitude. The time required to perform complex tasks may easily be cut in half by the application of proven HE design criteria.

The ultimate test of value is how well the system performs its mission. If the human operator, maintainer, or controller can perform his job efficiently, effectively, economically, and safely, the system has been well human engineered. If there are errors or accidents due to the human element, perhaps the system was not adequately human engineered.

4.2.2 Problems from lack of HE. Until recently, it has been difficult to obtain detailed data directly related to problems resulting from the lack of HE. However, many problems found during T&E (see previous paragraph) are evidence of the lack of a good HE effort during the design and development phase. Some of the problems are resolvable, but it costs more to do so during this phase. Problems found during the operational phase are still more costly to resolve. Sometimes problems are identified only after a crucial incident. A non-military incident receiving national attention is worth mentioning because it showed the lack of HE, was so costly, and affected so many people -- the problem with the Three Mile Island Nuclear Power Plant. It has provided pressure to bolster a HE effort in the nuclear power industry. The accident investigation findings (ref. 3) state that:

> "Human factors engineering has not been sufficiently emphasized in the design and layout of the control rooms. The location of instruments and controls in many power plants often increases the likelihood of operator error, or, at the very least, impedes the operator in efficiently carrying out the normal, abnormal, and emergency actions required of him".

With this disregard for HE principles, it was inevitable that an accident should have occurred. It is, of course, difficult to obtain data as to the cost in total dollars, time, and effort lost because of this accident, but it is not hard to imagine the small percentage cost of a reasonably sound HE effort in comparison. The temptation is always present to avoid this small percentage cost, and to hope that power plant design engineers have sufficient skill to incorporate all necessary HE design features. However, proper knowledge of HE principles and criteria is too much to expect without HE training. Typical HE design criteria violations which have occurred in power plant control room design are as follows:

a. Instrumentation and controls are located beyond the operator's normal duty station and visual envelope; in some cases, operators' backs are positioned towards the displays which they must monitor.

b. Displays are located to allow erroneous readings due to parallax.

c. Displays and controls are mislabeled according to their function.

d. Displays and controls are arbitrarily located without functional grouping.

e. Panel layouts for similar systems are designed as mirror images of each other, thereby violating HE principles of transfer of training.

f. Annunciator audible warning systems are misused to the point of serving more to rattle the operator

> and overload his sensory mechanisms than to focus his attention on the specific problem at hand.

More recently, 1986, production of a machine gun was curtailed because of HE problems disclosed by field testing. While the weapon reportedly passed with outstanding accuracy and reliability, problems involving human engineering resulted in a decision to cancel the solicitation for bids for a second production run (ref. 4). Similar design deficiencies have been found in all Military Systems --- missile systems, surface ships, space systems, command and control systems, land vehicles, generators, small arms, and support equipment.

REFERENCES

1. Crites, C.D., Miniature Event Recording as a Technique for Personnel Subsystem Test and Evaluation, AFHRL-69-16, Air Force System Command, WPAFB, September 1969.

2. NAVSEA AOE-6 Contract Design Human Factors Engineering Review and Disposition of Problems, Final Report, NAVSEA, Washington DC February 1985.

3. Tedesco, Robert L., NUREG 0560, Nuclear Regulatory Commission Staff Report, May 1979.

4. Fulghum, David, Machine Gun Field Tests Reveal Problems, Defense News, February 10, 1986.

5. HE PROCEDURES FOR REQUIRING ORGANIZATIONS

5.1 General. The specification of HE requirements is critical to the successful accomplishment of any program effort. These requirements are both of a directed and practical nature. Paragraph 4.2 (Value of HE) presents a few practical HE requirements along with their value. This section presents the documented government HE requirements including their origins. A listing of specifications, standards, and other applicable documents is contained in appendix B. These documents are cross-referenced by service and this guide's paragraphs. The HE requirements, which direct the requiring organization, are more general and slightly different from the more detailed performing organization requirements. The performing organization's requirements, as presented in section 6. (HE procedures for contractors), are derived from the requirements presented in this section.

5.1.1 Policy documents. HE requirements derive from Department of Defense Directive (DODD) 5000.1, Subject: Major System Acquisitions. This directive states, "As a management precept, operational suitability of deployed weapon systems is an objective of equal importance with operational effectiveness." Human factors is defined as part of operational suitability. General HE T&E requirements are set forth in DODD 5000.3.

5.1.2 Implementing Requirements.

5.1.2.1 Army. Implementing requirements for Army system acquisition, are set forth in Army Regulation 1000-1. Specific HF requirements during system acquisition are given in AR 602-1. In some instances, major subordinate commands have supplemented this regulation to provide specific guidance and responsibilities relative to their organizations, e.g., MICOM and TECOM Supplements to AR 602-1. AR 602-2, covering MANPRINT (MANpower and PeRsonnel INTegration) has recently been promulgated and provides guidance for implementation of HFE as an interdependent discipline with manpower, personnel, training, system safety, and health hazard assessment.

5.1.2.2 Navy. Implementing requirements for Navy system design and acquisition are in instructions from the Secretary of the Navy (SECNAVINST 5000.1b), Chief of Naval Operations (OPNAVINST drafted), Naval Air Systems Command (NAVARINST 3900.10), and Naval Sea Systems Command (NAVSEAINST 3900.8). For example, NAVSEAINST 3900.8 states, "Human Factors shall be fully considered in all ship, ship systems, subsystems, equipment and software development and acquisition programs, and applicable to all phases of design and acquisition under the responsibility of COMNAVSEA." (NOTE: When the Naval Material Command (NAVMAT) was disestablished in 1985, NAVAIR was designated the lead Systems Command for human factors in the Naval Material Establishment, and this, NAVARINST 3900.10 establishes human factors policy for NAVAIR, NAVSEA, and the Naval Space and Warfare Command.)

5.1.2.3 Air Force. The implementing regulation within the Air Force is AFR 800-15, Human Factors Engineering. This regulation establishes the policies and responsibilities for incorporating human factors engineering into the mainstream engineering and program management of each Air Force organization engaged in acquisition programs. HFE is defined as that component of systems engineering which influences system design to the degee necessary to ensure integration of the human performance required to effectively operate, maintain, support, and control the system in its intended operational environment. Human Engineering is one of five elements of the total HFE program, the others being biomedical, manpower and personnel, training, and test and evaluation. HE is that element of HFE pursued as a part of the hardware and software engineering effort that applies knowledge about human capabilities and limitations to system/ equipment design and development to achieve effective system and human performance.

In accordance with AFR 800-15, Air Force systems command (AFSC) maintains a command office of primary responsibility (OPR) for HFE and requires subordinate echelons to do the same. Specific program offices ensure that the appropriate HFE effort is planned for and implemented in all systems with a significant man-machine interface.

5.1.3. Contract documents.

5.1.3.1 Tasking. MIL-H-46855, establishes and defines the HE requirements for systems, equipment, and facilities. MIL-H-46855 is particularly important to the requiring organization and potential performing organizations. It is used primarily by the requiring organization to place HE provisions into the contract for performing organization compliance. Paragraph 5.3.5.1.2.2 describes how the requiring organization may go about tailoring this specification for the HE portion of the program RFP. The specification, the data items (see 5.3.5.1.3), and the standards are government and industry coordinated and approved by DOD. The appendix to MIL-H-46855 is a guide for tailoring the specification (see 5.3.5.1.2).

5.1.3.2 Data. Associated data requirements are found in DOD 5000.19L, Acquisition Management Systems and Data Requirements Control List, Data Item Descriptions (DID Form 1664), DI-H-7051 through DI-H-7059. These data items must be selectively applied, tailored, and justified based on the phase of system acquisition and the acquisition strategy as approved by the system program manager, as well as matching the tailored MIL-H-46855.

5.1.3.3 Design criteria. MIL-STD-1472 is a set of human engineering design criteria and principles used to achieve mission success through integration of the human into the system, subsystem, equipment, and facility. It is used to achieve effectiveness, simplicity, efficiency, reliability, and safety of system operation, training, and maintenance. Other specific HE design requirements are in military specifications and standards. HE design principles and design data are in HE guides, handbooks (see Appendix B), and general literature.

5.2 Organizational considerations. The HE function can be found at various organization levels (e.g., the Army small system HE manager may report directly to the program manager.) The job of the requiring organization HFE manager usually includes the HE task. Occasionally there will be separate requiring organization managers who specialize in training, training equipment, personnel requirements, or biomedical data. HE is also described by or contained in, programs or organizations with a variety of names. Some of the names under which HE operates are crew systems, ergonomics, human factors, human factors engineering, human engineering, engineering psychology, behavioral sciences, bioengineering, bioastronautics, and MANPRINT. Whatever the title, it is important that HE be able to communicate vertically to its management and laterally to the other technologies or program groups which serve its needs and which it serves, in turn. HE programs should be coordinated with system engineering, maintainability, system safety, reliability, integrated logistics support, and other HFE functions including biomedical, personnel, and training.

5.3 Application of HE during system acquisition. The purpose of this section of the guide is to assist requiring organization personnel in performing their day-to-day tasks. For the managers or users who have had considerable experience, it may be used for a review or checklist to be sure that they are doing all of the tasks that they should. For users who are new to HE work, most of what is provided herein will be useful to help accomplish their several tasks. New HE personnel will find that HE offers both variety and a challenge. In general, the workload is rigorous. It is the nature of the HE tasks to offer a seemingly unending quantity of problems and opportunities. There is really no point at which the job is totally finished. It is the task of the human engineering specialist to choose and work the tasks which are most significant to the program at any given point in the acquisition process. The following paragraphs provide assistance in system acquisition areas of:

a. Source data to initiate the HE effort.

b. Planning and scheduling information.

c. Coordination between HE and other disciplines and with the performing organization program manager.

d. Possible allocation of effort to consultants or subcontractor organizations.

e. Preparation of HE portion of the request for proposal.

f. Proposal evaluation.

g. Customer monitoring of performing organization.

The above activities are depicted in typical sequential order in figure 3. This figure also shows which activities are performed by the customer and the contractor. The first five activities must be performed by the customer. No activities are actually required to be performed by the contractor until the "proposal preparation" activity. However, it is recommended that these activities, if performed by the contractor, occur at approximately the same time that the customer is performing them. One way to accomplish this is with the contracting of studies.

5.3.1 Mission data sources. New concept development and system programs need a source or sources of mission data from which to initiate the HE concept exploration and later program phase analysis and design efforts. These data are in addition to the understanding of which HE requirements are derived from what documentation (described in the previous section.) Mission data are needed to provide an overall background of program data from which to develop new HE concepts or program detailed requirements. Initially, new program requirements are based on particular previous program study reports and requirements developed from research and exploratory development program phases. There are essentially five sources of data available to requiring organization HE personnel assigned to a new acquisition program. They are listed below and described in more detail in the following paragraphs.

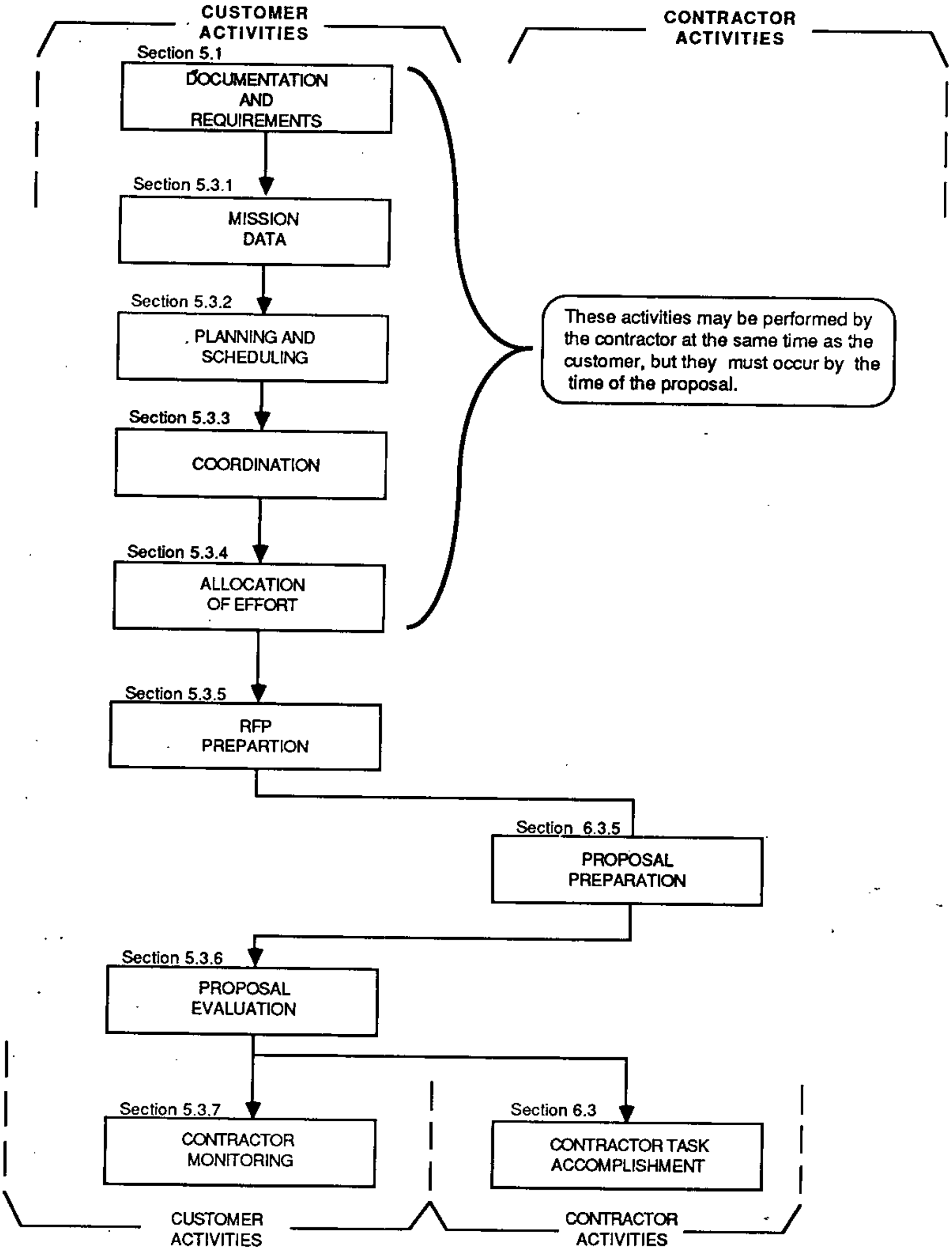


FIGURE 3. HE activities during system acquistion.

a. Data from development and planning organizations on studies determining feasibility (mission feasibility and concept formulation). R&D system paper studies developed by service laboratories' or by contractors' independent R&D.

b. Data from other previously developed but somewhat similar programs.

c. Data obtained from the potential service user organizations.

d. Generation of concept exploration program and HE system analysis data from scratch.

e. Analysis of new technology capabilities.

5.3.1.1 Studies. During the normal evolution of a system program, government development and planning organizations, and laboratories will fund paper/software analysis studies of the various proposed programs to help determine feasibility. These early concept evaluations (R&D studies) will determine the feasibility of the proposed program. When these studies are available for review, they should contain direct reference to HE, Crew Systems, or the man-machine interface. If they do not, they should contain at least some notion of the system functional relationships with implications for the man-machine allocation. A discussion of the planned crew system or displays and controls should be included in the documentation. Mission analysis, including scenarios, flight profiles, and possible time lines should contain direct implications for operator tasks.

5.3.1.2 Previous similar programs. Another useful source which will contain considerably more detail, but may not be as directly related to any particular need, will be similar, previously developed concepts or programs. Quite possibly, requirements for previous similar programs will be much the same in terms of: specifications and standards, planning and scheduling, coordination, allocation of effort, Request For Proposal (RFP) data, and methods of contract monitoring. HE test results from the operational T&E effort may also be useful. As a word of caution, it is recommended that before previous program data are utilized, the success of the HE portion of the program be determined. Perhaps the best way to find sufficient previous program data is to seek out the HE managers of those programs. Both the details of what was required for that program and the success of the man-machine interface resulting from these requirements should be determined.

5.3.1.3 User organization inputs. Communication, both direct conversation and correspondence, with the potential user organization will provide excellent information as to the new program needs and desired functions. Information can be obtained as to the user's experience with previous systems and to any innovative ideas they may have for the new system.

5.3.1.4 Generation of new data. HE must be involved in the concept exploration phase. Specifically HE performs mission analysis (scenarios and mission profiles) as necessary, functional analysis and allocation of requirements (to man, machine, or software), system specification development (human performance/human engineering), and system trade studies. Specific techniques to be used are described in section 6.3.6.3. They include functional flow diagrams, decision action diagrams, and operational sequence diagrams.

5.3.1.5 Application of new technology. Part of the requiring organization HE manager's job is to monitor specific technology areas continually for new man-machine interface concepts, e.g., automated speech technology. He should not have to start to develop or gather new technology data at the last moment. He must also stay abreast of significant decisions made at higher levels, in order that adequate HE research efforts can be planned and implemented.

5.3.2 Planning and scheduling. Planning and scheduling data enables the HE manager to track the sequence of events and determine if the HE inputs will have the optimum impact on design. Planning and scheduling information is generally easier to obtain than the mission source data. However, budget sufficient for performing and monitoring the HE effort is often not easily obtained. The following should be helpful in program planning, scheduling, and budgeting the HE effort.

5.3.2.1 Program control. The program control function will be established by the program manager and will include data on planning and scheduling activities and on analysis of resources. This includes the programming of performing organization, in-house, and review activities so that they mesh smoothly. It also includes documentation and management reporting. The principal techniques used to perform this planning and scheduling are the Work Breakdown Structure (WBS) and the event network (See 5.3.2.2 and 5.3.2.3).

5.3.2.1.1 Program phases. Programs may be expressed as RDT&E budget (and other) designations, i.e., Research, Exploratory Development, Advanced Development, Engineering

Development, and Operational Systems Development (see table II). Programs may also be expressed in terms of acquisition process, including milestone reviews and approvals, i.e., concept exploration, demonstration and validation, full-scale development, and production and deployment.

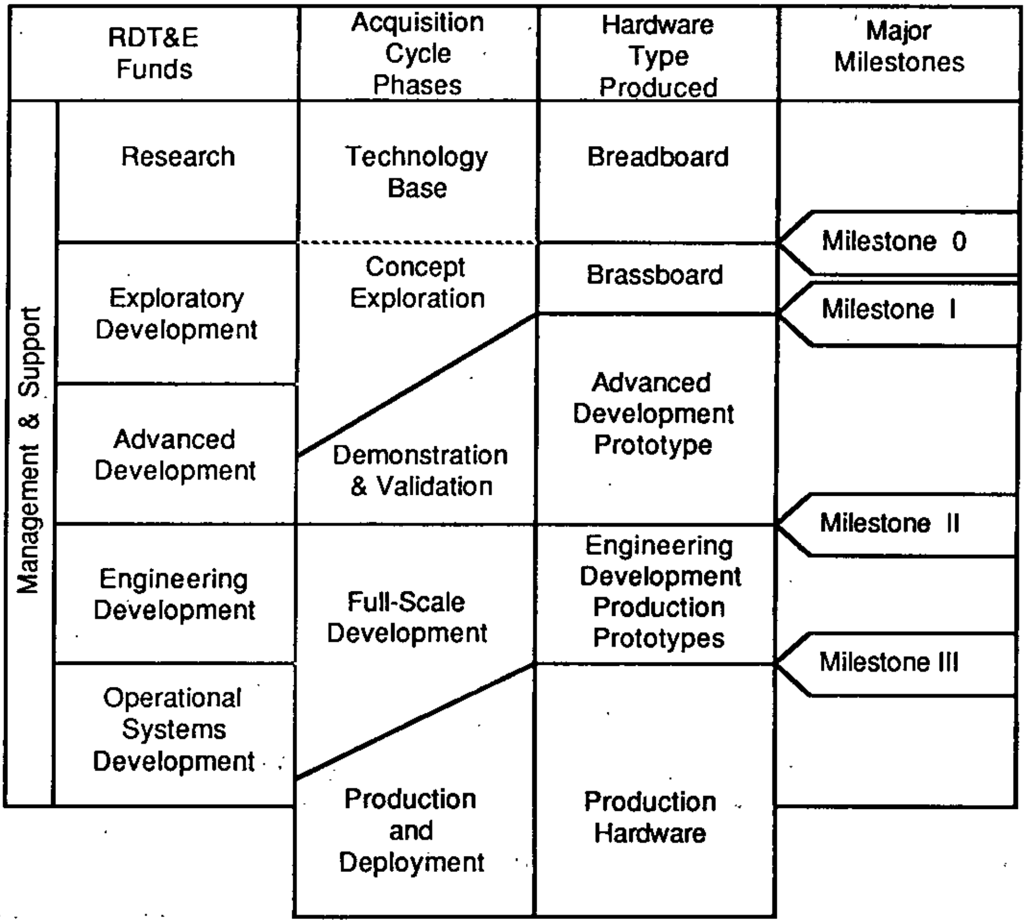
5.3.2.1.2 HE time-phasing. The HE manager should review the overall program schedule and WBS to insure that the HE functions as described in MIL-H-46855 and derived from his program source data effort (see 5.3.1) will occur at the proper time to be compatible with the other program functions. Every program has unique scheduling requirements. The HE manager must understand the type of program schedule so that he may understand the time-phased need for the principal portion of the HE effort. It is seldom too soon to initiate the HE portion of any program.

5.3.2.2 Work breakdown structure. The WBS is a numbered and indentured list of the development efforts to be conducted in the program, their subdivisions, and their interrelationships. The WBS is useful to the requiring organization for planning, costing, and scheduling of HE efforts. The format is determined by the project office and MIL-STD-881. It should reflect the specific goals of the program and the resources available to meet them. Figure 4 shows a partial example of a WBS for a hypothetical program. The location of HE or HE in relation to the other WBS elements may vary considerably from program to program.

5.3.2.3 Event network. The event network is a time phased work diagram. It is prepared, based on an analysis of the WBS and an analysis of the sequence of tasks and reviews required to carry out the proposed development efforts. Each Phase of the program should be broken down into blocks, each representing a discrete event. A discrete event is a portion of the program involving a single function, such as RFP preparation, kickoff meeting, design reviews, significant tests, or in some cases two or more closely coordinated functions, performed by a single group, such as a performing organization or a requiring organization facility, in a period of time that is also a discrete unit in the total sequence of events. That is, a discrete event may take place at the same time with other events or in series with the other units chronologically. Thus, similar functions may be repeated in the various phases. In such cases, they are listed as separate events in the network. The event network should identify the following items:

a. The flow of events, including those that are

TABLE II Acquisition cycle interrelationships



RDT&E Funds		Acquisition Cycle Phases	Hardware Type Produced	Major Milestones
Management & Support	Research	Technology Base	Breadboard	
	Exploratory Development	Concept Exploration	Brassboard	Milestone 0 Milestone I
	Advanced Development	Demonstration & Validation	Advanced Development Prototype	Milestone II
	Engineering Development	Full-Scale Development	Engineering Development Production Prototypes	Milestone III
	Operational Systems Development	Production and Deployment	Production Hardware	

Work breakdown structure Index

Program C-XXA

RFP no. ____

Contract no. ____

DATE

Line no.	Work breakdown structure elements/tasks							Material program code and/or WBS code	Eng. Dev.	Prod.		Eng. Dev. Prod. Cont. line item	Eng. dev. SOW paragraph number	Prod. SOW paragraph number	Specification number
	0	1	2	3	4	5	6 (Level)								
336			System Project Management					010600	X	X		0001	01060		
337				Systems Engineering Mgmt.				010610	X	X			010610		
338					Config. Development			01061 AO	X				01061.1	010610	
339						Baseline		01061AA	X						
340						Trade Studies		01061AB	X						
341					Design Definition			01061BO	X				01061.1		
342						Specifications		01061BA	X						
343						Design req./object		01061BB	X						
344						Config. Desc.		01061BC	X						
345						Trade Studies		01061BD	X						
346					Design Verification			01061CO	X				01061.1		
347						Design Reviews		01061CA	X						
348					Reliability/Maintainability			01061DO	X	X			01061.1	01061.2	
349					Experience Retention			01061EO	X	X			01061.1.2		
350					Safety Engineering			01061FO	X	X			01061.1.3		
351					Survivability/Vulnerability			01061GO	X	X			01061.1.6		
352					Human Factors Engr.			01061HO	X	X					
353						Human Engr.		01061HA	X	X					
354						Biomedical		01061HB	X	X					
355						Manning		01061HC	X	X					
356						HE Test and Eval.		01061HD	X	X					
357					Technical Integration			01061JO	X	X					
358					Mission Analysis			01061KO	X	X					

FIGURE 4. Sample work breakdown structure (WBS).

performed in parallel and those performed in sequence with other events.

b. The program functions to be performed in-house by the requiring organization and those to be performed by performing organizations.

c. The level (HQ, or other) of each guidance and review task.

5.3.2.4 System baseline. In addition to the WBS and event network, another program management tool that must be monitored is the system baseline. This is a description of the system being developed in terms of program requirements, design requirements, and configuration. These aspects of the baseline may be established at any point in a development effort to define a formal departure point for control of future changes in the program or the design of hardware. The baseline is documented by approved program and contract documents and by specifications and drawings prepared by the performing organization.

5.3.2.5 Budget. The HE manager's budget is of concern in terms of what he can do to monitor the program and what support he may obtain from labs or Research, Development, and Engineering (RD&E) centers. On small programs his duty as system acquisition HE manager may be in addition to other duties or he may be responsible for many small system/equipment acquisitions. Major system acquisition requires the full time assignment of several HE personnel to perform the necessary planning, scheduling, and management review functions. DOD-HDBK-248 indicates that crew systems is only 1.6% of the cost for a weapon system. The HE manager determines the performing organization's budget indirectly in that the more tasks he requires as part of the contract, the more budget the performing organization must have. However, task assignments should be made both on the basis of program need and relative capability of the requiring or performing organizations to do the job (see 5.3.4). There is a secondary effect on the HE manager in that the more tasks the contractor performs the more review by his organization is required.

5.3.3 Coordination. This activity is important in that it will identify and designate focal points to insure efficient working relationships and exchange of information. It will enable the collection and distribution of HE information. It will facilitate the identification of existing information, procedures, and techniques so that effort will not be duplicated. It will help identify lessons learned and help coordinate results. The result will be an improvement in HE techniques, methods, and management procedures.

5.3.3.1 With customer program manager. The HE manager must tell the requiring organization program manager what HE can do for the program. Included in this should be data as to previous program experiences (see 5.3.1.3) and scheduling data. The HE manager should be sure that the program manager understands the need for MIL-H-46855 (if it is required).

5.3.3.1.1 Drawing approval. In particular, the program manager should understand the need for performing organization HE approval of all drawings having an impact on the man-machine interface (see section 3.5 of MIL-H-46855). The knowledge that the requiring organization program manager will support HE analysis, design, and T&E will assure that the performing organization program manager will support it and the resulting hardware will indeed include the necessary HE criteria.

5.3.3.1.2 WBS organization. If there is any problem with the inclusion of HE in the WBS, it should be discussed with the program manager and program control personnel as soon as possible. The WBS created by the requiring organization should dictate that used by the performing organization. Any problems in the original will only cause problems for the performing organization HE effort later on. The WBS indenture level that calls out HE should be as high as possible in order to provide emphasis on the importance of the effort.

5.3.3.2 Intraorganization. This coordination is important to insure that other organizations and disciplines within each service are receiving the proper support from HE and vice versa. In addition to the program manager, the technology organizations illustrated in table I should be contacted on a day to day basis to integrate the analysis, design, and test support that HE has to offer and determine if they have additional information to provide on these subjects. Responsible personnel in the research labs, RD&E centers, and equivalent should be contacted to determine the extent they are involved and exchange information. The HE effort must be integrated into the total system program effort. In order to accomplish this interchange, meetings, training, and documentation could be provided to familiarize the appropriate personnel with HE. Table III shows the relationship of several important HE functions to other related program functions and to the acquisition phases.

5.3.3.3 Interorganization. Although not required, coordination with the other services HE personnel can be

TABLE III Relation of HE functions to other program functions and acquisition phases

PROGRAM PHASES:	CONCEPT		DEMONSTRATION VALIDATION	FULL SCALE DEVELOPMENT	PRODUCTION/ DEPLOYMENT
	RESEARCH	EXPLORATORY DEVELOPMENT	ADVANCED DEVELOPMENT	FULLSCALE ENG. DEV.	PRODUCTION/ DEPLOYMENT
HUMAN ENGINEERING ACQUISITION FUNCTIONS	• EXPERIMENTS • STUDIES • MOCKUPS • SYSTEM ANALYSIS • TASK ANALYSIS • PLANS		• TASK ANALYSIS • DETAILED DESIGN • MOCKUPS/ • PROTOTYPES • DEMONSTRATIONS • PROCEDURES DEV.	• DETAILED DESIGN • PRELIM. EVAL. • DEMONSTRATIONS • PROCEDURES DEVELOPMENT	• FORMAL T&E
HUMAN ENGINEERING INTERFACES WITH RELATED AREAS	• BIOMEDICAL • PERSONNEL REQUIREMENTS • MAINTAINABILITY • RELIABILITY • SAFETY • SYSTEM ENGINEERING • ILS		• BIOMEDICAL • PERSONNEL REQ. • MAINTAINABILITY • PROJECT DESIGN • SYSTEM ENG. • ISD/TRAINING • PRELIMINARY LIFE-CYCLE COSTS	• BIOMEDICAL • LOGISTICS • PUBLICATIONS • MAINTAINABILITY • PROJECT DESIGN • SAFETY & RELIAB. • ISD/TRAINING • LIFE CYCLE COSTS • TECHNICAL T&E	• BIOMEDICAL • PUBLICATIONS • MAINTAINABILITY • SAFETY • ISD/TRAINING • OPERATIONAL T&E
OBJECTIVES	TECHNOLOGY RESEARCH	PAPER STUDIES	CRITICAL ISSUES EVALUATED	ENGINEER EVAL. DT&E AND OT&E	OPERATIONAL HARDWARE
DOD PROGRAM MILESTONES	△ MILESTONE O APPROVAL OF MISSION NEED AND PROGRAM INITIATION	△ MILESTONE I APPROVAL TO DEMONSTRATE SELECTED ALTERNATIVES	△ MILESTONE II APPROVAL FOR FULL-SCALE ENG. DEV. AND LIMITED PROD. FOR OT&E	△ MILESTONE III PRODUCTION RELEASE DECISION	

useful, and is strongly recommended where technical HE data on common items may be involved. There is sufficient probability that all requiring organizations would benefit from the interchange of data on similar aspects of their different programs. Both methodologies and design requirement solutions should be discussed. The participation in HE tri-service, NASA, and industry conferences/meetings is encouraged for the exchange of useful data.

5.3.4 Allocation of effort. The normal allocation of the HE effort is from the requiring organization through the contract SOW to one or two contractors. However, there are several possible variations on this. The following present a few alternatives to the normal HE work allocation:

5.3.4.1 Alternative allocation of effort. Although the system requirements are generally assigned for development by a contractor, the assignment of all HE functions to the same contractor is not automatic. It is possible that the prime contractor does not have the capability to perform a complete or even a partial HE effort. The contractor may propose the apportionment of HE tasks to other sources. Or the requiring organization HE manager may decide that the best capability to perform certain HE tasks exists within service labs, RD&E centers, or test centers. Another performing organization may be selected to perform the HE effort. Numerous small HFE companies provide complete HE services in analysis, design criteria, and testing. Although some companies do not provide the complete HE effort as defined in MIL-H-46855, they do provide a thorough knowledge of system acquisition and of HE effort monitoring.

5.3.4.2 Additional coordination. In addition to the problems of determining whether the requiring organization or other sources do have a better capability to provide a portion of the HE effort, the HE manager takes on the added tasks of coordination between split HE effort allocations. This also requires that the proper budget is provided along with the time and personnel for the lab/test center to do the job.

5.3.5 RFP preparation. HE inputs to the Request For Proposal (RFP) vary considerably depending on the size and nature of the procurement. This section provides information on both major and nonmajor acquisitions as well as traditional and streamlined acquisitions.

5.3.5.1 Traditional acquisitions. The RFP preparation effort is by far the most significant single factor in insuring an adequate HE program. All program requirements must be included in the RFP package initially. Based on all of the previously developed source data and allocation decisions, the HE manager is able to provide HE inputs to the RFP. These inputs should generally be provided to four separate portions of the RFP. These are the preliminary system specification, the SOW, the Contract Data Requirements List (CDRL), and source selection criteria. Another possible section which may contain HE data are the proposal preparation instructions.

5.3.5.1.1 Preliminary system specification. The preliminary system specification should contain a paragraph (generally paragraph 3.3.7) in accordance with MIL-STD-490 which calls out the Human Performance/Human Engineering requirement including, for example, MIL-STD-1472. It is appropriate for HE to provide inputs to other specification sections. Specifications are presented in more detail in paragraph 7.2.2.8

5.3.5.1.2 SOW inputs. The major portion of the HE RFP effort may be described in the SOW, which should indicate the particular type of work the requiring organization HE manager feels must be performed. This may include, if justified by need, trade-offs, and mockups or simulations. If there are any particular HE objectives requiring emphasis, such as crew size or critical performance, these should be so stated. It is generally better to include all the HE efforts for the program in a single section of the SOW rather than apportion them to each of the applicable subsystems. The contractor should respond in the same manner so that the total HE program may thereby be prepared and reviewed with less effort.

5.3.5.1.2.1 Selective application of MIL-H-46855. The method of determining the general applicability of MIL-H-46855 to traditional programs is called out in paragraph 30.0 of the MIL-H-46855 appendix. The HE manager is urged to carefully read these provisions before selecting MIL-H-46855 as a program requirement. It should be further noted that if a customer organization HE manager has already been assigned to a program, the chances are high that MIL-H-46855 should also be required. Conversely, if MIL-H-46855 is not required, the need for the HE manager is questionable.

5.3.5.1.2.2 Tailoring. During the past few years, the subject of tailoring has gained prominence, presumably because of DOD directives describing system acquisition methods. The need for tailoring is based on the concept that the reason many system acquisitions cost so much is that they are designed and built per specifications or constraints which in many cases are not really 'useful' or appropriate either to that particular program or for a particular design phase. Tailoring is an attempt to modify specifications to require only that which is useful to the planned system acquisition phase.

5.3.5.1.2.2.1 Tailoring considerations. There is little question as to the short term cost-effectiveness of HE specification tailoring. Before tailoring is accomplished by either the requiring organization or contractor, a few extremely significant factors must be considered:

a. The probability that the program will complete the full acquisition cycle.

b. The nature of the specification tailoring savings as short term only, long term only, or both short and long term.

c. The amount of short term savings due to tailoring.

d. The cost to change the system design to meet long term system performance requirements (e.g., maintainability and operability) not necessary for the initial acquisition phases.

e. Life-cycle costs associated with waiving the reliability, maintenance, and operability requirements normally specified.

f. The comparison between items c), d), and e) above.

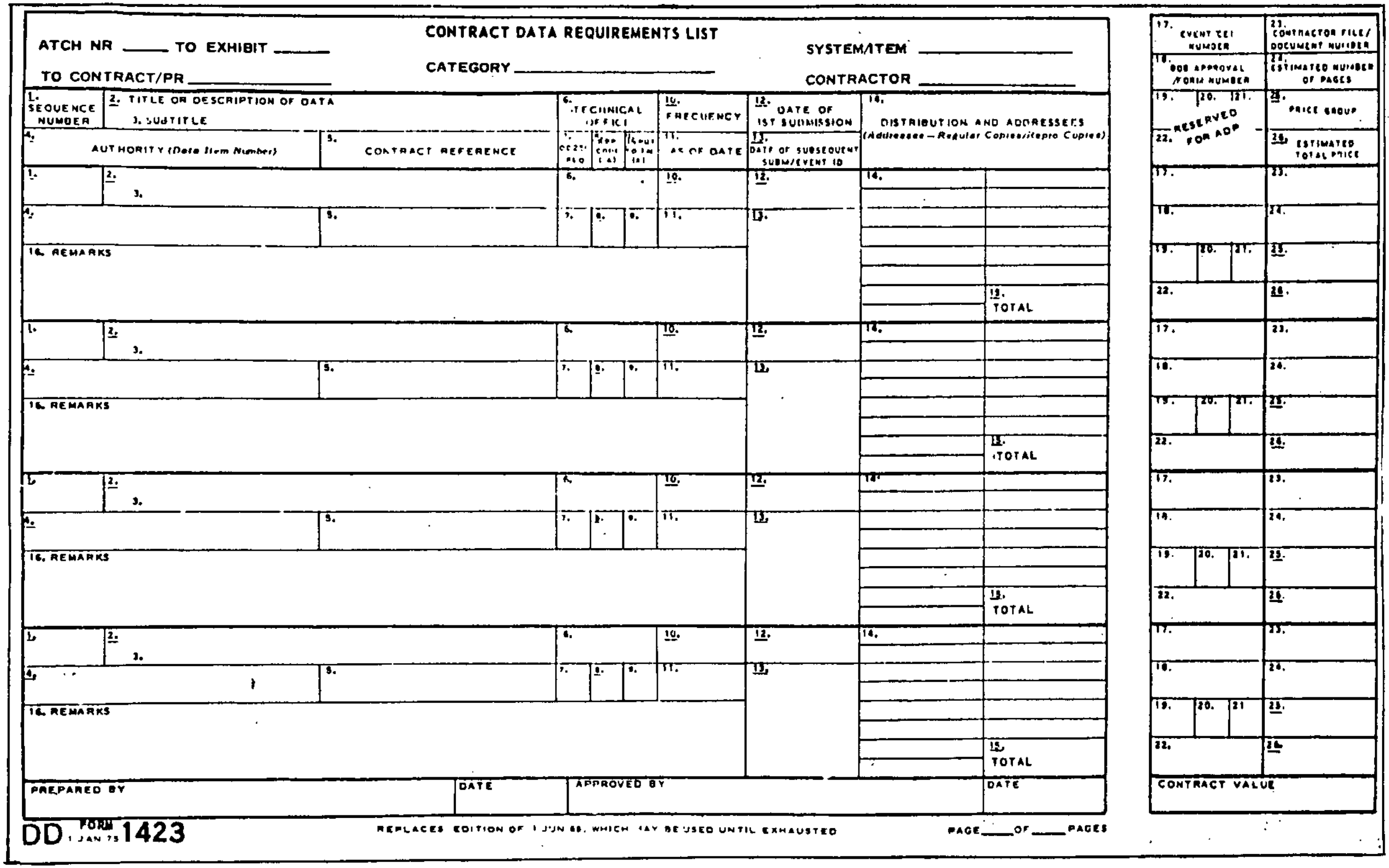
The answer to the first factor is "most probable". Very few programs ever fail to pass their milestone review meetings. Therefore, both long term Life Cycle Costs (LCC) and short term savings are significant. If the savings are short term only, they need to be balanced against possible increased life cycle costs that they could cause. These costs could be for Engineering Change Proposals (ECP'S), system design revisions, operator or maintainer errors resulting in costly failures, equipment malfunctions, or safety hazards.

5.3.5.1.2.2.2 MIL-H-46855 tailoring. The recent concept of tailoring as applied to HE is somewhat ironic in that MIL-H-46855 has always clearly stated that it may be invoked on contracts either in its entirety or selectively. In their HE Plan, the contractor should always describe those HE tasks which they determine are most cost effective to perform. In accordance with MIL-H-46855 and the HE Plan Data

Item (DI-H-7051), the contractor provides what they feel is a tailored version of the HE tasks to be accomplished (or not to be accomplished) for the program. The customer HE manager should determine the general applicability of MIL-H-46855 to the particular program and the specific paragraph applicability. The method for doing this is included as a tailoring appendix to MIL-H-46855.

5.3.5.1.3 HE data items. Depending on the phase of the acquisition, the budget, the acquisition strategy, and with the approval of the Data Management Officer and the program manager, the HE program manager may include any of the HE Data Items. The HE program manager will use the contractor generated data, as appropriate, in support of the decision making milestones. Each HE task may involve some form of contractor-prepared plan, list, form, analysis, or data. If the customer requires preparation and delivery of any of these, they must be identified as a data item. Each separate HE data item must be included on a DD form 1423, or contract data requirements list (see figure 5) which is the CDRL which must be included as part of the contract. Each DD form 1423 must refer to an authorized DID which can be found, listed by title, in DOD 5000.19-L Volume II, Acquisition Management System and Data Requirements Control List (AMSDL). An example of the Critical Task Analysis Report (CTAR) DID is given in figure 6. Tailoring of the DID's to meet the specific data requirements is authorized (block sixteen on DD form 1423). DD form 1423 must also include a specific contract reference (e.g., SOW, para. X.X.X.X) that specifies and authorizes the work to be done for documentation in each data item. Also to be filled out are blocks establishing the dates, delivery and destinations, approval authority, and approval procedures. The customer HE manager should check with the lead data manager and data deliverable instructions when calling out CDRL deliverables. Precise procedures for requiring data items from contractors may vary from one customer organization to another. In 1979, the following updated series of human engineering DIDs were published with ARMY\MIRADCOM as the office of primary responsibility:

DI-H-7051, "Human Engineering Program Plan" (HEPP)
DI-H-7052, "Human Engineering Dynamic Simulation Plan" (HEDSP)
DI-H-7053, "Human Engineering Test Plan" (HETP)
DI-H-7054, "Human Engineering System Analysis Report" (HESAR)
DI-H-7055, "Critical Task Analysis Report" (CTAR)
DI-H-7056, "Human Engineering Design Approach Document-Operator" (HEDAD-O)
DI-H-7057, "Human Engineering Design Approach



CONTRACT DATA REQUIREMENTS LIST

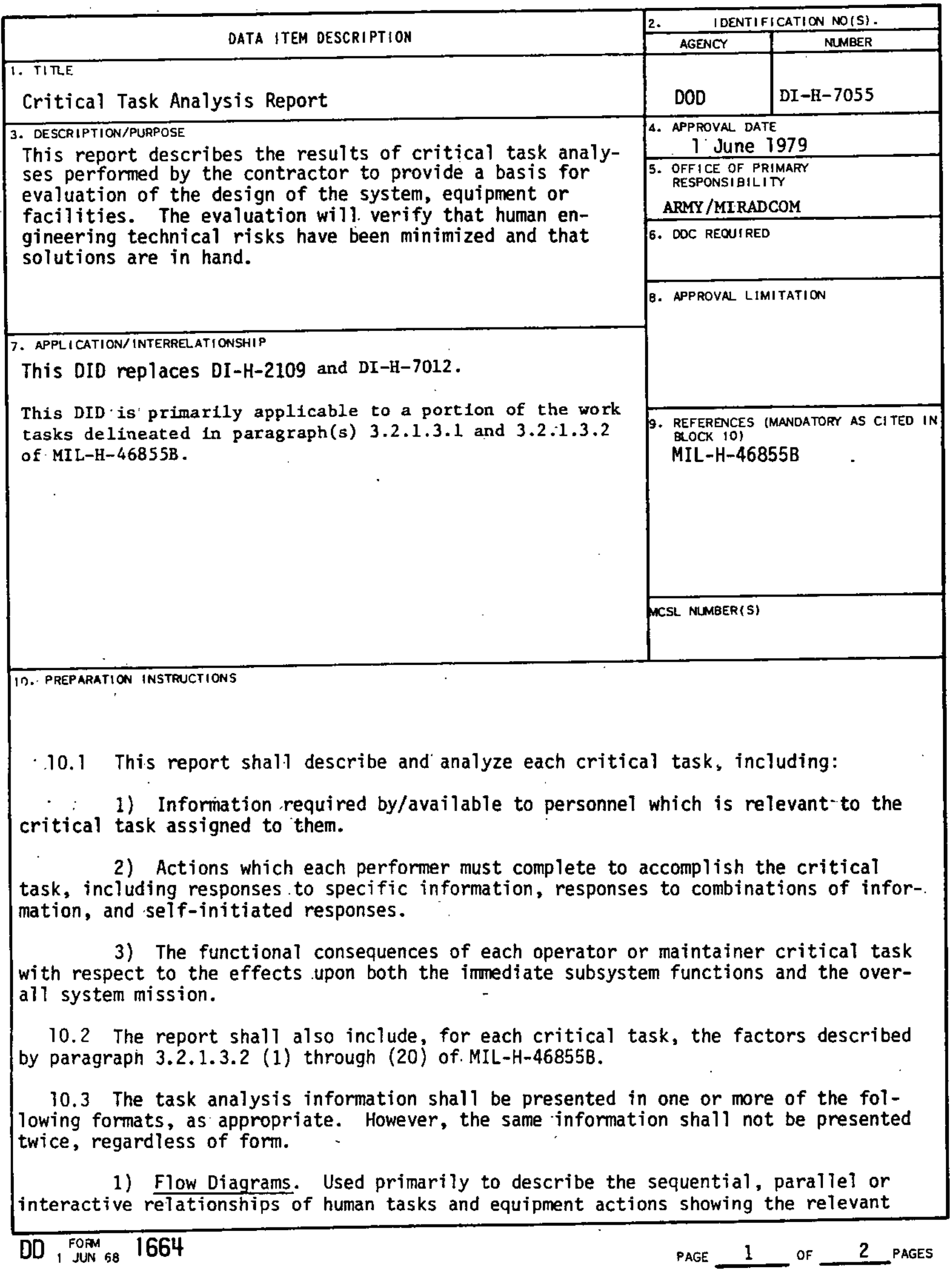
ATCH NR ____ TO EXHIBIT ____
TO CONTRACT/PR ____
CATEGORY ____
SYSTEM/ITEM ____
CONTRACTOR ____

1. SEQUENCE NUMBER
2. TITLE OR DESCRIPTION OF DATA
3. SUBTITLE
4. AUTHORITY *(Data Item Number)*
5. CONTRACT REFERENCE
6. TECHNICAL OFFICE
7.
8.
9.
10. FREQUENCY
11. AS OF DATE
12. DATE OF 1ST SUBMISSION
13. DATE OF SUBSEQUENT SUBM/EVENT ID
14. DISTRIBUTION AND ADDRESSEES *(Addressee – Regular Copies/Repro Copies)*
15. TOTAL
16. REMARKS
17. EVENT TEI NUMBER
18. DOD APPROVAL /FORM NUMBER
19.
20.
21.
22.
RESERVED FOR ADP
23. CONTRACTOR FILE/ DOCUMENT NUMBER
24. ESTIMATED NUMBER OF PAGES
25. PRICE GROUP
26. ESTIMATED TOTAL PRICE

PREPARED BY
DATE
APPROVED BY
DATE
CONTRACT VALUE

DD FORM 1 JAN 73 1423
REPLACES EDITION OF 1 JUN 68, WHICH MAY BE USED UNTIL EXHAUSTED
PAGE ____ OF ____ PAGES

FIGURE 5. Sample DD Form 1423.



DATA ITEM DESCRIPTION

2. IDENTIFICATION NO(S).

AGENCY	NUMBER
DOD	DI-H-7055

1. TITLE

Critical Task Analysis Report

3. DESCRIPTION/PURPOSE

This report describes the results of critical task analyses performed by the contractor to provide a basis for evaluation of the design of the system, equipment or facilities. The evaluation will verify that human engineering technical risks have been minimized and that solutions are in hand.

4. APPROVAL DATE

1 June 1979

5. OFFICE OF PRIMARY RESPONSIBILITY

ARMY/MIRADCOM

6. DDC REQUIRED

8. APPROVAL LIMITATION

7. APPLICATION/INTERRELATIONSHIP

This DID replaces DI-H-2109 and DI-H-7012.

This DID is primarily applicable to a portion of the work tasks delineated in paragraph(s) 3.2.1.3.1 and 3.2.1.3.2 of MIL-H-46855B.

9. REFERENCES (MANDATORY AS CITED IN BLOCK 10)

MIL-H-46855B

MCSL NUMBER(S)

10. PREPARATION INSTRUCTIONS

10.1 This report shall describe and analyze each critical task, including:

1) Information required by/available to personnel which is relevant to the critical task assigned to them.

2) Actions which each performer must complete to accomplish the critical task, including responses to specific information, responses to combinations of information, and self-initiated responses.

3) The functional consequences of each operator or maintainer critical task with respect to the effects upon both the immediate subsystem functions and the overall system mission.

10.2 The report shall also include, for each critical task, the factors described by paragraph 3.2.1.3.2 (1) through (20) of MIL-H-46855B.

10.3 The task analysis information shall be presented in one or more of the following formats, as appropriate. However, the same information shall not be presented twice, regardless of form.

1) Flow Diagrams. Used primarily to describe the sequential, parallel or interactive relationships of human tasks and equipment actions showing the relevant

DD FORM 1 JUN 68 1664

PAGE 1 OF 2 PAGES

FIGURE 6. Sample DID.

DI-H-7055

10. PREPARATION INSTRUCTIONS (continued)

antecedents and the consequences of each operator action.

2) Tabular Presentation. Used to describe discrete units of a given task measured along a time-base or other quantitative performance criteria. This mode of presentation may be used to show a level of detail that cannot be encompassed in the flow diagrams.

3) Narrative Description. Used to describe tasks which can be satisfactorily accomplished by any of a number of optional procedures which may be chosen by the operator. Such description shall specify the concepts and objectives of the task to be performed rather than the concrete procedures to be employed.

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FIGURE 6. Sample DID(continued).

Document-Maintainer" (HEDAD-M)
DI-H-7058, "Human Engineering Test Report" (HETR)
DI-H-7059, ."Human Engineering Progress Reports (HEPR)

Only minimum essential data items should be selected. The underlying objective of the DID's is to provide the customer information with which to verify that the system HE performance, design, and program requirement are being met, and to support the decision making process. The contractor may also propose tailoring of HE tasking directly or as indicated in their HEPP (DI-H-7051) if one is required. Other data items may also be tailored. The tailoring of the data items must correspond to the tailoring of MIL-H-46855 as it applies to the procurement involved. The data items may be omitted if not necessary or they may be modified to delete any ineffective or costly portions which do not apply to the particular program.

5.3.5.1.3.1 HE program plan. The HEPP is one of the most commonly called out data requirements. By requiring the HEPP, the customer will be able to see how the contractor intends to perform all of the applicable and essential tasks of the program. For example, the contractor should show how their effort is to be productive in impacting the system and hardware design. To be effective the HEPP preparation and delivery should be scheduled in a way as to permit recognition of foreseeable problem areas, and identification of efforts required to investigate and correct these problems. Figure 7 is an example of a schedule for a HEPP in relation to the acquisition phases. A list of major HE tasks and the HE DIDs are shown indicating their proposed relationship. The sample schedule proposes activity/event and deliverable sequences along with effort level (high or low). There must be an effective working relationship with design engineering established at the onset of the program and carried through to its conclusion. HEPP demonstration of such a relationship, as well as scheduling of HE assessment so as to clearly impact system design should be a factor in the source selection process. A sample HEPP, for new ship construction is included in appendix C. DI-H-7051, Human Engineering Program Plan (HEPP), is the most inclusive HE Data Item and may be used alone. It may be noted that MIL-H-46855 requires HE Program Planning. However, the only reasonable way to specify a HE Program Plan is to list a requirement for (DI-H-7051) in the CDRL.

If a Preliminary HE Plan is required as a part of the total program proposal, a detailed HE plan should be finalized for approval subsequent to the customer - contractor guidance meeting. When this plan is approved by the customer, it will

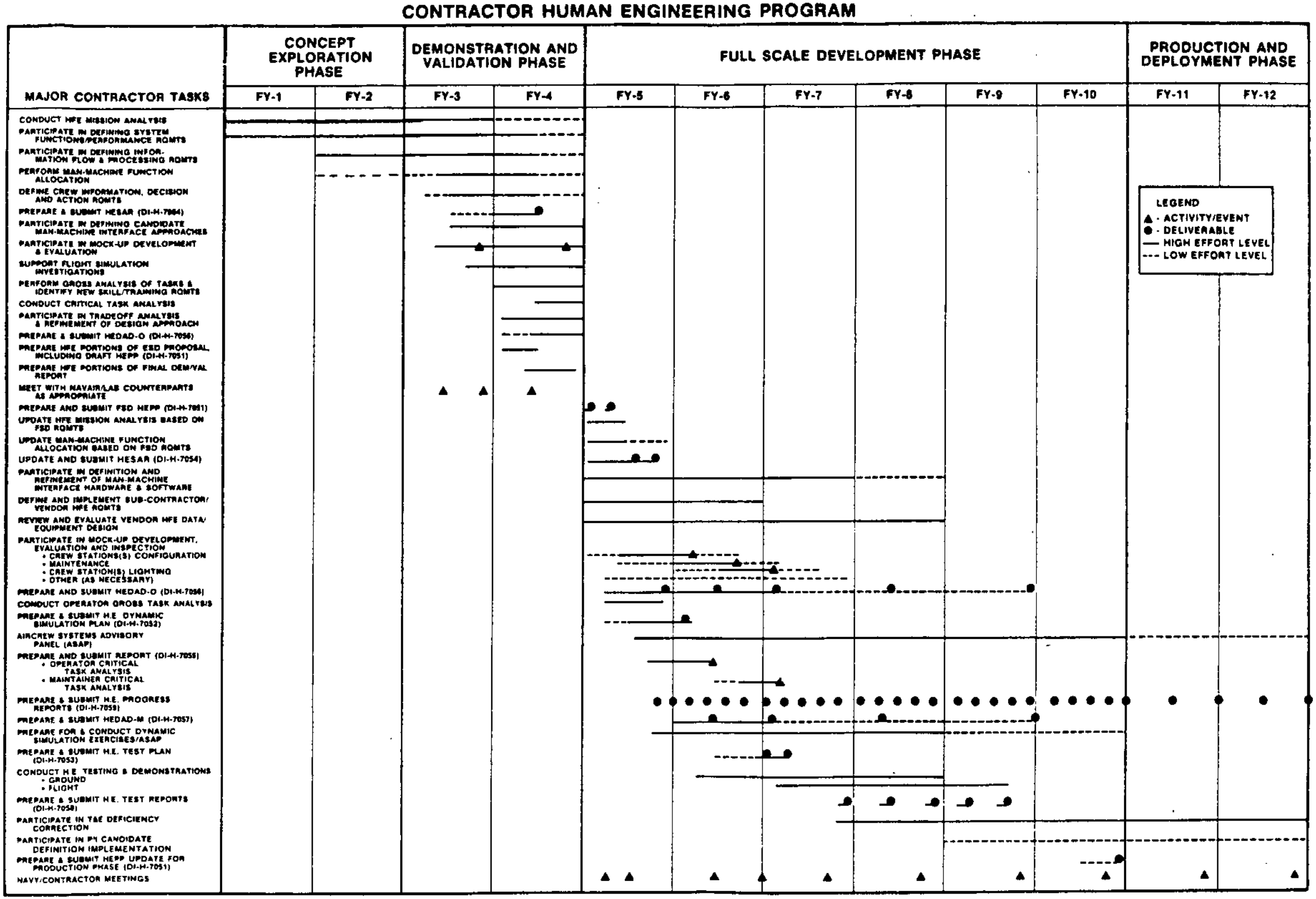


FIGURE 7. Hypothetical HEPP schedule.

be used by the contractor to direct their program efforts (see 6.3.7) and should be used by the customer to maintain conversance with the program and anticipate HE needs. If any changes to these efforts (as described by the plan) occur, the contractor must report and justify them to the customer.

5.3.5.1.3.2 HE dynamic simulation plan. The HEDSP should be called out when the customer wants to insure that the contractor will obtain the best utilization of dynamic simulations. Dynamic simulation would normally take place early during Full Scale Development (FSD). It (they) could also take place as part of the demonstration and validation phase. The implication of requiring this plan, the HEPP, or the HE test plan is that the effort to prepare the plan is more than balanced by the more effective use of HE resources to perform the activities in accordance with more formal documented planning provided by the deliverable data requirement.

5.3.5.1.3.3 HE test plan. The HETP should be specified to insure that human performance requirements for operations and maintenance of a system are met and reported to the customer. It should identify the types of tests to be conducted, test subjects, how they compare to user population, and data collection and reporting techniques. This information should enable the customer to determine the influences of the human operators and maintainers and their performance on total system effectiveness and reliability. It should indicate how the test program results will influence the design and apply to follow-on equipment or similar systems. Depending on the nature of the program, the plan may not be required. Rather, the HEPP should expand its presentation of T&E to include material otherwise covered in this HE test plan. More often than not, a total program plan is required for formal T&E. HE testing should be included as a part of the total program T&E plans which are prepared by the customer and contractor T&E. Neither the HETP or the HETR is generally required for informal developmental testing. When required, this plan is called for during acquisition phases in which the T&E provisions of MIL-H-46855 are invoked -- during demonstration and validation, full scale engineering development, or occasionally production and deployment.

5.3.5.1.3.4 HE system analysis report. The HESAR is useful for evaluating new systems or major elements in a system and to report rationale for function allocation trades. The customer uses this information to evaluate appropriateness and feasibility of system functions and roles allocated to operators and maintainers. This report may be a means to the end of requiring HE on the program early on. It should be required during the concept or validation program phases or not at all.

5.3.5.1.3.5 Critical task analysis report. The CTAR should provide a list of critical tasks to be reviewed and the rationale for their selection. Accordingly, the methodology, level of detail and format of the report should be identified. The customer uses this report to verify that HE technical risks have been minimized and that identified "critical task" problems have been resolved. If required the CTAR should be developed and completed during the FSD portion of the program, specifically not later than the Critical Design Review (CDR). Prior to this time there is not sufficient data available on which the analysis may be based. After this time the information is too late to impact the system design. If the CTAR is required during the program demonstration and validation phase, the DID reference to MIL-H-46855 should be modified to indicate that not all 20 items under paragraph 3.2.1.3.2 "Analysis of Critical Tasks" need be identified. All 20 items are appropriate for the FSD program phase.

5.3.5.1.3.6 HEDAD-O. The customer uses these data to evaluate the operator interface to insure it meets the human performance and HE requirements. The HEDAD-O may be usefully required during the FSD, demonstration and validation, and even concept exploration program phases. It is most appropriate for the full scale development phase.

5.3.5.1.3.7 HEDAD-M. The customer uses these data to evaluate the maintainer interface to insure it meets the human performance and HE requirements.

5.3.5.1.3.8 HE test report. The customer uses this report to determine the compatibility of the human performance requirements, personnel selection criteria, training program, and design of the personnel-equipment/software interfaces. This is one of the more important and more frequently used data item descriptions since it provides hard data to validate that human engineering requirements have been met or to define the degree to which problems may exist. In addition to serving these purposes of acceptance and oversight insofar as compatibility with the user is concerned, such test data are also provided for feeding back into the system design or into later, newer designs. Because the extent of the report, by and large, will be a function of the system itself, degree of user-system interface, and acqusition phase, careful tailoring is suggested. As with all other data item descriptions, the tailoring of the HE Test report should be consistent with the tailoring of the tasking document--in this instance, MIL-H-46855.

5.3.5.1.3.9 HE progress report. The customer uses this report to identify progress, technical problem areas, and plans for next reporting period. It enables the HE manager to determine how the program is progressing in relation to the schedule of activities. The value of the progress report are limited to minimum essential information, the following should be considered.

a. The HEPR should be required only as frequently as necessary.

b. It should only report data not available in other CDRLs or at design review meetings.

c. If the HEDAD's are required, the progress report may not be necessary on small programs.

d. The report should provide only updates to past reports (reference DID).

5.3.5.1.4 Source Selection Criteria. As part of the RFP preparation, a source selection plan will be developed to include evaluation criteria against which the proposal will be evaluated. Source selection criteria content must follow the instructions to offerors. Allocation of emphasis to HE should insure a best effort response to the HE aspects of the RFP.

5.3.5.1.5 Draft RFP's. Frequently, in order to create a better quality RFP, a draft RFP is issued to potential competitors for their review and comment. Such drafts have advantages in that the customer can try out requests for particular program tasks, provisions, or methodologies. Industry feedback on draft RFPs has the potential for effecting substantial savings by pointing out unnecessary constraints. The contractor's responses to the final RFP are generally of better quality since they have had more time to work the requested proposal problem. The customer HE manager should participate in the draft review in order to suggest the kind of effort that he feels should be contained in the RFP.

5.3.5.2 Nondevelopment Items (NDI). If the acquisition is for NDI, MIL-H-46855 should generally not be called out. NDI refers to products that can be purchased off-the-shelf without development time or development costs. This applies to products built to commercial standards as well as military standards. To procure NDI's the government conducts a market investigation of user organizations of all candidates offered by industry. HE provides inputs to this investigation. Based on the results of this investigation, and factors such as needed additional test data the NDI procurement is initiated.

HE participates in the preparation of the NDI specification by providing HE requirements the NDI must meet. While differing degrees of NDI may be encountered, the common thread through the approach is to use already available items. HE effort, therefore, is focused on specifying performance requirements, rather than tasking and data provisions characterized by MIL-H-46855. If some development is involved, MIL-H-46855 can be applied judiciously; however, if the NDI contains no RDT&E authorization, MIL-H-46855 should not be specified.

5.3.6 Proposal evaluation. The HE manager should play an active role in the proposal evaluation process. HE must participate as a member of the source selection team to insure that the proposed approach to dealing with the system man-machine interface meets the criteria described in section 6.3.6. The requiring organization HE manager must develop the facts upon which to base source selection. He must be able to determine whether the potential performing organization understands what needs to be done. This includes understanding of the HE requirements and scope and magnitude of the project, realism of approach, risk assessment, and life cycle cost implications. The HE performing organization must clearly show that the requirements are recognized, that a preliminary analysis was made in arriving at the approach, and that the requirements will be satisfied in a timely and cost-effective manner. The areas in which tradeoff decisions will need to be made should be identified with candidate alternatives and the rationale and schedule for their selection. The requiring organization HE manager must check to insure intended compliance with HE provisions of the SOW, CDRL, and specification.

5.3.6.1 HEPP evaluation. If a preliminary HE Program Plan is called for, a significant part of the HE management evaluation can be made by a thorough review of the plan and portions of the proposal to which the plan relates. Evaluation ratings and rankings must be in accordance with the overall source selection plan established for the system.

5.3.6.2 Experience evaluation. The offerers' directly applicable and related HE experience should be evaluated. They must clearly indicate the relevance of experience gained in similar programs of equal or greater complexity. They may wish to provide "lessons learned" and to show how their experience will benefit the particular proposed program.

5.3.6.3 Interorganization evaluation. The relation of HE to other disciplines must be indicated as well as the relation of HE to program management. However, the latter relationship should not be evaluated as being right or wrong but is used by the customer for information. Consideration of design to cost or design to life cycle cost as it affects HE should also be evident in the proposal.

5.3.7 Contractor monitoring. After the contract award is made, monitoring can be accomplished in a number of ways. These are the HEPP, conferences, design reviews, trade study reports, CDRL reports, HE data file review, baseline configuration review, and frequent use of the telephone or visits to the performing organization and test facilities.

5.3.7.1 Program planning review. If an HEPP is required, it must be reviewed and modified if necessary within a few weeks from the start of the contract. A program kick-off meeting for just HE alone is a good idea to discuss any ambiguities in the plan and to make necessary changes. The meeting is also helpful in that the customer and contractor can meet face to face and go through the plan, section by section, prior to later important design reviews. The meeting should be at the contractor's facility in order that the facility itself and the work already performed can be shown to the customer (see 5.3.7.6). Once approved by the customer, the HE Program Plan will be the basis for the HE contractual compliance.

5.3.7.2 Data Requirements review. If progress reports are required, they must be reviewed and evaluated. The customer's HE data review function may vary from complete responsibility in the case of data submitted in response to HE CDRL items, or to just "comment" or concurrence action data. The scope and purpose of the review is to assure that the contractor's efforts are of acceptable quality and in accordance with the contract specification and work statement. The customer HE manager must also attend major design reviews such as the Preliminary Design Review (PDR) and Critical Design Review (CDR). He must insure that his contractor counterpart is a significant participant in the presentation of program data. The increased attention and emphasis on evaluation during early design phases have led to the frequent use of mockups to assist in design evaluations. If early development of mockups is required in the full-scale development phase, then it helps to serve as a design configuration aid. The HE manager may also wish to attend certain test and evaluation events which are significant to the man-machine interface. He may initiate design review reports and may participate in review of ECP's when required.

5.3.7.3 Baseline Monitoring. Frequently, the system design will progress by means of an evolving baseline configuration.

The baseline will probably start as that indicated in Section 6.3.2.2 Baseline Monitoring. In order to insure that all subsystems or elements of the WBS are directed toward the same configuration, a baseline with configuration control is maintained. It is modified only by agreement of all affected and the modifications are published for information and review to those organizations that should be involved, It is part of the HE manager's job to keep track of this baseline configuration and to insure that there are no potential existing HE problems associated with the design.

5.3.7.4 Data file review. During the period of design reviews (or at any convenient time), while the customer HE manager is visiting the contractor the contractor's HE data file should be reviewed. This file should contain copies of correspondence, reports, analyses, specifications, sketches, drawings, checklists, and test data reflecting HE actions and decision rationale. This review time can be well spent to assess how well the contractor is doing his job.

5.3.7.5 Contract monitoring limitations. Generally, during the period of program acquisition, the HE manager is available to answer performing organization questions, provide data, and give advice. However, in recent years, a few program acquisition phases have been competed. Hardware has been designed and prototypes constructed for a shoot-off. In this kind of a competition, it is not appropriate for the HE manager to provide help or information to one contractor without being very sure that the same help or information is provided to the other contractor In this situation, the total efforts of the customer's HE manager must necessarily be conducted only through procurement officials, if at all, and then with much greater care than if there were no competition.

5.3.7.6 Meetings. Within a few weeks after the contract award, a guidance meeting should be arranged between the customer and contractor to discuss what each of the two parties feels is the necessary HE (or HFE) effort for the program. The customer should tell the contractor his evaluation of the HE inputs to the proposal. If an HE Plan was submitted, this evaluation will be directed primarily to that item. The customer's HE monitor should provide the contractor with detailed guidance as to the problems and the needs the HE effort should address. The meeting may be used to discuss customer sources of analysis input data not previously known to the contractor. The contractor's choice of analysis, design, and test techniques may be reviewed. Significant human performance requirements should be defined to avoid later misunderstanding. HE will also participate in program design reviews such as the PDR and CDR. Results of HE efforts, including applicable trade studies and critical task analysis, will be reported. Derived HE design criteria and applicable HE design requirements should be presented (see 6.3.7.1).

6. HE PROCEDURES FOR PERFORMING ORGANIZATIONS

After the award of the contract, the largest portion of the program effort is in the hands of the contractor. Along with several other technologies, HE must refine its program planning and scheduling effort. It must initiate the development of system requirements, conduct design trade studies, participate in the design of the program development model, and evaluate the design model through the use of appropriate test techniques. This major section is provided to assist the performing HE organization in the accomplishment of this job. Section 5.0 should also be read to obtain the requiring organization's point of view of the procurement process.

6.1 Documented requirements. Contractor tasking requirements are provided directly by the contract statement of work. A listing of specifications, standards, and other requirements documents is contained in Appendix B. These documents are cross referenced by service and this guide's paragraphs. It is important to understand that the specifications, standards, and handbooks noted in Appendix B are typically imposed by a procuring activity on a contractor while the regulatory and policy documents are imposed on procuring activities by higher headquarters to provide a management framework for such activities. Such policy documents are usually not specified in contracts; however, they are included in Appendix B to provide a single integrated listing for customer and contractor readers of this handbook.

6.1.1 MIL-H-46855 and MIL-STD-1472. Generally, MIL-H-46855 and MIL-STD-1472 are specified contractually. MIL-H-46855, specifying HE tasking, is called out in the SOW; MIL-STD-1472, specifying HE design criteria, is cited in the system specification. The contract data requirements list (CDRL: DD Form 1423) contains any data items associated with MIL-H-46855 which are required by the customer. CDRL items typically include the HEPP, HETP, HEDAD, and HEPR. In addition to the documented requirements, the performing organization should be motivated to capitalize on HE to help design and develop the most efficient, effective, and safe system possible within the cost and schedule imposed.

6.1.2 MIL-H-46855 requirements. MIL-H-46855, establishes and defines the HE requirements for application to systems, equipment, and facilities. These requirements include the work to be accomplished by the performing (contractor) organization, or subcontractors in conducting an HE effort integrated with the total system engineering and development effort. It is not intended that all the requirements in

MIL-H-46855 should be applied to every program or program phase. It must be applied judiciously and tailored to fit the program (i.e., large and small systems/equipment, and complex, and noncomplex systems) or program phase and the acquisition strategy to achieve cost effective acquisition and life cycle ownership of defense material.

6.2. Program management. The HE function is found in various places in performing organizations. The function is also described by a variety of organizational names. The two basic areas in which HE operates are in staff support technology groups and in program project design groups. Some of the names under which HE operates are Crew Systems, Ergonomics, Human Factors, Human Factors Engineering, Human Engineering, Engineering Psychology, Behavioral Sciences, Bioengineering, Biotechnology, and Bioastronautics.

6.2.1 Project dedicated HE organizations. Many contractors do not have engineering staff organizations from which to obtain specialized technology skills such as HE. Their project organizations, including all project personnel, exist within the company only for the purpose of the project. They are hired for that project alone and they are laid off or completely reassigned to a new organizational group when their function for that project is completed.

6.2.2 Contractors without HE organizations. Contractors that build small noncomplex systems or equipment usually do not employ trained HE personnel. In order to comply with their HE requirements they must rely on HE documents (e.g., this guide) short training courses, consultants, or assistance from the requiring organization HE personnel. In a few instances, major contractors retain HE consulting or support subcontractors.

6.2.3 Relation of HE to program organization. The specific relation of HE to other groups within a program project, varies in accordance with the program RFP or the desires of the program manager. The RFP may suggest a relationship for HE by organization of the SOW or the WBS. The customer may informally request the location of HE within the project. In any case, HE is typically included as a part of System Engineering, Product Assurance, Logistics Engineering, Design Engineering or organizations equivalent to these. Within System Engineering, it may be located under Specialty Engineering or it may report directly to System Engineering. HE is typically found reporting directly to Project Engineering only on smaller programs, not major system acquisitions.

6.3 Application of HE during system acquisition. The performing organization should prepare their program management plan as a part of the proposed program development effort. Their plan should include the required HE and its organizational and functional relationship to the related technologies such as those listed in figure 1. The program manager must insure that the HE management job is assigned and funded at a level that will satisfy contractual requirements.

6.3.1 Initial activities. During the initial acquisition phase, as a minimum the first few HE activities must be performed by the customer (see 5.3). If any of these activities are also accomplished by a contractor they should occur at approximately the same time the customer is performing them (see figure 3). Regardless of previous experience on similar programs, the HE manager must be aware of the eventual service user; to determine their problems, needs, and recommended solutions. Questions such as the following should be asked:

a. Why is the new system/program needed?

b. What tradeoffs were (should be) considered in the man-machine functional allocation?

c. What does the user command anticipate to be the most critical operator tasks or issues?

d. Is there any particular human performance in terms of time or reliability that is required? This will include these factors to be considered: will human performance jeopardize mission performance; will system accuracy be degraded; will there be delay beyond time limits; will improper operation lead to system failure; will excessive maintenance downtime result; will there be degradation below required reliability; will there be damage to equipment; will system security be compromised; will injury to personnel occur?

e. What crew system problems does the user agency anticipate (e.g., manning levels, skill levels, work loads, duty cycles, stress)?

f. What, if any, solutions do the user agencies propose to solve their problem?

Although each of these questions should be asked, the responses should not be followed blindly. It is not the user agency or command's job to design the new system. The HE manager must remember it is up to his organization, with the program office guidance, to design the new system.

6.3.1.1 General availability of mission data. The source of data from which the performing organization HE effort starts on a new program varies in accordance with the system development phase and system/equipment size and complexity.

For the conceptual phase little, if any, HE data will exist which can be used directly to develop task analysis or man-machine hardware concepts. It will be necessary for the HE specialist to initiate development of these data (e.g., functional flow diagrams) from top level system functions and the mission objectives. Paragraph 7.1.2 (HE Analysis Techniques) of this guide describes these methods. If the HE effort is addressed to the advanced development phase, several alternatives should exist for the performing organization to obtain HE source data from which to start the effort.

6.3.1.2 Mission data sources. Source data may be contained in the RFP or included as an attachment to the RFP. Advanced development efforts are usually sufficiently large that several program reports should be available for gaining quick source data information. The information generated during the conceptual phase of the program should be studied to determine the concepts for the man-machine interface. Many of these reports are available through the program management while others are located at the requiring organization Development Planning Organizations and labs where the research and exploratory or feasibility work was conducted or monitored. The performing organization should not hesitate to ask the requiring organization for any of his sources of existing HE related program data. The types of general program data which should be of assistance to HE users are the:

a. Mission Objective

b. System Requirements

c. Operational Performance Requirements

d. Environmental Factors

e. Mission Analysis

f. Information Flow

g. Functional Flow

If there is a general lack of program data availability to a potential performing organization during a competitive program phase, and this lack is relatively independent of security classification considerations, this may be an indication that the potential contractor should not bid the particular program effort or might seek a subcontractor who has the expertise in that area. As most HE managers know, it is most difficult for them to initiate a major acquisition HE program without having performed a significant role in the preliminary research and exploration phases of the total program. The time to start gaining technical expertise is long before the RFP is issued.

6.3.1.3 Additional sources. Two additional sources of HE data are from previous similar programs and from HE personnel who have worked on those programs. Previous similar program data should be examined because the methodology used to provide the HE data will probably be applicable to the new program. Often certain operator functions or tasks on a new program are nearly identical to those on a previous program. HE managers or analysts should be contacted to find out what documentation exists in total from the previous programs. They may be able to describe particular problems and solutions that may not have been documented but would be most appropriate to the HE effort on the new program. After contract award the contractor may discuss in detail the availability of source data with both the project office and, with their approval, the user command/agency. If not already answered, questions such as those in paragraph 6.3.1 may be presented in order to gain a better understanding of the program HE problems, needs, and solutions.

6.3.2 Program control. During recent years, the scheduling and budget aspects or system acquisitions have sometimes become paramount, even at the cost of system performance if necessary. In order to maintain complete control of total program scheduling, subsystem, and discipline, managers must schedule their particular tasks in relation to the principal tasks/events of the total program. Overall program control is established by the performing organization program manager, This includes analysis and design review activities, WBS documentation, and management reporting.

6.3.2.1 HE scheduling. The HE manager should perform HE planning and scheduling by starting with the total program milestone chart. He should add the appropriate HE tasks from MIL-H-46855 and the HE data and requirements from the CDRL. In general, these tasks could include operations analysis, definition and allocation of system functions, potential equipment selection, task analysis, design criteria application, equipment procedures development, test and evaluation, and any significant studies or simulations. Inputs and outputs of these tasks should be included. The chart should be started by scheduling HE products at the latest time that they can be used effectively. The starting points and time span for HE analysis and other tasks are made by estimating the time it will take to complete each task. If manpower utilization has not been planned, an approximate estimate should be made based on previous program experience (yours or others). Based on the HE task start times, all data inputs to the HE tasks should be scheduled. This first schedule may not work but it is a necessary starting point for iterations. Manpower needs may have to be adjusted; some tasks may be reduced to meet the schedule requirements of the overall program.

6.3.2.2 Baseline monitoring. A method frequently used by program management to keep both the program moving and the design improving at the same time is the establishment of a baseline configuration. The design is controlled by drawings and documents describing the total system. The initial configuration is established by the program manager with the assistance of the chief engineer (or equivalent) and others. Prior to the program CDR informal meetings are called to review changes to the baseline. After CDR a more formal change board is established to control the necessary design changes and their accompanying documentation. After the CDR, the baseline is bought-off and design changes must be approved and paid for by the requiring organization (by way of ECP's).

6.3.2.2.1 Typical baseline configuration. A typical baseline configuration might start out during the conceptual phase as a description of the system in terms of required system performance and design requirements. This should eventually evolve into configuration item performance and design requirements by the end of the advanced development (validation) phase. Configuration item product definition must be maintained through the full-scale development and production phases.

6.3.2.2.2 Baseline configuration use. The baseline system design provides a single source for all program groups to quickly reference. This is most necessary in order to make quick and accurate trade studies to determine significance of cost and performance trade-offs. The baseline configuration provides a model which can be used for planning and scheduling purposes. It is imperative that manufacturing and engineering are using the same system configuration. It is imperative that HE personnel monitor the baseline configuration to be sure that it includes proper consideration of the man-machine interface and necessary HE design criteria.

6.3.2.3 Budget. The recommendation of accurate manpower required to perform the HE program tasks is one of the most needed and most difficult portions for this guide to provide. The best teacher of task man loading is experience.

6.3.2.3.1 Budget allocation sample. A budget allocation example of HE manpower estimates excluding T&E support (see figure 8) has been developed to assist HE managers who are new to the job of estimating HE work level effort in relation to analysis and design tasks to be performed. At best, the chart must be considered as an approximation. There are too many variables involved to lay out an accurate allocation of scheduled HE manpower. If HE managers have had any experience with this kind of budgeting and scheduling, they

Note: Assume no separate operations analysis effort
assume small precontract effort

Time (% of schedule shown)

Types of activities	0	10	20	30	40	PDR	60	70	80	90	CDR
Operations analysis:											
Scenarios	25%	5%				5%					
Mission profiles	15%	10%				5%					
Definition and allocation of system func.											
Functional flows	25%	25%	20%	10%		5%					
Operator capabilities estimation	10%	10%	5%								
Function allocation	10%	20%	30%	25%	20%	10%	10%				
Equipment identification		10%	10%	5%		5%					
Analysis of tasks											
Gross task analysis		5%	20%	20%	25%	10%	10%	5%			
Critical task analysis				15%	20%	20%	20%	20%	15%	10%	
Workload analysis					10%	10%	20%	20%	20%	20%	
Design support				10%	10%	15%	25%	40%	50%	55%	
Supervisory and clerical	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	
	100	100	100	100	100	100	100	100	100	100	

%

FIGURE 8. Hypothetical example of program manpower estimates.
(up to time of critical design review (CDR))

may be better off to disregard the chart and rely on their experience. The primary variables in the chart are the types of analysis and design to be performed and the program schedule. The manpower estimates have been made as percentages of total manpower available to do the HE tasks. The available manpower could vary from less than 1 to as many as 20 persons depending on the HE portion of the total program and the total program size. The numbers across the top of the chart represent percent of the schedule through CDR. Depending on the program, they could represent weeks or days. The two milestones are the PDR and the CDR. The PDR is often referred to as the initial design review. It is the point in the schedule where the design specifications and drawings receive preliminary approval by the customer. The CDR, or final design review, is generally the time at which the design receives the approval from the customer.

6.3.2.3.2 Budget variations. As indicated, there are variations in the types of HE analysis and design required. Operations analysis may or may not need to be performed, depending on the program organization and what work has been performed prior to this effort. Some programs will require more analysis in some areas and less in others. For example, programs with large operational crews tend to require more emphasis on man-machine functional allocations and workload analysis.

6.3.2.3.3 Budget estimate. A rule of thumb that is frequently used by performing organizations as a budget starting point for the HE effort is 1% of the total initial exploratory development (if there was one) or advanced development for large programs. As indicated in paragraph 5.3.2.5, DOD-HDBK-248 indicates that crew systems development costs have been 1.6% of weapon system development costs. There are several variables that can increase or decrease this percentage budget amount. It assumes a complete HE effort in accordance with MIL-H-46855. It assumes an average size operational and maintenance crew. As the program evolves into full scale engineering development, this percentage drops significantly due primarily to the higher expenditures for Full-Scale Engineering Development (FSED) rather than a diminished HE effort. The single largest variable that affects the budget is the decision of the performing organization program manager. If insufficient budget is provided to perform all of the HE tasks required by the SOW, he must be informed of the consequences of the inadequate budget. If he is not convinced (see 4.2), priorities must be established for each of the HE tasks and the total level of effort must be adjusted accordingly.

6.3.2.4 Organization. The combination of planning, scheduling, WBS, and budget implies an organization of HE specialists to perform the work. The HE manager must establish an HE organization which reports directly or indirectly to the performing organization program manager. The HE manager who is in charge of the organization should be thoroughly experienced from significant man-machine efforts on previous system/equipment acquisition programs. The HE manager should be responsible for the primary control, direction, supervision, and management of the technical HE aspects of the program. The manager should perform, or direct the accomplishment by personnel directly under the manager's supervision, the technical tasks of the HE program. The HE manager should be responsible for the implementation of the following HE program tasks:

a. Provide a single point of contact for HE related matters.

b. Revise and provide input to all plans and contractual documents related to HE.

c. Maintain approval authority on all items related to HE contained in the CDRL.

d. Coordinate HE related matters with program management and all program elements and disciplines.

e. Provide for investigation and reporting of all test and evaluation human initiated failures including all incidents and accidents related to HE.

f. Participate in all system requirements and design reviews to assure that: all HE specified requirements are complied with; HE schedule and CDRL deliveries are compatible; HE analysis techniques permit integration and use in a cost-effective manner; and established HE criteria are consistent with cost performance and scheduling requirements

g. Provide informal technical support to program engineering activities.

h. Participate in program baseline configuration control activities including the review and approval of all system configurations and changes thereto that involve the human operator or maintainer.

6.3.3 Coordination. Having determined what HE tasks are required in paragraph 6.3.1 and what the program schedule is in paragraph 6.3.2, the HE manager must coordinate the necessary HE program tasks with the program managers and others. Of all the disciplines involved in the design and development of a military system, HE requires the most coordination, primarily laterally to other disciplines but also vertically to management. Because the HE "raison d'etre", the human element, is a part of most program subsystems, many program disciplines are significantly affected, and therefore, should require considerable coordination.

6.3.3.1 With the customer's HE manager. The contractor's HE manager must coordinate with the procuring agency HE manager to provide the required DID inputs, schedules and to identify and resolve problem areas. These discussions should include progress reports, including work completed, scheduled tasks, with agreements and direction, and an evaluation of progress. Coordination by scheduled weekly telecons is a common way to accomplish this.

6.3.3.2 With the contractor's program manager. The contractor's HE manager must coordinate with the program manager to insure he has sufficient budget. The performing organization HE manager must also tell the program manager what HE can do for the program. Included in this should be data as to previous program experiences and scheduling data. The need for MIL-H-46855 and MIL-STD-1472 (if they have been called out) should be explained. In particular, the program manager should understand the need for HE review of all drawings having an impact on the man-machine interface. This requirement should be supported by the requiring organization program manager.

6.3.3.3 With other technologies. The HE effort affects every portion of the total system that has a man-machine interface. HE personnel apply the operator/maintainer capabilities and limitations in studies and specifications to the design and development of the weapon system and their support equipment and procedures. In order to do this, HE works with all of the technologies listed in table I.

6.3.3.3.1 Project design organizations. Upon initiation of full-scale engineering development, the contractor HE organization frequently assigns specific HE personnel to support specific project design organizations (e.g., avionics, crew station design, or communications). In this way the individuals may become expert at dealing with specific types of HE problems associated with particular design groups (e.g., speech interference levels and communication problems). Appropriate HE design criteria for each type of hardware will be correctly applied.

6.3.3.3.2 Other organizations. In coordination with personnel requirements specialists, HE should use the operator/maintainer task analysis to develop manning requirements to operate and maintain the weapon system. HE should participate in trade studies to arrive at the most efficient and cost effective man-machine interface. Typically, HE should also work with training specialists to develop the required skill and numbers of personnel, the training and training support necessary for the operation and maintenance of the entire system. HE works with safety and medical personnel on personnel safety and life support matters. Coordination with such disciplines as system safety, maintainability, and reliability is not just to ensure that the necessary system requirements are met but that they are not duplicated by other groups.

6.3.3.3.3 Functional activities related to other organizations. Coordination is also accomplished to insure that other disciplines are receiving the proper support from HE and vice versa. In addition to the program manager, the organizations representing the disciplines/technologies listed in table I should be contacted to inform them of the analysis, design, and test support that HE has to offer. The HE effort must be integrated into the total system program. Table III shows the relationship of several important HE functions to other related program functions and to the acquisition phase. The deployment phase is not shown on this chart.. Both a typical and important example of such coordination would be the inputs to HE in regard to mission operations analysis or outputs from HE analysis as to proper crew size. If there are subsystems which will be severely affected by the results of the HE effort, the appropriate customer and contract or managers should be forewarned. It is, of course, up to the contractor HE manager to see that the particular HE analysis, design, or test effort is well documented for presentation to the HE customer and affected contractor subsystem organization.

6.3.4 Allocation of effort. It is an unusual situation that a prime contractor would allocate a complete HE effort to a subcontractor or even an associate contractor. However, the use of consultants, subcontractor, and associate contractor to perform portions of the total HE program is not unusual. Competent consultants are available to work specialized aspects of HE, particularly in the biomedical area. A few consultants may be helpful in the area of computer design and analysis techniques.

6.3.4.1 Planning of split efforts. If an acquisition contract is split between two or more large performing organizations, and one is not designated as prime, an integrating agency or organization is necessary to coordinate the effort. The allocation of HE effort should be as described in a plan developed by the integrating agency/organization. If required, associate organization HE plans should be incorporated in some manner into an integrated HE plan. This integrated plan should describe the level of effort each associate organization must maintain. It must describe the HE tasks (including task analysis formats) each must perform and the HE data outputs from those tasks, which will be submitted to the integrator in accordance with the HE program schedule. The plan should be prepared in the same manner as described in DI-H-7051.

6.3.4.2 Subcontractors. The HE effort to be performed by subcontractors is generally proportional to the dollar value of their contract and the nature of their work. It is primarily the job of the prime organization HE manager to decide how much HE the subcontractor shall perform. Because the prime performing organization is always responsible for the total HE effort, both prime and sub may wish to have more of the total effort done by his organization. Frequently, when the requirement for MIL-H-46855, including the HE plan, is levied on the prime contractor, the prime will not pass the requirement on to the subcontractor(s). Nearly always when the requirement for MIL-STD-1472 is levied, this will be passed on down to the sub(s). The reason for this is that it is both easy and cost effective to informally coordinate between a prime and subcontractor to insure that HE methodology (e.g., MIL-H-46855) is performed correctly. It is extremely difficult to redesign subcontractor equipment to incorporate HE design criteria (e.g., MIL-STD-1472) which had not been required originally. It is easy and cost effective to require in its original application.

6.3.5 Proposal preparation and tailoring. If the requiring organization has issued a draft RFP, the contractor responds by providing a critique and suggestions. With this additional knowledge, the contractor should produce a better quality proposal. The contractor HE manager should participate in the draft review in order to suggest the kind of effort that he feels should be requested in the RFP.

6.3.5.1 Proposal contents. Once the RFP is officially issued, the decision as to how to respond is invariably made by the offeror's program manager within the limitations of the proposal evaluation criteria supplied with the RFP. The program manager may simply choose to respond in kind to each of the requested tasks listed in the RFP statement of work (SOW). As a minimum, the offeror must state agreement with the SOW or take exception to those portions he does not wish to comply with. The offeror should also indicate acceptance of the CDRL item(s). Frequently, this means providing a preliminary copy of their HEPP in accordance with MIL-H-46855 and DI-H-7051. If a preliminary HEPP is required, most of the proposed HE effort may be contained in the plan. If the plan is not required, the HE effort should be described in the technical portion of the proposal. In some cases, an HEPP is submitted although not required per the RFP. In any case, the following subjects should be included in the plan or the HE portion of the proposal:

a. Procedures that are proposed for complying with MIL-H-46855 requirements. These include anticipated trade studies and analysis, design, and evaluation techniques intended to be provided. The plan also includes proposed tailoring (see 6.3.6.2.1.1).

b. The company's organizational elements and (if possible) personnel selected to implement the HE program.

c. The HE efforts accomplished (and lessons learned) during previous program phases should be summarized.

d. The proposed HE participation in simulation, mockups, equipment detail design, testing, and verification should be described.

e. Special HE objectives (e.g., crew size and performance) and anticipated problems should be included along with the proposed means to meet these objectives and solve these problems.

f. A time-phased schedule showing initiation and completion dates of significant HE milestones.

When the plan is used to describe the HE effort, this effort should be an integral part of the total program management and engineering effort. The plan should include details of the implementation of each task identified by the tailored application of MIL-H-46855. The plan should describe the requirements for HE management required to support the program through the total period of the contract. The plan should detail the HE interfaces with all levels of program management. It should show clear evidence of specification tailoring consideration and of design-to-cost and design-to-life cycle costs. The cost of imposing HE requirements should be evaluated against the benefits that will be realized.

6.3.5.2 <u>Customer contact</u>. After the issuance of the RFP and before the contract award it is important to understand that the customer's evaluators are not free to converse with prospective contractor organizations on an informal day-to-day basis. During this period everything should be documented and coordinated through the appropriate contracting officer.

6.3.6 <u>Contract performance</u>. The accomplishment of all of the HE activities required in the contract SOW and CDRL generally requires the performance of analysis, design support, and T&E It requires the participation in program meetings, and the preparation of appropriate contract deliverables in accordance with the required DID's. It also requires the necessary planning and scheduling. The following sections provide guidance in accomplishing these activities.

6.3.6.1 <u>Meetings</u>. The indiscriminate use of meetings can be a significant waste of time, effort, travel, and related costs. However, certain meetings are essential.

6.3.6.1.1 Kickoff meeting. If the new program has sufficient HE implications to warrant an HEPP (see 6.3.6.2.1) it most probably would benefit from an initial HE guidance meeting within a few weeks of the contract award. The contractor should suggest this meeting as part of their HEPP, even if not required by the customer. There is no substitute for a face-to-face discussion of what the contractor intended in his proposal (preliminary HEPP) or what the customer interpreted from the proposal. Furthermore, this guidance meeting provides an opportunity to focus on the system specification and statement of work, paragraph-by-paragraph if necessary, to ensure a mutual understanding between the contractor and the customer of what is expected of both parties. At this time the contractor may ask for detailed guidance. The customer may wish to offer technical data. The contractor may request help or obtain advice in solving various kinds of program problems. The priorities of all the various HE activities should be discussed and agreed to. The meeting may be used to discuss the results of previous related program phase efforts and for the customer to pass the documented HE data on to the contractor.

6.3.6.1.2 Design reviews. HE must participate in all major design reviews such as the System Design Review (SDR), Preliminary Design Review (PDR), and Critical Design Review (CDR). The performing HE organization should present the results of HE analysis and design support efforts. Examples of the types of information to be reviewed are:

a. Operating modes for each display station, the displays and controls used for each function.

b. The format and content of each display and the control and data entry devices.

c. HE aspects of hardware and facility design such as design for the user population (anthropometry), workspace design, environment, maintainability, and accessibility.

d. HE aspects of the user-computer (software) interface.

This information should be presented in sufficient detail to allow the requiring organization to determine human usability adequacy. Technical Interchange (TI) meetings on any HE subject may also be held at the request of the customer or contractor.

6.3.6.2 Data item descriptions. Contracts almost always contain a list specifying exactly what data products the contractor must deliver. This list is called the Contract Data Requirements List (CDRL, DD Form 1423). Standardized data preparation instructions have been developed for the many products which might be contracted. These reporting requirements are called Data Item Descriptions (DIDs, DD Form 1664). For a specific contract, the appropriate DIDs are selected and included in the CDRL by the customer. The CDRL of data item requirements (deliverables) should be in agreement with (and follow from) the HE tasking statement in the SOW. The DIDs pertaining to HE are as follows:

DI-H-7051,	"Human Engineering Program Plan" (HEPP)
DI-H-7052,	"Human Engineering Dynamic Simulation Plan" (HEDSP)
DI-H-7053,	"Human Engineering Test Plan" (HETP)
DI-H-7054,	"Human Engineering System Analysis Report" (HESAR)
DI-H-7055,	"Critical Task Analysis Report" (CTAR)
DI-H-7056,	"Human Engineering Design Approach Document-Operator" (HEDAD-O)
DI-H-7057,	"Human Engineering Design Approach Document-Maintainer" (HEDAD-M)
DI-H-7058,	"Human Engineering Test Report" (HETR)
DI-H-7059,	"Human Engineering Progress Reports (HEPR)

These DIDs specify in detail how to prepare the plans or the results of the HE activities which must be performed by the contractor and delivered to the customer. The first three of these HE DIDs apply directly to the HE planning process and the other six apply to the method of reporting the results of the HE activities. In addition to the following material HE personnel should read the customer DID information contained in paragraph 5.3.5.1.3

6.3.6.2.1 <u>HE program plan</u>. The HEPP is usually written in preliminary form as part of the total program proposal. Although not written in the style of most proposals, it serves (in effect) as the contractor HE proposal. Generally, and if specified by the contract, it will be rewritten for customer approval shortly after contract award. The HEPP serves as the vehicle describing the proposed HE activities, the HE schedule in relation to the program milestones (see figure 7), the level of effort, the methods to be used, the design concepts proposed, and the test and evaluation program. All this is provided in terms of an integrated effort within the total project. A sample generic HEPP, for new ship construction, is included in appendix C

6.3.6.2.1.1 <u>Tailoring</u>. The opportunity for tailoring is an extremely important part of the HEPP. One purpose of this HE procedures guide is to help the contractor to better understand how a cost-effective HE effort can be obtained through tailoring. The paragraphs on techniques (7.1.2, 7.2.2, and 7.3.2) describe detailed activities (analysis, design, test and evaluation.) What these activities produce, and the effort they require are indicated. The contractor's activities, as described in the plan, should consist of both what is and what is not proposed.

The HE customer is just as interested in what portions of MIL-H-46855 the contractor does not feel are cost effective to perform as in what portions will be accomplished. The customer knows what total effort can be accomplished for the proposed dollars or manhours. If the HE plan promises to deliver too much material for too few hours, that will cause a lack of credibility. Tailoring is absolutely essential for smaller system/equipment acquisition programs. In a somewhat similar manner, the role of MIL-STD-1472 needs to be identified. The possible need to tailor MIL-STD-1472 is superfluous. The application of the standard in its entirety to a program costs little if applied early. The few situations which might arise that would incur a system cost or performance decrement as a result of misapplication of the criteria are easily solved.

Where MIL-STD-1472 criteria are clearly not applicable due to absence of the particular hardware or system functions for which the criteria were intended, it is not necessary to call out all the exceptions. This task is generally too tedious to be of value. The error of omission in not calling out the application of pertinent criteria is more serious than the error of commission, calling out criteria which would apply to nonexistent hardware or system functions. The error of omitting the requirement for appropriate design criteria could easily lead to a costly ECP, or worse yet, to ignoring the needed criteria and risking the consequences of the degraded man-machine performance.

6.3.6.2.1.2 Relation to other organizations. The HEPP section on the HE organization and its relation to the rest of the program is important in that too often HE is treated as an end in itself. Because the purpose of the HE effort is to impact the system design, it is necessary that the HE organization be located within the total program at a high enough level to have organizational influence as well as within an organization that clearly has a direct role in the creation of the system design. The contractor may wish to describe in the plan the actual/planned types of interface material (e.g., reports, memos, task analysis) that HE receives from other organizations and the data HE provides for other organizations.

6.3.6.2.1.3 Planned activities. The sections on HE in system analysis, equipment detail design, test and evaluation, etc., should be used to show the specific HE technique the contractor intends to use. The techniques may be those described in this guide or others that the contractor believes would be particularly effective. These sections of the HEPP should also describe the results of performing the technique and how these results affect the program effort. A total flow diagram of each of the HE activities in relation to the program schedule and other program activities and organizations may be used. Diagrams or tables showing the planned areas of interest of each of the program subsystems or hardware configuration item may be indicated, i.e., operational and maintenance aspects of hardware/software which are affected by HE considerations.

6.3.6.2.1.4 Additional considerations. The HEPP is generally required during either the validation or full scale development program phases. The plan should be coordinated with contractor program management prior to its release to the customer.

6.3.6.2.2 HE dynamic simulation plan. As indicated in paragraph 7.3.2, dynamic simulation techniques tend to be more expensive than some of the other design techniques. They should be used only when it is necessary to gather data on critical human performance. This planning should insure the most cost effective use of the simulation effort. It should insure that the necessary data are obtained and that the data impact the design and other program areas. Section 7.3.2 of this guide provides information on the rationale for selection of dynamic simulation techniques, including their use in relation to analysis, design, and test. When required, this plan may be called for during the full scale engineering development phase. The plan should be coordinated with appropriate contractor engineering personnel prior to the release to the customer.

6.3.6.2.3 HE test plan. As indicated in the DID, the purpose of this plan is to provide both the customer and the contractor with the details of the intended testing of personnel with equipment/software to show compliance with system specifications. When required this plan may serve as the principal means of planning for validating human performance requirements, personnel selection criteria accuracy, training adequacy, and design adequacy in terms of the personnel equipment/software interface.

6.3.6.2.3.1 Proposed HE T&E techniques. Part of the purpose of this guide is to provide suggestions for HE T&E techniques. This plan should include descriptions of the techniques along with rationale for their selected use. A description of test equipment is provided along with the T&E techniques in section 7.3.

6.3.6.2.3.2 Quality assurance compliance. As part of the test data analysis (i.e., how the data collected will be used), the plan should describe if the collected data is to be used as formal proof of quality assurance compliance. Such compliance should be indicated as being either by analysis, inspection, demonstration, or measurement. This formal compliance may be provided by the HETR (DI-H-7058) or by the total program test report. The plan should be coordinated with contractor T&E personnel prior to its release to the customer.

6.3.6.2.4 HE system analysis report. As indicated in the DID, one of the major purposes for this report is to provide the rationale for, and the results of, the personnel-equipment/software allocation trade. Section 7.1.2 provides suggested techniques that may be used to perform this analysis. This report should not be used to duplicate data available in other engineering reports; however, the results of functional allocation trades are seldom reported elsewhere. The material presented in this report should, of course, be coordinated with system engineering prior to its release.

6.3.6.2.5 Critical task analysis report. The preparation of this report is dependent on existence of critical operator or maintainer tasks. The existence of critical tasks is a function of the system design and the definition provided herein (3.1) and MIL-H-46855.

6.3.6.2.5.1 Critical task considerations. It is the contractor's job to design systems which minimize the occurrence of critical tasks. This is done by designing equipment/software and procedures such that either there are parallel system functions which occur or functions with feedback loops which provide higher inherent system reliability and thereby minimize the possibility of critical tasks.

6.3.6.2.5.2 Additional considerations. This report should be coordinated with contractor system engineering prior to its release to the customer.

6.3.6.2.6 HEDAD-O. The operator design approach document must describe the layout, detail design, and arrangement of crew station equipment having an operator interface, and the operator tasks associated with the equipment. The document must also describe the extent to which the human performance requirements, MIL-STD-1472 design criteria, and the requirements of other applicable HE documents specified in the contract have been incorporated in the crew station equipment. Results of operator task analysis must be presented as part of the rationale supporting the layout, design, and integration of crew station equipment.

6.3.6.2.6.1 Detailed contents. The operator design approach document must contain the following crew station and operator-related information: a list of each item of equipment having an operator interface, a list of specifications and drawings approved by HE, and a description of the crew station emphasizing HE design features. Design features to be described are: each crew station and each item of crew station equipment; each control/display panel; operator vision to crew station items of equipment and operator external vision; environmental factors; normal and emergency ingress and egress; crew station lighting characteristics and lighting control systems; crew station warning, caution, and advisory signals; seating, restraint systems, communications systems, and communications systems control; any special design, layout, or arrangement features required by the mission or system environment; and multiple operator stations design, if applicable. Other information required includes geometric layout of the crew stations; rationale for HE design, layout, and arrangement of each item of the crew station having an operator interface; and narrative which provides rationale for any need to deviate from MIL-STD-1472.

6.3.6.2.6.2 Use of the material. The HEDADs are not intended to be documents which describe the contractor system design. Rather, they should only describe the HE portion of the design. They should agree with but not duplicate other design CDRL deliverables that are available to the customer. The material in the HEDAD may be used and presented by HE in summary form at the full scale engineering development design reviews. As with other HE deliverables, these reports should be coordinated with contractor program engineering prior to their release to the customer.

6.3.6.2.7 HEDAD-M. The maintainer design approach document must describe the characteristics, layout, and installation of equipment having a maintainer interface and tasks associated with the equipment. This document must also describe the extent to which HE requirements have been incorporated into the design, layout, and installation of equipment. Results of maintainer operator task analysis must be presented as part of the rationale supporting the layout, design, and integration of crew station equipment.

6.3.6.2.7.1 Detailed contents. The HEDAD-M must contain the following crew station and maintainer-related information: a list of each item of equipment having a maintainer interface, a list of specifications and drawings approved by HE, and a description of system equipment, emphasizing HE design features. Design features to be described are: location and layout of system equipment; design of equipment; and installation of equipment. Other information required includes: equipment maintenance requirements, maintainer requirements, and task requirements, environmental considerations, safety, limitations, a list of special tools and equipment, results of task analysis supporting layout, design, and installation of equipment, a narrative with rationale for any need to deviate from MIL-STD-1472, and sketches, drawings or photographs of equipment, alternatives to baseline design, and layouts.

6.3.6.2.7.2 Use of material. The uses of the HEDAD-M material are similar to the uses for the HEDAD-O. Although HE usually provides output data directly to maintainability and logistics organizations, the HEDAD-M could be a means to supply much of these data (e.g., maintenance crew size, maintenance access).

6.3.6.2.8 HE test report. As indicated in paragraph 6.3.6.2.3, HE Test Plan, this report is closely associated with the HE test and evaluation effort described in that plan. This report may serve as the principal means of validating human performance requirements, personnel selection, training, and design of the personnel equipment/software interface. If so, the report should indicate proof of MIL-STD-490 Quality Assurance compliance. Such compliance should be indicated as being by analysis (paper or computer) MIL-STD-1472 inspection, mockup or prototype demonstration, or measurement using the HE test and evaluation equipment such as that indicated in paragraph 7.3.2.6. In addition to providing the results of human performance evaluation and equipment/software physical characteristics compliance with HE design criteria the HE test plan also serves to report HE related incidents. This report should not be redundant to the total program test and evaluation formal report. If it is intended that HE test and evaluation be reported in a total program report, this report should not be required. However, the total program T&E report may reference this report. As a minimum this test report should be coordinated with the contractor test and evaluation organization prior to its release to the customer.

6.3.6.2.9 HE progress report. The HEPR is the best way to document the significant day-to-day HE activities, including status summaries of all HE design recommendations and action items. Summary results of HE analysis, mockup evaluations, demonstrations, etc. are appropriate for reporting. The results of significant trade studies should also be reported.

6.3.6.3 HE analysis process. Generally, the analysis process starts with the system mission as described by a baseline scenario. The mission objective and functions that must be performed by the system are identified, described and sequenced. These functions are then analyzed to determine their proper allocation to personnel, software, or equipment, or some combination of these. Once allocated, the personnel functions are further analyzed to determine the specific operator/maintainer tasks which must be performed to accomplish the functions. The tasks are further detailed to show estimated time and space relationships. All tasks are reviewed to determine their criticality and critical tasks are analyzed in detail. Workload analysis is performed to evaluate allocation of functions to the crew. HE analysis techniques for performing many of these tasks are provided in 7.1.2.

6.3.6.4 HE design support process. A typical design support activity starts with the results of the analysis activity. These results are translated into hardware and software derived design requirements which are, in turn, written into the applicable specifications and included in the hardware drawings and software programs. In order to evaluate these derived requirements (e.g., operator time critical and reliability critical requirements), studies and laboratory tests may be accomplished. Mockups and models may be constructed or dynamic simulations performed. Also included in the hardware and software design are the inherent HE requirements which may be taken from MIL-STD-1472 and similar HE standards. A significant part of the HE activity is to coordinate with the designers and others to insure that the HE requirements are incorporated into the hardware and software designs. HE design support techniques for accomplishing many of these tasks are provided in 7.2.2.

6.3.6.5 HE test and evaluation Process. The HE T&E effort is frequently referred to as Human Factors Test and Evaluation (HFTE). The HFTE effort starts early with planning, which may include the preparation of an HETP (see 6.3.6.2.3). Whereas the planning effort is generally accomplished by the same HE personnel who have performed the analysis and design support work, the remaining HFTE activities may or may not be performed by a new group of HE personnel located at the test site. The HE/HFTE personnel should start by reviewing the program HE data file (see 6.3.6.6) including HE design criteria and rationale. They should become thoroughly familiar with all of the equipment/software personnel interfaces. Part of their job should be to determine applicability of the design criteria. They should also reevaluate the equipment to determine if operator/maintainer tasks originally determined to be critical are still in that category. They should look for new critical human performance tasks. One of the major HFTE activities is monitoring tests. HFTE personnel should review the full scale equipment design, in either the static or dynamic (in use) condition, to determine compliance with MIL-STD-1472 design criteria. HE personnel should validate derived human performance requirements including skills, skill levels, numbers of personnel, and training requirements. They should determine if planned procedural use of the equipment/software is satisfactory. Their efforts should include preliminary analysis of HFTE problems and recommended solutions. These should be documented and reported. HE test reports and progress reports will be prepared as applicable (see 6.3.6.2.8 and 6.3.6.2.9). HE test and evaluation techniques for accomplishing many of these tasks are provided in 7.3.2.

6.3.6.6 HE data file. The contractor's human engineering organization should establish and maintain all HE and HE related data generated on the program in the HE Data File. These data, such as the HE plan, analyses, design review results, drawings, checklists, and other supporting background documents reflecting HE actions and decision rationale, should be maintained and made available to the procuring activity at the contractor's facility. Typically, these data will be reviewed at various contractor meetings such as design reviews, audits, demonstrations, and T&E functions. The data file is organized to provide traceability from the initial identification of HE requirements during analysis or system engineering through design and development to the verification of these requirements during test and evaluation of the approved design, software, and procedures.

6.3.7 Basic considerations. Previous sections of this guide indicated the importance of MIL-H-46855 to the accomplishment of the HE effort. It is the purpose of this section to briefly present basic considerations not covered in the MIL-H-46855 requirements or other data presented in Sections 5. and 6. These considerations consist of the type of data required to start any HE effort, when to perform the effort, the level of detail required, and the type of specific results normally expected from the HE effort. Other paragraphs of this guide deal with these basic considerations in relation to specific HE techniques, but this paragraph pertains to these basic considerations in relation to the overall HE effort.

6.3.7.1 Data inputs. There is a large variation in the degree to which data inputs such as mission requirements, system requirements, or operational concepts will be supplied by the customer or by contractor program organization other than HE. Frequently mission analysis and functional flow diagrams are not provided to the HE group. In this situation this type of information must be generated by HE. Other technologies such as software design and displays/controls provide data to HE as to the software and hardware capabilities and limitations. Data inputs pertaining to human performance and previous system experience have to come from research, literature, or from personnel experience. The specific data sources for these inputs are either too numerous or too intangible to list here. The data inputs for the later design and test phases of HE are obtained from HE analysis or from other technologies.

6.3.7.2 Timing. Without the proper scheduling, the HE analysis, design, and testing effort can turn out to be of little use to the system design. It is not sufficient just to perform these HE efforts. It is 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. Occasionally, the HE efforts are performed on a portion of a program that later evolves to the point where the HE effort must be performed again to be pertinent. Sometimes the results of the effort are premature to their use by other technologies. However, all too often HE tasks are performed as an after-the-fact documentation exercise or just a workaround procedure that appears in a technical publication. The later the analysis, design, or test is performed, the less chance there is to impact the crew station or other man/machine interface. Late findings of serious HE problems can be extremely expensive in redesign and in retraining, or worse yet, late inputs may be disregarded to the extent of causing serious system failures and accidents.

6.3.7.3 Level of detail. Just as the HE effort may be performed too soon or too late, the analysis, design, or testing detail can be performed at too gross or too detailed a level. The following guidance pertains to various aspects of determining the appropriate level of detail for HE efforts.

6.3.7.3.1 Analysis. A discussion of the definition of various levels of analysis is contained in other guide paragraphs: The level of analytical detail that should be performed is significant to the HE manpower effort. Analysis must be performed judiciously to insure that proper emphasis is given to each of the various task or mission functions which are candidates for HE analysis. The human engineer or HE manager should decide which level of analysis will lead to worthwhile data or useful design criteria. For example, new system designs or programs often contain functional requirements that are identical to previously designed and tested systems. There is no point in repeating a detailed analysis, design, or test that has already been accomplished. It is simply not cost effective, especially when new program schedules and manpower budgets generally are extremely limited.

6.3.7.3.2 Functional allocation. The level of analytical detail achieved during functional allocation trades must suffice to permit positive allocation of functions to operators, equipment, of software. The functional allocation analyses have not been performed satisfactorily if the answers to the trades tend to come out as a combination of operator/equipment/software allocations. More detailed task analysis should be performed only on critical tasks or in accordance with required Data Item Descriptions.

6.3.7.3.3 Design support. If other organizations have the charter to perform the detailed design of program hardware, it behooves HE personnel to provide more than the human performance and HE design criteria. The details of the complete design, including specifications and drawings should not be performed by HE. On the other hand, HE personnel cannot offer just negative criticism of other organizations' designs. All inputs must include sufficient detail to support the designer in terms of shortcoming details and possible remedial actions.

6.3.7.3.4 HE T&E. The HE T&E observer or manager should decide what level of T&E will lead to worthwhile data or useful design criteria. For example, there is no need to examine new system portions which are identical to satisfactory old systems. On new system designs, it may be necessary to examine data down to as much detail as a tenth of a second. If the HE program has been properly managed, all system potentially critical tasks should have been previously indicated for special HE T&E considerations. In any case, the need to gather human performance related T&E field data more accurately than a tenth of a second is extremely doubtful. In a similar manner, the HE observer should maintain adherence to the rules for significant figures and common sense when gathering data on light levels, sound levels, reach envelope measurements, etc.

6.3.7.4 Applications. The purpose of performing the three major HE activities (analysis, design, and test) is to help develop and justify a system design. The purpose of doing HE analysis to successively detailed levels is to "drive out" or identify more and more significant detailed design requirements. Examples of such data are: how many and what kinds of personnel will use the system; what the crew performance limits are in terms of time, space, force, and reliability; and what the possible alternative solutions are. Design requirements must be incorporated into mockups, drawings, and specifications. The end product of HE T&E is to verify system design, discover system inadequacies, and provide recommendations for design or other system changes. In addition, a by-product may be to provide information for a data bank of human performance and crew systems design related data to be used on later programs. Generally, the outputs of these efforts should be condensed and otherwise modified to make them easily understood by program personnel who use them and are not trained in HE techniques. Tables IV, XII, and XIV in section 7. provide possible applications for each of the HE techniques presented in this guide. It may be useful for the applications or specific output data to be prioritized in some manner to show that there are certain absolutely essential system HE design requirements or modifications. The risk of not doing this is to have insignificant results acted upon and critical data ignored. All findings must be well documented and files must be maintained. By themselves, verbal inputs (HE outputs) as to analysis, design, or T&E results have little chance of acceptance.

7. HE TECHNIQUES

Included herein are data on the use of HE techniques from the system concept formulation stage through hardware test and evaluation. This handbook provides guidelines to help the HE analyst select, for a given program, just which techniques should be performed, when and how to perform them, and how their results will be used. It provides the basis for matching particular techniques to particular applications, and describes in detail how to construct and use the various techniques. It should be noted that whereas the samples and examples may pertain to a particular product (e.g., aircraft, tank) they are generally applicable to all vehicles, workstations, or wherever personnel are involved. This is applicable regardless of analysis, design, or T&E techniques.

7.1 HE analysis activities. In order to develop HE performance criteria and hardware HE design criteria, and to accomplish the required analysis described in MIL-H-46855, a concerted analysis effort must be accomplished. The general HE analysis process is described in 6.3.6.3. The following material describes both on-going HE analysis responsibilities and the techniques used to accomplish the effort.

7.1.1 On-going analysis responsibilities. Initial development of man-machine interface concepts must be concurrent with advanced development of system concepts. During this formative period of system development, the human engineer has a number of important responsibilities:

a. Major participation in the allocation of system functions to man, machine, or software, or combinations thereof;

b. Assurance that each candidate system functional implementation is feasible in all respects from a HE standpoint;

c. Identification and detailed analysis of critical tasks;

d. Analysis of crew workload;

e. Performance and documentation of preliminary hardware trade studies pertaining to HE considerations;

f. Identification of potential HE problem areas which may require attention;

g. Preparation of inputs to subcontractor RFP packages as applicable.

These tasks are often accomplished by the process of breaking them down into smaller and smaller elements to the point where they can be handled. At the smaller element level, significant aspects of the total problem can be examined in detail. Answers to several detailed questions/problems are more easily obtained than answers to a few top level question/problems.

7.1.2 HE analysis techniques. Over the years, human engineers have developed a number of powerful tools and techniques to aid in applied HE work. The following subparagraphs describe the characteristics of the techniques. Information is supplied as to what the technique is, what it is intended to do, and why it is useful. Much of this information is presented in tabular form in table IV. By listing each of the techniques in one table, they may be more easily compared for selection and use. An explanation of each of the selection evaluation characteristics is provided in table V. Procedures for the construction of each technique are provided. When significant, the limitations as to what the technique will not do are pointed out. Also included are sample formats to illustrate the layout and details of several of the techniques. Table VI is provided to show the various applications of the various analysis techniques. If existing techniques will not accomplish the required analysis task, then new techniques should be developed. The development of new paper and pencil analysis techniques may not be difficult. The primary drawback in doing this is the extra educational process that is required to assist those wishing to understand, review, or otherwise use the analysis.

7.1.2.1 Mission profiles. Mission analysis is the first step in the system development required for the establishment of human factors design criteria. The system mission or operational requirements are a composite of requirements starting with general operational requirements and progressing through specific operational requirements, The mission requirements define the system in terms of limits of operation necessary for fulfilling the weapons system mission activities.

7.1.2.1.1 Description. Mission profiles, along with scenarios, are the two most used techniques to perform mission or operations analysis. The total analysis process must start with mission profiles because the human factors engineer must have a good idea of the operational situation or events that will be confronting operators and maintenance personnel in newly conceived systems. Mission profiles are generally associated with aircraft analysis but may be readily adaptable to other types of systems where appropriate. Although historically mission analysis has been performed by groups other than human factors, such as system engineering or operations analysis groups, it is important that human engineering personnel be key members of such an

TABLE IV Studies techniques selection chart

Alternative analysis techniques	Selection evaluation characteristics																			
	Most applicable program phase				Relative complexity			Used for		Breadth		Relative time to perform			Relative cost			Relative cost effectiveness		
	Conceptual	Validation	FSD	Production	Simple	Average	Complex	Gross analysis	Detailed analysis	Single task	Multi tasks	Short	Medium	Long	Low	Medium	High	Low	Medium	High
1 Mission profiles	x				x			x		x		x			x					x
2 Mission scenarios	x				x			x		x	x		x	x		x			x	
3 Functional flow diagrams	x	x			x			x			x	x	x		x	x			x	x
4 Decision/action diagrams	x	x			x	x		x			x	x	x		x	x				x
5 Action/Information requirements	x	x				x			x	x			x			x			x	
6 Function allocation trades	x	x				x		x	x		x	x	x			x			x	
7 Time lines	x	x				x		x	x	x	x	x				x				x
8 Predetermine time std.	x	x				x		x	x	x	x	x				x				x
9 Flow-process charts	x	x				x			x	x			x			x			x	
10 Op. sequence diagrams	x	x					x		x		x			x			x		x	
11 Task descriptions	x	x	x		x			x	x	x			x			x		x	x	
12 Workload analysis		x	x	x		x		x	x	x	x		x			x			x	
13 Correlation matrix	x	x			x				x		x	x			x					x
14 Link analysis	x	x	x			x			x		x		x			x			x	x
15 SAINT	x	x					x		x		x			x			x		x	
16 TLA-1	x	x					x		x		x			x			x		x	
17 SWAT	x	x					x		x		x			x			x		x	
18 SIMWAM	x	x					x		x		x			x			x		x	
19 WOSTAS	x	x					x		x		x			x			x		x	
20 HOS	x	x					x				x			x			x		x	
21 OWLES	x	x					x		x		x			x			x		x	
22 CADET	x	x					x		x		x			x			x		x	
23 DATA STORE	x	x	x			x		x	x	x			x			x			x	

TABLE V. Explanation of selection evaluation characteristics

Across the top of table IV, Analysis Techniques Selection chart, are a number of selection evaluation characteristics. The purpose of this characteristics list is to make evaluative comments as a part of a tradeoff analysis between the various listed analysis techniques. Some techniques are obviously better than others for certain types of programs, program stages, or analysis efforts. The following list describes in detail what is meant by each of the evaluation characteristics.

MOST APPLICABLE PROGRAM STAGE

The phase of a program that is best suited to the use of this technique: Conceptual Phase, Validation Phase, Full-Scale Development Phase, and Production Phase.

RELATIVE COMPLEXITY

The category that best describes this technique when compared to other techniques.

USED FOR

The category that best describes the level of detailed analysis for which this technique may be used.

BREADTH

Indicates the relative quantity of different tasks that may be simultaneously handled by using this analysis technique.

RELATIVE TIME TO PERFORM

The time category that best describes the time to perform this technique for a given task, when compared to other techniques.

RELATIVE COST

The category that best describes the relative cost of this technique when compared to other techniques.

RELATIVE COST EFFECTIVENESS

The category that best indicates relative cost effectiveness of this technique when compared with other techniques.

TABLE VI
Human engineering analysis techniques data applications

Specific analysis techniques	Applications									
	Mission effectiveness criteria	Detailed design requirements	Concept formulation ideas	Personnel req. information	Operational procedures dev.	Training system dev.	Maintenance system dev.	System operational eval.	Additional HF analysis	HFE data store information
1 Mission profiles	•		•						•	
2 Mission scenarios	•		•						•	
3 Functional flow diagrams		•	•		•	•	•		•	
4 Decision/action diagrams		•	•		•	•	•		•	
5 Action/information requirements		•	•						•	
6 Functional allocation trades		•	•			•	•		•	
7 Time lines	•	•	•	•	•	•	•	•	•	•
8 Predetermined time standards	•	•	•	•	•	•	•	•	•	
9 Flow process charts	•	•	•	•	•	•	•	•	•	
10 Operational sequence diagrams	•	•	•	•	•	•	•	•	•	
11 Task descriptions	•	•		•	•	•	•	•	•	•
12 Workload analysis	•	•	•	•	•		•	•	•	•
13 Correlation matrix		•	•			•		•	•	
14 Link analysis		•	•		•		•	•	•	
15 SAINT	•	•		•	•	•	•	•	•	•
16 TLA-1	•	•	•	•				•	•	•
17 SWAT	•	•		•			•	•	•	•
18 SIMWAM	•	•		•				•	•	•
19 WOSTAS	•	•		•				•	•	•
20 HOS	•	•		•				•	•	•
21 OWLES	•			•				•	•	•
22 CADET	•	•		•			•	•	•	•
23 DATA STORE	•	•	•	•	•	•	•	•	•	•

analysis team since the analysis is critical and impacts of the human element must be considered.

7.1.2.1.2 Procedure. The procedure for constructing mission profiles is easy to follow. The term mission profile derives its name from the typical side view format illustrated in figure 9. The profile, in this instance, is a plot of the aircraft flight in terms of total distance traveled (or time) from home base. Significant mission events or functions are noted on the plot. Mission "profiles" other than the illustrated example are also used to indicate the flight path in terms of latitude and longitude such as would be observed in a plan view in a manner similar to a horizontal situation display. These particular plots are often referred to as graphic scenarios. Significant aircraft functions are plotted along the route at the points of their planned occurrence. Each function describes a clearly distinguishable start and completion point for a mission segment.

7.1.2.1.3 Use. Along with the initiation of new programs, there is invariably the issuance of top level program objectives and systems operational requirements. It is a combination of these objectives and requirements with the past experience of previous similar systems which combine to create the mission profile data. If all essential operational requirements cannot be logically and realistically included into one profile, then others must be developed to cover all functions in a reasonable context. Although mission scenarios are sometimes developed before mission profiles, they generally follow the profiles and use the mission profile functions to interact with scenario threat and other event data. In addition to feeding into the scenarios, the mission profile data are used in the development of the functional flows. Table VI illustrates several output applications that apply to mission profiles.

7.1.2.1.4 Comparison to other techniques. The inherent characteristics of the mission profile analysis technique when compared to other human factors engineering techniques are summarized in table IV. Mission profiles should be developed as early as possible in the program schedule.

7.1.2.2 Mission scenarios. Along with mission profiles, mission scenarios are a popular operations analysis technique used to derive program data in general, and HE data in particular.

7.1.2.2.1 Description. Scenarios are developed from the threat/concept and the mission profiles, and they must fully describe the events implied by the profile. Rather than using a special format for scenarios, they are often written in straight forward narrative. This narrative should describe the proposed mission in detail, identifying key events and

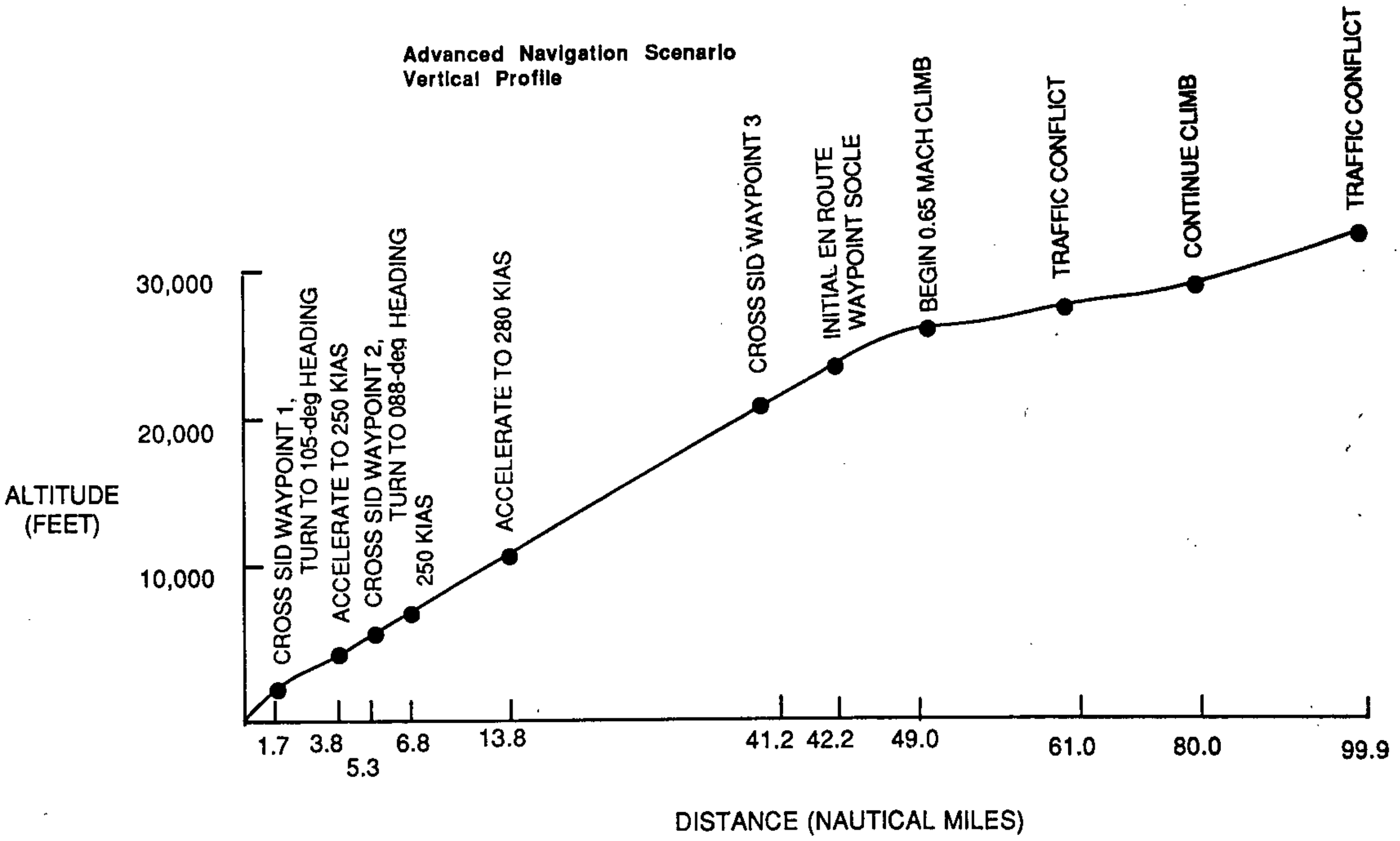


FIGURE 9. Sample mission profile.

implied requirements that might otherwise be overlooked. This includes all essential system functions, such as failure modes or emergency procedures. Elements of the scenario should be sufficiently detailed to convey an understanding of the mission, and to permit a breakout of mission variations relating to features such as a) mission phases, b) the activity performed in each phase, c) the approximate degree of accuracy for each activity, d) time, and e) any interdependencies of activities as to sequence, coordination, information transfer, etc.

7.1.2.2.2 Procedure. There are no precise rules for writing scenarios; however, there are a number of factors that should be considered for inclusion in them. These factors are:

a. Assumed operational tactics and weather conditions. (e.g., sea state)

b. A listing of subsystems and their proposed capabilities (e.g., sensor range, navigation accuracy, etc.)

c. Postulation of a geographic position - this would include boundaries and terrain elevations.

d. A selected starting point in terms of time and location.

e. Placement of both threats and unknowns within the geographic area.

f. Adherence to the previously developed mission profile(s) in terms, routes, and distance.

g. Development of limited profiles (performance) for each of the unknown and hostile tracks (contacts).

h. Determination of the location of threats/targets.

i. Based on subsystem capabilities, determination of when sensors are active and what their capabilities are as to target/threat detection.

j. Development of available target identification techniques.

k. Utilization of all significant system capabilities.

l. Development of hostile target nullification techniques.

m. Completion of the scenario until the threats are destroyed or the system capabilities are depleted or sucessfully countered.

n. Repeat of the scenario under different conditions of weather, threats, degraded operations mode etc.

The scenario should identify which tactics appear to be feasible, which may overstress the system, and which mission functions must be broken down to lower, more detailed levels in order to determine their feasibility and operation within the context of the scenario. If possible, the user command should be contacted to obtain information to assist the development of the scenarios.

7.1.2.2.3 Use. All of these data will be used while performing the various analysis techniques such as functional flows, decision/action diagrams, and action/information requirements. Table VI indicates the output applications, including mission effectiveness criteria, which result from performing mission scenarios.

7.1.2.2.4 Comparison to other techniques. Mission scenarios are compared to other analysis techniques in table IV.

7.1.2.3 Functional flow diagrams. Functional flow diagrams are the most popular systems technique used for the determination of system requirements. Functional flow diagrams can provide a detailed outline of all system requirements. They may be used as an extensive checklist of system functions that must be considered in assuring the ability of the system to perform the mission. This analysis of system functions is required to determine solutions for later trade studies. Functional flows are necessary to determine effectively which system functional elements should be performed by operators, equipment, software or some combination of these.

7.1.2.3.1 Description. Starting with system or mission objectives, functional flows are developed iteratively for more and more detailed system requirements down to the level of specific operator tasks. In general, during the construction of higher level flows, no distinction should be made between operator, equipment, or software implementation of system functions, The lack of distinction is for the purpose of conducting unbiased system trade studies. Functional flow diagrams are often referred to as functional block diagrams, functional flows, or functional flow block diagrams. All of these terms refer to the same analysis technique. It may have evolved from the use of schematic block diagrams that depict the relationships between various equipment items in a system. The most significant difference between the schematic diagram and the functional flow is the addition of the verb to the noun label in each schematic block, by the use of verb-noun functions, the system is prevented from becoming prematurely committed to an arbitrary design implementation solution. A function may be defined as a verb-noun phrase that must be accomplished by a system. All functions can be broken down or divided into more detailed functions.

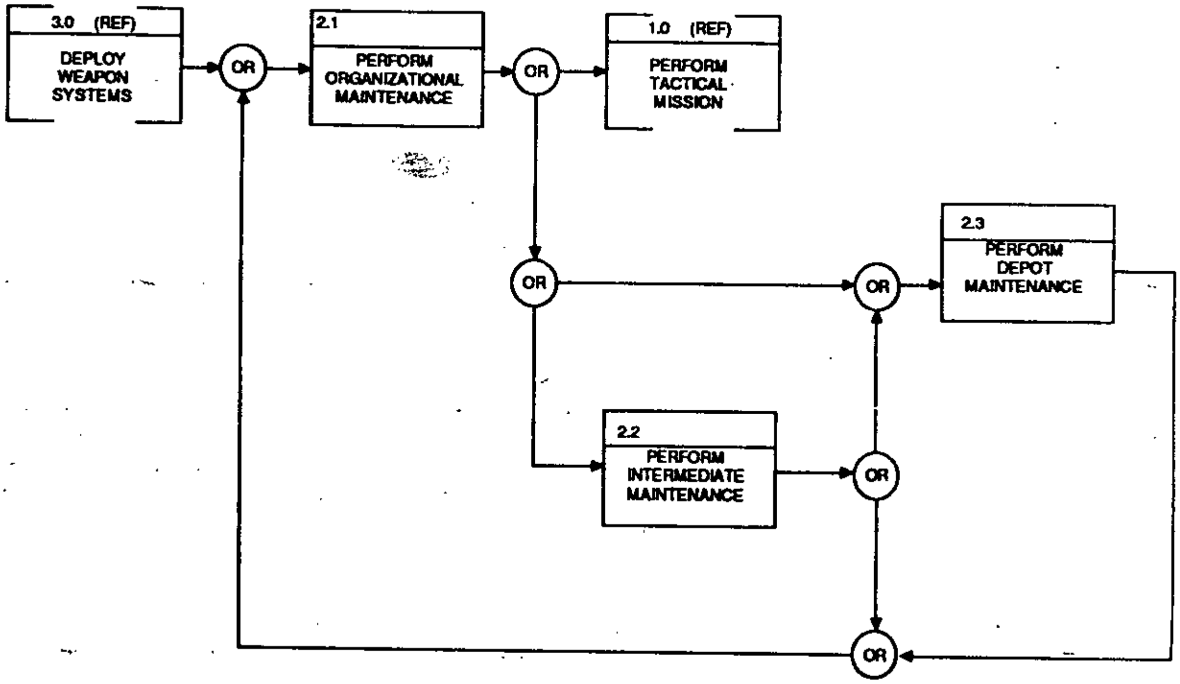
7.1.2.3.2 Procedure. Sample functional flows are shown in figure 10. These flows are constructed by arranging in system sequential order all of the various functions that are believed to pertain to a particular system (or subsystem, depending on level of detail). Each function is a verb-noun combination. Occasionally nouns are assumed and adjectives are added. Each individual function is contained within a rectangular block. Each block is numbered for reference, more or less according to its sequence on the page.

7.1.2.3.2.1 Reference block. If the function is repeated in other portions of the total series of functional flows, the same number should be used and the block may be drawn as a reference block. Each functional flow diagram contains a reference to its next higher functional flow through the use of a reference block. Reference blocks may also be used to indicate functions occurring at the same level on different pages. The blocks in figure 10 that are broken in the middle are reference blocks. The numbers are important to insure traceability either back to the higher level functions or between functions.

7.1.2.3.2.2 Symbols. The functional flow symbology used in figure 10 is typical. The direction between the function blocks indicates the normal sequence of occurrence of system functions. Contrary to the ground rules for constructing schematics, the arrows between functional flow blocks should show the general flow of the diagram toward the right and, if necessary, down. Arrows should not be used on either the top or bottom of the blocks, They should enter the block from the left and exit to the right. Wherever arrows are joined or split out, they should be connected by an "and", "or", or "and/or" gates or junctions as indicated in the sample. The significance of the "and" junction is that all of the following or preceding functions must be performed. The "or" junction indicates a choice between two or more of the following or preceding functions as to which one is performed. The "and" and "or" junctions may be combined if it will not cause confusion and page space is limited.

7.1.2.3.2.3 Functions. A function is that which must be accomplished by the system. All functions can be broken down or divided into more detailed functions. Top level and first level functions tend to be identical for similar systems. A specific operational requirement may call for modification to these higher level functions; however, the changes generally occur to the lower level functions. For large programs, such as a complete air cushion vehicle system, they are gross system operations. The second level functions would then tend

First-level maintenance functional flow diagram



Third-level functional flow diagram for support facilities

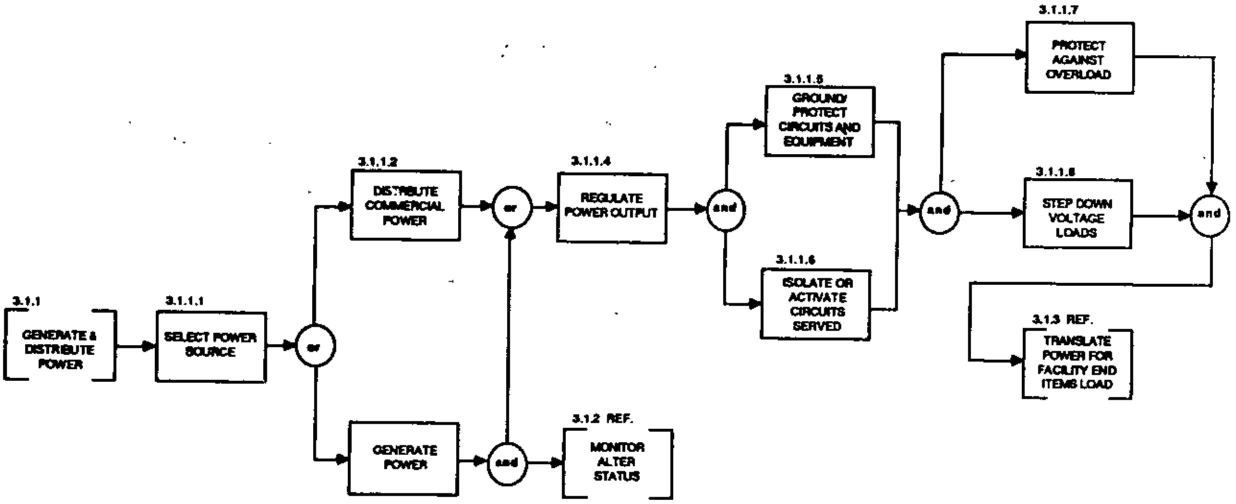


FIGURE 10. Sample functional flows.

to describe system operational (or maintenance) functions within the various mission phases. The third level may define specific functions with measurable performance units. Functional allocation between operator, equipment and software may occur at this level. Fourth level functions may be the level at which gross operator task analysis may occur. The total concept of functional level detail or definition must be based on the total size or scope of the particular system to be analyzed. Naturally, the smaller the system being worked, the more detailed the corresponding numerical level of functional analysis will be. Larger systems or programs will require more levels to get to the same degree of detail. In view of this possible ambiguity as to functional level definition versus program scope, it is recommended that the parties concerned, i.e., requiring organization and performing organization, agree on the definitions before considerable effort is expended on this or similar techniques. The definition of functional levels is not as important as the assurance that analysis is conducted to a sufficient degree of detail to determine significant operator performance requirements, particularly the details of critical operator tasks. The reference number groups recommended for use with each of the levels is as follows: 1.0, 2.0, 3.0 ... for top level functions: 1.1, 1.2, 1.3 ... for first level functions: 1.1.1, 1.1.2, 2.1.1 ... for second level functions; and 1.1.1.1, 1.1.1.2, 2.1.1.1 ... for third level functions and so on.

7.1.2.3.2.4 Requirements. Once the functional flows are constructed, the functions and subfunctions should be reviewed and analyzed in depth for probable variations related to the system requirements. Even during early development, both alternative mission requirements and the expected downstream developmental impact of such alternatives should be appraised to produce an early estimate of likely crew interface requirements, capability, special provisions needed, potential problems and probable solutions. In some cases, the analyst may also need to produce preliminary workload data and to provide information for manning and training estimates. In any case, he must anticipate a wide variety of possible requirements to form a judgment for both crew performance feasibility, support requirements and development needs.

7.1.2.3.2.5 Construction. Some of the essential features to remember about the procedure for constructing functional flows are as follows:

a. Functional flow blocks must contain a verb and a noun.

b. It is essential to initiate the flows without any allocation to operator, equipment, or software.

c. Each expanded level of functional flow will contain more and more detailed information. The detail may be carried on to as many levels as appropriate. It is normally necessary to go to at least the third level,

d. Functions are numbered in a manner which preserves continuity of function and logical breakout from function origin.

e. The diagram should be organized so that one can easily find the input and follow the flow through the function blocks to the resulting output.

f. It is generally good practice to limit the size of the diagrams. They should be divided up if too large for foldout pages in documents. Reference blocks may be used. If designed for display on walls, the functional flows may be of relatively large size.

7.1.2.3.3 Use. Functional flow diagrams are extremely useful to the human factors engineer for a number of reasons.

a. The functional block numbering system provides a rationalized traceability from lower to higher level functions and between functions at the same level. Functional flows are flexible in that a change in one part of a total functional flow generally causes minimal effect on other parts. Because of this, they are easy to use to show the effects of preliminary functional allocation trades to man, machine or software. Because of this flexibility and ease of use, they are ideal technique to use for the rapid analysis of system functions proposed by other program personnel such as subsystem designers. Functional flows are the ideal way to show the relationships between functions. They may be structured in such a manner as to show as many as forty or fifty different functions on one foldout page. If wall space is available, complete systems or subsystems may be laid out, depending on the level of detail desired.

b. Functional flows are relatively easy to develop. Whereas some human factors engineering analysis techniques require special training prior to their use, the functional flow diagram requires only minimal training. The functional flow diagrams are also a relatively fast analysis technique and accordingly, they tend to be very cost effective. The only reason for not using this analysis technique would be to use another technique in its place, such as the decision/action diagram (see

7.1.2.4) which incorporates most of the same features of the functional flow. Functional flows do not contain information pertaining to decisions and time-based information flow, although functional flows tend to be sequential. Functional flows generally do not indicate operator, equipment, or software allocations, except at a lower, more detailed level. The data for the functional flows originally come from the operations analysis program effort. Data for more detailed lower level functional flows also come directly from the higher level flow-diagrams and from subsystem design groups. In a similar manner to all other analysis techniques, functional flow diagrams are not an end in themselves. There is little or no point in constructing them if they are to be completed only to be filed away.

c. As more and more detailed functional flows are developed, specific system requirements begin to emerge. These requirements may then be documented by incorporation into system specifications.

d. As previously indicated, functional flows are used to assist in the performance of functional trades (i.e., trades performed to choose between or among two or more functional alternatives). The results of the trades should evolve into detailed system requirements or specifications. The functional flows are seldom adequate to develop detailed system requirements where operators are involved. Additional analysis techniques such as time lines, requirements allocation sheets, or operational sequence diagrams need to be generated to develop system requirements pertaining to system decision functions or time constraints.

e. Review of table VI indicates several specific output applications that result from performing functional flow analysis.

7.1.2.3.4 <u>Comparison to other techniques</u>. Table IV indicates numerous evaluation characteristics of the functional flow as compared to other analysis techniques. The technique is best used during concept formulation and early phases of demonstration validation and perhaps full scale development. In summary, functional flows provide a detailed and comprehensive inventory of all system requirements and an extensive checklist of system functions and factors that must be considered in assuring ability to perform the mission. Properly structured, the inventory will proceed from functional indentures common to all similar systems (e.g., land vehicles, surface ships, and aircraft), through indentures peculiar to a type (e.g., trucks, landing craft, and fighters) and on to functional elements that are specific to mission operations. Detailed analysis of the functions is necessary to determine detailed system requirements, possible equipment, and man/equipment trades in order to effectively determine which elements performed by equipment and which should be performed by man.

7.1.2.4 Decision/action diagrams. The decision/action diagram is a technique similar to functional flows. It is used to show the flow of required system data, in terms of operations and decisions. Like functional flow diagrams, decision/action diagrams may be developed and used at various levels of detail. The initial decision/action diagram charts are concerned with gross functions without regard to whether functions are performed by man, machine, software, or some combination of these. The decision/action diagrams prepared subsequent to tentative man-machine-software function allocations will reflect this allocation in the decisions, operations, and branching which are represented. At the program concept formulation stage, however, these charts would ordinarily be prepared at a detailed level only for the more critical man-machine functions.

7.1.2.4.1 Description. This technique may also be referred to as information flow charts, decision logic diagrams, or operation/decision diagrams. The term, information flow charts, generally refers to a type of decision/action diagram that has a vertical orientation on the page rather than the left to right horizontal orientation that decision/action diagrams use (see 7.1.2.9, flow process charts). Special symbology may also be used with the information flow charts at a more detailed level to indicate allocations to man or machine (e.g., single line symbols mean manual, double line mean automatic).

a. The decision/action diagrams are so similar to functional flow diagrams that the use of both techniques is not recommended. The most significant difference between the two techniques is the addition of the decision blocks (diamonds) to the functional flow diagrams. The decision/action diagrams are generally used when the program is software oriented.

b. In that it records the sequence of operations and decisions which must be performed to satisfy a definite system function, the decision/action diagram is similar to the flow charts used by computer programmers. Both charts are based on binary choice decisions and intervening operations. There are two important reasons for using binary decision logic as a standard in performing decision/action diagramming:

1. To expedite communications through use of simple yet universally applicable conventions.

2. To provide for easy translation of decision/action flow charts into logic flow charts for computerized sections of the system.

c. A decision at a general level may split into several decisions at a more detailed level, for example:

General level:	- Do any targets need identification processing?
Specific level:	- Do any newly entered targets need identification processing?
	- Do any target tracks need confirmation of tentative identification?
	- Do any confirmed identifications need rechecking?

d. Each of these more detailed decisions may have associated with it one or more detailed operations. Similarly, an operation at a general level may break down into more detailed decisions and operations.

e. The example in figure 11 is a gross level detection and tracking function. No functional allocation has been made to man or machine. Note that at this level the chart is applicable to several detection and tracking systems - the decisions and operations are essentially common between them. Even here, however, the usefulness of the flow chart diagramming technique is apparent because it makes the analyst begin to consider implementation alternatives, such as:

1. By what means can any given signal be compared with known targets in the system?
2. How can probable targets be marked so their reappearance can be readily recognized?

f. The information necessary for the initiation of decision/action diagrams comes from the mission profiles and scenarios. Data for more detailed lower level decision/action diagrams may come directly from higher level flow diagrams and from subsystem design groups as equipment detailed characteristics become well defined.

7.1.2.4.2 Procedure. The procedure for constructing decision/action diagrams is essentially the same as that for functional flow diagrams, They are constructed by arranging

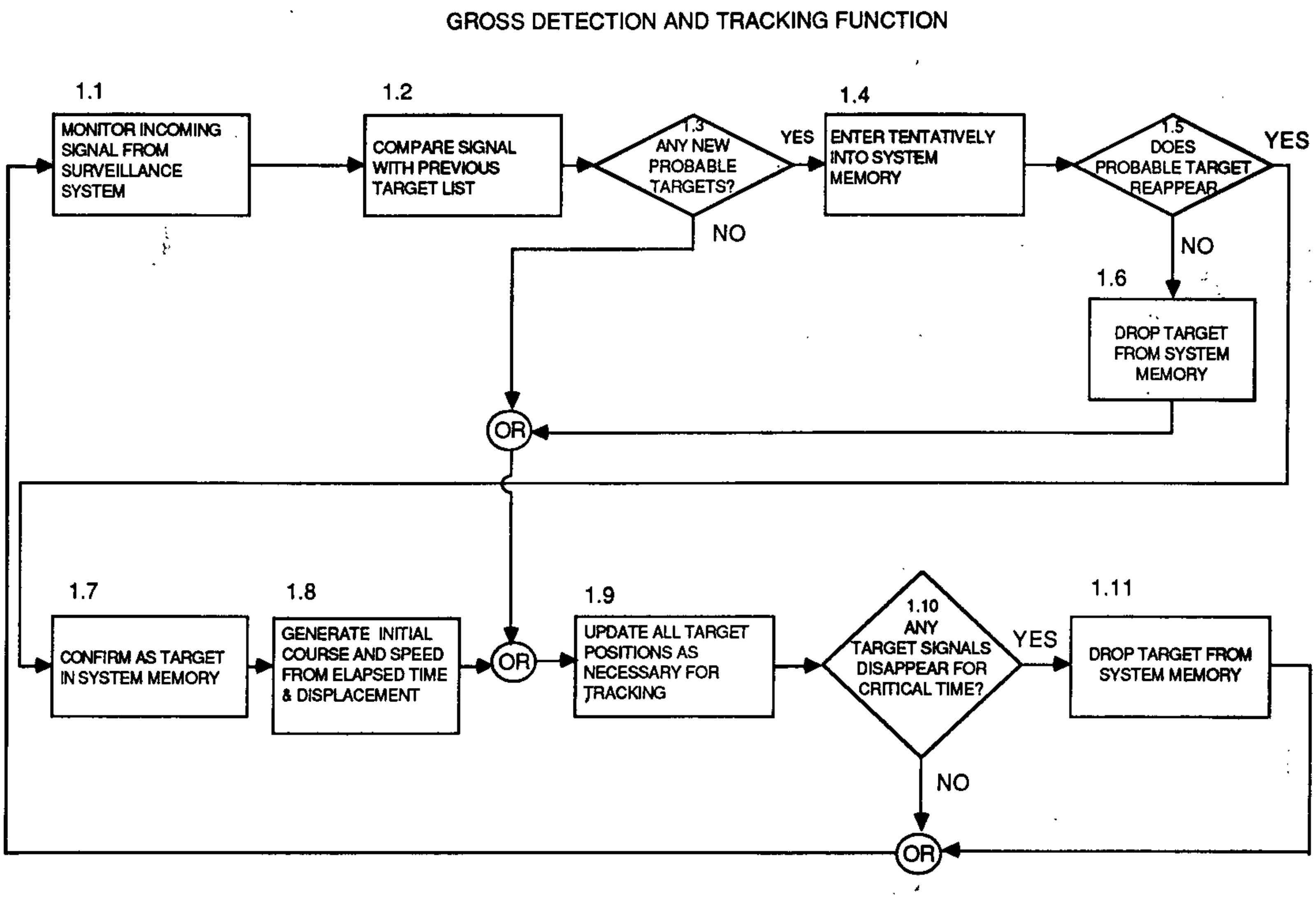


FIGURE 11. Sample decision/action diagram.

in sequential order all of the functions and decisions that pertain to a system or subsystem (depending on level of detail). Each function is a verb-noun combination with occasional adjectives or other modifiers. Each function phrase is relatively short and is contained within a rectangular block. Each decision function is placed in a diamond shaped outline symbol and is written in a question format that may be answered with a binary, yes-no, response. Both the functional action blocks and the decision diamonds should be given reference numbers in a manner similar to the numbers assigned to functional flow diagrams. The numbers are important to ensure traceability between decision/action blocks. The decision diamond blocks may be drawn in solid or dashed lines to indicate primary decision functions or shared decision functions, respectively. The use of arrows between function/decision blocks is similar to functional flows. Note that flow paths should be complete. Every path should either recirculate or end in a valid exit with a reference block. The junction between arrows are handled with "and", "or", or "and/or" gates in the same manner as with functional flows (see 7.1.2.3).

7.1.2.4.3 Use. The results of the decision/action diagram analysis are used to develop specific system requirements and assist in the performance of trade studies. Additional analysis techniques such as time lines are almost always needed following the construction of the decision/action diagrams in order to investigate the effect of the critical system parameter, time. Worthwhile computer simulations have been successfully performed with the addition of time data to detailed decision action diagrams that include preliminary allocations of functions to operators. Table VI indicates several specific output applications that result from performing decision/action diagrams. The technique is well suited to initial development of software programs in general, and display software in particular.

7.1.2.4.4 Comparison with other techniques. Review of table IV indicates a preference for performing decision/action diagrams during the earliest phase of a program.

7.1.2.5 Action/information requirements. Given the functional flows, or decision/action diagrams, analytic procedures for performing preliminary functional allocation are somewhat dependent on the analyst and his objectives. For the purpose of performing functional allocation trades, one alternative technique is to make the allocation from the level of the detail provided in the functional flows. However, experience suggests that more detail than that provided at the functional level may be desirable before making allocation trades.

7.1.2.5.1 Description. A format which has been useful in

APPROACH REQUIREMENTS ANALYSIS			TRADE-OFF INFORMATION AND DATA INTEGRATION		
APPROACH-LAND FUNCTIONAL REQUIREMENTS	ACTION REQUIREMENTS	INFORMATION REQUIREMENTS	RELATED INFORMATION REQMT'S SOURCES/PROBLEMS	RELATED ACCIDENT FEATURES	RELATED SURVEY COMMENTARY
1.0 INITIATE PRE-APPROACH PROCEDURES	1.0.1 REVIEW APPROACH INFORMATION	1.0.1.1 APPROACH ORIENTATION 1.0.1.2 APPROACH CONSTRAINTS • APPROACH • REQMT'S • OBSTACLES • HAZARDS • WEATHER • MINIMA	APPROACH PLATE DATA • OBSTACLE LOCATION • COURSE/PATH DATA • TERRAIN CHARACTERISTICS • HAZARDS • MINIMUM DECISION ALTITUDES POSITION DATA	DATA MISINTERPRETED/ NOT USED EFFECTIVELY. HAZARDS MIS-APPRAISED. NAVIGATION POSITION ERRORS	• CAN'T REMEMBER ALL DETAILS • STUDY TIME IS LIMITED WHILE SETTING UP APPROACH • IMPROVE TO EMPHASIZE BASIC DATA-CRITICAL DATA BOLDER, E.G., GO-AROUND HDG./ALT. • NEED CLEAR PICTURE OF POSITION SITUATION
	1.0.2 COORD. WITH APPROACH CONTROL	1.0.2.1 COMMUNICATION •PATH DESIGNATION • UNIQUE LIMITS /CONSTRAINTS • ENVIRON. COND. • BARO. PRESS.	COORDINATION AND CONFIRMATION OF APPROACH CLEARANCE ALTIMETER SETTING	CLEARANCES/PROCEDURES ARE MISUNDERSTOOD/NOT FOLLOWED/ IN ERROR. ALTIMETER MISSET/ MISREAD. CONFUSION OF • INCHES MERCURY VS. MILLIBARS • SEA LEVEL VS. FIELD ELEVATION REF.	• NEED PROCED. FOR BETTER COORD. BETWEEN AIRPLANE AND TRAFFIC CONTRL TO IMPROVE UNDERSTANDING OF SITUATION/CONTRL INST. • IMPROVE ALT. DISPLAY • STD. SET REF. ELEV. • REDUNDANT SETTING CHECKS

FIGURE 12. Sample action information requirements form.

producing functional allocation detail in an appropriate context is the technique "action/information requirements." Figure 12 illustrates such a form. Use of this format helps in defining those specific actions necessary to perform a function and, in turn, those specific information elements that must be provided to perform the action. It breaks up the referenced "functional requirement" into useful groupings of "action requirements" and "information requirements." This particular sample format is expanded to include detailed aspects of the function such as related information requirements, sources, and problems. Related accident features and survey commentary are also included in this example. However, the precise format of this particular form does not need to be rigidly controlled.

7.1.2.5.2 Procedure. The procedure for developing or completing action/information requirements forms is much more informal than that for most analysis techniques. Often the three columns illustrated on the left side of the form in figure 12 are all that are used. The first column is used to list the function and function number from the functional flow diagrams. The second column is used to list each of the action requirements indicated by the function. The third column is used to list the information requirements that come from the listed function. If more detail is desired for the preparation of the allocation trades, additional columns may be added on the right side of the form. In the example in figure 12, related information requirements, sources, and problems are listed. A second column lists related accident features and the third column lists any other commentary. In this case, the column is used for survey results pertinent to the function being scrutinized. Additional data could be listed, such as the capabilities of operators or equipment for handling these functional requirements.

7.1.2.5.3 Use. Use of this technique provides information to: a) identify equipment which satisfies the system requirements, b) perform associated man/equipment capability tradeoffs for preliminary functions allocation, c) integrate similar or correlated system/action/information requirements to develop new concepts, or d) easily pair action requirements with possible control hardware and information requirements with possible display hardware. The information used to construct these forms comes primarily from the functional flows. Additional data may be obtained from subsystem design engineers. The results obtainable from this analysis technique are used by human factors engineers in the performance of functional allocation trades.

7.1.2.5.4 Comparison to other techniques. Table IV compares the use of this analysis technique to other techniques. The action/information requirements forms should be used after the functional flows but before the functional allocation trades. The appropriate time during the program to perform this analysis technique would therefore be during the concept formulation or after early phases of demonstration and validation. It is not recommended if there is relatively little difficulty in obtaining sufficiently detailed functions from which functional allocation trades may be performed.

7.1.2.6 Function allocation trades. With the completion of the functional flow diagrams, decision/action diagrams, or action/information requirements, it is appropriate to perform preliminary trade-off studies of man-machine allocations for each of the functions being considered. Too often the allocations are based only on past experience, or worse yet, the allocations are simply arbitrary. A rationalized choice of functions is necessary for optimum system design. These man-machine allocations provide the baseline for down-stream efforts relating to crew task control/display operations requirements, crew station configuration concepts, workload evaluation and crew station design, development and evaluation. Additionally, function allocations dictate crew workload and significantly affect manning, training and procedures requirements. Early appraisals of the allocation impact on these requirements are necessary as part of the initial HE review process. Early appraisals that anticipate program and operational requirements are reflected in the earliest system development phases.

7.1.2.6.1 Descriptions. Working in conjunction with project subsystem designers (perhaps as a team to do this task) and using the functional flows, etc., plus their past-experience with similar systems, the human engineer makes a preliminary allocation of the actions, decisions, or functions shown in the previously used charts and diagrams to operators, equipment, or software. The assignment of the functions, actions, or decisions to operators, equipment, or software must be based on: a) the known limitations of operators, b) the state of-the-art performance of hardware and software, and c) estimated performance to be required in terms of speed, accuracy, and load. The need for a cooperative effort between subsystem designers and human engineers at this point is extremely important. Each must contribute to make the allocations meaningful. There are three specific techniques recommended to perform the details of the function allocation trade.

7.1.2.6.1.1 First technique. The first technique is simply that of "trial and error" substitution of each of the alternatives into a system or subsystem model. Each alternative is then evaluated on a basis of total system or subsystem reliability or speed. This technique has some obvious drawbacks. It is not recommended for a systems analysis where a large number need to be allocated. The technique lends itself for use to computer analysis much better than manual (paper and pencil) analysis. Computer-aided techniques that may be used for this type of analysis are described in following paragraphs of this guide.

7.1.2.6.1.2 Second technique. The second technique is based on an evaluation matrix (see figure 13). Candidate subsystem functions are listed and compared against the "Fitts List" (ref. 1) man-machine capabilities (see table VII). The form used to perform this technique is called a functional allocation screening worksheet. Plausible operator roles or equipment functions (e.g., operating, monitoring, maintaining, programming, communicating, etc.) are identified using the screening worksheet. By comparing the functions to be performed with the inherent capabilities of man or machine to accomplish the functions, operator and equipment tasks are allocated. The comparison is evaluated and, based on the analyst's judgment, a weighted numerical score is assigned to each function/capabilities criteria relationship.

7.1.2.6.1.3 Third technique. The third technique is also based on an evaluation matrix and is often referred to as a design evaluation matrix. In this technique, candidate subsystem alternatives are listed and compared against selected criteria for allocation (response time, error rate, operability, cost, etc.). As in the case of the screening worksheets, the evaluation criteria are weighted since some factors are obviously more important than others. Each of the function/evaluation criteria relationships is assigned a numerical score, as to how each function best meets the selected evaluation criteria. This third technique is well suited for use in complying with MIL-H-46855 requirements (i.e., Paragraph 3.2.1.4 of that specification). Human engineering criteria such as that in MIL-STD-1472 may be used as the selection evaluation criteria. Figure 14 is a sample matrix used for a crew size trade study.

7.1.2.6.2 Procedure. The procedure for accomplishing the first of the three functional allocation trade techniques is actually the same as the procedures for accomplishing some of the other human factors analysis techniques. The procedure for the second two are similar to each other but not similar to the first.

7.1.2.6.2.1 Trial and error method. The trial and error method may be performed once one of the alternatives for a particular function is tentatively chosen, the alternative should be evaluated for use by performing one of the analysis techniques on it. For example, the time line analysis technique should be used to evaluate an allocation trade where either operators or equipment are chosen to perform time critical tasks. The resulting allocation choice is then the solution that best meets the system time requirements. In a similar manner, other allocation trades may be accomplished to evaluate man-machine functional performance in terms of

KEY:

rated score → 5/25 ← weighted score

SCALE 1-5 5 BEST

HYPOTHETICAL TRACKING FUNCTIONS	INHERENT OPERATOR CAPABILITIES					INHERENT EQUIPMENT CAPABILITIES			TOTAL SCORE		PROPOSED ALLOCATION			
	DETECTING SIGNALS IN THE PRESENCE OF HIGH NOISE ENVIRONMENT (X5)	RECOGNIZING OBJECTS UNDER VARYING CONDITIONS OF PERCEPTION (X4)	HANDLING UNEXPECTED OCCURRENCES OR LOW-PROBABILITY EVENTS (X4)	REASONING INDUCTIVELY (X1)	PROFITING FROM EXPERIENCE (X2)	RESPONDING QUICKLY TO SIGNALS (X3)	PERFORMING PRECISE ROUTINE REPETITIVE OPERATIONS (X2)	COMPUTING AND HANDLING LARGE AMOUNTS OF STORED INFORMATION QUICKLY AND ACCURATELY (X4)	OPERATOR	MACHINE	OPERATOR	BOTH	MACHINE	
													EQUIPM'T	SOFTWARE
1. DETERMINE IF TARGET TRACKS IN SYSTEM	5/25	2/8	3/12	3	3/6	3/9	4/8	1/4	81	41	X			
2. ACTUATE SEQUENCE	1/5	1/4	1/4	1	1/2	1/3	1/2	1/4	20	24		X		
3. PUT NEXT TARGET IN TRACK LIST UNDER CLOSE CONTROL	1/5	1/4	1/4	1	1/2	9	5/10	1/4	21	43			X	X
4. ADVANCE HOOK ON DISPLAY TO TRACK COORDINATES	1/5	1/4	1/4	1	2/4	3/9	5/10	1/4	70	39	X			
5. DETERMINE IF HOOK LINES UP WITH PRESENT TARGET POSITION	4/20	2/8	2/8	3	2/4	3/9	4/8	1/4	73	40	X			
ETC...														

FIGURE 13. Sample functional allocation screening worksheet (evaluation matrix).

TABLE VII Man/machine capabilities (Fitts list)

MAN EXCELS IN	MACHINES EXCEL IN
Detection of certain forms of very low energy levels	Monitoring (both men and machines)
Sensitivity to an extremely wide variety of stimuli	Performing routine, repetitive, or very precise operations
Perceiving patterns and making generalizations about them	Responding very quickly to control signals
Ability to store large amounts of information for long periods - and recalling relevant facts at appropriate moments	Storing and recalling large amounts of information in short time-periods
Ability to exercise judgment where events cannot be completely defined	Performing complex and rapid computation with high accuracy
Improvising and adopting flexible procedures	Sensitivity to stimuli beyond the range of human sensitivity (infrared, radio waves, etc.)
Ability to react to unexpected low-probability events	Doing many different things at one time
Applying originality in solving problems: i.e., alternative solutions	Exerting large amounts of force smoothly and precisely
Ability to profit from experience and alter course of action	Insensitivity to extraneous factors
Ability to perform fine manipulation, especially where misalignment appears unexpectedly	Ability to repeat operations very rapidly, continuously, and precisely the same way over a long period
Ability to continue to perform when overloaded	Operating in environments which are hostile to man or beyond human tolerance
Ability to reason inductively	Deductive processes

TRADE OPTIONS

WEIGHTING FACTOR	⑩	⑤	⑤	④	④	③	③	③	②	①	
EVALUATION CHARACTERISTICS	Cost	Autonomy	Response Time	Multimission/ Flexibility & Growth	Reliability	Safety	Rescue Capability & EVA	Replanning	Operating Weight	Other	SCORE
One crewmember	5	2	5	3	2	1	1	1	5	2	
	50	10	25	12	8	3	3	3	10	2	126
Two crewmembers	4	4	4	4	3	4	4	4	4	5	
	40	20	20	16	12	12	12	12	8	5	157
Four crewmembers	1	4	3	5	3	4	4	4	4	1	
	10	20	15	20	12	12	12	12	8	1	122

OUTCOME : two crewmember option by **20%**

CELL INDEX FACTOR KEY
1= unfavorable
2= slightly unfavorable
3= neutral
4= favorable
5= very favorable

- Evaluation characteristics are analyzed with respect to crew considerations only

WEIGHTING FACTOR KEY
1= low weight
10= high weight

FIGURE 14. **Sample Design Evaluation Matrix.**

reliability. The following paragraphs will indicate which techniques are best suited for testing particular performance parameters.

7.1.2.6.2.2 Evaluation matrix. Functional allocation screening worksheets are constructed by listing each of the several functions to be allocated on the left side of the worksheet. Two sets of evaluation criteria are listed across the top of the sheet. The first set pertains to operator capabilities; the second set pertains to equipment capabilities. Each of the capabilities evaluation criteria is taken from the often used "Fitts List" table VII. In order to balance out each of the evaluation capabilities, each one against all the others, numerical weightings have been assigned as appropriate for the system being analyzed. For example, "response to signals" may be particularly important as compared to "inductive reasoning" and it should therefore be weighted more heavily. Although not a part of the "Fitts List", such factors as cost may be added to these other characteristics. Such parameters are generally considered for evaluation using the design evaluation matrix technique discussed in the following paragraph. Whenever an evaluation characteristic (across the top of the sheet) is applicable to a listed function (left side of sheet) a weighted "X" is placed in the column/row intersection. The actual evaluation is made by totaling up each of the weighted "X"s" for the "operator" versus the "equipment" allocation. The results of the allocation are tabulated in the far right-hand columns as either "operator", "both", or "equipment." The "both" column is used when the sums from both sides of the worksheet are within approximately 80% of each other. A more detailed analysis may be required to obtain a detailed breakout of operator or equipment allocation. If a more precise evaluation of each of the functions is desired, a numerical score (e.g., 1-5) may be used rather than just an "X" to indicate how well a particular "Fitts List" evaluation characteristic applies to a function. This procedure is used in the figure 13 construction. The number entered in the row/column intersection is the weighted evaluation factor times the score. As with the simpler method indicated above, the total scores are added up on each side of the worksheet to obtain a proposed functional allocation. It should be noted that whereas this technique does not insure the absolutely best allocation of functions, it goes a long way beyond the "gut-feel" method so often used.

7.1.2.6.2.3 Design evaluation matrix. Construction of the design evaluation matrix is similar to the functional evaluation screening worksheet in that the subsystem alternatives are listed along the left side and the evaluation factors are listed across the top of the sheet. The main difference is that the trade to be performed is not necessarily between man or machine for a particular single subsystem or functional listing. The trade to be performed is between each of the alternatives listed along the left side of the sheet. Another difference between the two techniques is that the lists for the design evaluation matrix tend to be of several crew or equipment alternatives rather than just operator versus equipment alternatives (See figure 14). The evaluation characteristics listed across the top of the sheet pertain more to performance parameters than to inherent capabilities. The evaluation characteristics should be weighted and the suitability of a particular functional alternative to an evaluation characteristic should be scored on a scale of 1 to 5. The addition of each of the weighted scores determines the best alternative.

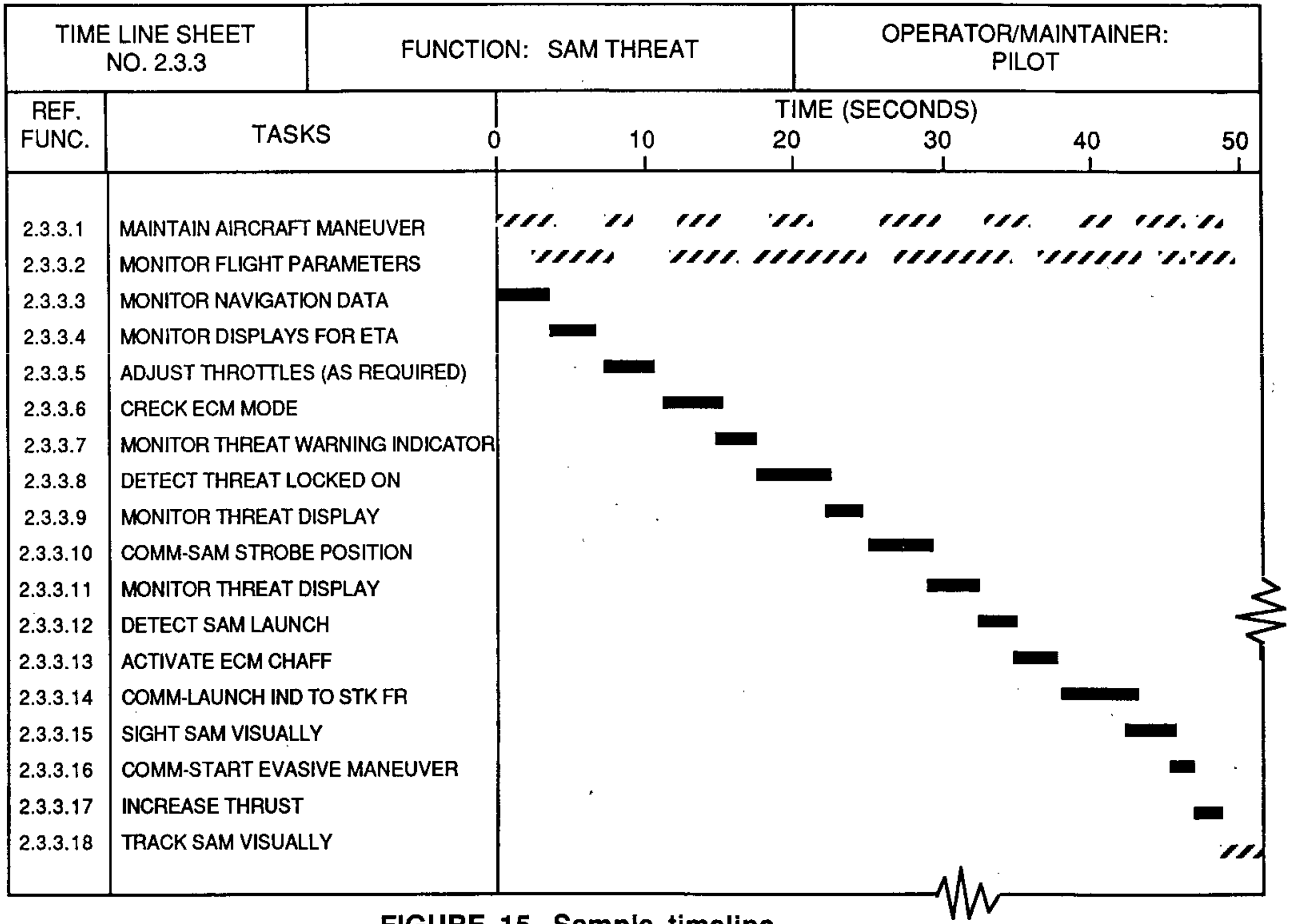
7.1.2.6.3 Use. Initial function allocations are typically obtained from information taken from mission requirements, functional flows, or other preliminary analysis diagrams. Function aspects such as difficulty, priority and criticality are appraised and operator/equipment methods for meeting the requirements are evaluated. The results of the function allocation trade are used to: a) determine impact of crew tasks, skills and information needs; b) appraise related crew task capability and limitations; c) identify corresponding control/display concepts; d) trade specific and detailed control/display/crew performance capabilities; e) perform extensive task analysis and workload evaluations; and f) identify control/display/crew operations requirements in order to proceed to g) crewstation configuration development.

7.1.2.6.4 Comparison to other techniques. These techniques are compared to other human factors engineering analysis techniques in table IV. Functional allocation studies are best performed early in the program.

7.1.2.7 Time lines. Time lines (or timelines) are one of the most basic techniques used by HE analysts. The two parameters in which HE analysts are most interested are time and errors. There is no better way to analyze just the parameter of operator time performance than by the use of time lines. Time lines serve two purposes. First, they permit an appraisal of time-critical sequences to verify that all necessary events can be performed. Secondly, they provide an integrated task time chart to assess the occurrence of incompatible tasks and to serve as a baseline for workload evaluation. A typical time line example is shown in figure 15.

7.1.2.7.1 Description. In order to establish the time base for the timelines, data from previous systems (if available) may provide the most reliable information. If this type of time data base does not exist or is not adequate, the use of a Predetermined Time Standard (PTS) is recommended (see 7.1.2.8).

7.1.2.7.2 Procedure. Each time line should be related to a



TIME LINE SHEET NO. 2.3.3	FUNCTION: SAM THREAT	OPERATOR/MAINTAINER: PILOT

REF. FUNC.	TASKS
2.3.3.1	MAINTAIN AIRCRAFT MANEUVER
2.3.3.2	MONITOR FLIGHT PARAMETERS
2.3.3.3	MONITOR NAVIGATION DATA
2.3.3.4	MONITOR DISPLAYS FOR ETA
2.3.3.5	ADJUST THROTTLES (AS REQUIRED)
2.3.3.6	CRECK ECM MODE
2.3.3.7	MONITOR THREAT WARNING INDICATOR
2.3.3.8	DETECT THREAT LOCKED ON
2.3.3.9	MONITOR THREAT DISPLAY
2.3.3.10	COMM-SAM STROBE POSITION
2.3.3.11	MONITOR THREAT DISPLAY
2.3.3.12	DETECT SAM LAUNCH
2.3.3.13	ACTIVATE ECM CHAFF
2.3.3.14	COMM-LAUNCH IND TO STK FR
2.3.3.15	SIGHT SAM VISUALLY
2.3.3.16	COMM-START EVASIVE MANEUVER
2.3.3.17	INCREASE THRUST
2.3.3.18	TRACK SAM VISUALLY

FIGURE 15. Sample timeline.

higher level functional requirement. The functional flow title and number should be indicated on the time line sheet for reference (see figure 15). Other information such as location of the function and the type of function is desirable. Each of the subfunctions or tasks are numbered and listed along the left side of the sheet. The time units of interest (hours, minutes, or seconds) are indicated across the top. A time scale of suitable length is selected such that the total time period of interest fits on to the worksheet. It is recommended that once the scale for a sheet is chosen, it be adhered to for all portions of that time line sheet.

7.1.2.7.3 Use. Almost all the techniques previously presented are sources of data to be used in preparing time lines. Generally, the most common source of material for a time line analysis is a detailed level functional flow diagram; one that is sufficiently detailed to have tasks allocated to the operators as the result of functional allocation trades. Table VI shows the wide variety of applications or outputs for which time line analysis data may be used.

7.1.2.7.4 Comparison to other techniques. Table IV indicates the relationship between time lines and the numerous technique evaluation characteristics. Review of this table indicates that time lines are best used during and after concept formulation but before full scale development.

7.1.2.8 Predetermined time standards (PTS). The PTS were originally developed to overcome the problem of rating operator performance. They were developed as an answer to criticisms of inconsistency and subjectivity leveled at other methods of work measurement, (stop watches, time records, etc.). The underlying premise of all systems using predetermined time standards is that the time necessary to perform certain fundamental motions in work is constant. Accordingly, all such systems construct the unit times or work standards from the times for basic motions making up the work operations.

7.1.2.8.1 Description. There are several different systems which were developed independently of one another, and each has its own particular method of showing the factors which affect the basic motion times. The essential principles of PTS are the identification of each basic body motion and the assignment of a predetermined time to that motion. Predetermined element times have been developed by analysis over a large number of tasks, and are generally accepted as being a consistent source of data for building of time standards. The analysis is made by identifying the motions used either by observation or synthesis of a proposed method and then by applying the predetermined times to the recorded motions. The primary advantage of a predetermined time system is the elimination of the necessity of estimating the task time. A major predetermined time system is Methods Time

Measurement (MTM) (ref. 2).

7.1.2.8.2 Procedure. This discussion will be limited to MTM. Data store, which is a part of Index of Electronic Equipment Operability, is another PTS and is included in section 7.1.2.23. The use of MTM forces a comprehensive and detailed look at the tasks being used. In order to classify and measure the motions involved in a task, users of this system must concentrate on these motions. Once they are classified and measured (if measurement is required), times for these motions are available from published tables of data (See table VIII). Then they need only add together these times to establish the time required for the task. The time and definition data results from research involving careful study of high-speed motion pictures of industrial operations. The time values are given in terms of Time Measurement Units (TMU's). Each TMU has a time value of .00001 hour, or .0006 minutes. Thus, total TMU's for a combination of tasks should be multiplied by .0006 to convert from TMU's to minutes. Caution should be used prior to performing time studies to this degree of accuracy (see 6.3.7.3). Time increments of less than 0.1 seconds are seldom of significance where humans are involved in total system performance. If time is that critical to total system performance, the human should be taken out of the loop.

7.1.2.8.3 Use. In the absence of similar prior systems, actual hardware, prototypes or mockups where human performance can be measured or otherwise obtained, PTS techniques are useful HE tools for determining with reasonable accuracy, times to perform specified tasks when procedures and dimensional characteristics are defined.

7.1.2.8.4 Comparison to other techniques. Table IV indicates the relationship between PTS and the numerous technique evaluation characteristics. Review of this table indicates that PTS, as with timelines, is best used during and after concept formulation but before full scale development.

7.1.2.9 Flow process charts. This technique is one of several HE techniques which are derived from industrial engineering procedures.

7.1.2.9.1 Description. Flow Process Charts (FPC's) are basically plots of the sequence of operator activities or information transfer as a part of a system. The plots or flow of activities and information exchange are plotted in time sequence. Figure 16 is an example of such a plot. It is very similar to the information flow chart mentioned previously. The difference between the two techniques is that the FPC's use a wider variety of symbology and are generally performed at a more detailed operator task level. The FPC symbology is

TABLE VIII
Sample methods time measurement tables

REACH

Distance Moved in Inches	Time TMU				Hand in Motion	
	A	B	C or D	E	A	B
1 or less	2.0	2.0	2.0	2.0	1.6	1.6
1	2.5	2.5	3.6	2.4	2.3	2.3
2	4.0	4.0	5.9	3.8	3.5	2.7
3	5.3					
4						
5						
6						
7						
8						
9						
10						
12						
14						
16						
18						
20						
22						
24						
26						
28						21.7
30				22.9	16.3	23.2

Data
would be entered
here

CASE AND DESCRIPTION	
A	Reach to object in fixed location, or to object in other hand or on which other hand rests
B	Reach to single object in location which may vary slightly from cycle to cycle.
C	Reach to object jumbled with other objects in a group so that search and select occur.
D	Reach to a very small object or where accurate grasp is required.
E	Reach to indefinite location to get hand in position for body balance or next motion or out of way.

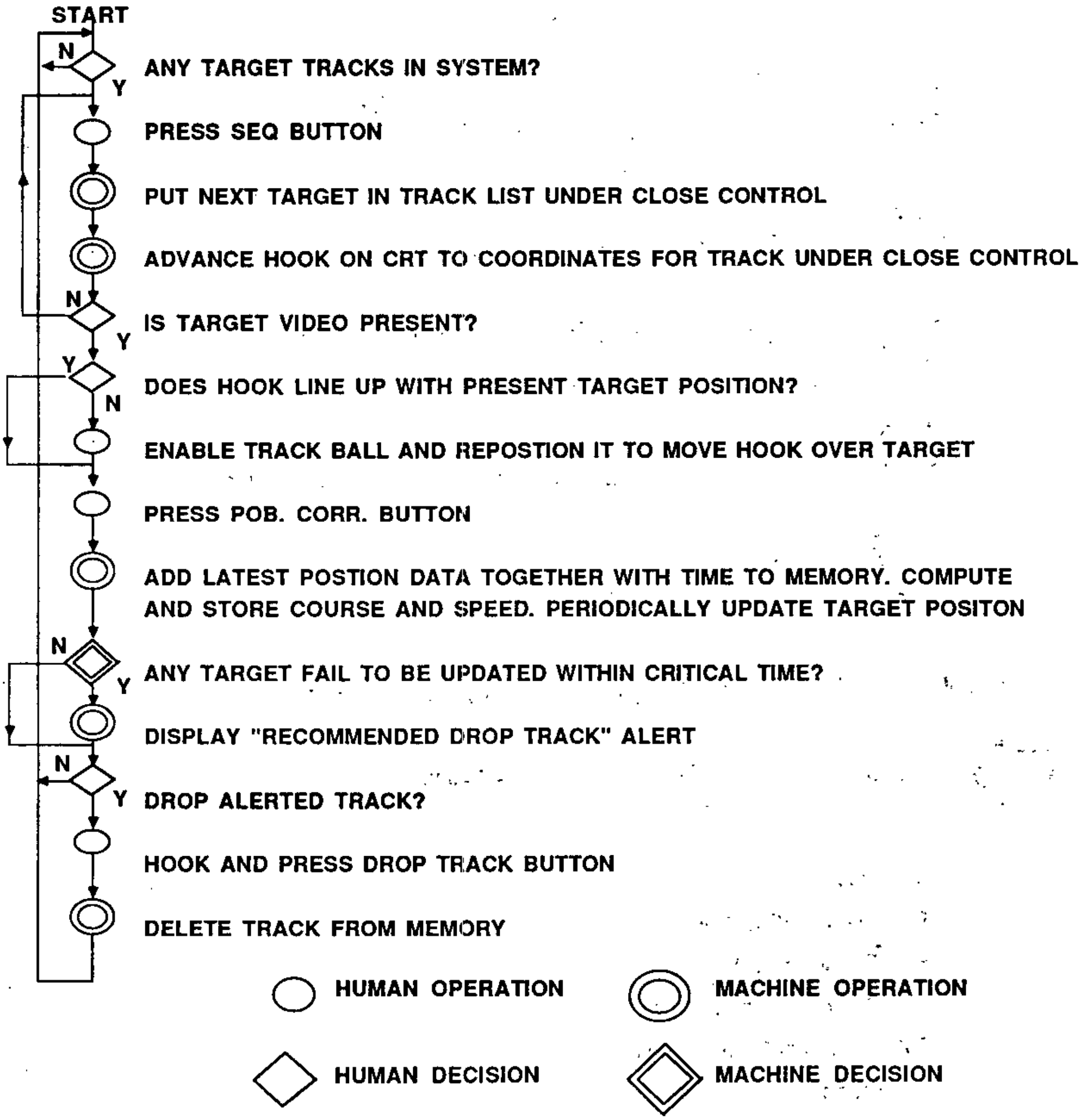


FIGURE 16. Sample flow process chart.

Symbology

○	Operate	- an action function, to accomplish or continue a process. (Sometimes used for received information)
□	Inspect	- to monitor or verify quantity or quality. An inspection occurs when an object is examined. (Sometimes used for action)
⇨	Transmit*	- to pass information without changing its form.
◡	Receipt*	- to receive information in the transmitted form. (Sometimes used for stored information)
◇	Decision	- to evaluate and select a course of action or inaction based on receipt of information.
▽	Storage	- to retain. (Sometimes used for transmitted information)

* - Mode of transmission and receipt may be indicated by a code letter within the

⇨ and ◡ symbols.

V - Visual
E - Electrical/Electronic
S - Sound (verbal)
IC - Internal Communication
EX - External Communication
T - Touch
M - Mechanically
W - Walking
H - Hand Deliver

(Special combinations of symbols are shown in Figure 19)

FIGURE 17. FPC AND OSD symbology.

shown in figure 17. The symbology is consistent with the ASME (American Society of Mechanical Engineers), flow chart standards,

7.1.2.9.2 Procedure. The FPC is oriented vertically, frequently with a time scale to one side or another of the function or task symbology. Each task performed by the operator is recorded with the proper symbology (see Figure 16) and with a brief description of the task. A time value, and perhaps a distance, are also recorded if appropriate. Start and stop points of the charted activity are indicated. In preparing these charts, the HE analyst should ensure that all logical possibilities are included, all loops are completed or terminated in a valid exit, and all tasks are capable of being performed by the operator. The following aspects must be considered: a) how each operator will make decisions, b) what the criteria are to be used for decision making and c) what information requirements must be met to provide a basis for decision making.

7.1.2.9.3 Use. The purpose of constructing the flow process charts is to aid in developing and evaluating concepts for each operator station. If a single operator station is being analyzed, it is a good technique to use; however, if more than one station is being analyzed, a separate chart must be developed for each station. The Operational Sequence Diagram (OSD), which is discussed in the following section (7.1.2.9), is a better technique to use for multiple operator station analysis. Table VI indicates the applications or outputs from the FPC's.

7.1.2.9.4 Comparison to other techniques. A comparison of the FPC technique with the other analysis techniques is indicated in the table VI.

7.1.2.10 Operational sequence diagrams. The OSD is probably the most powerful single manual analysis technique that the HE analyst can use. This is because of all the outputs and applications that derive from its use (see table VI), it is particularly useful for the analysis of highly complex systems requiring many time critical information-decision- action functions between several operators and equipment items. The OSD has been used on numerous Military programs such as HAWK, Polaris, and AWACS.

7.1.2.10.1 Description. The OSD was derived from the FPC. It retains the same basic attributes of the FPC. It is a graphic presentation of operator tasks as they relate sequentially to both equipment and other operators. OSD symbology also meet the ASME flow chart standards. The OSD is an FPC expanded in terms of channels or work stations. By using symbology to indicate actions, inspections, data transmitted or received, data storage, or decisions, the OSD shows the flow of information through a system. The information flow is shown in relation to both time and space (work stations). The OSD may be used to develop and present the system reaction to specified inputs. It is one of the cheapest and quickest ways to simulate the system. Whereas mockups and prototypes may be more complete for some simulation aspects, they are more expensive. Computer programs are also generally more expensive, depending upon how often they are used. In the OSD, the interrelationships of operators and equipment (man-machine interfaces) are easily visualized. Whenever information transferred is mismatched with the format to be received, interface problems are clearly indicated. Operator activities are sequentially categorized. Decision and action functions are clearly identified and task frequency and load become obvious.

7.1.2.10.2 Procedure. A sample OSD is shown in figure 18. An explanation of OSD symbology is included in figures 17 and 19. The following several instructions describe how to construct the OSD:

a. In a similar manner to FPC's, the flow of events and tasks is always from the top of the sheet toward the bottom. The operators and machines are entered into the column headings on the OSD. It generally proves convenient to place in adjacent columns the operators and the machines with which they interface. Also, it helps to group together all of the operators and equipment of a specific functional division (e.g., Weapons Control). In some cases, the operators or maintainers and equipment in a system will have been specified by the time the OSD is constructed. However, if the people and equipment have not been specified, the analysts will have to specify them tentatively. In either case, in the process of doing the OSD, it may be found that too many or too few operators or machines have been selected. The reason for doing the analysis is to "drive out" crew size and interface requirements.

b. The OSD is initiated by the first event designated by the scenario (see 7.1.2.2). The event and event times are written in the two left-hand columns. All of the machines or men who will receive the input are shown and the transmission/reception mode is noted by using the appropriate letter code. The subsequent actions taken by the crew/equipment (operations, transmissions, etc.) as they react to the input are shown. External outputs are plotted in the far right-hand column. As the reactions are plotted, the analyst should be cognizant of the time required to perform the actions. The process of plotting the inputs and subsequent reactions is continued as dictated by the events given in the

SECOND-LEVEL FUNCTION: 2.4.1 PERFORM PRESTAGING CHECKOUT

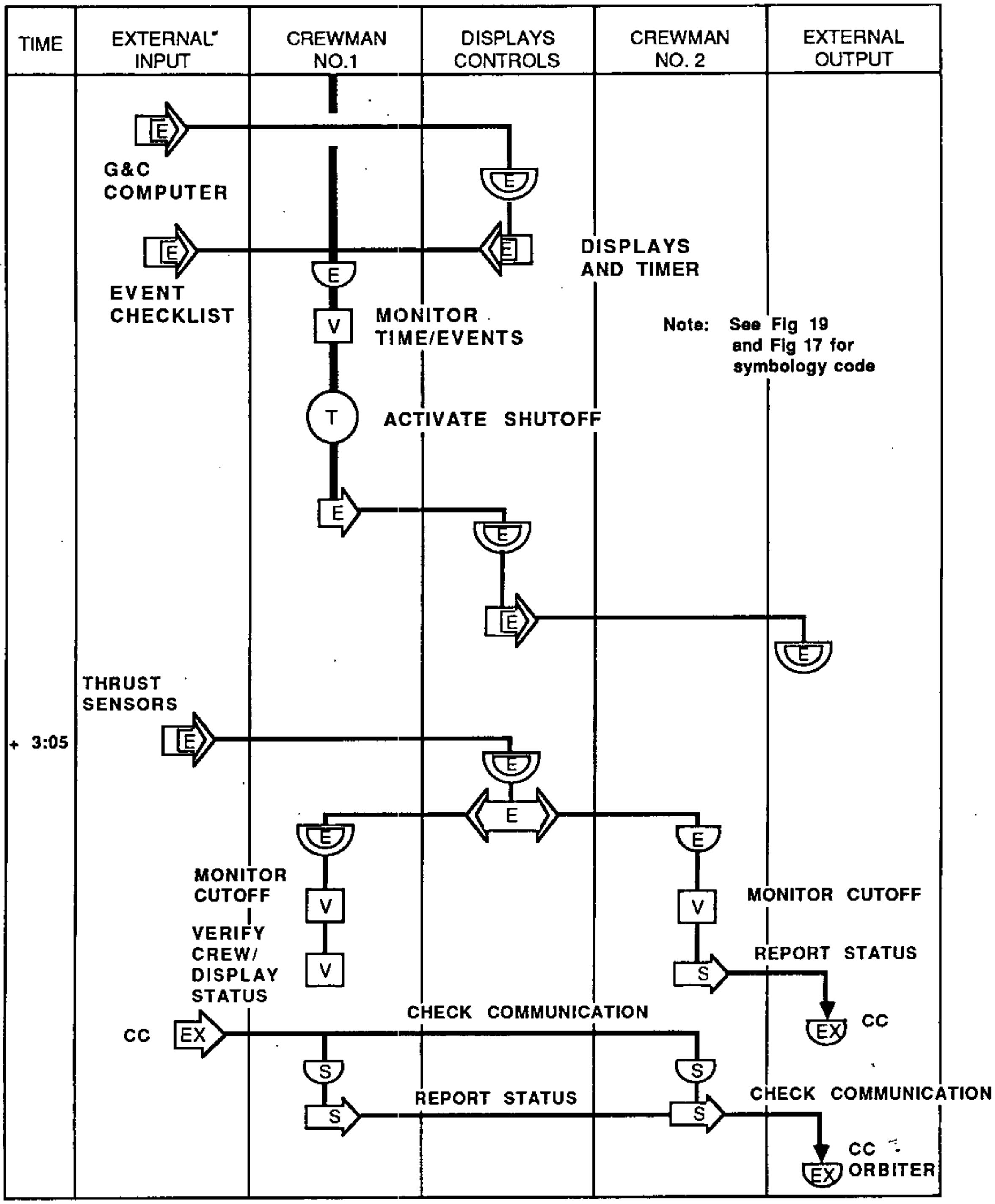


FIGURE 18. Sample operational sequence diagram.

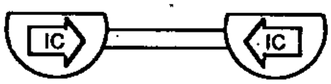
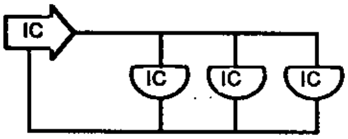
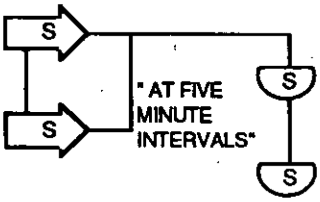
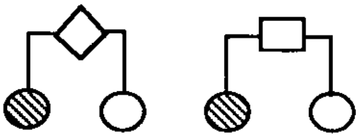
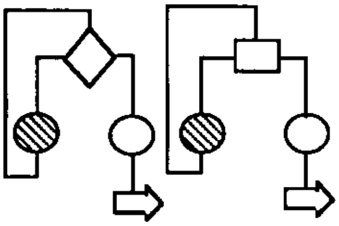
	Exchange of information or discussion by two principals involved. Used with appropriate source codes.
	Acknowledgement of receipt of information used with appropriate source codes.
	Continuous flow of information throughout event Receipts are picked off where needed in sequence without repeating entire process. Time intervals may be indicated as shown.
	Double symbols indicate automatic transmission, receipt, storage or operation.
	DECISION LEFT NO RIGHT YES INSPECTION NO GO GO
	A repeated process usually repeated until a desired condition exists before continuing. Note: The last repeat of several may be shown in normal sequential order to give a clearer picture of the event.

FIGURE 19. Special combinations of OSD symbols.

POSITION : DRIVER DUTY: VEHICLE CHECKOUT AND START

TASK	TIME (MIN)	ELEMENTS			REMARKS (PRECAUTIONS, ETC.)
		CONTROL	ACTIVITY	INDICATION	
1.1.1 ENGINE START	0.1		OBSERVE	SUPPORT CREW SIGNAL	PROCEDURE PERFORMED PER CHECKLIST
	0.05	APU BAT.SW	PRESS/MONITOR	ON	DECISION TO USE APU
	0.05	APU FUEL SW	PRESS/MONITOR	ON	
	0.05	APU START	PRESS		
	0.5		MONITOR	START	
	0.05	ENGINE FUEL MASTER SW	PRESS	ON	
	0.05	AUX FUEL PUMPS	PRESS	ON	
	0.05		OBSERVE	FUEL PRESSURE	VARIABLE TIME ESTIMATE
	0.05	ENGINE START	PRESS		
	0.05		PRESS	ENGINE PARAMETERS	

FIGURE 20. Sample task description.

scenario or narrative. No attempt is made to keep the actual space between scenario time events proportional to the time itself.

c. It is important to remember that the reader of an OSD should be clearly shown the operation of the system, and all of the steps shown on the OSD should be described by a brief notation describing the process or action. As with the case of the FPC the HE analyst should be sure that all logical possibilities are included, all loops are completed or terminated in a valid exit, and all tasks are capable of being performed by the operators.

7.1.2.10.3 Use. The reason the OSD is so useful in terms of outputs is simply that so much must go into it. The integration of all the data that goes into a typical OSD is generally a tedious and time consuming process. Experience has shown that the construction of OSD's requires trained individual with analytic skills. The information to construct an OSD may come from scenarios, functional flow diagrams, time lines, decision/action diagrams, work station layouts, or other sources. If the HE analyst is dependent on other organizations for this information, he must conduct numerous interviews of other organization personnel or have an extremely efficient program requirements documentation effort to draw on. Table VI indicates several specific output applications that result from performing an OSD analysis.

7.1.2.10.4 Comparison to other techniques. Table IV indicates the numerous evaluation characteristics of the OSD as compared to other analysis techniques and indicates the OSD should be used during the earlier program phases. Also, it should be emphasized that the OSD is like any other paper simulation technique in that it must be validated as soon as practical in an environment closely similar to the actual working environment. Although much more complex, OSD's are somewhat similar to decision/action diagrams. Often when decision/action diagrams are used, OSD's are not. Another technique that is similar to the OSD is the Functional Sequence Diagram (FSD). Its format is very nearly identical to the OSD's. It is easier to construct but does not provide as much useful information as the OSD. The difference between the two techniques is that the FSD does not make a distinction between operators and equipment.

7.1.2.11 Task descriptions. Task descriptions, as a distinct analysis technique, are not used as much today as they were several years ago. Newer manual and computer-aided techniques are being used in place of them. However, they are presented here because they still have unique characteristics that are suited to particular analysis applications. Task descriptions are one additional human factors engineering tool that can be used to help define personnel requirements in complex systems. Taking the data developed by the use of previous analysis techniques, task descriptions can be developed which will:

a. Test the man-machine system interface to ensure compatibilities with operator abilities.

b. Contribute to the development of training programs, training manuals, and job aids for personnel who will be involved in the operation and maintenance.

c. Assist in the personnel procurement and associated manpower planning process.

7.1.2.11.1 Description. Task descriptions are developed from the functional allocation process data. Task descriptions provide a basic reference for subsequent design and development of the entire personnel subsystem. A task description is essentially a statement of basic task requirements. It can assist in design finalization by identifying operability or maintainability problem areas, or by defining operator activities with specific equipment. Task descriptions received considerable emphasis in the Air Force Systems Command Manual 375-5 system engineering process several years ago. In a few instances, the same worksheet forms are still being used today. The level of detail in an adequate task description depends largely upon the complexity and criticality of a given system, or the expected levels of difficulty in training and manning the system. Generally, the level of detail for specifying task activities used is about the same as that in an instruction manual for a novice. A good task description could easily become a procedural manual for the job. Figure 20 is an example of a detailed task description, and it illustrates the kinds of elements that must be identified.

7.1.2.11.2 Procedure. Task descriptions should proceed from general task statements to specific display, control, and decision activity details. In the example of figure 20, functions that have been allocated to man during the functional allocation process are listed along the left side of the analysis form. Under the heading "Elements" the task activities are listed. These are tasks that may be classified as actions, perceptual motor activities, straight monitoring, communicating and decision making or problem solving. The associated controls and displays are listed along with the activity. Remarks that have to do with the activity are included in the far right hand column. These remarks, which might include contingencies which can severely affect the mission or system success, are identified; particularly because of their impact on operator skill level requirements. Major environmental conditions affecting a mission cycle, or any segment of it should be included in the remarks column. Machine malfunctions that might occur during a critical mission task should also be included. If there is a particularly high probability of human error, these data should be indicated in the remarks column. The corresponding times for each of the operator task elements has been estimated and included in a column next to the task column. It should be noted that task descriptions need not be highly structured, but can be modified to fit the requirements of various systems.

7.1.2.11.3 Use. Table VI indicates several specific output applications that result from the use of the task description technique.

7.1.2.11.4 Comparison to other techniques. Table IV summarizes the characteristics of task descriptions as compared to all the other analysis techniques. Task descriptions are prepared at any time during the program; however, they are of less value during the time period following production decision. The technique, being more narrative in form than pictorial, gives less visibility to items of analysis interest such as task or time relationships. Problems which are generally discovered as a result of performing time line analysis are not as apparent as a result of using this technique. The length of the time blocks used in time line sheets "displays" the time relation between each block. This relationship is harder to see as just a number in task descriptions.

7.1.2.12 Workload analysis. Workload analysis provides an appraisal of the extent of operator or crew task loading, based on the sequential accumulation of task times. Application of this technique permits an evaluation of the capability of the operator or crew to perform all assigned tasks in the time allotted by mission constraints. As capability is confirmed, hardware design requirements can be more precisely designated. Conversely, as limitations are exposed, alternate function allocations and operator or crew task assignments are considered and implemented.

7.1.2.12.1 Description. Workload analysis or workload profiles, as they are often referred to, are a graphic presentation of an operator's workload constructed by plotting percentage of task involvement against a time base (see figure 21). Although workload analysis depicts individual activity, its greatest effectiveness is realized when several operator/ maintainer positions are plotted together on the same graph. By doing this, any unbalanced workload distributions among the operators become readily apparent. Earliest possible workload appraisals are needed to assure that resulting task loads are within the scope of the crew size and capability. Workload analysis was developed to verify that no combination of tasks required more task load capacity, or time to perform than is available. One concept in workload analysis is to divide the operator tasks into

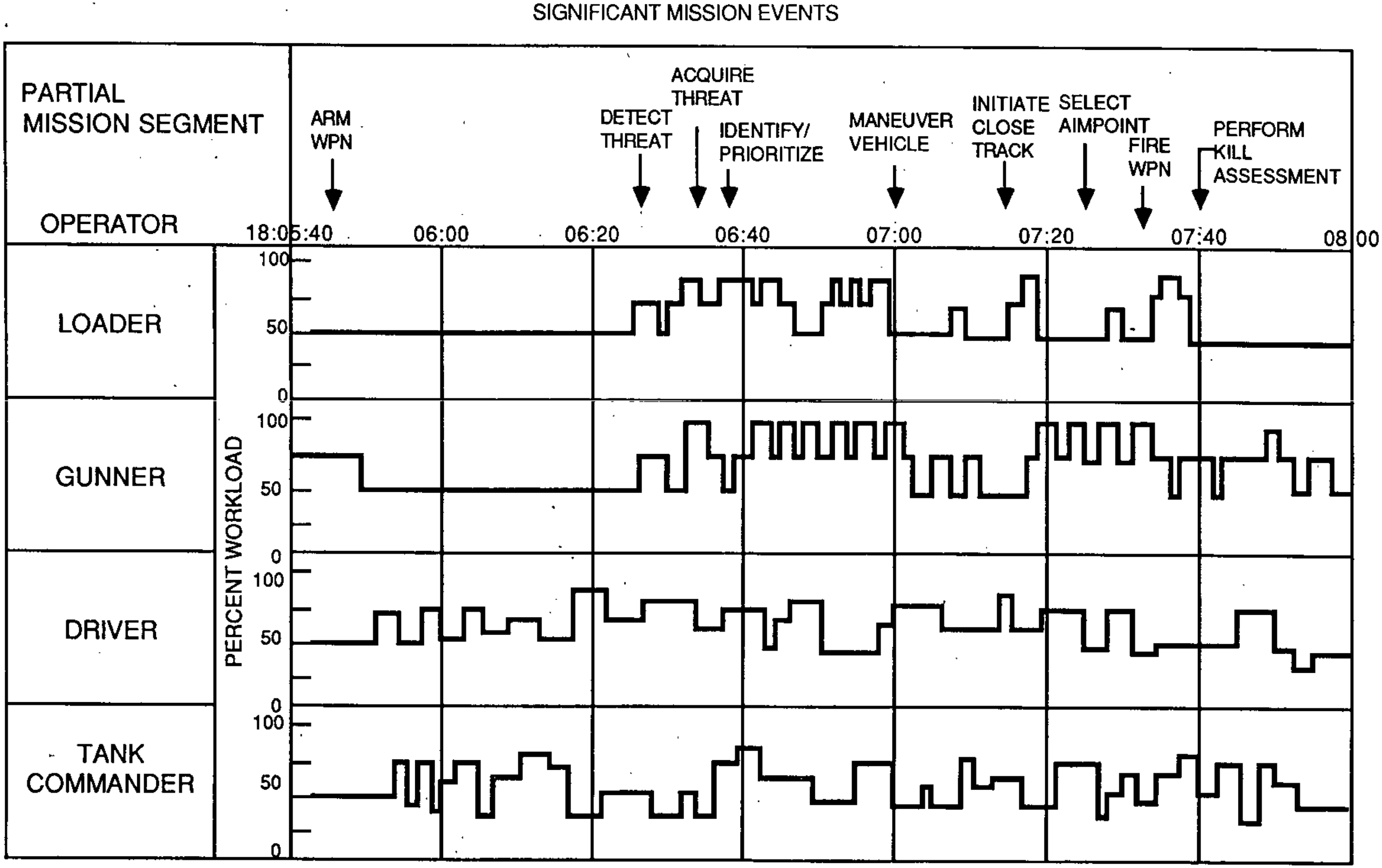


FIGURE 21. Sample workload analysis profile.

categories corresponding to perceptual-motor channels. This analysis refinement concept does not necessarily have to be accomplished in order to successfully perform workload analysis. However, the more detailed the analysis, the better the output data. The following guidelines should be noted.

a. In some situations, operators can effectively perform more than one task at one time. However, it is obvious that an operator cannot accomplish two tasks simultaneously if both tasks require the use of a single perceptual-motor channel nearly 100% of the time. The workload analysis chart exposes such conditions when properly developed. When such conditions are noticed, it is apparent that one of two things must be done. Either a task must be given to another operator or the operator must be provided with some type of equipment assistance.

b. The task loading estimates may come from several sources. For example, the task may be the same as, or similar to, another task in another system which is in actual operation. Task time data from previous systems is generally the most reliable since it has been verified in practice. When such information is not available, the next best data is the use of PTS techniques to establish task times (see 7.1.2.7).

c. When experienced operators or other data sources are not available, the HE analyst, together with knowledgeable project designers, must make an "educated guess" about the task workload implications. The HE analyst will have to do what he does with all problems of this sort; he will have to break the task down into its simplest elements and extrapolate from what he knows about other subtask elements.

7.1.2.12.2 Procedure. In application, workloads are estimated at either a gross level or detailed level in terms of both time and number of perceptual-motor channels considered for analysis. As workload situations tend to become more critical, shorter time increments are examined. Also, as workload increases for a given situation and as the situation becomes more critical, it is desirable to make workload assessments on the basis of each of the operator's perceptual-motor channels. These are generally listed as: external vision (distance vision), internal vision (within an armored personnel carrier or console panel area), left hand, right hand, feet, cognition, audition, and verbal channels. The following workload estimate ground rules should be used:

7.1.2.12.2.1 Calculations. Workload calculations are based on estimates of the time required to perform a given task divided by the time allowed or available to perform the task. The analyst is cautioned that if he evaluates workload by considering each of the distinct perceptual motor channels he cannot equate a 75% loading on each channel to an overall 75% loading. The precise summation effects of all or several of the channels cannot be accurately predicted. Quite possibly the results of a 75% loading on each channel would result in a total overload situation (>100%). The analyst is also cautioned not to average workload over the time increments being considered. A workload estimate of 100% and an estimate of 50% for two sequential tasks occurring with in a given time increment must be considered as an overall estimate of 100% (not 75%). If it is necessary to provide visibility to the 50% loading situation, then the time increments must be broken down into smaller time periods. The point of the analysis is to discover significant workload conditions including peaks, not to mask them out.

7.1.2.12.2.2 Operator loading. In general, workloads over 100% are not acceptable, between 75% and 100% are undesirable, and under 75% are acceptable provided that the operator is given sufficient work to remain reasonably busy. Prior to current revisions, MIL-H-46855 contained an appendix that described the conditions where operator workload analysis should be performed. The implication was that operator loading in excess of 75% should receive special scrutiny.

7.1.2.12.2.3 Estimating. Since the process of estimating workload is based on the estimate of time required to do the task, it is only as accurate as that data. It is also limited by the knowledge of the time available to do the task, and it is limited by the unknown discrete channel summation effects. Depending on these variables alone, the accuracy of most workload assessments are probably in the ±20% range. If more accurate assessments are required, full scale simulations of the crew tasks may be necessary.

7.1.2.12.2.4 Charts. The workload analysis may be made up of a simple continuous chart from the beginning to end of a mission, or there may be several charts, each of which expands a particularly critical segment of the mission. As previously indicated, the time scale should be commensurate with task complexity, e.g., 15 minute intervals may be all that is necessary for simple workload analysis evaluations and 5 second intervals may be required for more complex tasks. Whatever intervals are used should be common for the total group of tasks and operators when they interact.

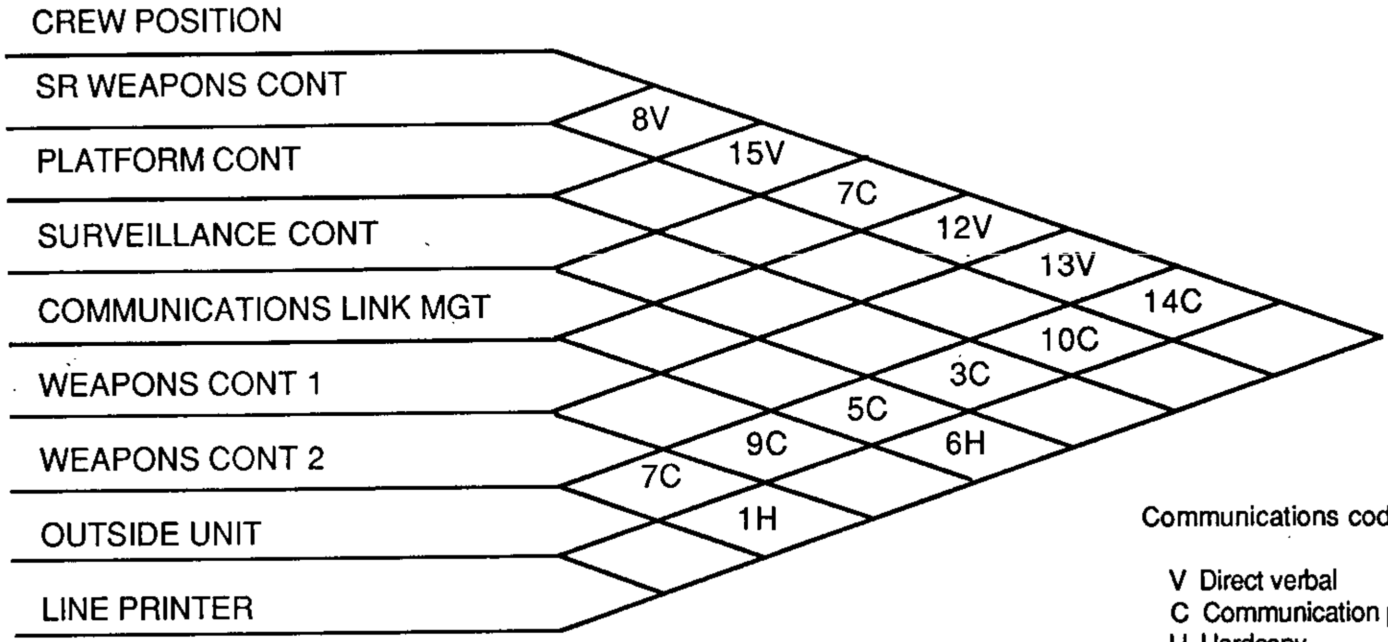
7.1.2.12.3 Use. Table VI indicates the applications or outputs of workload analysis.

7.1.2.12.4 Comparison to other techniques. An evaluation of workload analysis as compared to other techniques is shown in table IV. Workload analysis is most generally performed after concept formulation when sufficient other analysis has been performed in order to develop the input data to workload analysis. It continues past development and possibly past FSD (production decision).

7.1.2.13 Correlation matrix. The correlation matrix, or correlation chart, is one of the simplest and easiest, analysis techniques,to use. It is constructed in a manner similar to a highway map mileage chart. It is generally used after the development of OSD's for the purpose of summing up all of the links between each of the operators, operator workstations, or equipment. Figure 22 is an example of a correlation matrix.

7.1.2.13.1 Description. The correlation matrix is a summary of the communications occurring during a hypothetical function. Although correlation matrices are of use by themselves to determine the frequency of use of the various links or interfaces between system man-machine components, they are more often used as an intermediate analysis step between the OSD and link analysis. The following section indicates how the correlation matrix is used as an input to link analysis. The reason for having a list of the relative frequencies of use of the communication paths, or whatever sort of man-machine links there are, is to locate each of the many machine workstations (or functions) so that the paths between them are as short as practicable. For example, if crewman "A" is required to pass ten times as many messages to crewman "B" as he does to crewman "C", then it stands to reason that he should be located much closer to crewman "B".

7.1.2.13.2 Procedure. All of the man-machine components of the system that are listed across the top of the OSD and that are of interest to the analyst are listed in a vertical column. As can be seen from the example in figure 22, parallel lines are extended to the right at angles up and down from each of the listed workstations. This results in diamond shaped blocks at the intersections of the rows coming out from each listed workstation. The number of links between each of the listed man-machine workstations are counted up from the OSD (each link should be drawn in on the OSD). The total quantity of links is placed in the diamond shaped block that represents the intersection of the rows coming out from the workstations. Although not absolutely required, it may be just as important to add a letter symbol as an estimated criticality of the data transfer, or links, between workstations. The intersecting blocks and total matrix would, of course, have to be made large enough to put all of the data as to number of links of each kind (high, medium, low criticality) in each of the intersecting blocks. Letter symbology may also be used to indicate the type of data link, e.g., direct voice, interphone, printer.



Communications code:

V Direct verbal
C Communication panel
H Hardcopy

FIGURE 22. Sample correlation matrix.

7.1.2.13.3 Use. The correlation matrix can not be performed without OSDs or similar techniques preceding them. The matrix is of most use as input to link analysis. Table VI shows the various applications of the correlation matrix data.

7.1.2.13.4 Comparison to other techniques. Table IV evaluates the technique against all the other analysis techniques. As previously indicated, the timing for the performance of the correlation matrix is dependent on the OSD. It should be performed during the Concept Formulation phase, after Milestone I or whenever the OSD analysis has taken place.

7.1.2.14 Link analysis. This analytic tool is often used as a first step in developing an optimized panel, workstation, or work area layout. It is frequently used to verify the adequacy of design layout. Its purpose is to depict graphically the frequency or criticality associated with each of the various interactions occurring between operator and equipment or between one operator and another. The HE analyst first starts with the operator and equipment interaction (links) that were established during functional analysis. The data generated by the OSD's and the correlation matrix are the major source of link analysis data. If the link analysis is being performed on a particular panel layout, there may be little of the operator-to-operator links involved. If the link analysis is performed on a tactical work station for a system such as the HAWK, Trident, or AWACS, however, the operator-to-operator interactions are extensive.

7.1.2.14.1 Description. There are basically two types of link analysis as represented by the two previously indicated situations: the panel layout and the tactical compartment (or other type of multiple operators work area). The term link analysis is equally applicable to both situations. The terms adjacency layout diagrams and flow diagrams are sometimes used to describe link analysis as it pertains to multiple operator work areas. Figure 23 shows an adjacency layout diagram.

a. The term Spatial OSD (SOSD) is sometimes used to describe link analysis of a console or panel layout. As its name indicates, the SOSD is the OSD flow of data and functional symbology superimposed on a picture of the particular console or panel of interest. Figure 24 illustrates this. The items that are missing from the OSD in this form are the time scales, the outside events, and the columns and headings. All of the symbols and links are exactly as they are indicated in paragraph 7.1.2.9 operational sequence diagrams. Whereas the OSD indicates workstation relationships, it does not do

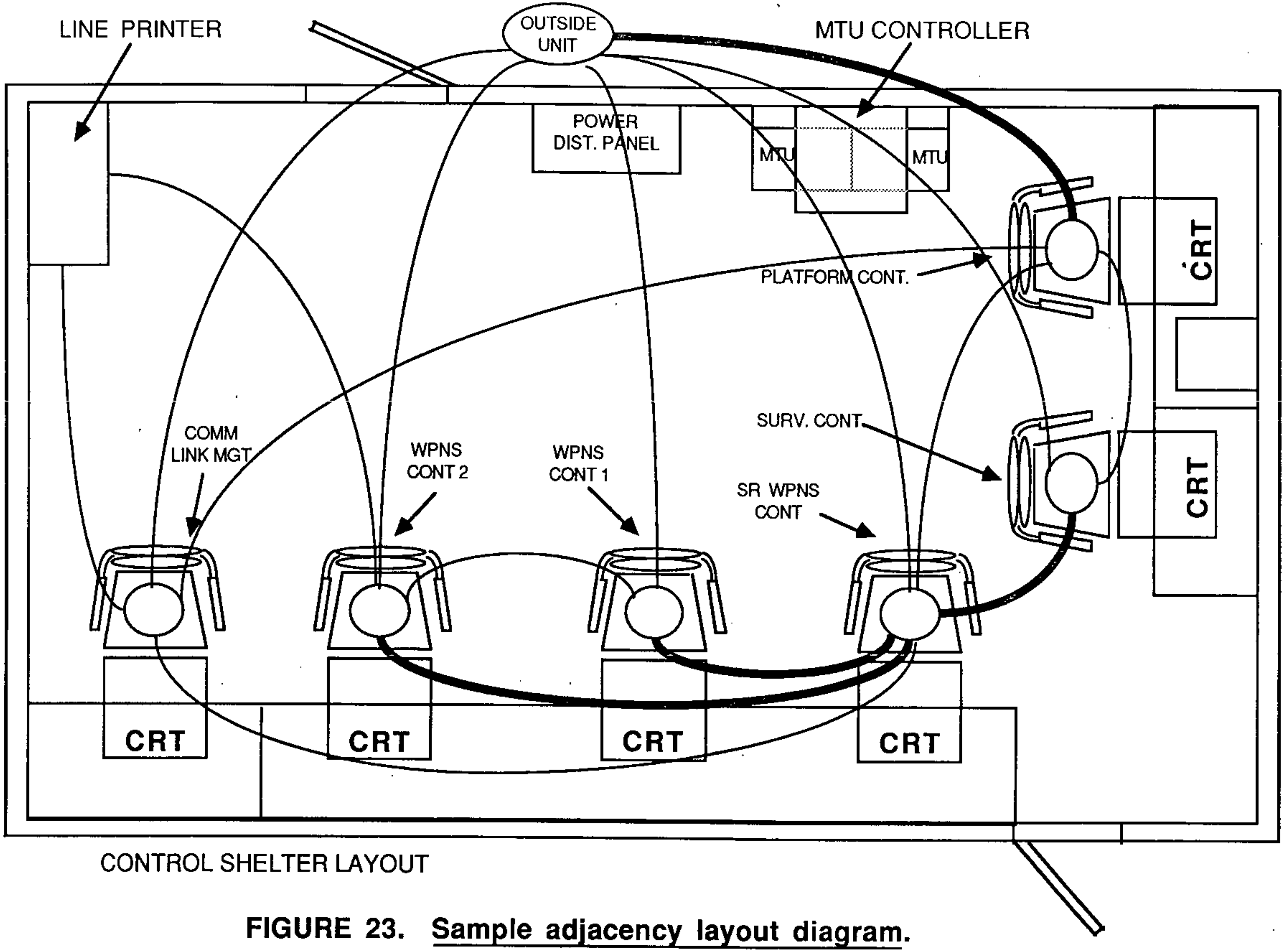


FIGURE 23. Sample adjacency layout diagram.

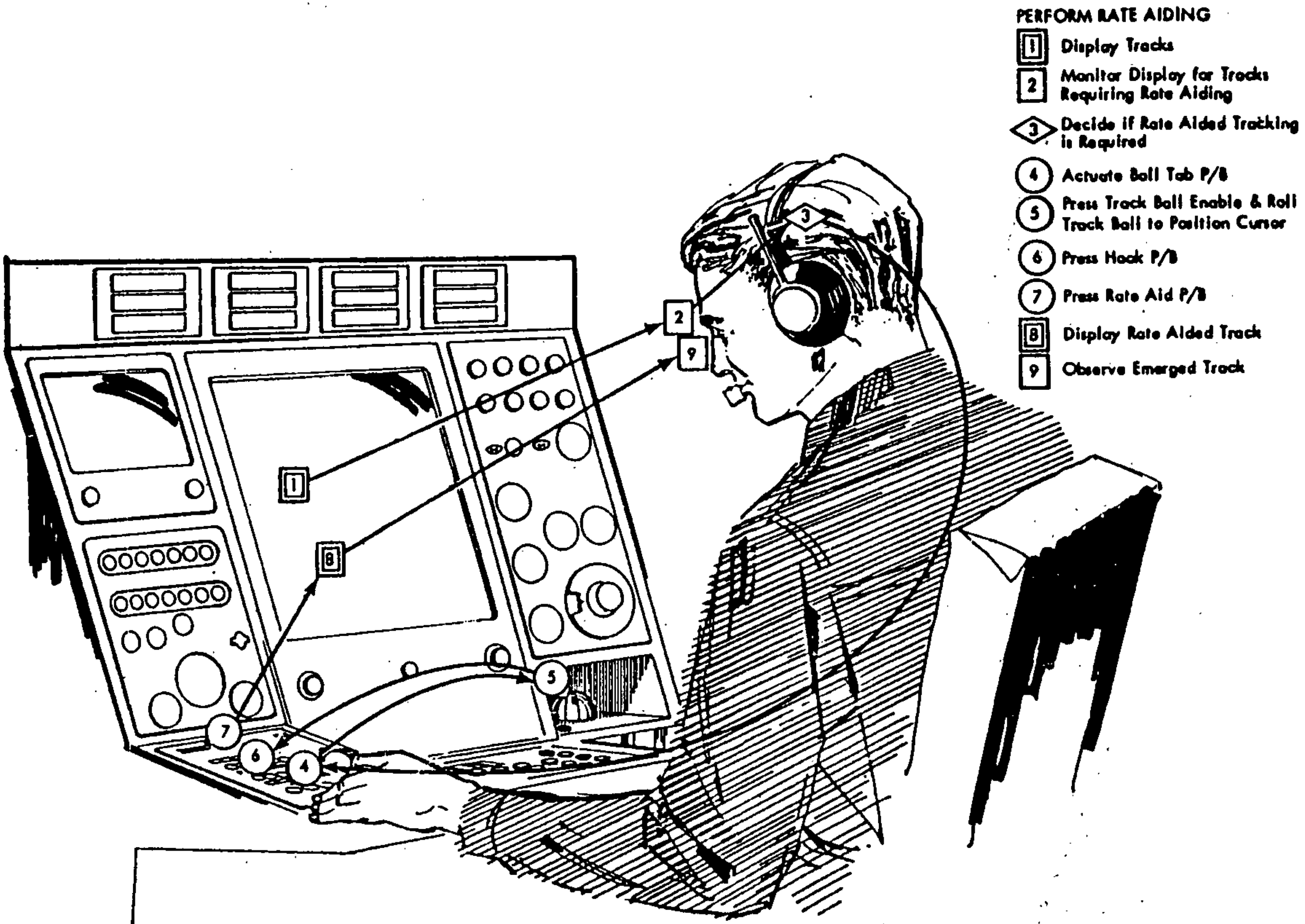


FIGURE 24. Sample link analysis.

this nearly a well as link analysis does. The SOSD may also be used for verifying work area layouts and the adjacency layout diagrams used to verify console layouts. However, the latter situation is unusual.

b. The adjacency layout diagram type of link analysis is dependent on the correlation matrix. Beginning with the correlation matrix and a console or area layout, all interactions (links) required to perform a particular functional task are examined in terms of the frequency with which they occur and their criticality. If the criticality is assigned a numerical value, it may be multiplied by the frequency in order to obtain a weighted link value. The panel or work area is overlaid with the weighted links permitting a picture of all the interactions taking place within the system being analyzed. The system design is then modified to shorten the distance between the controls or displays or workstations that are connected by the weighted links.

7.1.2.14.2 Procedure. There are several variations in the detailed step by step procedure for constructing a link analysis diagram. The variations are dependent on the type of link analysis being used and the type of layout being analyzed, i.e., console or work area.

7.1.2.14.2.1 Symbols. Basically, the first step in performing the flow diagram or SOSD analysis is to choose symbology for each of the system functions being manipulated or arranged. It is strongly recommended that the OSD symbology be used (see figure 17). Symbology for the system components is not as important as the functions because the drawing of the panel or work area shows what the components are without the need for any symbols. Adjacency layout diagram special symbols, such as circles for operators and squares for equipment, may be chosen for each of the of categories. In this type of analysis the frequency of use and criticality of links between workstations are emphasized rather than the flow sequence. The choice of line coding for each of the various types of links must be made. There is no standard for use as a guide, but the factors that should be considered are frequency of use, criticality, and type of communication link (e.g., voice, printer). Often the line width of the link indicates either the frequency of use or the weighted value of the link. The frequency of use times the criticality is the weighted value of the link. A criticality value of 1, 2, or 3 is recommended. The higher the total number (criticality times frequency), the more significant the link. Often this number is labeled right on the link. As previously indicated, the value for the frequency of use comes from the correlation matrix (figure

22) or directly from the OSD's (figure 18).

7.1.2.14.2.2 Preparation. In either case, the last step in the technique is to draw on an overlay, or to draw directly onto the design layout, the links and symbols selected. It is important to have selected a drawing that is to scale. If the SOSD technique is being used, the analyst starts at the beginning of the SOSD with the OSD symbology and proceeds to the completion of the total task (see figure 24). If the adjacency layout diagram technique is being used, the HE analyst starts with the operator who appears to be the busiest. He places the related components around the operator, moving them, as necessary, to minimize link crossings (if significant) and to shorten link lengths, especially those with high weighted link values. It should be emphasized that additional changes undoubtedly will be required once the system is constructed in the form of full scale mockups or as prototype hardware. Regardless of a paper analysis, the system requires an interactive review.

7.1.2.14.3 Use. Table VI lists the applications or outputs for which link analysis data may be used.

7.1.2.14.4 Comparison to other techniques. Table IV indicates the comparison between link analysis and the numerous other techniques. In summary, the figure indicates that link analysis should be used during the first or middle phases of a program.

7.1.2.15 Systems Analysis of Integrated Networks of Tasks (SAINT). SAINT is a network modeling and simulation technique developed to assist the system designer and human engineer in design and analysis of complex man-machine systems. The technique requires creation of a system model consisting of discrete task elements, resources, task relationships and system state variables.

7.1.2.15.1 Description. It is a computer-aided technique that can be an aid in performance analysis. It can model system dynamics; simulate system inputs, outputs, decisions, data flow, and control flows. SAINT has been developed by the Air Force Aerospace Medical Research Lab along with Purdue University and Pritsker and associates. It is a modeling and simulation technique developed to assist in the design and analysis of complex man-machine systems. SAINT provides the following:

a. SAINT provides a powerful capability for modeling and analyzing complex man-machine systems. The technique's conceptual framework allows the development of system models in which men, machines, and the environment are represented. This permits an analyst to investigate the impact of modifications to the man-machine-environment interface on overall system performance. In addition, such investigations can be performed without a significant investment in equipment and time and without necessitating a commitment to prototype hardware development.

b. SAINT enables an analyst to input a description of the system to be analyzed. The system description includes the tasks performed by the resources, the precedence relations among tasks, the flow of information through the system, and the effects of environmental stressors on task performance. It also allows the specification, evaluation, and monitoring of state variables which represent processes that change status continuously over time. In addition, modeling capabilities are available for representing the dynamic interaction of tasks, resources, and state variables in an overall systems context.

c. The system description serves as input data to the SAINT simulation program. It automatically performs an analysis of the model developed and provides summary information concerning resource utilization, task performance, state variable status, and a wide variety of other system performance measures.

d. SAINT consists of a symbol set for modeling systems and a computer program for analyzing such models. SAINT provides the conceptual framework for representing systems that consist of discrete task elements, continuous state variables, and interactions between them. While SAINT was designed for modeling manned systems in which human performance is a major concern, it is potentially applicable to a broad class of systems those in which discrete and continuous elements are to be portrayed and quantified and whose behavior exhibits time-varying properties. SAINT provides a mechanism for describing these dynamics so a systematic assessment can be made of the relative contribution system components made to overall system performance.

7.1.2.15.2 Procedure. Systems are created as graphical networks of task activities with which one or more operators interact. Each task in a network is described as to how its performance affects the overall system and how it is related to other tasks within the system. The graphical operator/task analysis system description is entered into the SAINT computer program for automatic performance assessment. Employing Monte Carlo techniques, SAINT permits the simulation of probabilistic and conditional task performance descriptions and precedence relationships. It also permits the collection of statistical estimates of system performance. Another major capability of the program is the identification of system characteristics effects in response to system-internal or external simulated events. By design, the SAINT technique does not require the user to perform any computer programming although experience in this field is extremely helpful. Users are assumed to be knowledgeable of task analysis. The results of a task analysis are used as the inputs to the SAINT computer program. The output of SAINT consists of task and mission performance estimates.

7.1.2.15.3 Use. SAINT is not a prewritten system model. The user applies SAINT by generating a system model in the SAINT symbolic language to invoke corresponding FORTRAN subprograms (batch). The output consists of task and mission performance estimates. This includes summaries of system state variable time histories, resource utilization and other system measures defined by the user. In addition assessments of the effect of component task characteristics on overall system performance are provided. Table VI shows the applications for which SAINT may be used.

7.1.2.15.4 Comparison to other techniques. Table IV provides a comparison between SAINT and the several other techniques.

7.1.2.15.5 Controlling agency:

Aerospace Medical Research Laboratory
Aerospace Medical Division, AFSC
WPAFB, OH 45433

7.1.2.16 Time line analysis (TLA-1).

7.1.2.16.1 Description. The acronym TLA-1 derives from "Time Line Analysis program model one." It is generally referred to as TLA-1 rather than the complete descriptive title. As its complete title indicates, TLA is a time line analysis model. It is used to identify and focus attention on tasks and subsystems that contribute significantly to excessive crew workload. The human operator is assumed to have nine activity channels for task performance. It is also used for workload analysis in a manner similar to the workload techniques presented in this section. It is strongly oriented towards cockpit analysis although it is easily adaptable to any crew station.

7.1.2.16.2 Procedure. The TLA-1 computer-aided analysis technique is initiated by the preparation of scenarios and crew task data. The HE analyst generates scenario data from sources such as performance data and operations manuals. If the analysis is for a completely new system or equipment item the data may come from existing similar systems or equipment items. Since operator tasks are the basic work units from which all TLA-1 crew workload statistics are derived, they must be identified for every control, display, and communication link. It is possible to catalog over 2,000 tasks for one analysis effort. The tasks are categorized by subsystems. Each task description contains a task code number, a task description/name, task duration time and the channel activity (left hand, right hand, external vision internal vision, cognition, etc.).

7.1.2.16.2.1 Worksheet. After the scenarios and tasks have been defined, the analyst develops the detailed task sequence required to execute the scenario. Worksheets are used for this detailing. In the process of filling in the details on the worksheet, the HE analyst specifies all the data that will be entered onto the various input data coding forms.

7.1.2.16.2.2 Coding. The next step is the input data coding. Each of the six sets of input data has a fixed-format coding form that the analyst uses. These data coding forms are for subsystems data, task data, events/procedures, phase data, mission data, and output report and plot request coding.

7.1.2.16.2.3 Reports and plots. One of the most powerful features of TLA-1 is the wide variety of workload analysis data formats that are available. There are six digital reports and four data plots that can be requested. By specifying various variables for each of these output formats, there are literally thousands of data records that can be selected or output for a mission. Obviously, not every conceivable report and plot will be requested at any one time. Standard sets of reports and plots have been defined that can be specified by number. The items in these standard report sets have been selected to provide a general visibility of the workload situation for a scenario. As high workload problems are isolated, the analyst can be more selective of the output types and exercise tighter control over the variables so that successive data outputs can expose the nature of the workload problems in more detail.

7.1.2.16.2.4 Computer program. The TLA-1 computer program is divided into the executive, input, processor, and output modules. The executive module processes all control cards and initiates the other three modules. All mission data are input through the input module and output to an external permanent file. The processor performs all the calculation functions and outputs the results to an external file. The input to the processor comes from the data stored by the input module. The output module inputs report requests and acts to produce the requested reports using the data from the two external files created by the input module and the processor module. There may be up to three sets of external (different configurations of the same mission) input to create some reports. Outputs from the TLA-1 program are to tape, printer, and plotter. A tape is used to store the mission data input and the processed data for later use by the report generation function. The tape consists of two files. The first contains the mission data input. The second contains the processor output used by the report generator function.

7.1.2.16.3 Use. The input required consists of: a) the mission description in temporal terms, b) crew member activity channel parameters, c) crewmember task/event allocations and d) task/event time parameters. The output to the printer consists of seven reports:

a. Mission Scenario
b. Crewman Workload Profile
c. Crewman Workload Summary Statistics
d. Task Channel Activity
e. Subsystem Activity
g. Subsystem Activity Summary
h. Task List

The plotter output consists of a workload summary, a channel activity summary, a workload histogram, and a mission timeline. Figure 25 is a sample channel activity summary and figure 26 a sample workload histogram plot. Table VI indicates the applications or outputs of TLA-1 compared to the outputs of other analysis techniques.

7.1.2.16.4 Controlling agency.

NASA Langley Research Center
Hampton, VA 23665

7.1.2.17 Subjective Workload Assessment Technique (SWAT).

7.1.2.17.1 Description. SWAT consists of two major elements: a) a set of scales which defines workload as consisting of three factors, namely; time load, mental effort load, and psychological stress load, and b) a psychometric method which determines the mathematical rule combining these dimensions and generates a single quantified, interval-level workload scale. Time load is expressed as that fraction of total time that the subject is busy. Mental effort load is a scaling of the amount of attention and concentration required to perform the task. Psychological stress load is an expression of the state of confusion, frustration, or anxiety which cause a need for greater concentration and determination.

7.1.2.17.2 Procedure. SWAT is a simplified rating procedure with high potential sensitivity. It can handle simultaneous measurement of multiple factors contributing to workload. Minimal assumptions are required to generate the workload scales. The interval level of measurement permits

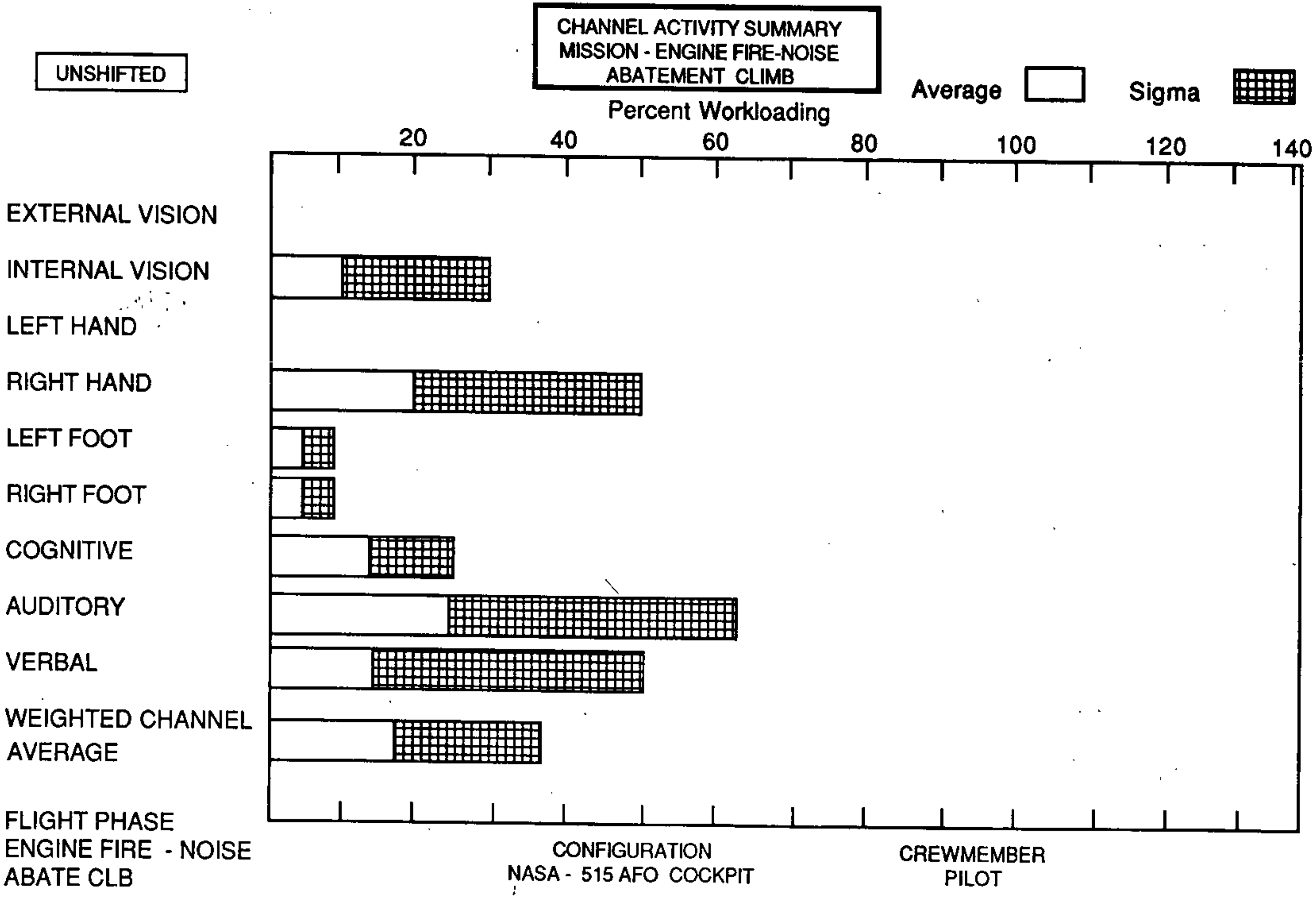


FIGURE 25. Sample channel activity summary.

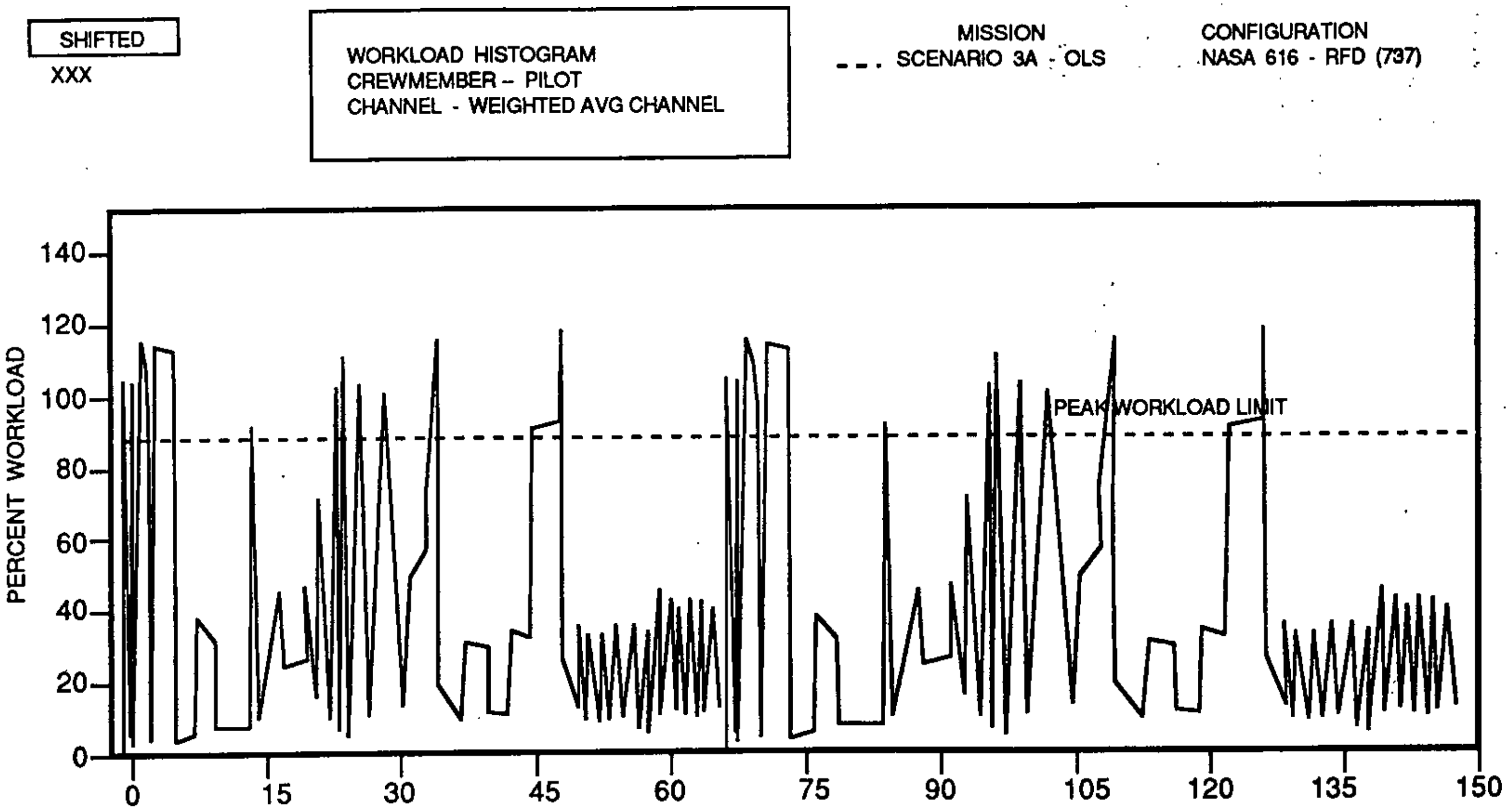


FIGURE 26. Sample workload histogram plot.

parametric statistical analysis and comparability across subjects and task. The individual subjects participating in the rating exercises are calibrated by way of a standardized task process from which the test subject's individual rating scale and group norm scale are determined through measurement and scaling analysis. The subjects then participate in the event scoring phase for accomplishment of the experimental task.

7.1.2.17.3 Use. It requires: a) an individual rating scale, and b) group norm scale. It produces: a) a prototype analysis of each subject's data, b) correlation coefficients to relate each subject to respective prototype groups, and c) separate analyses of subjects in prototyped groupings. Table VI shows the applications for which SWAT may be used.

7.1.2.17.4 Comparison to other techniques. Table IV provides a comparison between SWAT and the several other analysis techniques.

7.1.2.17.5 Controlling agency:

AFAMRL
Workload and Ergonomics Branch
Human Engineering Division
WPAFB, OH 45433

7.1.2.18 Simulated Interactive Microcomputer Workload Analysis and Modeling (SIMWAM). SIMWAM is used to develop and exercise models of operator activities and workloads in air detection and tracking operations aboard surface ships. Task definitions, flow relationships, and task parameters are based on documentation including Operational Stations Books for Combat Information Centers.

7.1.2.18.1 Description. SIMWAM, a family of computer programs, simulates the functioning of a man-machine system represented as a network of tasks. It is particularly applicable to multi-operator systems in which assignment of particular tasks to operators can be varied in real-time to alleviate excess workload. SIMWAM is further described as follows:

a. The software language is BASIC and the computer is a TRS80.

b. A mission, or any general enterprise and the performance of the mission are viewed as comprising tasks. The definition of a task is completely general. Often tasks are human activities which accomplish some subgoal of the mission, or they are instrumental in moving toward completion of the mission. As human activities, tasks will often occupy one or more operators for some amount of time. Therefore, resources will usually be consumed in accomplishing tasks.

c. Operators in SIMWAM represent resources. Usually operators correspond with personnel, but this is not necessarily the case. An operator could be a piece of equipment, a computer, etc. At a control point, there are lists of called and interrupted tasks. Ideally, these should be started immediately. Usually, however, operator resources are limited and operators are not interchangeable. Certain tasks require the services of a particular operator or set of operators. These resource requirements may result in conflicts so that the operator assignment process in SIMWAM may be likened to a fight between tasks to secure the services of specific operators. Tasks which succeed in obtaining operators will be started at the current control point. Tasks which fail will remain called or interrupted, as the case may be, perhaps to be started at a later control point.

7.1.2.18.2 Procedure. In interactive SIMWAM, no use is made of task priorities or task calls. This program has no idea of how to resolve conflicts between operator requirements or how to determine which tasks to attempt to start next. It does however, determine the next control point and update task status and time matrix data. It then presents a menu allowing the user to review current task status, review current operator status, perform task starting, or exit from the program. From the task status display the user can designate a single task. A transaction screen showing task status, number of completions, operator requirements, and operator status appears. The user can assign operators by keyboard entries. If an attempt is made to assign an operator who is currently working on another task, a query is displayed asking if that task is to be interrupted. Operator assignments to tasks are input until a sufficient number of operators are assigned at which time the task is placed on the start list. The difference between automatic and semi-automatic operation involves tasks having probabilistic calls. In automatic operation, one task in the set is selected automatically using a random number generator as previously described. In semi-automatic operation, the set of tasks having probabilistic calls and the probability indicators are displayed. The program waits for the user to select the task to be called.

7.1.2.18.3 Use. It requires a model of the system being analyzed. It provides: a) a task summary with task number, start time, end time, duration, completion number operators assigned, task interruptions, and terminations; b) a task status with time expended and call status for each task; c) operator workload showing busy/idle times, and d) time matrix showing time expended on each task by each operator. Table VI shows the applications for which SIMWAM may be used.

7.1.2.18.4 Comparison to other techniques. Table IV compares SIMWAM and several other techniques.

7.1.2.18.5 Controlling agency:

Naval Sea Systems Command
SEA61R2
Washington, D.C. 20362

7.1.2.19 WOrkSTation ASsessor (WOSTAS).

7.1.2.19.1 Description. WOSTAS is a balancing tool in a multi-crewmember workstation environment. It is a heuristic interactive, computerized model that accepts mission-oriented task requirements. By application of scheduling and line balancing concepts, it generates alternate scheduling schemes of tasks to work stations. The task allocations consider balancing the degree of physical effort among workstations. The model is designed to study repeated, cyclic task sequences in a multi-operator work station environment.

7.1.2.19.2 Use. It requires: a) the crew mission in network form with tasks and durations, b) a time window during which tasks must be completed, c) the relative extent of language, intellectual, perceptual and psychomotor abilities required for each task in the mission network, d) fatigue characteristic of each task, and e) the probabilities of alternative paths and task priority constraints. It produces: a) a complete schedule of tasks among crew members, b) performance measures associated with free time at workstations, and c) ability and fatigue characteristics of assigned tasks. Table VI lists WOSTAS applications.

7.1.2.19.3 Comparison to other techniques. Table IV provides a comparison between WOSTAS and other techniques.

7.1.2.19.4 Controlling Agency

Psychology Services Branch
Office of Naval Research
Washington, DC 10375

7.1.2.20 Human Operator Simulator (HOS).

7.1.2.20.1 Description. HOS simulates the perceptual, cognitive, and motor functions of the operator, as well as the operating characteristics of the machine. It produces summary information on sequences of operator procedures and the predicted time required to perform each procedure. HODAC (Human Operator Data Analyzer/Collator) converts the data generated by the HOS into a form suitable for use by a HE analyst. HODAC can produce ten reports. The analyst can control the extensiveness and specificity of the reports. He communicates his requests to HODAC by means of a control card language developed specifically for this purpose. HOS uses three major computer programs to complete a simulation.

a. HAL, (HOPROC Assembler/Loader) the assembler/loader accepts inputs and converts them into a form which HOS can use in simulation.
b. HOS executes the procedures and functions.
c. HODAC analyzes the simulation results.

7.1.2.20.2 Procedures. These three programs are written in FORTRAN IV. No assembly language subroutines are used. HOS employs a user language (HOPROC) to describe operator procedures and crewstation control function (batch inputs).

7.1.2.20.3 Use. It requires: a) description of operator processing, b) functional characteristics of controls and displays, and c) crewstation/equipment layout (see table IX). It produces: A procedure sequence summary, predicted procedure performance times. HODAC produces timeline analysis of operator tasks, statistics on time spent per control/display, and workload loading analysis (time occupied/time available). Table VI shows the applications for which HOS may be used.

7.1.2.20.4 Comparison to other techniques. Table IV provides a comparison between HOS and other analysis techniques. HOS is a difficult technique to apply properly. The user must input information and data which may not be readily available and must exercise extreme care when making assumptions when structuring input to avoid questionable results. As noted in Table IV, HOS is a complex, time-consuming and high cost technique. Accordingly, any use of HOS should be approached with caution. Inclusion of the HOS description herein is not for purposes of advocacy, but to note the above caveats for the benefit of customer personnel who must evaluate proposed HE analysis efforts that may consider this technique.

7.1.2.20.5 Controlling agency:

U.S. Naval Air Development Center
Warminster, PA 18974

7.1.2.21 Operator Workload Evaluation System (OWLES).

7.1.2.21.1 Description. OWLES is a SAINT based operator workload evaluation system developed for the Precision Location and Strike System (PLSS). It examines information presentation, decision making, and procedures implementation for a menu-driven, interactive computer terminal serving as the PLSS operator console.

7.1.2.21.2 Procedure. OWLES uses integrated computer-aided manufacturing definition (IDEF) to analyze the functions the system performs so the SAINT task network can be traced to

TABLE IX Sample HOS crewstation input data

```
SYSTEM                     DEMO PROGRAM -- RADAR PLOTTING
METRIC                      0  25  -50

DISPLAY SECTION
RADAR DISPLAY                25  0 0 0.5  0 26 28 OFF
RADAR SCALE                14 0 1 0.5 -10.23 30.3 43.25 32
RADAR CENTER               25 0 1 0.5 0 26 28 0 0

CONTROL SECTION
LOAD                        1 0 1 .5 -21.2 18.8 66 DUMMY
RADAR MODE                 23 0 0 0.5 -6.5 12.13 1.8 0
HOOK VERIFY                23 0 0 0.5 -10.5 0 0 0
ENTER RADAR CONTACT        23 0 0 0.5 -4 15.25 3.6 0
TRACK BALL                 20 0 1 0.5 0 0 0 0 0

SYMBOL SECTION
RADAR CONTACT STATUS 16 0 0 0.5 0 26 28 BLANK
RADAR CONTACT POSITI 18 0 0 0.5 0 26 28 0 0
HOOK                 16 0 1 0.5 0 26 28 ON
HOOK RADIUS          17 0 1 0.5 0 26 28 .125
HOOK POSITION        18 0 1 0.5 0 26 28 0 0

OPERATOR FUNCTIONS
TRACK BALL POSITION    2   0   1   1   .04   0

MODEL SPECIFICATIONS
1. ROTARY SWITCH A   7 2 0 0.04 3.0 3 0 .36
2. ROTARY SWITCH B   7 2 0 0.04 2.2 3 0 .36
3. ROTARY SWITCH C   7 2 0 0.04 1.8 3 0 .36
4. ROTARY SWITCH D   7 2 0 0.04 1.6 3 0 .36
5. ROTARY SWITCH E   7 2 0 0.04 1.5 3 0 .36
6. ROTARY SWITCH F   7 2 0 0.04 1.4 3 0 .36
7. ROTARY SWITCH G   7 2 0 0.04 1.2 3 0 .36
8. TOGGLE SWITCH     7 2 0 0.04 0.6 3 0 .36
9. VARIAC A          8 2 0 0.05 3.2 2 360 360 110
10. VARIAC B         8 2 0 0.05 2.7 2 360 360 110
11. VARIAC C         8 2 0 0.05 1.6 2 360 360 110
12. IDIOT LIGHT      5 1 0 0.04 0 3
13. INDICATOR LIGHT 5 1 0 0.04 0 3
14. NUMERIC DISPLAY 5 1 0 0.04 0 3
15. CONTINUOUS DISP 5 1  .02 .04 0 3
16. DISCRETE SYMBOL 5 1 0 0.04 0 3
17. CONTINUOUS SYMB   5 1 .02 .04 0 2
18. POSITIONAL SYMB   5 1 .02 .04 0 2
19. HAND MIKE        7 2 0 0.04 5.1 3 0 .5
```

TABLE IX Sample HOS crewstation input data (continued)

```
20. TRACKBALL          9 3 .02 .04 4.4 2   360 360 71  10
21. FOOTSWITCH          7 4 0 0.04 7.2 3 0 3.5
22. PUSHBUTTON         7 2 0 0.04 2.2  3 0 .5
23. PUSHBUTTON         7 3 0 0.04 2.2  3 0 .5
24. THUMBWHEEL         7 2 0 0.04 0.3 3 1 1
25. SCREEN DISPLAY      5 1 .02 .04 0 2
26. PUSH TO TURN A     8 2 0 0.04 1.8 2 360 360 170
27. VARIAC D           8 2 0 0.05 1.8 2 360 360 170
28. PUSH TO TURN B     8 2 0 0.04 1 2 360 360 170
29. VARIAC F           8 2 0 0.05 1 2 360 360 170
30. FLIR GRIP SWITCH7 3 0 0.04 2.5 3 0 .26
31. REAL/DISC SYMBOL    5 1 0 .04 0 2
END OF MODEL SPEX

HUMAN OPERATOR SPEX
EYES                   0   51   -22   0    75   92
HANDS                  10.5   25   -50   -10.5  25   -50
FEET                   32   55   -122   -32   55   -122
SHOULDERS              22   0   -16   -22   0   -16
HIPS                   17   0   -75   -17   0   -75
END OF HUMAN SPEX
```

the system design concept. It provides a simple representation of the human information processing and decision making in response to presented information. It also reflects the amount of mental versus physical effort by tracking how often different kinds of tasks are executed.

7.1.2.21.3 Use. It requires: a) functions decomposition to the level of specific keyboard entries and resulting display changes, b) estimates or data on individual activity duration and rules (conditional logic) for information processing and decision making, and c) probabilities of error. It produces: a) information pathways and flow statistics, b) times for completing activity sequences, c) frequency of each decision outcome, and d) error counts for data entry and menu selection tasks. Table VI shows the application for which OWLES may be used.

7.1.2.21.4 Comparison to other techniques. Table IV provides a comparison between OWLES and other analysis techniques.

7.1.2.21.5 Controlling agency

Armstrong Aerospace Medical Research Laboratory
Wright-Patterson Air Force Base, OH 45433

7.1.2.22 Computer Aided Design and Evaluation Techniques CADET). CADET was developed to upgrade crew station design evaluation capabilities and help keep evaluation techniques in step with the continually increasing complexity of man-machine interaction of newer crew systems. Because of this complexity, in-depth analysis of man and machine interaction is necessary to insure that crew workloads are maintained at acceptable levels.

7.1.2.22.1 Description. CADET is a collection of computer programs for analysis, design, and evaluation of crewstations. Currently, it consists of four programs: reach assessment, workload assessment, display format design, and a system simulation program. These programs are accessed through a user friendly interface which enables users to select programs either directly or by menu. This interface contains all the system control language necessary to run each of the programs. The user is not burdened with the requirement of learning the VAX/VMS Digital Control Language (DCL) before attempting to use these programs. In addition the interface contains a collection of utility programs for creating and editing files and maintaining the directory of files needed to run these programs. CADET software language is DCL and FORTRAN and the computer is a VAX. The capabilities of the four CADET tools are:

a. Reach assessment. This tool enables users to evaluate crewmember accommodation to the crew station. The program contains an anthropometric data base which is then used to evaluate reach within the defined crew station. The program generates the percentage of the population which can reach each of the control devices. The reach assessment portion of CADET is comprised of the Crewstation Assessment of Reach (CAR-IV), described in 7.2.2.2.11.

b. Workload assessment. This tool is provided by the HOS program. This program computes workload by modeling the human perceptual, cognitive (recall), and motor functions. To use this model the user must define the operator procedures and functions to be performed, the hardware procedures and functions, and the locations of each of the controls the operator is required to use.

c. Display format design. This tool has been the most heavily used by the CADET system. It enables users to easily create crew station display formats. These formats can be saved in permanent storage and later restored for further modifications or printing.

7.1.2.22.2 Use. It requires: a) crew station design with the relative position of each switch, button, or control input device to the design-eye point, b) operator procedures and functions to be performed, c) process inputs and outputs, d) time to complete each process, and e) relationships among the processes within the system. It produces: a) charts showing the percentage of the population which can reach each of the control devices, b) workload in percentages of time spent using each hand, foot, and the eyes, c) mental effort for each individual operation and on a mission basis, d) crew station design formats, e) process completion time, waiting time, and resource utilization, and f) statistics for both the entire system and for each process. Table VI shows the applications for which CADET may be used.

7.1.2.22.3 Comparison to other techniques. Table IV provides a comparison between CADET and other analysis techniques.

7.1.2.22.4 Controlling agency:

USAF Crew Systems Development Branch
Flight Control Division
WPAFB, Ohio 45433

7.1.2.23 Data store. Data store is officially known as an Index of Electronic Equipment Operability. It is commonly called Data Store, which is the name given to the particular document in the set of five that lists operator time and reliability estimates to be used with the Index of Electronic Equipment Operability (ref.3).

7.1.2.23.1 Description. Data store was developed by the American Institute of Research under contract to the U.S. Army Electronic Proving Ground Electronic Warfare Department. The purposes of the index are to:

a. Predict the average time required for, and reliability of, operator performance.

b. Provide a quantitative basis for identifying specific human engineering design problems and developing recommendations for overcoming or minimizing these problems.

c. Organize the results of the evaluation in a form which facilitates due consideration for selection and training requirements.

Two general types of information concerning the equipment to be evaluated must be obtained before the index can be successfully applied to the equipment.

a. Equipment information. Data concerning the equipment should include layout of the equipment, where and how it will be installed, the mission it is intended to accomplish, reaction time in meeting mission objectives, and detailed information about the displays and controls available to the operator.

b. Operating information. The second type of required information for the evaluation should contain a detailed description of the activities required of the operator/maintainer during normal and emergency modes of operation.

The index is based on the independent assessment of the performance time and operator reliability associated with each of the three aspects of input, mediating process, and output for each behavioral step. Time and reliability are a function of certain characteristics of each of the three aspects of behavior. Relevant categories of characteristics for each aspect of behavior are presented in the data store, along with time and error estimates attributable to each. The first major step of the evaluation, therefore, is determining the characteristics relevant to a particular step of behavior being analyzed and then matching these characteristics with those contained in the data store. A sample page from the data store is presented as table X. This example related to the output aspect of behavior associated with the movement of a joystick control.

7.1.2.23.2 Procedure. The application of the index requires the completion of six major steps or processes. These are listed briefly in the following:

a. Organize equipment and operation information. Data obtained from task analyses and other sources must be analyzed into behavioral steps and sequenced by mission phases of operation.

b. Collect evaluation data. This step includes the

TABLE X Sample data store card

JOYSTICK
(may move in many planes)

BASE TIME = 1.93

Time added	Reliability	
		1. Stick length
1.50	.9963	a. 6-9"
0	.9967	b. 12-18"
1.50	.9963	c. 21-27"
		2. Extent of stick movement (Extent of movement from one extreme to the other in a single plane.)
0	.9981	a. 5-20 deg.
.20	.9975	b. 30-40 deg.
.50	.9960	c. 40-60 deg.
		3. Control resistance
0	.9999	a. 5-10 lbs.
.50	.9992	b. 10-30 lbs.
		4. Support of operating member
0	.9990	a. Present
1.00	.9950	b. Absent
		5. Time delay (Time lag between movement of control and movement of display.)
0	.9967	a. .3 sec.
.50	.9963	b. .6-1.5 sec.
3.00	.9957	c. 3.0 sec.

identification of relevant components, parameters, and dimensions for each step; matching these values with the data in the data store; and entering the appropriate values on the evaluation sheet. Entry to this information in the data store would be accomplished by first identifying that the output aspect of behavior being analyzed was, for example, through movement of a joystick (see table X). The joystick then is the component level of analysis. Further analysis of the behavior would reveal the relevant parameters, such as stick length, control resistance, etc. for the particular situation. Finally, the relevant dimensions of the behavior, such as the actual length of the stick could be determined. It is at this level, dimensions, the matching of the behavior being analyzed with the content of the data store occurs. In most cases, more than one parameter will be relevant to the aspect of behavior being analyzed. In these cases, the times and reliabilities associated with the various dimension values for the parameters concerned are combined. This combination is a simple addition for time values and a multiplication of reliabilities.

c. Score evaluation sheet. Step scores are computed for each aspect of behavior and across aspects for total step scores by adding together the relevant time entries and multiplying together the reliability estimates. These totals are entered on the evaluation sheet.

d. Summarize results by component. Total values for each component of the input, mediating process, and output aspects of behavior are computed across the steps of each phase of the mission. The values are entered on the component summary form.

e. Derive recommendations: Based on the results of the evaluation listed above, recommendations may be developed in the areas of redesign, training, and selection.

7.1.2.23.3 Use. The inputs to the index are good hardware drawings and procedures. In general, the latter the stage of equipment development at which the evaluation is performed, the more complete and accurate will be the information available to the evaluator. Because the results of evaluation are numerical in nature, there may be a recurrent tendency to overemphasize the results. It must be pointed out that these results are meaningful only when interpreted within the context of all that is known about the equipment. Divorced from this context, the results may be misleading. In particular, the results of the human reliability analysis do not provide absolute four place accuracy. The analyses are only useful for comparative human reliability estimates, e.g., to compare one procedure to another or one hardware configuration to another.

7.1.2.23.4 Comparison with other techniques. Data store is one of the few techniques, along with PTS, that provides time estimates and a method for using them. Table IV shows a comparison of data store to other analysis techniques.

7.2 HE design support activities. The purpose of the HE design support activity is to provide a man-machine system design which incorporates all necessary HE design criteria. The man-machine interface design is not limited to portions of system equipment, but includes software design, procedures, work environments, and facilities associated with the system functions requiring personnel interaction. This activity is accomplished, in part, by converting the results of the analysis activity into HE training and skill level design criteria. It is also heavily dependent on the selection of applicable MIL-STD-1472 design criteria. The general HE design support process is described in 6.3.6.4. The following describes both on-going HE design support responsibilities and the techniques used to accomplish the effort.

7.2.1 On-going design support responsibilities. Although not limited to the full-scale development phase, most of the HE design support activities will take place at this time. These activities and responsibilities include:

a. Assure that HE inputs are incorporated into system design requirements documentation.
b. Development of design concepts for each operator/maintainer work station to the point that it is reasonably assured that such a work station arrangement is easily operable.
c. Identification of potential HE problem areas which may require attention.
d. Preparation of inputs to subcontractor RFP packages, as applicable.

7.2.2 HE design support techniques. Many of the most useful design aids, tools, or techniques which are appropriate for use of HE are presented in the following sections. Depending on the nature of the program, only a portion of them would normally be used. Sufficient time or HE effort does not exist to use all of the techniques for a single program. Much of the data presented are also organized into tabular form in table XI. By listing the techniques in one chart they may be easily compared for possible selection and use. Table XII shows typical applications from their use.

7.2.2.1 Design criteria checklist.

7.2.2.1.1 Description. The checklist is a series of equipment and facilities design requirements taken from human engineering standards, e.g., MIL-STD-1472, MIL-HDBK-759, and guides. Often during the early stages of a program, a checklist is developed by HE analysts 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 checklist may be divided up into sections or categories of

TABLE XI
Design techniques selection chart

<table>
<tr><th rowspan="3">Alternative techniques</th><th colspan="16">Selection evaluation characteristics</th></tr>
<tr><th colspan="4">Most applicable program phase</th><th colspan="3">Relative complexity</th><th colspan="3">Relative time to perform</th><th colspan="3">Relative cost</th><th colspan="3">Relative cost effectiveness</th></tr>
<tr><th>Conceptual</th><th>Validation</th><th>FSD</th><th>Prod/deploy</th><th>Simple</th><th>Average</th><th>Complex</th><th>Short</th><th>Medium</th><th>Long</th><th>Low</th><th>Medium</th><th>High</th><th>Low</th><th>Medium</th><th>High</th></tr>
<tr><td>1 Design criteria checklist</td><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td></td><td>x</td></tr>
<tr><td>2 Drawings</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>3 Visibility diagram</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>4 Reach envelopes</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>5 Mockups</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td><td>x</td><td>x</td><td></td><td>x</td><td>x</td></tr>
<tr><td>6 Models</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td><td>x</td><td></td><td>x</td><td>x</td><td></td></tr>
<tr><td>7 Manikins</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td><td></td><td></td><td>x</td><td>x</td></tr>
<tr><td>8 Specifications</td><td></td><td>x</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td>x</td><td></td><td>x</td><td></td><td></td><td>x</td><td></td></tr>
<tr><td>9 COMBIMAN</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>10 CAPE</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>11 CAR- IV</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>12 CUBITS</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td></tr>
<tr><td>13 CREW CHIEF</td><td>x</td><td>x</td><td>x</td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td></td><td>x</td><td></td><td>x</td><td></td></tr>
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Table XII

Human engineering design techniques data applications

	Applications								
Specific HFE design techniques/tools	Concept formulation ideas	Detailed design requirements	Personnel requirements information	Operational procedures development	Training system development	Maintenance system development	System operational evaluation	Additional human factors analysis	HFE data store information
1 Design criteria checklist		•			•	•			
2 Drawings	•	•			•	•	•	•	•
3 Visibility diagram	•	•			•		•	•	•
4 Reach envelopes		•			•	•	•	•	•
5 Mockups	•	•	•	•	•	•	•	•	
6 Models		•	•	•	•	•	•	•	
7 Manikins		•				•	•	•	•
8 Specifications		•	•	•	•	•	•	•	•
9 COMBIMAN		•					•	•	•
10 CAPE		•						•	•
11 CAR-IV		•		•			•	•	•
12 CUBITS		•		•			•	•	•
13 CREW CHIEF		•		•		•	•	•	•

design criteria corresponding to major equipment or facilities characteristics. These categories might be visual displays, audio displays, controls, etc. The checklists generally have a space to the right of each listed item of design criteria. This space is divided into three columns: compliance, noncompliance, and not applicable. Figure 27 is a sample page from such a checklist.

7.2.2.1.2 Procedure. The HE evaluator reads the item of criteria, observes the item of hardware (or mockup or drawing), and checks the appropriate space for applicability and compliance. Many checklists provide additional space to include comments as to the reason for noncompliance or other remarks appropriate to the listed design criteria item. The checklist procedure if further described as follows:

a. The HE evaluator should initiate the use of the checklist with at least some knowledge of the purpose or function of the design item being evaluated. He must have a good working knowledge of the checklist criteria which he will be using. He should determine if the item of hardware has had any previous checklists completed on it, even if the hardware was only in drawing form at the time. The more formal test and evaluation procedure will occur when the item being evaluated is at least in the prototype hardware stage of development. Less formal checklist test and evaluation may take place with hardware drawings or possibly mockups. In any case, the evaluation should take place on a noninterference basis, i.e., the gathering of the checklist data should not interfere with the conduct of any other test aspects. The use of the checklist is essentially a static operation, as opposed to a dynamic test which requires observation of operators performing their tasks and equipment properly responding to the operator's manipulation.

b. The checklist evaluation will result in a verification of the fact that the design item meets all pertinent HE design criteria. If some design criterion is found not in proper compliance, then this information will be provided to design engineering personnel. In some situations, there may be satisfactory rationale as to why an item of hardware does not or should not meet the HE design requirements. In this case, a request for deviation to HE design criteria may be submitted to the program office for their approval.

7.2.2.1.3 Use. This technique is used more often than any other to evaluate design hardware. It is an excellent way to gather quickly qualitative data on system hardware

MIL-STD-1472 compliance	YES	NO	N/A	COMMENTS & DESPOSITION
5.1.2.1.1.2 Access- Providing that the integrity of grouping by function and sequence is not compromised, the more frequently used groups and the most important groups should be located in areas of easiest access. Control-display groups required solely for maintenance purposes shall be located in a position providing a lesser degree of acess relative to operating groups.				
5.1.2.1.1.3 Designation- Functional groups may be set apart by outlining with contrasting lines. Where such coding is specified by the procuring activity, and where gray panels are used, noncritical functional groups (i.e., those not associated with emergency operations) shall be outlined with a 1/16 -inch (1.6 mm) black border (27038 of FED-STD-595), and those involving emergency or extremely critical operations shall be outlined with a 3/16- inch (4.8mm) red border (21136 of FED-STD-595). As an alternate method, contrasting color pads or patches may be used to designate both critcal and noncritical functional areas, subject to prior approval by the procuring activity. When red compartment lighting is used, an orange-yellow (23538 of FED-STD-595) and black (27038 of FED-STD-595) striped border shall be used to outline functional groups involving emergency or extremely critical operations. Critical and noncritical control-display areas in aircraft crew stations shall be delineated in accordance with MIL-M-18012.				
5.1.2.1.1.4 Consistency- Location of recurring functional groups and individual items shall be similar from panel to panel.				
5.1.2.2 Location and Arrangement- Whenever an operator must use a large number of controls and displays, their location and arrangement shall be designed to aid him in determining which contrtols are used with which displays, which equipment component each control affects, and which equipment component each display describes.				
5.1.2.3 Arrangement Within Groups- Controls and displays within functional gorups shall be located according to operational sequence or function, or both.				
5.1.2.3.1 Left-to-Right Arrangement- If controls must be arranged in fewer rows than displays, controls affecting the top row of displays shall be positioned at the far left; controls affecting the second row of displays shall be placed immediately to the right of these, etc.				

FIGURE 27. Sample MIL-STD-1472 checklist page.

components. However, in order to be of real value, there must be considerable detail contained within the checklist. Depending upon how the checklist is structured, the amount of detail required for review can extend the time required to perform the checklist. Use of the checklist requires more knowledge of basic HE design criteria than system performance. Table XII shows the applications for which the checklist may be used.

7.2.2.1.4 Comparison to other techniques. Table XI provides a comparison between the checklist and other design support techniques. The use of this particular technique is strongly advised for both design and T&E program activities. If not used, there is significant risk that lack of critical design compliance requirements will be overlooked. The disadvantages associated with the use of the checklists are that they produce binary data; the design criteria being verified is either in compliance or not. However, many criteria items have the potential for an exact quantitative evaluation; thus considerable data will be unrecorded. The checklist is used for evaluation of hardware only. In its present, generally agreed-to formats, the checklist will not evaluate personnel skills, quantities, training, technical publications, etc.

7.2.2.2 Drawings.

7.2.2.2.1 Description. Engineering sketches and drawings are precise outline drawings (usually void of shading) used to provide information as to the design of the item, facility, or subassembly which is a component or part of the total system. By a logical procedure of depicting related drawing "views", intricate and complicated shapes are clearly shown. Exact and detailed sizes are provided without ambiguity. Individual parts are identified for assembly and are located in the assembly in their correct functional position. In addition, descriptive notes provide information as to materials, finishes, and directions for manufacture and assembly. Engineering drawings or sketches of interest to HE personnel may be further categorized as a) hardware drawings, b) workspace layout drawings, c) console drawings, and d) panel drawings. Console drawings in particular, should contain information as to the man-machine interface, for example, the Seat Reference Point (SRP) and Eye Reference Point (ERP) should be indicated. Interface Control Drawings (ICD's) are another type of drawing that should require HE review. As their name implies, these drawings are used to describe and to eventually control proposed interfaces between components, subsystems, or different performing organization's equipment items. Vision plots (see figure 28) and reach envelopes (see figure 29) are two additional types of drawings of particular interest to HE.

7.2.2.2.2 Procedure. Generally, engineering drawings are used by HE personnel to review the design concepts. However, the HE group may actually prepare engineering drawings for their own use and the use of others. The development of engineering drawings by HE are predicated on the data necessary to initiate the drawings including the drawing equipment and the skills of engineers, draftsmen, or industrial designers. The following should be noted:

a. The preparation of workspace layout drawings requires skill in descriptive geometry. The HE analyst must be able to project views and cross sections of the workspace geometry and the human subject into various auxiliary planes which often are not parallel to the normal planes of the three-view orthographic engineering drawings. Also, for purposes of visual clarity and understanding, perspective drawing techniques should be understood and used. The ability to mentally visualize the geometry of workspace layouts and to accurately prepare drawings depicting the interface relationships can save time and effort during mockup studies.

b) More normally, HE personnel use engineering drawings developed by project design personnel. They must, of course, be sufficiently knowledgeable of standard drawing practices to understand the information being presented. HE design criteria checklists (see figure 27) may be used along with fractional scale plastic manikins to insure the HE adequacy of the design. Once this adequacy is assured, the drawings should be approved, to indicate HE design application compliance.

7.2.2.2.3 Use. If HE specialists have prepared the engineering drawings, it should be assured that the drawings incorporate all appropriate HE design criteria and that HE approval (see 5.3.3.1) is automatically provided. If the drawings are prepared by other project engineering personnel, HE should thoroughly review them to insure the inclusion of appropriate HE design criteria. The HE design criteria checklists should be used at this time. Completion of the checklists will provide justification for HE approval (or lack of same) of the drawings. In addition to HE design verification, engineering sketches, and drawings specify the detailed design of the hardware item. They provide a baseline configuration record (see 5.3.7.3 and 6.3.2.2), they provide inputs to initiate mockup construction, and they provide manufacturing with the necessary data from which to produce the hardware product. Table XII shows several applications for drawings.

7.2.2.3 Visibility diagrams.

7.2.2.3.1 Description. The vision plot or visibility diagram is a special diagram to show the vision envelope of specific system operators. An analysis of their vision envelope capabilities can be provided by multiple views of the operator in front of the console or other instruments and controls. However, rather than showing the side, top, or front views, the visibility diagram shows the actual view from the operator's eye (ERP). Figure 28 is a sample cockpit visibility diagram, the envelope is a plot of angles both to the left and right of the operator's sagittal plane (directly forward) and up and down from the horizontal plane through the ERP.

7.2.2.3.2 Procedure. Visibility diagrams are developed in accordance with specific procedures such as those detailed in MIL-STD-850. The HE analyst or draftsman preparing the drawings works from the two or three view orthographic drawing of the operator work station. Through descriptive geometry techniques, he measures the angles from the ERP to significant items shown in the orthographic drawings. Windows, instruments or controls are generally the primary items of interest in the visibility diagrams. The angles to several points on each of the significant items are measured and plotted in order to approximate the shape of the item. All straight lines shown on the orthographic projection (with the exception of vertical lines and lines within the horizontal plane through ERP) will be plotted as curved lines. Straight lines below the horizontal plane will curve up, and above the plane will curve down. Software is now being developed to construct computer aided design visibility diagrams.

7.2.2.3.3 Use. Visibility envelopes are useful to determine what operators can and cannot see. Their use in cockpit or flight deck design is extremely critical to determine where window posts are located in reference to the pilot's runway vision at various landing approach geometries. Whereas new aircraft design aerodynamic considerations tend to dictate flat angle smooth surfaces around the aircraft cockpit area, these considerations cannot violate the pilot's minimum vision requirements as described in military specifications. The visibility diagram provides a technique for making the specification comparison. It further provides a record of the system design and generally avoids the cost of preliminary mockups which would otherwise be constructed just to evaluate operator vision. Table XII shows additional applications for visibility diagrams (vision plots). Finally, it is important to understand that the above techniques for developing vision plots and visibility diagrams apply to aircraft flight stations and are not readily adaptable to other types of vehicles, such as tanks, trucks, or ships.

7.2.2.4 Reach envelopes.

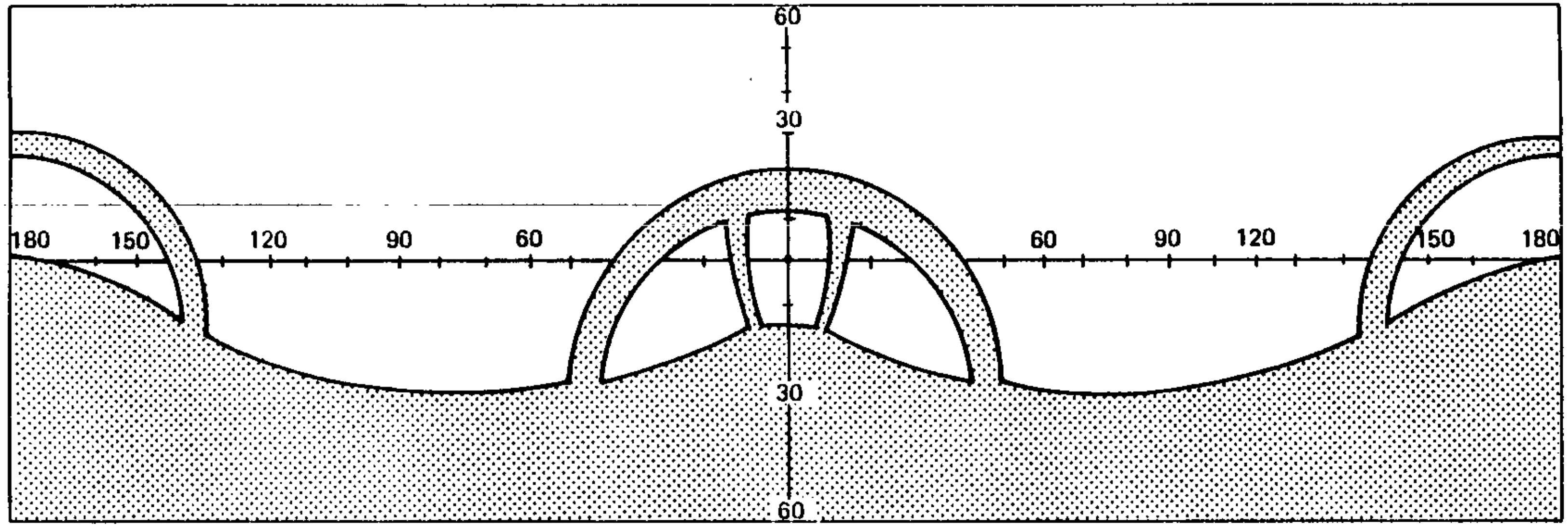


FIGURE 28. Sample cockpit visibility diagram.

7.2.2.4.1 Description. Reach envelope drawings describe the envelope within which controls must be placed in order to be successfully reached by the subject operator. Until recently, the operator has generally been described as one with a 5th percentile functional reach. Recent bimodal male-female populations may not include sufficient data to calculate the lower limit percentile for determining the desired reach envelope. The envelopes vary for the 5th percentile operator for known populations. This is because of variations of seat design and shoulder and lap constraints. Reach envelopes are also developed and used for overhead reach.

7.2.2.4.2 Procedure. The procedure for developing reach envelopes is simply to modify or adapt existing data or to develop new data. Functional reach is always the parameter of main interest. Measurements are made with the subject's thumb and forefinger tips pressed together. Secondary parameters such as shoulder height are also of interest and combine with functional reach to provide the total reach envelope data. Information showing appropriate combined reach data are available in DH 1-3 and a few other sources. If, because of peculiarities in the particular new system seat and the operator restraint system, it is not possible to use previously developed data, then new data can be developed. This will require the gathering of appropriate size and number of subjects to match the population and the seat to be used in the new system. The following procedural data should be noted.

a. Reach capability data must be taken for each of the subjects under various conditions, such as a pressure suit, seat back angle, and shoulder restraint, and in various directions and heights in relation to the SRP or ground reference plane. Once the data are obtained, statistical distributions of reach data may be plotted and a percentile curve or statistical estimate may be selected and prepared.

b. The envelope drawings are then plotted and overlaid onto the console or cockpit drawings. The SRP or other hardware datum reference is necessary to establish where the reach envelope should be located.

c. Examination of two or more different orthographic views of the control panel hardware, which are overlaid by the envelopes, will determine if the necessary controls are within the operator's reach or if the controls and operator must be moved closer together.

7.2.2.4.3 Use. Reach envelope drawings are important to proper console design, particularly if the operator is restrained and the console is large with side wraparound panel areas or vertical panel areas which project above the eye reference point (ERP). Proper use of reach envelope drawings will save later mockup construction effort.

Engineering drawings and sketches may be validated prior to the use of mockups and prototype hardware. If properly presented, reach envelopes may be easily understood by non-HE personnel and can be very useful as a part of hardware design review presentations. Figure 29 illustrates a sample reach envelope drawing. Table XII shows the applications of reach envelope drawings.

7.2.2.5 Mockups.

7.2.2.5.1 Description. Mockups should be constructed as a significant part of the development of the man-machine system. They should be considered as tools which are used to evaluate the system design before the actual manufacture of system hardware. Mockups are generally of three basic types:

7.2.2.5.1.1 Class I. Class I is used primarily, for determining basic shape, allotting space, proving concepts familiarizing personnel with the basic design of the system/equipment and the presentation of new ideas. It is usually made of inexpensive materials (heavy cardboard, cardboard with a foam core, fiberboard, low grade plywood, etc.) and is proportionally but not dimensionally accurate unless so requested. Unless otherwise specified, complete structure is not simulated (hidden structure is not simulated, repetitive type structure is simulated using skip spacing, e.g., every other one, or every third one, etc.). Internal components are represented as actual small items of hardware or by cutouts of drawings or photographs of the items. The external dimensions of the mockup are usually not critical. Internal dimensions having to do with workspace design, displays, and controls should be reasonably precise. Mockup plans can be sketches, development layouts, coordination sheets, or oral descriptions.

7.2.2.5.1.2 Class II. Class II is used, primarily, to assist in development of system/equipment detail design and as a demonstrator for customer evaluation. It is constructed from a good grade of wood, metal, or plastic. Overall dimensions and sizes of parts, features, etc., are as close to drawing tolerance as practical. The location of features and parts, the spacing of frames, stringers, etc. are held to drawing tolerances. All structure is simulated except hidden parts which would be inaccessible after the mockup is completed. In hidden part areas, accuracy is not maintained; instead of frames, stringers, etc., simple braces for strength are used. Installations and materials in critical areas are per mockup drawings. If operational hardware is desired, the degree of operation must be specified. The number and type of operations that may be provided cover a wide range. The more complex mockups are little different than simulators. Plans can be sketches, layouts, and coordination sheets.

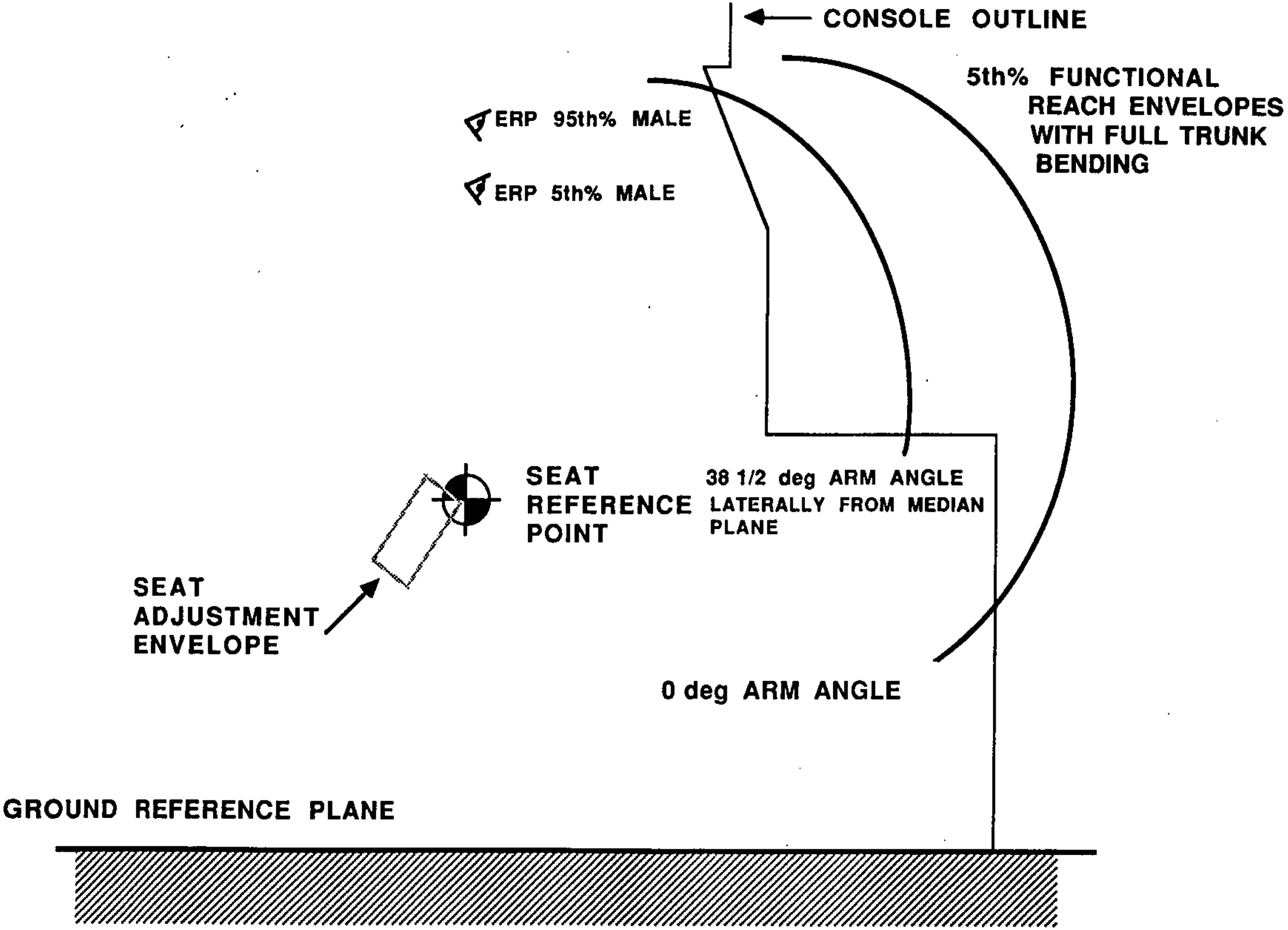


FIGURE 29. Sample reach envelopes.

7.2.2.5.1.3 Class III. Class III is primarily an engineering/ manufacturing/simulation vehicle or facility and is used to determine the layout of plumbing lines, the layout of wiring runs, the size and installation of systems/ equipment, and to prove out all installations prior to actual production. This mockup is normally constructed after production contracts have been negotiated and the number of contracted items is sufficient to warrant the expense. It is usually constructed of production type materials, metal, plastic, or a good grade of wood. Structural items and external features of installed equipment (black boxes, pumps, actuators, etc.) are to production tolerance and of production materials except where material substitution is authorized. Internal features of installed equipment are not required. All attachments, wiring, connectors, plumbing, and other hardware shall be identical to that which will be defined on the production drawings except where deviations are authorized. Actual equipment is used whenever specified or whenever its use is practical. Mockup drawings should be released production drawings and or completed layouts.

7.2.2.5.2 Procedure. The mockups should be made initially with the easiest to use and cheapest material possible. Various thickness 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 the 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 dynamic. The console panel drawings which were glued to the plywood may be replaced by the actual displays and controls.

7.2.2.5.3 Use. Wiring, cabling, piping, and ducting may be designed to visualize three-dimensional problems from scaled down, two-dimensional drawings. Measurement of operator/ maintainer subject reach, handling, and manipulating capabilities, clearance spaces, access opening, and vision envelopes can be determined and compared with the system design requirements for verification. Photographs, video tapes or motion pictures may be made to provide coordination aids and maintain records. It is cheaper to develop a static mockup or even a functional mockup, which includes the proposed electrical wiring, than it is to build prototype hardware with numerous design errors. A functional mockup makes it possible to study the performance of personnel in simulated operational situations. The HE specialist can thereby evaluate operational 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, video tapes or movies provide an aide to design presentation reviews and, later on, to training system development. Table XII provides the applications of mockup construction in tabular form for comparison to other design techniques.

7.2.2.5.4 Comparison to other techniques. Table XI provides a comparison between mockups and other design support techniques, including models.

7.2.2.6 Models. Occasionally, when the fabrication of full scale mockups of hardware or facilities would be too elaborate or expensive to construct, scale models are used in their place. Unfortunately, the use of scale models negates much of the value for HE because of the lack of good HE evaluation tools such as three-dimensional scale model manikins. Models are more easily transported and stored than mockups. Models are useful to perform some logistics analyses, but cannot be well used to perform, for example, MIL-STD-1472 checklists (see figure 27).

7.2.2.7 Manikins.

7.2.2.7.1 Description. A tool useful for evaluation of engineering drawings and sketches is the two-dimensional articulated plexiglas manikin. A set of these manikins may be obtained (MIL-HDBK-759A provides a set of cutouts) or prepared in a range of sizes and scales for use by HE or project design groups. They are usually made to represent two-dimensional anthropometric aspects of humans as seen from the side. For maximum flexibility, a large number of sizes, shapes, and scales which correspond with engineering drawing practices, (e.g., 1/10 and 1/4 scale) will be required.

7.2.2.7.2 Procedure. The manikins are used by placing them in the workspace positions indicated on the drawings and articulating the figures to various reasonable positions to check for conditions of interference, access, or reach availability. To a limited extent, visual envelopes may be checked. If the required percentile population of users is known, e.g., 5th through 95th percentile, then the manikins should be used to check to determine if the design is compatible with anthropometric parameters represented by the 5th and 95th percentile manikins. Because the manikins are made of clear plastic, it is easy to see the amount of interface or overlap if the manikin's dimensions exceed the space provided on the scaled drawing.

7.2.2.7.3 Use. Frequently, the manikins may be used by engineers or draftsmen to illustrate a drawing with sketches of various sized personnel in various critical positions. The manikins are used as a template around which the engineer or draftsman would draw the outline of the properly scaled person in the desired articulated position on the drawing. The use of these manikins is most worthwhile during drawing preparation and evaluation. Whereas the cost of the manikin procurement (in terms of a full set of sizes and shapes) is several hundred dollars, they tend to save this expenditure by the proper initial design of mockups and prototype hardware rather than the costly redesign of the same. The manikins do have limitations in that they cannot possibly be completely and properly articulated. The manikins are therefore only an approximate tool. They cannot be used by themselves to determine precise design compliance or deviation from criteria. Other forms of manikins have been developed for full scale use in escape systems and other similar hazardous use. Their use is more appropriate to the test and evaluation phase of HE rather than the design phase. Table XII presents a list of applications for manikins.

7.2.2.8 Specifications.

7.2.2.8.1 Description. One of the most important methods to use in insuring the adequacy of HE design in the system is to include applicable human performance requirements and HE design criteria in the hardware and software specification. The two types of specifications focused in these areas include:

a. Type A - System specification. This type of specification states the technical and mission requirements for a system as an entity, allocates requirements to functional areas, and defines the interfaces between or among the functional areas.

b. Type B - Development specifications. Development specifications state the requirements for the design or engineering development of a product during the development period. Each development specification shall be in sufficient detail to describe effectively the performance characteristics that each configuration item is to achieve when a developed item is to evolve into a detail design for production.

7.2.2.8.2 Procedure. The HE specialist should insure that applicable HE design criteria are incorporated into each appropriate hardware item specification. Appendix B contains a listing of applicable specifications, standards, and handbooks with a cross reference to the applicable service. Because it is self tailoring it is reasonable to reference all of MIL-STD-1472 in the hardware (typically, a Type A) specification. All hardware items which make up the total system require individual specifications. In accordance with MIL-STD-490, which describes how to prepare a specification, Paragraph 3.3.7 of the specification should be used to describe the requirements for human performance and HE. Additional paragraphs that should be considered for HE inputs are 3.2.1 performance characteristics, 3.2.2 physical characteristics (crew space, access for maintenance, etc.), 3.2.4 Maintainability (design complexity, etc.) and 3.2.7 environmental conditions (wind, rain, temperature, sea state, etc.).

7.2.2.9 Computerized Biomechanical Man-Model (COMBIMAN).

7.2.2.9.1 Description. COMBIMAN is a CRT graphic display man-model system used primarily in the design and evaluation of crewstations and workplaces. It is comprised of a system of programs developed to assist in the design process by providing an interactive, computer graphics assisted engineering tool. It produces a three dimensional man-model that can be viewed from any plane or angle. The man-model is based on a 35 link-skeletal system. The following further describes COMBIMAN:

a. Because a worker functions in three-dimensions, it is difficult to evaluate adequately a workplace from a two-dimensional drawing. While mockups provide a three-dimensional representation, construction of a good one is both time consuming and costly. The mockup evaluation is also limited, because it is difficult to find subject operators who adequately represent the anthropometric variability of the user population, a limitation which has led to erroneous conclusions. A mockup requires some cost and effort to modify. Thus, it can become an obstacle to design change.

b. COMBIMAN does not share these handicaps. It is a three-dimensional model which may be moved about and viewed from any angle. Since the man-model and workplace design exist only on a CRT display and in a computer memory, there is no significant investment of time or materials in effecting modifications. Because the user can modify the design easily while sitting at the display, the resistance to change is eliminated and experimentation is encouraged. Alternative designs may be thoroughly evaluated and then permanently recorded by means of a pictorial plot or tabular printout of the workplace data and man-model.

c. The variable geometry of the COMBIMAN allows the user to define quickly a series of man-models which represent the entire anthropometric range of a given user population. A variety of special problems can be evaluated by generating realistic ranges of certain body segments, while proportioning the remaining segments to achieve a reasonable configuration. With COMBIMAN, the operator can specify a certain sitting eye height and the program will generate a man-model with realistic proportions. The user is prevented from selecting an unrealistic combination of body-segment dimensions by constraining equations with are derived from the actual anthropometric data base of the population being considered.

d. The man-model itself is constructed in three stages. The first stage is the generation of the link system consisting of 35 segments which correspond functionally to the human skeletal system. The second stage is the definition of the enfleshment ellipsoids (a three-dimensional ellipse) about the link system joints. The third stage of man-model construction is connection of the ellipsoid silhouettes by tangent lines.

e. COMBIMAN is run on an IBM 360/370 computer in FORTRAN.

7.2.2.9.2 Procedure. The two most important applications of COMBIMAN are in (a) the design of workplaces, and (b) the evaluation of workplaces. The other features of the model (variable anthropometry, reach envelopes, visibility plots, etc.) are used in support of these two primary applications.

7.2.2.9.2.1 Design. Starting with a list of requirements for a workplace, the designer can call up the man-model to which he has assigned dimensions representative of the population of intended operators. The designer can then quickly define the various control display panels around the man-model indicating the corner points with the lightpen. These are then connected by lines to indicate the panels which are not only created on the display, but are also entered in the three-dimensional storage arrays and can be printed for future use. The designer can cause the coordinates of a point to be displayed simply by pointing the lightpen and pressing a button. The displayed coordinates are in inches, full scale with respect to a meaningful reference point rather than in arbitrary units which would have to be scaled or converted in order to be understood.

7.2.2.9.2.2 Constraints. Frequently, the area available for the workplace is predetermined or at least constrained by some maximum dimensions. The size and location of some control panels may also be known. If workplace constraints are known in advance, they may be entered from one or any combination of these input devices: lightpen (on CRT), keyboard (on CRT), punched cards, magnetic tape storage, and disc storage.

7.2.2.9.2.3 Clutter reduction. The user can temporarily prevent certain characteristics of the workplace from being displayed, without removing them from the workplace storage arrays. To eliminate the projection of a particular control panel, the user simply points the lightpen at the panel and presses a button. This technique allows the operator to unclutter a very complex workplace.

7.2.2.9.2.4 Workplace evaluation. After the workplace has been designed around the man-model, the designer may evaluate the workplace by the following method.

a. A major feature of the COMBIMAN is its utility in evaluating workplaces. These generally fall into three categories: existing workplaces; conceptual workplaces (which have not been constructed, but exist as an engineering drawing); and workplaces generated with the lightpen in on-line design operations.

b. Once a workplace has been entered into the program, it exists in three dimensions and can be made to interact with the man-model. Although the CRT is a two-dimensional display, two orthogonal views are simultaneously projected and can be rotated for viewing at any angle. If the user wants to take a closer look at some feature of the display, that feature can be magnified to the desired sizes. Regardless of the scale of the display, all coordinates and dimensions are stored in full scale.

7.2.2.9.2.5 Body segment dimensions. Presently, the operator has several options in defining the body segment dimensions for the man-model:

a. Direct Measure: Specific individuals are entered into the model from the keyboard or punched cards. Although this method is rarely used in designing workplaces, it is very useful for the validation of the model, which is in progress.

b. Stored Individual Data: Data from anthropometric surveys are stored on computer tapes. Dimensions of a selected individual can be recalled and used to dimension the man-model.

c. Data Base Summary Statistics: Percentiles computed from large samples are used to define the man-model. Because a 5th percentile man is a theoretical assemblage of 5th percentile body segments, the user may wish to select a separate percentile value for each of the critical variables by selecting the desired value from a list of displayed percentile values. The lightpen is used to check off the desired percentile value as each critical dimension is successively underlined.

d. Computer-Aided Dimensioning: Assists the user in generating abstract, but realistic man-models from anthropometric survey data.

This last method is most useful for workplace evaluation. The user starts by defining the body characteristic most relevant to the evaluation. This characteristic may be a dimension (such as sitting height, arm length, etc.) or a mass (such as total body mass or some segment mass) and can be defined either as an actual measure or a percentile value. Of all the methods for dimensioning a man-model for workplace evaluation, this one is the most useful. It is both fast and accurate. It allows the user to call up a wide range of man-models with critical dimensions determined by the nature of the task.

7.2.2.9.2.6 Three dimensional geometry. COMBIMAN can define a complex range of head and eye positions with great accuracy. Because of this capability, the incorporation of visibility plots into the COMBIMAN programs was a logical development. In addition, because of the ease and accuracy with which the program handles three dimensional geometry, the COMBIMAN visibility plots contain additional information which increases the utility of the output, specifically, the three-dimensional coordinates of the workplace with respect to the viewing angle. Using the cockpit as an example, the visibility plot program scans the frame of the canopy and plots the vertical viewing angle for each integer degree within the horizontal field-of-view. The printout shows the three-dimensional coordinates of the canopy frame at each five-degree increment of the horizontal angle. These coordinates are given in the aircraft coordinate system, so that any point in question may be precisely located on the cockpit drawing. Such a correlation between look-angle and workplace coordinates makes this type of visibility plot extremely useful to the design engineer. It provides accurate feedback of the effect of hardware modifications on the external visibility of the pilot. When evaluating the external visibility characteristics of a certain cockpit, the designer can easily vary any of the following:

a. Size of the operator (such as sitting eye height based on relevant anthropometric surveys).

b. Seat adjustment (vertically, horizontally, or both).

c. Head position (which may be a complex function of upper body position).

d. Visual restrictions (helmet, helmet-mounted displays, etc.).

7.2.2.9.3 Use. Whereas COMBIMAN requires inputs of a) an anthropometric data base (or) user-supplied link data, and b) crew station geometry in terms of panels and controls extracted from an existing data base or created interactively via light pen input, it produces: a) reach analysis, b) field of vision, c) on-line design manipulation capability, d) hard copy of displayed graphics, and e) hardcopy reports detailing the crewstation design. Table XII shows the general applications of COMBIMAN in comparison to other design techniques.

7.2.2.9.4 Comparison to other techniques. Table XI provides a comparison between COMBIMAN and other design support techniques.

7.2.2.9.5. Controlling agency.

AF Aerospace Medical Research Lab.,
HE Division, Workload & Erogonomics Branch
WPAFB, Ohio 45433

7.2.2.10 Computer Accommodated Percentage Evaluation (CAPE). Crew cabs, cockpits, and many other workspaces traditionally have been designed without knowledge of the proportion of the user population that is accommodated with safety and full capability. In cockpit design, for example, designers have been directed to develop crew stations that accommodated 5th through 95th percentile operators. However, crew system designers are generally designing for the 5th through 95th percentile population only one dimension at a time. The combination of all the necessary dimensions that make up a workspace design, limits the operators to a much smaller actual range than 5th through 95th percentile. It has been shown that more than 52 percent of the 1964 population of naval aviators would be excluded when 5th and 95th percentile critical limits are imposed. This led to the development of CAPE which is a Monte Carlo model for generating representative pilot anthropometric features, a link-man model and an adjustable workspace model so that the workspace accommodated percentage could be estimated and maximized.

7.2.2.10.1 Description. The CAPE model has two options: exclusion demonstration and cockpit analysis. Each option, and its underlying model with components, is described in summary form below.

a. An exclusion demonstration determines what percentage potential population is excluded from a workspace design with respect to each anthropometric feature entered into the program. This CAPE option may be considered to be composed of two components, an exclusion limits component and a Monte Carlo sample generator.

b. The Exclusion Limits provides for the entry, storage, and utilization of user-provided standard score limits of anthropometric variables required for exclusion studies. For each variable involved in an exclusion demonstration analysis, high cutoff and low cutoff values must be input by the user. This component of the analysis provides for the sequential testing, element by element, of Monte Carlo generated standard score vectors to determine if the vectors are within the limits set by the high and low standard score boundaries (populations of standard scores have means of zero and standard deviations of one.). Rejection of any component test is defined as nonaccommodation of that (sample subject) feature vector.

c. 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. The cockpit analysis option of the CAPE program can be thought of as being composed of four components: a) a pilot link system component, b) a sample pilot generator component, c) a component characterizing a seat-cockpit layout, and d) cockpit testing component.

7.2.2.10.2 Procedure. The Monte Carlo Sample Generator Component generates quasi random vectors of standard scores that match a user-provided correlation or correlation square-root matrix. It is based on a method which generates standard score feature vectors with a given correlation matrix. Conformable vectors of quasi-random normal variants generated by a subroutine are premultiplied by the square root of the desired correlation matrix to produce a quasi-random standard score vector. This vector can be viewed as a sample subject feature vector whose elements have been converted into standard scores. The program uses batch FORTRAN with a SUPER FORTRAN option.

7.2.2.10.3 Use. Although CAPE has been designed for use in cockpit analysis, design, and evaluation, it may be used to maximize the population of personnel to be accommodated in any workspace. The following should be considered.

a. One disadvantage in using this technique for workspace evaluation is that it requires special training to use, both from the standpoint of the user and the programmer. The cost of computer use may or may not be significant depending on several variables. It is interesting to note that design criteria do not exist that will allow the design of man-machine interfaces to accommodate 90 percent of the population. MIL-STD-1472 criteria will allow the accommodation of 90 percent of the population for only one dimension (or parameter) at a time. It would be extremely difficult, if not impossible, to develop these anthropometric criteria for all workspace design situations.

b. If this technique is not used, specially selected subjects whose anthropometric data approach the percentile extremes may be used to test the workspace design. However, these subjects are extremely difficult to find and they are not a satisfactory means of determining just what user population is actually accommodated. Another method is to measure all significant workstation dimensions that relate to critical anthropometry and compare them to MIL-STD-1472 design criteria. The effect of this would be to waive the presumed design requirement to provide for 90 percent of the user population.

7.2.2.10.4 <u>Comparison to other techniques</u>. Table XI provides a comparison between CAPE and other design support techniques.

7.2.2.10.5 <u>Controlling agency</u>.

System Integration Division
Pacific Missile Test Center
Point Mugu, California 93042

7.2.2.11 <u>Crewstation Assessment of Reach (CAR-IV)</u>.

7.2.2.11.1 <u>Description</u>. CAR-IV is an interactive design evaluation tool that determines the percentage of a population accommodated by specific crew station geometry. This tool includes elements that incorporate the crew station geometric description and perform the accommodation analysis. Accommodation is expressed in terms of reaching controls (clenched fist, finger tip, hand extended) and maintaining minimum head clearance. The following further describes the CAR-IV technique:

a. The user must define an operator sample and the geometry of the crewstation, as well as certain environmental conditions. The model produces a variety of data pertaining to the ability of operators to be appropriately positioned in the crewstation and to reach the designated controls.

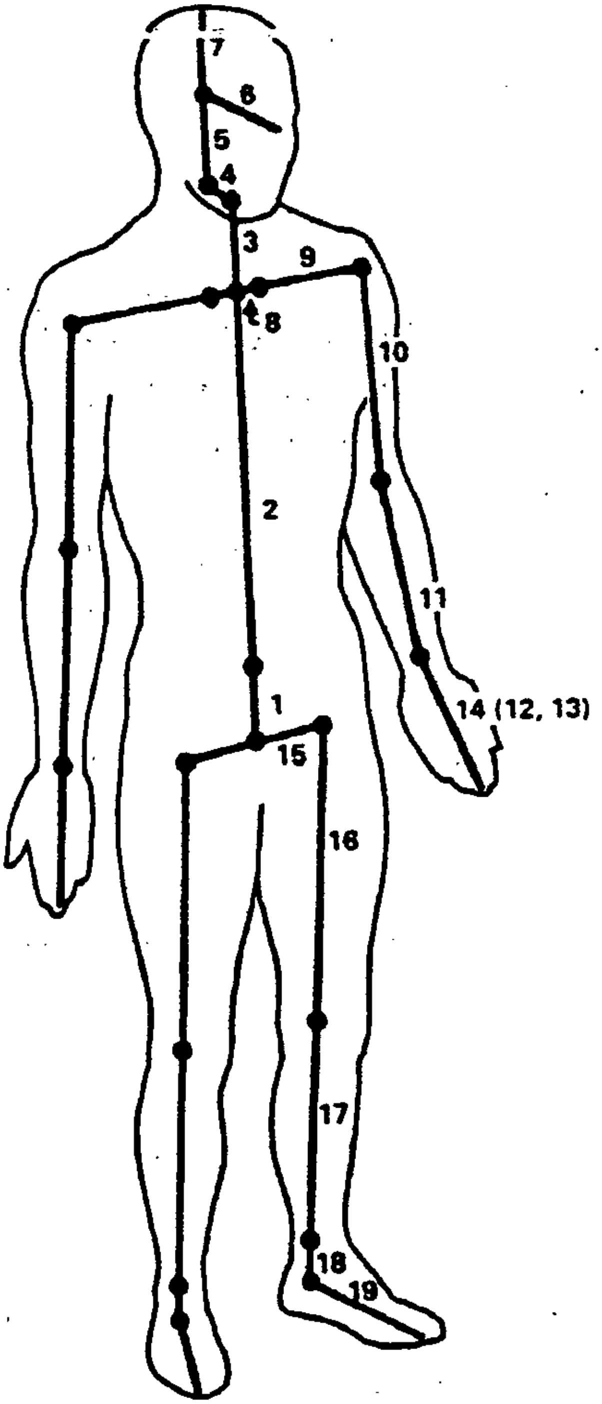
b. When entering operator sample data, the user can input either the actual body measurements of individuals or the user can request that CAR generate a sample population using a Monte Carlo process. When generating a sample, the user specifies the means, standard deviations, and correlations of standard measurements found in anthropometric source books (e.g., DOD- HDBK-743). In either case, body measurements for the sample population are transformed into internal links (i.e., lines connecting centers of motion which correspond roughly to the major skeletal bones). Figure 30 illustrates the CAR link person.

c. In crewstations with adjustable seats and Design Eye Point (DEP) anchorage, CAR attempts to position each operator's eye at the DEP, along a Line-Of-Sight (LOS) angle defined by another point in the crewstation.

d. The operator's seat definition consists of a seat back angle, seat pan angle, seat adjustment, and harness. The seat adjustment is defined by the SRP (the center of the line segment formed by the intersection of the seat back and the seat pan), the furthest down-forward position of the seat, and the furthest upward-back position of the seat. The user defines the harness by specifying the position along the horizontal shoulder line where the harness meets the shoulder.

e. A maximum of fifty controls may be specified for the crewstation. Controls are defined in terms of body part location (hand or foot), grip appropriate for the control (clenched, fingertip, or extended), the harness condition (locked or unlocked), and the control location. An additional point representing the limit of the linear range of movement is specified for adjustable controls.

f. CAR analyzes the ability of an operator in the sample to reach a control by beginning at the lumbar joint and adding links in succession in the direction of that control. The links are constrained by angular limits of motion associated with each link joint as affected by environmental factors, including the harness conditions and type of clothing. Since the link lengths calculated for the operator sample are for a nude operator, CAR allows the user to specify that the operator is



1- LUMBAR
2- THORACIC
3- NECK (VERTICAL)
4- NECK (HORIZONTAL)
5- HEAD (LOWER)
6- EYE
7- HEAD (UPPER)
8- INTERCLAVICULAR
9- CLAVICULAR
10- HUMERAL
11- RADIAL
12- HAND (CLENCHED)
13- HAND (FINGERTIP GRIP)
14- HAND (EXTENDED)
15- PELVIC
16- FEMORAL
17- TIBIAL
18- ANKLE
19- FOOT

NOTE: LINKS 8-19 HAVE BOTH
RIGHT AND LEFT LINKS

FIGURE 30 Sample CAR link-person model.

wearing either summer or winter clothing. The clothing specification modifies the appropriate link lengths and their angular limits of motion.

7.2.2.11.2 Procedure. All program functions are menu-driven, giving the user simplified control over program execution. The user is prompted by significant keywords. If the information in any prompt is insufficient, the user may enter a question mark and the program will respond with more detailed information. The program has been designed primarily for interactive use and includes extensive error and data consistency checks. In addition to interactive data entry, the program will also accept operator sample and crew station data as ASCII files created external to CAR using an editor program.

7.2.2.11.3 Use. The user supplies the following items: a) anthropometric database (or) specific anthropometric values, b) physical geometry of seat, canopy, and controls, c) position of operator in crews station, and d) population/accommodation criteria. The results include: a) population measurements file, and b) population percent that can position to DEP within seat adjustment, maintain head clearance, and reach primary hand and leg controls under restrained and unrestrained conditions. CAR-IV can be used as both an analysis and design tool, since it is completely interactive in usage and has been validated with human performance data. CAR-IV can also be easily adapted to computer graphics techniques, is easily transportable from one computer system to another, has a fast "turn around" time, is run very quickly and economically, and can be used in an interactive fashion. Table XII shows the applications for which CAR-IV may be used.

7.2.2.11.4 Comparison to other techniques. Table XI provides a comparison between CAR-IV and other design techniques.

7.2.2.11.5 Controlling agency.

HFE Technology Development Branch
Navy Air Development Center
Warminster, PA 18974

7.2.2.12 Criticality/Utilization/Bits of Information (CUBITS).

7.2.2.12.1 Description. CUBITS is a set of computations for determining the amount of space which should be allocated to a control or display. The computations can be done by hand or they can be computerized. CUBITS computes the size of the control or display based on how important it is (criticality), how often it is used (utilization), and how much information an operator gets from the display or transfers to the control (bits of information). From a set of CUBITS computations or a CUBITS simulation, the HE specialist can determine how big to make a control or display. CUBITS does not address task or system performance, workload, vision, reach, escape, percentage of operator population accommodated or excluded by crew station dimensions or crew station compliance with specific military standards. The computerized version of CUBITS does not have a graphic display or interactive design layout capability and does not print graphic illustrations.

7.2.2.12.2 Procedure. CUBITS is used during the early design process as soon as the necessary data is available. From the CUBITS computations the HE specialist can determine precisely what size a control or display should be. The specialist uses this information in laying out controls and displays when designing a crew station. The HE specialist must first learn to use CUBITS and then assemble or generate the required data. The specialist then either does the computations by hand or enters the data at a computer terminal. CUBITS done by hand is time-consuming.

7.2.2.12.3 Use. CUBITS provides a systematic and logically derived method for allocating control and display space. Different HE specialists should come up with approximately the same answers using this technique.

7.2.2.12.4 Compared to other techniques. Table XI provides a comparison between CUBITS and other design techniques..

7.2.2.12.5 Controlling agency:

Man-Machine Integration Division
Naval Air Development Center,
Warminster, Pa. 18974

7.2.2.13 Crew Chief

7.2.2.13.1 Description. Crew Chief is a 3D graphical representation of a maintenance person and is used to simulate their activities. An established data base is used and can modify and adjust anthropometric parameters for clothing and protective equipment (e.g., cold weather, and chemical defense, etc.) There will be 10 to 12 starting postures and the simulation will allow manipulation of these postures and selection of tools or objects (e.g., screwdriver, wrench, etc.) that maintenance personnel might use. Crew chief will evaluate accessibility, physical and visual access, visual limits, body size, and strength.

7.2.2.13.2 Procedure. Crew Chief is currently still under development.

7.2.2.13.3 Controlling agency.

AF Aerospace Medical Research Lab.,
WPAFB, Ohio 45433

7.3 HE test and evaluation activities. In order to verify the human equipment or software aspects of system design to resolve HE problems, and to gather data for use in design of later systems, a concerted HE T&E effort must be accomplished. The general HE T&E (or HFTE) process is described in 6.3.6.5. The following describes both on-going HE T&E responsibilities and techniques used to accomplish the effort.

7.3.1 Ongoing test and evaluation responsibilities. The following material describes both ongoing HE T&E responsibilities and the HE T&E techniques used to accomplish the effort. During this period of system development, the human engineer has several important responsibilities:

a. Assurance that applicable HE T&E requirements are accomplished;

b. Demonstrate conformance of system, equipment, and facility design criteria;

c. Validate human performance requirements;

d. Confirm compliance with performance requirements where the operator or maintainer is a significant part of such system performance;

e. Obtain quantitative measures of system performance which are a function of man-machine interaction; and

f. Determine if undesirable design or procedural aspects have been introduced.

7.3.2 HE test and evaluation techniques. Many of the most popular T&E techniques which are appropriate for use of HE are presented in the following sections. As is the case with analysis and design techniques generally, only a few of these techniques would be used. Table XIII is provided to compare the T&E techniques on the basis of their time to perform, complexity, cost, and cost effectiveness. Table XIV shows typical applications from their use. Reference 3 provides additional information on several of the design techniques and tools including vision plots, reach envelopes, mockups, and manikins.

7.3.2.1 Direct continuous observation.

7.3.2.1.1 Description. 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 or on a clip board, or some of the more sophisticated techniques/tools may be used for recording events and times. Automatic recording techniques such as photographs, movies, and sound and video tapes may also be used along with direct observation.

TABLE XIII
Test and evaluation techniques selection chart

	Selection evaluation characteristics															
	Most applicable program phase				Relative complexity			Relative time to perform			Relative cost			Relative cost effectiveness		
Alternative techniques	Conceptual	Validation	FSD	Prod/deploy	Simple	Average	Complex	Short	Medium	Long	Low	Medium	High	Low	Medium	High
1 Direct continuous observation		x	x		x				x			x			x	
2 Direct sampled observation		x	x		x			x			x				x	
3 Spec. comp. summary sheet		x	x		x				x			x			x	
4 Technical manual function eval.			x	x	x				x			x			x	
5 HEDGE/HFTEMAN		x	x	x	x				x	x		x			x	x
6 Environment and engineering measurement equipment		x	x	x		x		x	x			x			x	
7 Systems records review		x	x	x	x				x	x		x			x	
8 Test participant history record		x	x	x	x			x			x				x	
9 Interviews	x	x	x	x		x			x			x				x
10 Questionnaires	x	x	x	x	x				x			x				x
11 Motion pictures		x	x			x			x				x	x	x	
12 Sound tapes		x	x		x			x			x			x		
13 Video tapes		x	x			x			x				x		x	
14 Photography		x	x	x	x			x			x				x	
15 Event recording		x	x			x		x	x		x	x			x	
16 Secondary task monitoring			x				x		x	x			x	x		
17 Physiological instrumentation			x				x		x	x			x	x		
18 Physical measurement		x	x			x			x			x			x	
19 Online interactive simulation		x	x				x			x			x	x	x	
20 Statistical analysis		x	x			x	x		x	x		x			x	

Table XIV Human engineering T&E techniques data applications

Applications	Concept formulation ideas	Detailed design requirements	Personnel requirements info	Operational procedures dev	Training system development	Maintenance system dev	System operational evaluation	Additional human factors analysis	HFE data store information
1 Direct continuous observation	•	•	•	•	•	•	•	•	•
2 Direct sampled observation	•	•	•	•	•	•	•	•	•
3 Spec. comp. summary sheet		•				•	•		•
4 Tech. manual funct. evaluation				•		•	•	•	•
5 HEDGE/ HFTEMAN		•				•	•		•
6 Env. and eng. meas. equipment	•	•					•		•
7 System records review			•	•	•	•	•	•	•
8 Test participant history record			•		•		•	•	•
9 Interviews	•	•	•	•	•	•	•	•	•
10 Questionnaires	•	•	•	•	•	•	•	•	•
11 Motion pictures	•	•	•	•	•	•	•	•	
12 Sound tapes	•	•	•	•	•	•	•	•	
13 Video tapes	•	•	•	•	•	•	•	•	
14 Photography	•	•	•	•	•	•	•		
15 Event recording	•					•	•	•	•
16 Secondary task monitoring	•		•				•	•	•
17 Physiological instrumentation	•						•		•
18 Physical measurement	•		•				•	•	•
19 Online interactive simulation	•		•	•	•			•	•
20 Statistical analysis		•	•				•		•

7.3.2.1.2 Procedure. The detail of the observed data is in accordance with the basic considerations indicated in section 6.3.7. The observer should be skilled at being able to discriminate what significant events occur during the test, and the types of equipment (e.g., zoom lens, boom mike, etc.). These events should be summarized and interpreted for later action. The observer must be familiar with the anticipated man-machine system performance. He will observe test participants while they are using either mockups or actual hardware. The observer should be particularly interested in obtaining data on operator task times and errors. Data as to the observer's estimates of participants training, skills, and quantities should also be recorded. Life support, safety, and hardware design criteria may also be observed. The use of the direct observation technique involves the use of mockups or hardware. Therefore, the most appropriate time to use this technique would be any time after the system concept has evolved sufficiently to produce three-dimensional mockups

7.3.2.1.3 Use. Observation is one of the most common methods of evaluating personnel and system performance. It is used to some extent in some form in every test and evaluation. Despite the increasing use of automatic recording devices, the requirement for direct observation will never be completely eliminated. Observation may be used on any portion of a total system, a subsystem, or on system components. It is useful for T&E of single task performance or the simultaneous operation of several tasks by several test participants. It is simple to perform in comparison with other T&E techniques. During the conduct of the test, it is possible for the observer to do more than simply record test occurrences. The observer may evaluate test data for possible recommendations or test action items. If direct continuous observation is not used, there is a risk of missing an overall impression of the test as well as random test events or details that would otherwise be overlooked.

7.3.2.1.4 Comparison to other techniques. Table XIII provides a comparison between this technique and other T&E techniques. One of the disadvantages of using this technique is the requirement for specialized observers for each of the different test aspects or categories. It is seldom possible for a single observer to learn a sufficient amount about all system aspects to perform an adequate job of observing all system tests. The use of continuous observation implies some periods of test observation that are not productive in terms of gathering HE T&E data.

7.3.2.2 Direct sampled observation.

7.3.2.2.1 Description. 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, of course, be those which coincide with the performance of critical tasks. The determination of anticipated critical tasks should be made on the basis of the program's preceding systems analysis effort. Best guess sampling for T&E data may be performed if possible critical tasks have not been predicted by analysis.

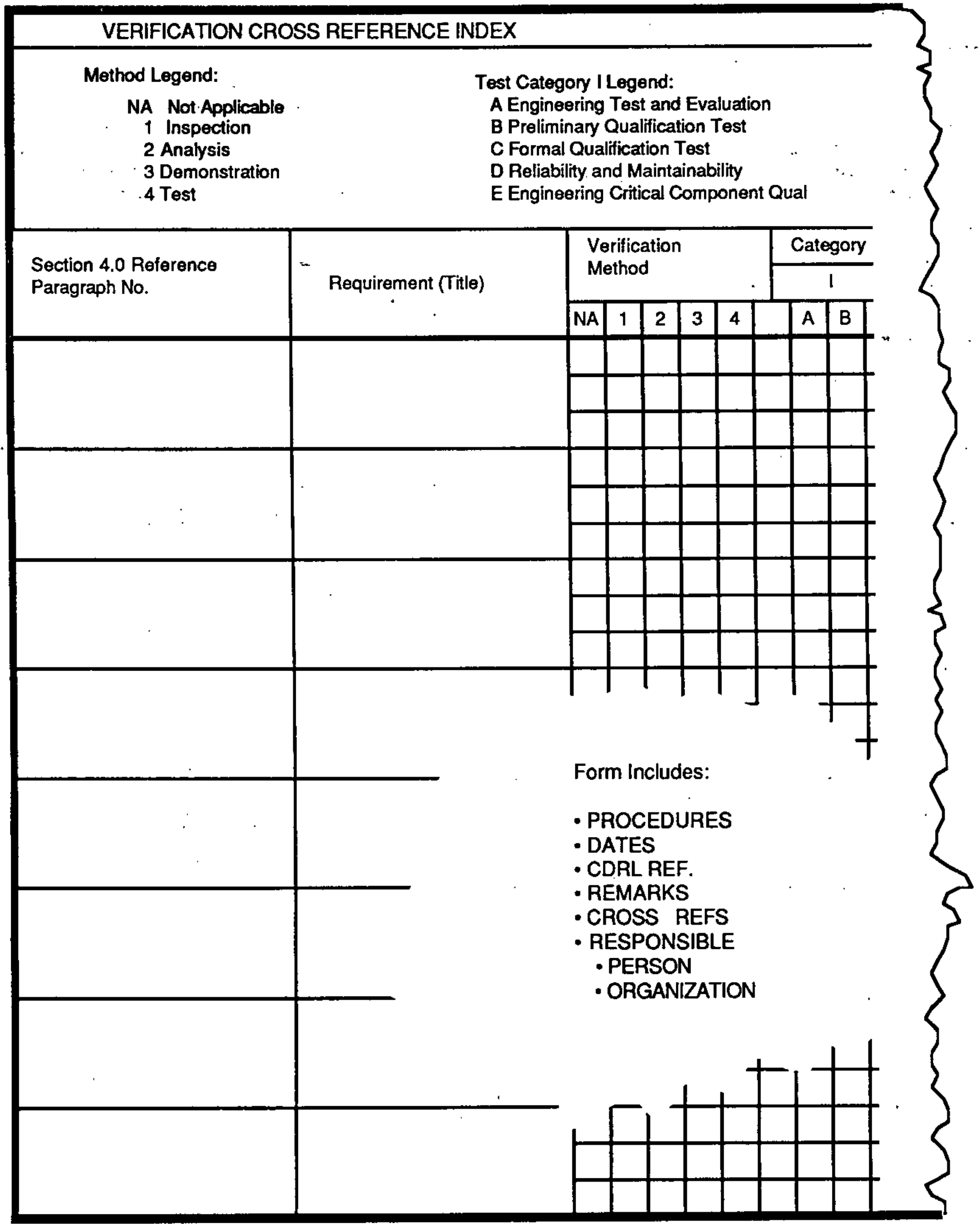
7.3.2.2.2 Use. The only difference in the use or validity of the sampled observation technique as compared to continuous observation is in cost savings and the risk of missing significant T&E data. It stands to reason that if the tests are not observed continuously, the test observers may be used to perform other HE T&E tasks on other tests or in data reduction and evaluation of previously conducted tests. The number of personnel required to perform HE T&E may be cut by a factor of one half or more. The disadvantage of the sampling technique is in running the risk of missing important operator performance data or other important HE related data. If critical tasks cannot be predetermined, test sampling should be performed with relative frequency. All basic categories or types of operator/equipment tasks should be observed several times in order to prevent skewed data.

7.3.2.3 Specification compliance summary sheet.

7.3.2.3.1 Description. This is a form that is used to verify that system performance is in accordance with specified Human Performance (HP) & HE requirements. Briefly, the total process of verifying HP & HE specification compliance is: first to decide the best method to verify the specification requirement (i.e., analysis, demonstration, inspection and measurement) 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 (see figure 31) is a way of summarizing this compliance or lack of compliance.

7.3.2.3.2 Procedure. The evaluator needs first to have a thorough knowledge of all HE aspects of the contract statement of work and the accompanying system specifications. In particular, he should understand the specification section 4. requirements (quality assurance/testing).

7.3.2.3.3 Use. This technique is used by only a few HE T&E organizations. However, this lack of use is not an indication of the lack of need for this type of evaluation. The contract and related system specifications are by far the most important program requirements. This technique is unique in that it zeroes in on these important requirements, rather than concerning itself with T&E of indirect system requirements. Table XIV shows the application for which this technique may be used.



VERIFICATION CROSS REFERENCE INDEX

Method Legend:

NA Not Applicable
1 Inspection
2 Analysis
3 Demonstration
4 Test

Test Category I Legend:

A Engineering Test and Evaluation
B Preliminary Qualification Test
C Formal Qualification Test
D Reliability and Maintainability
E Engineering Critical Component Qual

Section 4.0 Reference Paragraph No.	Requirement (Title)	Verification Method						Category	
								I	
		NA	1	2	3	4		A	B

Form Includes:

- PROCEDURES
- DATES
- CDRL REF.
- REMARKS
- CROSS REFS
- RESPONSIBLE
  - PERSON
  - ORGANIZATION

Legend: S = System Integration Demonstation (SID)
I = In-Plant

FIGURE 31. Sample Specification Compliance Summary Sheet.

7.3.2.3.4 Comparison to other techniques. Table XIII shows a comparison of this technique to other techniques. The Specification Compliance Summary Sheet is an excellent way to verify the Section 4. specification requirements. The only disadvantage associated with the use of this form is in the large amount of time required to fill it out. The effort preceding the use of this form may be considerable but that effort is a part of the already existing HE T&E program. If this technique is not used, there is a risk that some important aspect of HE design criteria may be overlooked both by designers and by test observers.

7.3.2.4 Technical manual functional evaluation.

7.3.2.4.1 Description. As its title would indicate, this technique is designed to evaluate technical manuals (TM's) 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

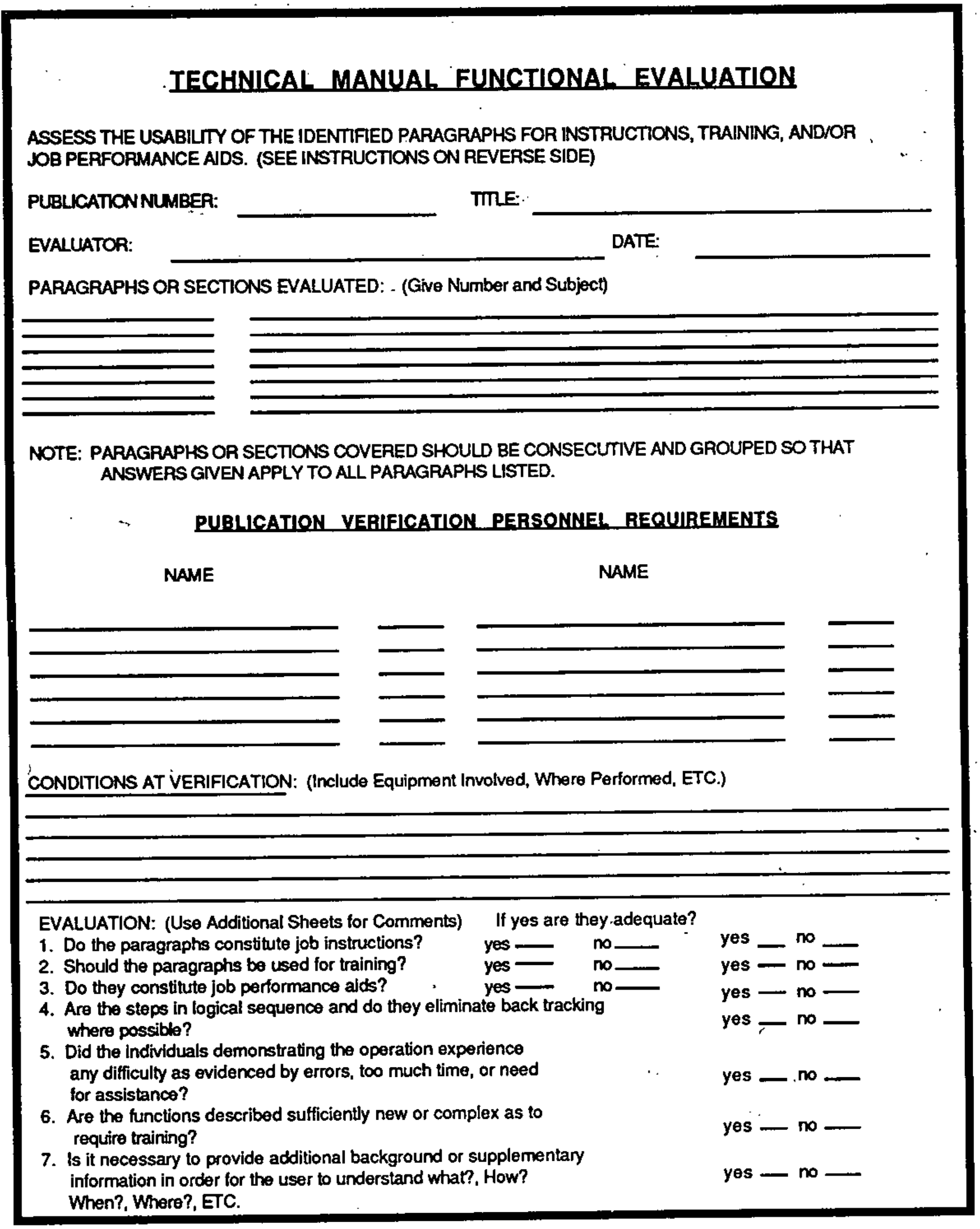
Job instructions tell how to accomplish a task by providing the step-by-step procedures along with the necessary illustrative drawings. Most technical publications which require validation or verification provide support for training. There are three major types of jobs performance aids which are identified as follows:

a. Job Guides (including inspection guideline manuals). These guides contain instructions for fixed-procedure tasks such as checkout, adjustment, removal, and replacement.

b. Fully Proceduralized Trouble Shooting Aids spell out the steps to follow in isolating malfunctions to a replaceable or repairable unit. The steps start with observable symptoms of malfunction.

c. Troubleshooting Decision Aids provide diagrammatic and supporting textual information which will help the technician decide what steps to take in isolating malfunctions to a replaceable or repairable unit.

The following sample evaluation form (figure 32) is structured so that the first three questions require two



TECHNICAL MANUAL FUNCTIONAL EVALUATION

ASSESS THE USABILITY OF THE IDENTIFIED PARAGRAPHS FOR INSTRUCTIONS, TRAINING, AND/OR JOB PERFORMANCE AIDS. (SEE INSTRUCTIONS ON REVERSE SIDE)

PUBLICATION NUMBER: ____________ TITLE: ________________________

EVALUATOR: ________________________ DATE: ____________

PARAGRAPHS OR SECTIONS EVALUATED: - (Give Number and Subject)

NOTE: PARAGRAPHS OR SECTIONS COVERED SHOULD BE CONSECUTIVE AND GROUPED SO THAT ANSWERS GIVEN APPLY TO ALL PARAGRAPHS LISTED.

PUBLICATION VERIFICATION PERSONNEL REQUIREMENTS

NAME ____________ NAME ____________

CONDITIONS AT VERIFICATION: (Include Equipment Involved, Where Performed, ETC.)

EVALUATION: (Use Additional Sheets for Comments) If yes are they adequate?

1. Do the paragraphs constitute job instructions? yes ___ no ___ yes ___ no ___
2. Should the paragraphs be used for training? yes ___ no ___ yes ___ no ___
3. Do they constitute job performance aids? yes ___ no ___ yes ___ no ___
4. Are the steps in logical sequence and do they eliminate back tracking where possible? yes ___ no ___
5. Did the individuals demonstrating the operation experience any difficulty as evidenced by errors, too much time, or need for assistance? yes ___ no ___
6. Are the functions described sufficiently new or complex as to require training? yes ___ no ___
7. Is it necessary to provide additional background or supplementary information in order for the user to understand what?, How? When?, Where?, ETC. yes ___ no ___

FIGURE 32. Sample technical manual functional evaluation form.

judgments: one dealing with the category of the section being evaluated and the other as to the adequacy. The two questions are to be answered by the test evaluator/observer, as well as the test participants. The remaining questions (4 through 7) deal with the qualitative characteristics of the technical manual.

7.3.2.4.2 Procedure. Most sections of the form are self-explanatory, however, the following sections should be completed as indicated:

a. Evaluator: Identify individual(s) interviewed or those contributing to the evaluation.

b. Paragraphs Evaluated: List only those paragraphs for which the evaluation applies. In some cases, this can be done in large blocks. There will be some events where several separate forms will have to be completed.

c. TM Verification Personnel Requirements: When verification is performed, the names and rate (rank) as well as skill code of the participants is required.

Prior to conducting this type of evaluation, the observer or evaluator must have a knowledge of the technical manual he is to evaluate. He must also be familiar with estimated system and operator/maintainer performance. The total technical manual functional evaluation process will result in either verification of the technical data or revisions or recommendations for new technical data. These revisions will be coordinated with the publications writers.

7.3.2.4.3 Use. Depending on the scope or charter of the HE T&E effort, technical manual evaluation may or may not be performed. If it is performed (by HE personnel), it may be accomplished at any time with the evaluation of any evolving systems (as opposed to future or existing systems.) The effort required to perform this evaluation is relatively low. Failure to perform this evaluation can result in several maintenance and operational mistakes that would otherwise have been avoided. The cost to perform the evaluation must be considered to be relatively low, particularly compared to the potential cost of the mistakes.

7.3.2.5 Human Factors Engineering Data Guide for Evaluation (HEDGE).

7.3.2.5.1 Description. HEDGE is a comprehensive T&E manual that can also be utilized as a T&E evaluation technique. It is designed to assist the HE engineer in the areas of test plan preparation, test conduct, test data evaluation, and analysis, and test report preparation. The HEDGE consists of two documents: the first contains detailed HE test data and the second is a guide book supplement that contains specific HE design criteria.

7.3.2.5.2 Procedure. The procedure of using HEDGE may be considered as a five step process. This procedure is well detailed on the first few pages of the manual. The first step requires that test items be classified as to vehicles, weapons, electronics, etc. The second step is to identify both the user functions and tasks related to this type of equipment; in other words, a selection is made of what to evaluate and the criteria to be used in the evaluation tests. The third step decides what human factor considerations and what item components are relevant. The test observer should review the task list and test item design description to identify which of the test item components presented in the matrix apply to the item under test, and which human factors considerations are important. In the fourth step, the test evaluator goes from the cells of HE considerations/task item components to cells containing the exact test criteria as indicated on a separate (opposite) page. The last step is to prepare the HE test plan which includes an "objective" (taken from HEDGE), "criteria" (taken from HEDGE), and "methodology" (taken from the HEDGE Supplement). The "data required" also are provided in both the HEDGE and HEDGE Supplement.

It is recommended that the test observer be thoroughly familiar with the HEDGE contents before he starts this procedure. The end products of this effort should be both itemized listing of all HE system deficient items and a general feeling of operator acceptance of the hardware item.

7.3.2.5.3 Use. HEDGE may be used on any program at any time during the program evolution. HEDGE is of more than normal value in that it provides both the basis on which to build an HE checklist (see 7.2.2.1) and all of the rest of the necessary HE T&E planning and conduct. As indicated in table XIV, HEDGE has broad applicability. No special test equipment is required to use with this technique and it will be of use with any military system. If HEDGE is not used, the appropriate HE test planning must be based on other less coordinated resources.

7.3.2.5.4 Comparison to other techniques. Table XIII shows a comparison of HEDGE to other technologies. The Navy T&E version Human Factors Test and Evaluation Manual (HFTEMAN) was derived from the U.S. Army TECOM HEDGE.

7.3.2.5.5 Controlling agency.

Human Factors Engineering Division
U.S. Army Test and Evaluation Command
Aberdeen Proving Ground, MD 21005

7.3.2.6 Environment and engineering measurement equipment. There are several different items of test or measurement equipment that are extremely useful to the HE test observer. A few of these T&E tools are presented in separate sections, but most are included here. Many of these tools require calibration and care should be taken to insure that the equipment has an up-to-date certification of its measurement capabilities. In addition many adjustments or calibrations are required in the field and users should be familiar with the use of the specific instrument before trying to collect actual test data. The following subparagraphs indicate the item of HE test equipment along with a brief description of its use:

a. Photometer. Measures ambient illumination over a range of levels from approximately .005 to 25,000 foot candles. This is an extremely useful tool. It is particularly valuable for verifying specification compliance with light level requirements. Sophisticated mockups or prototype equipment/facilities are required for the proper use. Most photometers are relatively easy to use.

b. Spot Brightness Meter. Measures small area brightness in foot-lamberts within angles of approximately one degree or less. This tool is most useful for measuring prototype hardware display brightness such as from LED's or CRT's. Specification compliance may be verified with the spot brightness meter.

c. Sound Level Meter and Analyzer. Measures steady state sound in the approximate range from 10 to 150 db for standard weighted noise curves. The analyzer provides octave band analysis for the more critical speech range center frequencies. Specification compliance in terms of noise curves and speech interference levels may be verified with this equipment. Hazards to test personnel may be checked prior to overexposure conditions. Most sound level meters are relatively easy to use.

d. Vibration Meter and Analyzer. Measures amplitude and frequency components of complex vibrations. The analyzer may be used to determine amplitudes at selectable frequency bands in a range from 2.5 Hz to 25 KHz. Potential vibration hazards to test participants may be checked before actual test exposure. Specification compliance may also be verified.

e. Thermometer. Measures air, surface, or liquid temperatures. May provide a digital readout in either Celsius (centigrade) or Fahrenheit. Should include capability for attachment to several temperature sensor probes.

f. Anemometer. Measures local air flow in the range of 0 to 1000 ft/minute. This device is most useful for determining crew comfort conditions.

g. Hygrometer or Psychrometer. Measures relative humidity by wet and dry bulb thermometer method. This device is also very useful for determining conditions for crew comfort.

h. Gas Tester. Permits convenient short-term sampling and evaluation of many toxic gases, vapors, and fumes.

i. Force, Torque, and Dimension Kit. Various instruments for measurement of a wide variety of operator or equipment forces, torques, and distances. The force measurement limits should be from 1/4 oz. to 250 lbs. Torque measurement should range from 1/2 in.-lb. to 160 ft.-lbs. A tape measure should be capable of measuring distances up to 50 feet. Scales should also be for measuring centimeters, millimeters, inches, and fractions of inches. A protractor is useful for angular measurement.

j. Anthropometry Instrument Kit. Allows measurement of significant body dimensions using the anthropometer, spreading calipers, sliding caliper, gonimeter, and tape measure. The measurement of test participants is critical to the evaluation of workspace layouts, particularly when egress and ingress are important considerations. Care should be taken to insure the proper measurement procedures are adhered to while obtaining participant anthropometric data.

7.3.2.7 System records review.

7.3.2.7.1 Description. There are a number of typical test and evaluation program records that may be useful for review by the HE 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.

7.3.2.7.2 Procedure. All that is required on the part of HE evaluators is to obtain permission to review the existing test records and to go ahead with the tedious task of looking through them. The evaluator should, of course, have some sort of system knowledge to know what he is looking for in terms of anticipated human performance. Typically, system records will contain test logs, maintenance records, and debriefing records. The HE evaluator may find data on equipment operation problems, technical publication inadequacies, human initiated errors, and training inadequacies.

7.3.2.7.3 Use. This technique is best used for gathering man-machine performance data. Because the HE evaluator does not actually observe the test, it is doubtful that sufficient evaluation can reliably take place just by reading a word description of what occurred. Human performance tests may have to be scheduled for the purpose of formal observation of HE personnel. Table XIV shows the applications derived from this technique.

7.3.2.7.4 Comparison to other techniques. Table XIII provides a comparison between this technique and other T&E techniques. The problem with a review of test records is that they tend not to be designed for gathering HE data. What the evaluator is able to obtain from these records may be misleading. There is significant risk that HE problems that could be readily apparent by direct observation, are unobserved or obscured by other less significant test data. In order to enhance the value of system records review, the personnel who initiate these records should be indoctrinated in the value of HE and HE T&E. It is generally agreed that the use of this technique is not typically required. It is recommended that it be performed only when direct HE observation is not possible. The debriefing records should be the most useful of all the system records normally available.

7.3.2.8 Test participant history record.

7.3.2.8.1 Description. 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 participation in the tests, if possible. Otherwise, the form may be completed as part of the post-test interview. The sample forms included in the following pages (figures 33 & 34) emphasizes participant training, experience in systems similar to the one being tested, and participation in previous testing related to the same over-all system presently being tested. These forms may need to be modified to suit the needs of the particular test situation.

7.3.2.8.2 Use. In collecting and reporting human subject test data HE personnel must comply with the applicable informed consent, privacy and related requirements or regulations. They must insure that the identity of the subject will not be made available to the public without their consent. The purpose or use of this form is to assist in the evaluation of the obtained test data. For example, if the test participant has had little or no experience in performing tasks similar to the ones he has been given to do as a test participant, and he does very well, then the conclusion is that the man-machine interface being tested has been well designed and developed. If, on the other hand, his performance is poor, the problem may or may not be due to poor man-machine interface design. A more experienced test participant will have to be given the same tasks to perform.

PS TEST PARTICIPANT HISTORY RECORD

NAME/RANK ______________________ DATE ______________

______________________ TIME ______________

TRAINING

COURSE	DATE	PARTICIPATION IN PREVIOUS TESTING

RELATED EXPERIENCE

FIGURE 33. Sample test participant history record.

PERSONNEL DATA FORM

A. To be completed by test participant.

1. NAME ______________________ 2. DATE __________

3. MOS ______________________ 4. ID No. __________

5. Crew Position (in the test) ______________________

6. Months of experience (in tested crew position) ______________________

7. Height __________ 8. Weight __________ 9. Date of birth __________

10 Length of service __________ years, __________ months

11. Civilian Education: (a) 1 2 3 4 5 6 7 8 9 10 11 12 13
14 15 16 (circle number of years)
b. Major area (if applicable): ______________________

B. To be completed for each participant by test control personnel.

12. Physical Profile:

P	U	L	H	E	S

13. Aptitude Scores: (a) CO ____ (b) FA ____ (c) EL ____ (d) OF ____
(e) GM ____ (f) MM ____ (g) CL ____ (h) ST ____ (i) GT ____
(j) SC ____ (k) EI ____ (l) GI ____ (m) CI ____ (n) AD ____
(o) SK ____ (p) TI ____ (q) AI ____ (r) AP ____ (s) PA ____
(t) MK ____ (u) WK ____ (v) AR ____ (w) MC ____

14. Latest MOS test score: ______________________

15. End-of-training test score: ______________________

16. Minimum performance (a) required: __________ (b) attained: __________

17. List of military schools and courses completed: ______________________

____

____

FIGURE 34. Sample personnel data form.

The time and effort it takes to complete the form is small, and the potential value of having the test participant's significant history is large. (ref. 5)

7.3.2.9 Interviews.

7.3.2.9.1 Description. The HE T&E interview technique is simply the process of the HE test evaluator discussing the test events with the participants. This discussion should be structured in order to insure that the most information is obtained in the least amount of time. Specific variations to the general interview technique may be of use for particular situations. For example, considerable test evaluation data may be obtained from training instructors. They are particularly knowledgeable in regard to student problems with new systems because of inadequacies in the system design.

7.3.2.9.2 Procedure. The first step in the process of conducting the interview is to develop a format for asking questions of the participants (interviewees). The format may be structured like a checklist to insure that all pertinent aspects of the test are considered. The second step is to select an interviewer who has had experience with the system being evaluated. It is important that he has observed the actual test conducted. The next step is to arrange a time to conduct the interview with the test participant. The following general guidance is applicable to interviews.

a. The interviewee should be questioned about the task he has performed. He should describe what he thinks his test task consists of in terms of his duties and those of others. His opinions should be obtained on the adequacy of the equipment, technical data, logistics, and preparatory training.

b. The interview should be conducted as soon as practical after the actual test, hopefully within a few hours. If possible, the interview should be conducted on a one to one basis rather than one interviewer questioning several participants at one time. The area selected for the interview should be relatively quiet with a minimum of distractions. The time taken to conduct the interview should be less than half an hour. Interviews which are longer than this start to be boring and become an imposition on the interviewee.

c. The HE interviewer must take care to insure that he is obtaining the interviewee's actual opinions as to the test situations and not what the interviewee thinks the interviewer wants to hear. The participant must be assured that he is not being graded in any way on his responses. The HE interviewer should try to quickly develop a rapport with participants. If the participant agrees, a tape recording may be taken of the interview. However, whether the participant agrees or not, some individuals tend to be intimidated by the use of tape recordings and caution must be used in this regard.

Another example of an interview technique is the "critical incident technique". The critical incident technique consists of a set of procedures for collecting observations of human behavior in such a way as to facilitate their potential usefulness in solving practical problems. A critical incident is any observable human activity, the purpose and serious effects of which seem clear to the observer. The five step procedure is basically as follows: a) Determination of the general purpose of the activity; b) Development of plans for collecting incidents regarding the activity and instructions to the persons who are to report their observations; c) Collection of relative objective data; d) Analysis of the data; and e) Interpretation and reporting of the statement of the requirements of the activity. The gathering of the series of incidents consists of inquiry as to most effective or ineffective behavior (or critical incident) of specified activities/jobs. Although the incidents may be secured by interviews, they may also be obtained by written responses The end product of the interview is a quantity of data (facts and opinions) to review and evaluate for the purpose of presenting system problems and recommendations, and in many cases system verification.

7.3.2.9.3 Use. The interview is one of the most significant evaluation methods used. It is a simple, low cost, quickly used technique. Every test involves a certain amount of test data that cannot be obtained through normal observation. Interviews with the test participants draw directly on this type of data and on the knowledge of the presently available system experts. Interviews do not require the use of test facilities. They may be conducted in an area remote from the test site. The following may be of help in conducting interviews.

a. The purpose of an interview is to find out either objective facts related to the system about which the interviewee has some knowledge, or subjective information, attitudes, or opinions about how he feels about some test aspect. The interview must be designed to obtain these facts with as much clarity and accuracy as possible.

b. The interview attains its greatest value from the relationship which is established between the interviewer and the respondent. In a properly conducted interview, where a genuine rapport is established between the interviewer and the interviewee, it is possible to obtain more detailed and reliable data than from the self-administered questionnaire.

c. One caution that must be pointed out in the use of interviews is bias on the part of the interviewer or interviewee. Ideally, the interview results in the interviewee supplying accurate information to the interviewer. However, the influence of bias can alter the results to such an extent that the answers are of little or no value in the final analysis. The interviewer may bias the interview by tone of voice, the way in which the questions are phrased, or even by facial expressions. These and other sources of bias can be greatly reduced through recognition of the problem and by training and experience.

d. Another caution associated with the use of interviews is that they cannot be used as a substitute for direct test observation. They should be used as one of several HE test and evaluation techniques. (ref. 6)

7.3.2.9.4 Comparison to other techniques. Table XIII provides a comparison between interviews and other T&E techniques.

7.3.2.10 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.

7.3.2.10.1 Description. The questionnaire provides a structured method for asking a series of predetermined questions in order to obtain measurable expressions of attitudes, preferences, and opinions. The design of a questionnaire which will produce valid and reliable results requires a measure of skill and experience. Unfortunately, questionnaire design and construction cannot be taught from books; the requirement for each test are somewhat different and present new and different problems. However, there are certain rules and principles of questionnaire design and administration which, when followed, eliminate some of the more common pitfalls which result in faulty questions and invalid results. The following material, especially the references, are intended to provide guidance for planning, designing, and administering the questionnaire.

7.3.2.10.2 Procedure. The method of questionnaire design applicable to the types of tests conducted by HE T&E personnel may be divided into seven logical steps.

a. Preliminary planning.

b. Selection of the question form

c. Wording of the questions.

d. Formulating the questionnaire.

e. Pretesting.

f. Administering the questionnaire.

g. Quantification and analysis of questionnaire data.

The preparation of a questionnaire requires great care and a background knowledge of the system to be tested. Knowledge also is required regarding the background of personnel to whom the questionnaire will be administered, and the type of analysis which will be made of the results. Too often a questionnaire is prepared with insufficient planning. The problems involved and the weaknesses in the design are frequently not recognized until such time as the results are interpreted. 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.

d. The rating scale

Each form has its merits and disadvantages of which the questionnaire designer must be aware and must weigh carefully before final selection. No one question form is superior to the others in all cases. In order to select one form over another, the designer must be aware of the advantages and disadvantages of each and choose that form which best meets the needs of the particular test situation. The following guidance is applicable to questionnaire design:

7.3.2.10.2.1 Wording. The most important, and also the most difficult, aspect of questionnaire construction is the wording of the questions, Most authorities agree that faulty or improper wording of questions accounts for the greatest source of error in the questionnaire technique. Errors and distortions in the final data are often caused by misunderstanding and misinterpretation of questions due to use of an improper vocabulary level and ambiguous phrasing. In addition to selecting the question forms and the wording questions it also is necessary to consider such factors as the sequence of the questions and the format for presentation and data collection. A check must be made of all questions to insure complete and accurate coverage of all data required by the test objectives and test critical issues.

7.3.2.10.2.2 Pretest. A questionnaire is subject to many variables and must not be assumed to be perfected until it has been subjected to trial use. The pretest provides an opportunity to try the questionnaire out on a small sample of respondents. The result of this trial may then be used to make revisions and improvements as necessary before test administration. The pretest is the final and validating step in the method of questionnaire construction.

7.3.2.10.2.3 Product. The product obtained from administration of the questionnaire consists of subjective words or phrases. This information may be quantified and converted to figures or numbers that can be tabulated and analyzed. The end product of the questionnaire may be a simple frequency distribution of responses to each question summarized in terms of numbers, proportions or percentages. The data may be further summarized to include averages, standard deviations, or correlations. The summaries also may include statistical analyses showing the statistical significance of differences or correlations obtained. These quantified data must then be tabulated and analyzed. The results usually are summarized in tabular form for inclusion in a final report.

7.3.2.10.2.4 Comparison to interviews. When compared to the interview, there are several similarities and differences with the questionnaire. Both the questionnaire and interview should be conducted within a few hours of the test for best results. Both techniques may be conducted away from the test area. Although the questionnaire must be more structured than the interview, the questionnaire may still include open-ended questions. The differences are in that HE personnel need not be present while the questionnaire is being filled out. The questionnaire is inherently easier to use in evaluation or analysis of the participant responses.

7.3.2.10.2.5 Use. The questionnaire is a subjective measurement tool for systematically obtaining attitudinal responses from a selected group of individuals. The function of the questionnaire is to communicate information. When properly formatted, it also aids in the tabulation of data and analysis of results. The questionnaire is used to assess a wide variety of qualitative variables such as acceptance, ease of use and preference. It may be administered to small groups of technical personnel, such as those involved in highly controlled engineering tests, or to larger representative cross-sections of service personnel. The following should be considered in the use of questionnaires.

a. Knowledge of individual or group attitudes provides valuable information regarding reactions, feelings, and preferences toward military systems. Since attitudes determine behavior, questionnaire responses of a representative sample of the population permit a reliable estimate of group reactions to systems in actual use. These results also may be used to anticipate and thereby avoid future developmental problems.

b. The questionnaire is appropriate for use in all types of tests. It should be used to obtain subjective data when objective measurement is not feasible and when qualitative data are needed to supplement objective measurements. However, it should not be used in place of direct observation techniques if observation is possible.

c. A disadvantage of the questionnaire is that test participants won't respond in writing to the degree that they would in talking in a response to an interview. The effort to write responses to open-ended questions is greater than the effort to talk. Another disadvantage of the questionnaire, compared to the interview, is the inability of the HE observer to pursue a participant response that is unexpected but potentially fruitful.

d. One of the most difficult problems to overcome in questionnaire design is the misunderstanding as to what a questionnaire is and how it should be used. Some believe that anyone who can write reasonably well and use a little common sense can construct a good questionnaire. The seriousness of this faulty assumption is illustrated in that an improperly designed and poorly worded questionnaire will still yield data in the form of numbers, e.g., frequencies or percentages. These numbers are amenable to statistical analysis and may even produce statistically significant findings. The real mistake is that these erroneous findings may be used to draw false conclusions which, in turn, contribute to faulty critical decisions regarding the utility of an item.

7.3.2.11 Motion pictures. This technique is similar to the use of video tapes (see 7.3.2.13). It is the process of filming participant performance as a part of a system test.

7.3.2.11.1 Procedure. As with video tapes, 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 picture effort on unsuccessful concepts. Permission to use cameras in secure areas must be obtained and the camera equipment and cameraman properly scheduled. Trained test participants must be available for observation of their appropriate tasks. The cameraman, and particularly the HE observer, should be familiar with the test operation being performed. The knowledge of when to take close-in footage of a particular critical task is important. As in the case with video cameras, a dry run is recommended to insure the filming is properly performed. Consultation with all personnel familiar with the anticipated test events is advised. The following equipment is necessary to implement this technique

a. camera and (film)

b. lens

c. lights

d. projector

e. screen

A tripod may be required, depending on the test situation.

7.3.2.11.2 Use. This technique was comparatively more useful before the development of video tapes. Video tapes are now become popular for that type of test and evaluation process. However, when compared to all other techniques, motion pictures still offer some advantages of: permanent precise records of observed events, repeated observations of the same event, slow and fast motion study of real-time events, use in hazardous areas, and record of task activities as well as the related background situation. The data gathered may be presented to large groups of people. The disadvantages are in the cost and effort to provide the proper equipment, particularly for processing and viewing the film. Skilled technicians are generally required for the filming of motion pictures. Motion pictures are not as useful as video tapes in that they must be processed to be viewed.

7.3.2.12 Sound tapes.

7.3.2.12.1 Description. The use of this technique is now so common that a description is somewhat superfluous. Tape recorders are both inexpensive and portable. They are used extensively for tasks other than formal test observation. Test observers commonly use sound tape recorders to maintain a complete record of test conversation and events. Test notes may be verbally entered by the observers themselves. The recorders may also be used to record participant interview comments. The recorder may be linked into the intercommunication system if such is used as a part of a large scale multioperator test. The use of both sound tape and video tapes together is frequently valuable.

7.3.2.12.2 Use. Sound tapes are now a well used test/evaluation technique. Their use is extremely easy and inexpensive. They have the same advantages as the video tapes in that they are a permanent record of events (audio), they may be repeatedly reviewed, they may be used with time tags if desired. In addition to this, sound tape recordings negate the need for detailed handwritten notes. One disadvantage to the use of the recordings is in the quality of the reproduction if a high ambient noise is present near the test data being recorded. Another possible disadvantage is if the test participant becomes self-conscious due to the use of the recorder. This would be more noticeable during an interview. There is also the problem of loss of data due to weak or dead batteries and time required to change tapes. If the tape recorders are not used, good note taking becomes much more important

7.3.2.13 Video tapes.

7.3.2.13.1 Description. This test and evaluation technique is the use of video cameras and related equipment to make video tape recording for detailed review and evaluation of operator and maintenance personnel tasks. The following may be of help in considering video tape techniques.

7.3.2.13.1.1 Half-inch video tape. The proliferation of inexpensive half-inch home video equipment and its usage has led to the capability for easy data gathering and analysis. This home equipment usually has between a 40 to 100 mm lens, about a 6 to 1 zoom ratio, and ever smaller cameras and recorders. The video tape comes in cassettes approximately 4 inches by 7.5 inches which allows for easier storage and handling. Currently the 8mm cassette equipment offers a camera and recorder in one handheld unit. Because these units are built to operate in normally lit houses they can record at fairly low light levels. In spite of this low light level capability, portable lighting should be provided if possible as better quality footage will result when high quality lighting is used. Most cameras provide a built in mike for including audio on the video tape. The more expensive VCR's provide freeze frame and slow motion play back capability to aid in any analysis. Half-inch video editing equipment is not readily available. This limits special editing effects such as composing, dissolve, and adding text and graphics to the original tape. In order to accomplish this, it would be best to convert the half-inch to three-quarter-inch tape for editing. It could then be converted back to half-inch if required.

7.3.2.13.1.2 Recording events. As with any of the other techniques amateur operators should observe several cautions. In order to obtain the best record of an event (i.e., test), operators should enlist the cooperation of the test conductor. In addition they should establish which portions of the test can be rerun or interrupted to aid in the taping. A script, or list of events, should be used so that the cameraman will know the sequence and timing of events. To obtain a good record of the event, the video taping is just as important as the test itself. Tape is cheap so several angles and views should be recorded if possible. Most amateur operators do not let the tape run long enough they should start taping approximately 20 seconds before a sequence begins and let the tape run 20 seconds after a sequence finishes. This will insure everything is captured on tape. In preparing the camera, the cameraman should set the lens filter and then adjust the white set on the camera to allow for the available light color temperature. Then the electronic iris should be set to balance the blue and red, if these features are available on the model being used. Trained test participants should be available for HE evaluator observation of their appropriate tasks. The camera operator(s) and particularly the HE evaluator coordinating the video data recording should be reasonably familiar with the test operation being performed. The knowledge of when to use the zoom lens to home in on a particular critical task is important. In order to be sure all the more critical tasks are properly recorded, dry (or test) runs of the test may be advisable. Consultation with all personnel familiar with the anticipated test event is recommended.

7.3.2.13.1.3 Equipment. The following equipment is necessary to implement this technique:

a. video tape recorder.

b. VCR portable camera

c. zoom lens

d. monitor

e. portable lights

Additional lenses, monitors, and tripods may be desired depending on the complexity of the test. Additional sound recording equipment may also be desired.

Problems associated with the use of video recordings involve: the logistics of transporting the equipment to the test site; the security of the equipment; permission to record any occurrences in secure areas (e.g., restricted, or classified areas); and request to perform recording on a possible test interference basis.

7.3.2.13.2 Use. There is little doubt that given the video tapes and proper display equipment, the use of this technique is of notable value. However, the cost effectiveness of the technique must be considered to be dependent upon the complexity of the test needing evaluation. Possible transportation and set up problems should also be considered before commitment to the use of this technique. The following considerations also apply.

a. Careful review of tape playbacks can reveal human errors and excessive task times not previously capable of being detected. The application of maintenance crew teamwork may be examined. Improper procedures may be thoroughly evaluated. Improper malfunction determinations may be traced back to the point of the original mistake. Technical publications and training can be methodically evaluated. The adequacy and proper use of tools may be verified.

b. Depending on how they are used, video tapes may account for less test interference than direct test observation alone. This would be true for an equal amount of test data gathered as a result of a relatively complex test. Once recorded, the data record is permanent and may be presented for use to numerous persons including the performing organization and requiring organization alike. The tapes may be easily stopped, started and backtracked for repeated observation. Each task may be thoroughly examined step by step. Test sequences that may not be properly recorded may be easily reviewed and retaken. Further advantages include the fact that observer errors are reduced, the observation can be recorded and observed remotely from what might be a hazardous or congested area. The tapes may have considerable use as training aids. They require no time to process, but motion picture films do. The tape itself is reclaimable: it may be used over and over again for different tests. The record of time tags along with the video is possible.

7.3.2.13.3 Comparison to other techniques. Table XIII provides a comparison between video tapes and other T&E techniques.

7.3.2.14 Still photography.

7.3.2.14.1 Description. This technique is perhaps too simple to be considered as such and should be described rather as a HE test and evaluation tool. It is, very simply, the process of taking photographs of whatever tasks, objects or events that are pertinent to the HE effort. As in the case of the video records, actual prototype hardware or mockups must be available to justify the use of the tool. HE test operators must be familiar the test to know when the critical tasks or events require the visual record. In addition to the camera, a tripod and special lighting may be required. Flash attachments are easily used. Depending on facility and agency requirements, a photographic pass may be required. The location of the test may restrict the use of cameras. Instant film type cameras are convenient in that they provide an instant picture for evaluation as to the need for additional pictures. However, the quality of the instant picture cameras tends to be inferior to those which produce the large 8 x 10 shots. The results of the photography generally are appropriate for inclusion in test reports or other HE test and evaluation reporting forms.

7.3.2.14.2 Use. Naturally, photography is a well used HE test and evaluation tool. It is easy to use and may be done quickly. The particular advantages gained in using this technique are similar to some of those for the video tapes and motion pictures, e.g., the photograph is a permanent record which may be reviewed, it may be used as a training aid, and decreases observer errors about what really happened. Photographs are used extensively in HE testing for analysis of anthropometric interface problems. Table XIV shows many of the general applications of the photography techniques.

7.3.2.14.3 Comparison to other techniques. Table XIII provides a comparison between photography and other T&E techniques. The obvious disadvantage associated with the use of this T&E tool is in the single frame static picture rather than the dynamic picture created by motion pictures or video tapes. A small problem may be created by the logistics of obtaining the photographic equipment and or camera personnel and the permission to use the equipment in the test area. Alternatives to photography are the more expensive video tapes or motion pictures or possibly a good fast-sketch artist assigned the duties of the HE test observer. In a few instances, a large number of descriptive words written in the test reports may substitute for a photograph of the situation or equipment that they are describing, but these descriptions are seldom completely satisfactory.

7.3.2.15 Event recording.

7.3.2.15.1 Description. This is a technique or method for recording real time test situation or event times. The equipment involved in the use of this technique varies in complexity from the stopwatch to complete systems. The more complex event recorder systems might include: an event recorder, battery pack, event control box and a signal cable. The event recorder itself should be capable of recording on several channels; the battery pack is to give portability to the operation; the control box is used to actuate the various channels in the recorder, and the signal cable is to electrically tie the control box to the recorder, other recording systems are provided which combine these units into one easily portable package.

7.3.2.15.2 Procedure. The sequence of events which might occur with the use of this technique may be as follows:

a. HE personnel who are to observe the particular test first become familiar with the planned test events. They estimate what tasks are more critical and should be recorded in terms of time performance. If the tasks to be monitored are particularly critical they may even perform a dry run of the test or plan to run multiple replications of the same critical task.

b. The total test may be divided into several functional tasks and each such assignment allocated to a separate channel. Examples of such task functions are reading technical publications, actuating controls, reading displays, and making adjustments.

c. The channel controls are easily activated for each of the task functions as they start and stop. It may be necessary to write start labels for each event on each of the channels plotted on the recorder chart paper roll. Figure 35 shows a sample of this type of annotated record.

For several years recording equipment has been available that does not require the use of the paper role for a record of events. 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 are later transmitted to the computer by connecting the device via a simple connecting cable. In this manner, computer written reports may be written in minutes. This device includes a space for written notes on an integral note pad. The direct outputs of each of these event recording techniques varies from handwritten notes to complete computer printouts of evaluated data. The eventual outputs are verification of task time data.

7.3.2.15.3 Use. Most HE test and evaluation efforts will require the use of one of the following but previously indicated event recording techniques or some variation thereof:

a. Event recorder and separate control

b. Combined function solid state memory data collector.

c. Stopwatch.

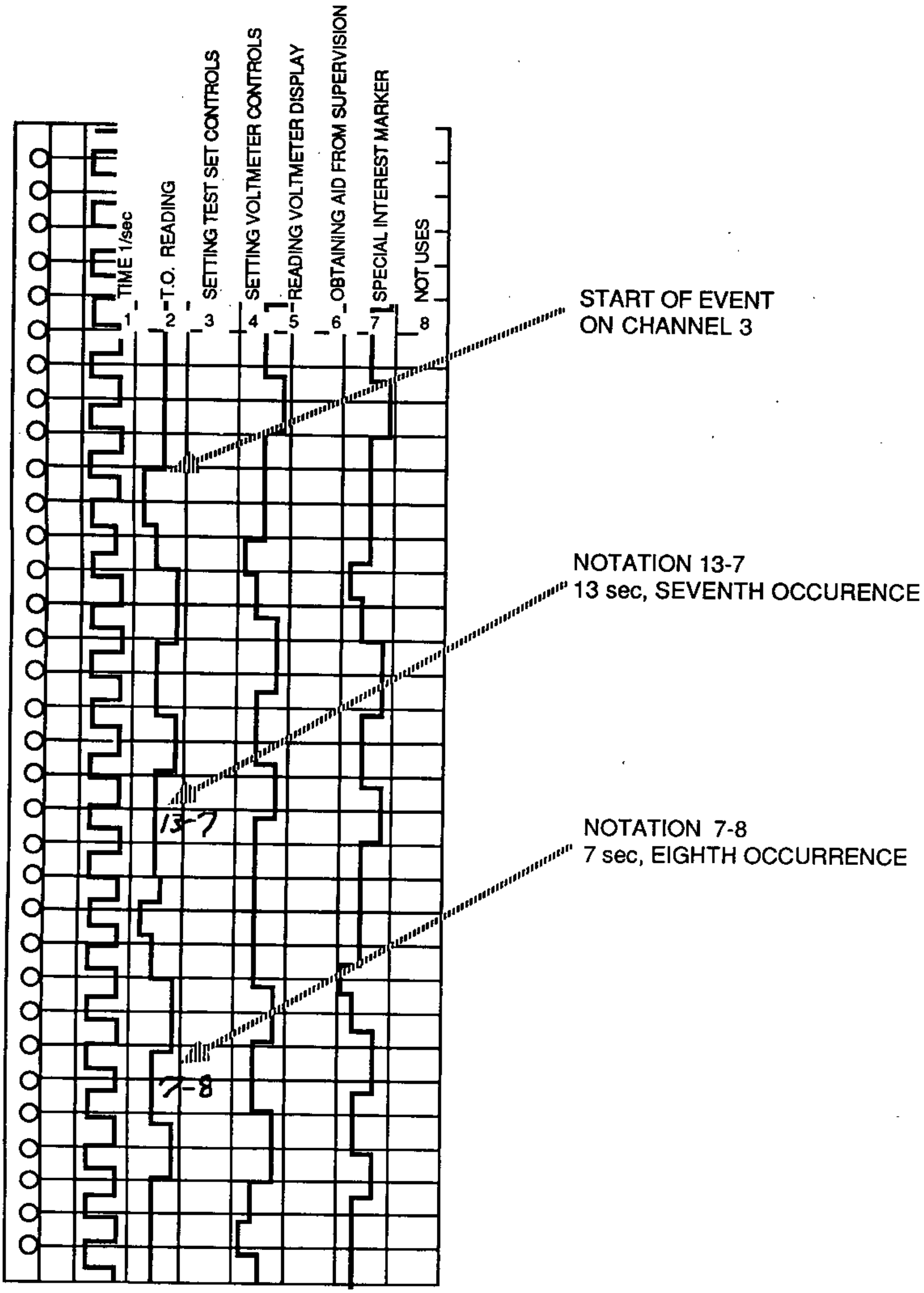


FIGURE 35. Sample annotated event record.

When critical test events must be recorded and evaluated, these techniques prove valuable for determining system/ operator time performance capabilities. Two of these techniques allow several task functions to be recorded at once. The observer may thereby direct more of his attention to the other aspects of the test. The stopwatch is, of course, by far the cheapest method of the three of recording time. It may, upon occasion, be the most cost effective. It is, however, more error prone than the other methods. The recordings made from the other two techniques can be used for timeline, task loading and time sharing analysis.

In general, all recording techniques will measure objectively human performance and provide useful data for the test as a whole. The techniques can be used with very little test interference, The training required to use the technique equipment varies with the equipment complexity but is generally uncomplicated. The data are applicable for time to accomplish tasks, evaluation and optimization of tasks involving team work, and the isolation of specific points that degrade turn-around times, loading times, and launch times. The technique may not be used for evaluation per se, but further analysis must be made of the data using other techniques. (ref. 7)

7.3.2.15.4 Comparison to other techniques. Table XIII provides a comparison between event recording and other T&E techniques.

7.3.2.16 Secondary task monitoring.

7.3.2.16.1 Description. For the purpose of determining crew workload, test participants are given both operational tasks and secondary tasks to perform. The secondary tasks may or may not be meaningless in relation to the rest of the test set up. They are, however, in no way necessary to the operational tasks being tested. The secondary tasks are performed with prototype hardware or hot mockups on special equipment that is instrumented through hardware or telemetry to record crew performance.

7.3.2.16.2 Procedure. The participant is instructed to perform the secondary tasks when not required to perform the operational tasks. The time taken to perform the secondary tasks is recorded and subtracted from the total time available. In this manner, the "crew workload required to perform the operational tasks is implied on the basis of the measured time (or effort) not spent doing those same operations

7.3.2.16.3 Use. This is a useful technique to measure crew workload particularly when it is not feasible to monitor directly the operational performance parameters. Because workload can be quantitatively measured in this case, it can be more accurate than many other workload evaluation techniques. The cost and effort to implement this technique is relatively high as compared to several other HE T&E techniques if the secondary task data are recorded automatically. However, the cost is inherently lower than monitoring operator performance on each of the operational controls (and, if possible, displays). There are two basically different types of secondary task monitoring. The first type uses secondary tasks that are completely unrelated to the system operational tasks. These are make work tasks. The second type is more sophisticated in that the secondary tasks are essentially the same as the required operational tasks. Test participants seem to have more motivation to do the more real secondary tasks rather than the make-work tasks.

7.3.2.16.4 Comparison to other techniques. Table XIII provides a comparison of this technique with other T&E techniques.

7.3.2.17 Physiological instrumentation.

7.3.2.17.1 Description. 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.

a. Physiological measurement requires more commitment from the test participants. The purpose of the instrumentation may be to monitor physiological parameters to insure that the participant remains in a safe range of performance. The implication of this is that there is a possible unsafe range of performance and therefore more commitment required on the part of the test participant. Even if this is not the case, the encumbrances of the test sensors on the participant are generally somewhat annoying.

b. When conducting tests with human subjects the applicable informed consent requirements and regulations must be complied with. The proposed test must be explained to the test subjects (i.e., nature, duration, and purpose of the test etc.). In addition all reasonably foreseeable risks (i.e., injury, death, inconvenience, and discomfort etc.) must be disclosed. The identity of the test subject will not be made available to the public without his approval. All tests must be approved by the appropriate agency and have subject informed consent before collecting data.

7.3.2.17.2 Procedure. Medical personnel must approve the test. Generally, they should perform the test set up of the instrumentation system. This would involve the attachment of the sensors in a manner to minimize their effect on the total test. Medical personnel must also be present during the test if any participant risk is involved. Electronics technicians may also be required to adjust the test instruments. In addition to the individual parameter sensors located on the participant, wire leads must be provided. Attached to the leads would be the appropriate transmitters (if telemetered), receivers, and amplifiers. Instruments for displaying parameter values and chart recorders will also be required. Parameters that might be monitored are as follows:

a. heart rate, blood pressure

b. respiration rate, volume

c. Galvanic Skin Response (GSR)

d. Electroencephalograph (EEG)

e. Electocardiograph (EKG)

f. body temperature

g. body movement including eye blink.

Upon completion of the test, medical personnel are required for analysis and evaluation of the resulting test physiological data.

7.3.2.17.3 Use. Physiological measurement is performed much more for research testing than for operational or field type testing. It is also used when there is a possibility of risk involved, for example, centrifuge runs. Physiological testing is seldom intended to measure total system performance, let alone the more normally monitored operator performance parameters of time and errors.

7.3.2.17.4 Comparison to other techniques. The cost to perform this type of testing is relatively high and the effort involved by HE, medical, and technical personnel is considerable. Because of the nature of the test itself, which would require the use of physiological instrumentation for safety, the testing must be considered to be performed on an interference basis. When physiologic monitoring is really needed, there is no substitute technique that may be used to obtain the necessary data. The only alternative of constantly stopping the test to take time out for the required measurements is unacceptable. By use of radio transmitters, the technique may be monitored remotely away from the test area. Notable use of this technique has been in manned space programs (ref. 8), Army system portability testing and Navy, and Air Force new aircraft flight tests.

7.3.2.18 Physical measurement.

7.3.2.18.1 Description. 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 are presented in this section. 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.

7.3.2.18.1.1 Anthropometry. Anthropometric measurements may be made of each of the test subjects to be used in a hardware prototype mockup test. These measurements are taken on the assumption that the test will indicate various areas of work space or work access verification. If problems are indicated, rather than designs verified, then detailed measurements are taken as to exactly how much of a work space problem exists. If much of the test is to hinge on the ability of the test participants to fit the equipment (e.g., vehicle egress), the subjects may be specially screened and chosen to fit the worst case (larger) population percentiles (95th or 98th percentile). If a subject with 98th percentile buttock-knee length the 98th percentile shoulder breadth can successfully egress with the given vehicle dimensions, then it may be assumed that most operators will be able to do the same at least in terms of egress space.

7.3.2.18.1.2 Oculometry. This is the technique of measuring the test participant's eye movement while he is seated at (in) a mockup or prototype hardware of the system being tested. The oculometer is used to view the participant's eye movement in terms of deflection rate and amount. The instrument and associated equipment is capable of recording the links between controls and displays, the dwell times on each, the total number of eye contacts, and the probability of next contact. The oculometer performance is at a half degree at 30 inches from the eye within an envelope 30 deg. up, 10 deg. down, and 60 deg. horizontal. Once these data are recorded, panel layout adequacy is verified by the quantity, location, and rate of eye movements.

Physical measurements may also include participant muscular strength, body weight, limb coordination, visual, and auditory acuity, and kinesthetic response.

7.3.2.18.2 Use. The use and value of these physical measurement techniques is as follows:

7.3.2.18.2.1 Anthropometry use. It is relatively easy to measure test participants to determine their anthropometric dimensions. The fact that these subjects either did or did not fit the particular mockup or prototype is also easy to note and record. The difficulty in the use of this technique is if and when particular anthropometric dimensions are required as test subjects. It is very difficult for HE observers to go out and find particular anthropometric dimensional subjects, particularly for combinations of measurements and for the extremes of the population (e.g.. greater than 90th percentile and less than 10th percentile). The real value in using anthropometric measurements is in the knowledge of how close the design, as represented by the mockup or prototype, comes to the specified user anthropometry. The disadvantage is the effort in finding subjects who properly represent the required population. If this technique is not used and work space clearances are critical to the test conduct, the HE observer runs a high risk in only guessing the anthropometric characteristics of the test participants.

7.3.2.18.2.2 Oculometry use. The oculometer technique is relatively complex and expensive to use. It cannot be run on a noninterference basis. It requires trained HE observers to use. The use of the technique is still somewhat experimental. The advantage in the use of the technique is that it is the ideal way to perform or verify console panel link analysis data. If not used, questionnaires or interviews may be used to determine subject reaction to panel layout adequacy.

7.3.2.19 Online interactive simulation. Previous HE T&E technique paragraphs have described techniques which rely heavily on prototype hardware or mockups. Also included in this guide are several techniques which do not use either mockups or hardware, but are instead computer program simulations of both the operator and equipment in the man-machine interface (e.g., CAR. CAPE). 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 application of specific procedures and equipment to specific operations. It is often difficult to make a sharp distinction between some computer simulation set-ups and functional mockups. The emphasis in the functional mockup is on an accurate representation of spatial dimensions and arrangements.

7.3.2.19.1 Description. 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. In some cases, simulators must actually provide deliberate distortions of certain parameters in order to yield operator responses that will be valid for the real world. The use of distortions is risky but often necessary to compensate for some parameter that cannot be provided for properly. Online interactive simulation presumes the use of a sophisticated computer and software. Test participant consoles must also be provided in a manner similar to the system consoles being simulated. The preparation of test participant operator procedures is a first step toward the complex job of constructing the real time interactive software. Online operation requires the construction of numerous operator controls in response to numerous displays and display formats. Operator and system performance outputs must also be provided for in terms of lists and time plots of events versus actions, errors, and reaction times.

7.3.2.19.2 Use. The reason for using online simulation is because of the ability to find out what might occur: to manipulate, to study, and to measure the model instead of the real world. There are several advantages to using online simulation as compared to other methods of T&E:

a. Simulators are frequently cheaper, faster, and easier to construct than the systems or prototype hardware they simulate.

b. Simulators can be instrumented to collect data that would be difficult or impossible to obtain from real systems and the data may be quickly reduced to usable form.

c. Simulators are extremely useful as training aids.

d. Simulators are easier to manipulate than the systems they represent.

e. Simulators may be used to perform tasks that would otherwise be hazardous to the test participants (e.g., crash landings).

f. Once the simulation program has been provided, alternative procedures or tactics may be easily manipulated.

g. A record of data may be kept for later playback,

The disadvantages in the use of online simulation as compared with other T&E techniques are as follows:

a. Simulation tends to invite over generalization.

b. Simulations may be wrong because of incorrect relationships that have been made to hold between variables, or assumed constraints may be in error.

c. Simulators may add ingredients of their own that will not be found in the real world system

d. Simulators, in general, are more expensive than the use of interview, questionnaire or other empirical data gathering techniques.

7.3.2.19.3 Comparison to other techniques. The time to use online simulation is generally before the construction of the hardware (and software) that it is to simulate. If this is not done, there is little point in the expenditure of the time and effort for the simulation. There are essentially two alternatives to the use of online interactive simulation. One simulation technique is the use of man model programs such as the CAR and CAPE models previously mentioned. The other alternative is the use of all the T&E techniques which utilize the direct or indirect data obtained from the actual prototype system hardware. Table XI shows a comparison of this type of technique to other techniques.

7.3.2.20 Statistical analysis.

7.3.2.20.1 Description. This section on statistical analysis techniques is applicable to both system analysis and evaluation. In order to maintain consistency between this section and other HE techniques sections, the details of the numerous statistical methods cannot possibly be provided herein. However, a few of the more commonly used techniques are briefly presented along with their use. These techniques have been grossly categorized into the two areas of: a) statistical comparisons, and b) user population selection.

7.3.2.20.1.1 Statistical comparisons. Statistical comparisons may deal with the parametric performance of two or more hardware items under consideration for use in the system design. Comparisons may also be made between different parameters in order to draw a conclusion or develop new and useful data. System trade studies often include performance data comparisons such as reliability statistics. The mean or average reliability for one hardware item being considered is compared to another hardware item. Additional factors such as standard deviations from the mean and item population are necessary to make a proper performance comparison. The confidence limit or level of the results of the statistical analysis are very important. These are obtained from the standard errors which are, in turn, a measure of the sampling uncertainty (e.g., sample size). Statistically derived data are of little value without an associated confidence limit (e.g., 95%).

7.3.2.20.1.2 User populations. User population selection deals with the selection of a sample from the total population. It is generally impossible to test or measure all items (or users) in a population set from which data is to be obtained and analyzed. Statistical methods exist for random or specific parameter (i.e., stratified) population sampling. Whether a total population or a sample of the population, the data obtained will be presented in distribution plots. These plots describe the frequency of occurrence of the individual parameter values in the sample tested. The form of the resulting distribution (e.g., Gaussian, Poisson, binomial) is important in selecting the appropriate statistical techniques to be employed and in the conclusions to be drawn from the data. For example, a bimodal distribution generally indicates that the data sample was actually drawn from two distinct populations and the application of standard statistical techniques may not produce the intended results. As a further illustration, recent trends in design criteria application require the combination of male and female population anthropometric data. This combination will produce bimodal distributions. In such situations, standard statistical techniques for determining cost effective design criteria (e.g., choice of 5th through 95th Percentile) can be erroneous.

7.3.2.20.2 Procedure. It is not the intent of this guide to provide the procedure for each of the many statistical analysis techniques. If the HE specialist has questions concerning data analysis and interpretation, consultation with a statistical specialist should be employed. This consultation should occur during the early planning stages. Errors in sample selection or data collection procedures cannot be corrected in the analysis. Statistical analysis that once was performed with the use of desk top mechanical calculators is now quickly performed by computer/software techniques. There are many personal computer statistical packages currently available. These packages, in conjunction with a good experimental design, will enable the HE personnel to complete a complex statistical analysis. If possible, statistical data should be collected in machine-readable form at the test site.

7.3.2.20.3 Use. Although HE itself is a specialized field, there are persons within this discipline who specialize in HE statistical analysis. The majority of HE personnel have little to do with the statistical analysis, both because of relative little need to do so and availability of a few well qualified persons who can perform the statistical analysis when needed. The following aspects of statistical analysis should be considered.

a. Comparisons or correlation between parametric data are useful to extrapolate from limited data bases. For example, if based on comparisons between evaluator's judgments of operator task reliability and actual empirical data, a high correlation seems to be evidenced, then this correlation can be quantified by the use of scatter diagram plots, regression curves, and correlation coefficients. The quantified correlation can be used, with some caution, to extrapolate to operator task reliability estimates which have not been field tested. Correlation data showing the relationship between anthropometric measurements can also be very useful.

b. Statistical methods are not used as often as they should be to evaluate parametric data used to perform trade studies. Often hardware selection between various brands and systems is made on the basis of quoted or derived performance data that is not statistically reliable (significant) or accurate.

c. Just as statistics can be of great value to the HE analysis and evaluation process, it can also cause problems. If the statistical analysis is attempted by persons with limited experience, it is easy to make mistakes both in the choice of particular statistical techniques and in the application of the techniques. At the same time, skilled but unscrupulous analysts have been known to purposely misuse statistics to "prove" an item of performance data which does not actually hold true. A thorough analysis should be made of any data which are crucial to a design decision and which could be suspect.

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8. Subject term (key word) listing.

Analysis
Design
Human Engineering
Procedures
Techniques
Test and Evaluation

APPENDIX A
MIL-H-46855B CROSS REFERENCE

APPENDIX A
MIL-H-46855 CROSS REFERENCE TO GUIDE

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DODD 5000.43	Acquisition Streamlining																		
DODD 5000.1	Major Systems Acquisitions									T					T			T	T
DODD 5000.2	Major System Acquisition Procedures									T									T
DODD 5000.3	Test and Evaluation									T					T				
DODD 5000.19L	Acq. Mgmt. Sys. & Data Requirements																		
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Mil. Specs.																			
MIL-H-46855	HE Reqt for Mil Sys, Eqpt and Facil	T	T	T	T	T	T	T	T	T					T	T		T	T
Mil. Stds.																			
MIL-STD-490	Specification Practices																		
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MIL-STD-1388-1	Logistics Support Analysis					T													
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MIL-STD-1472	HE Dsgn Criteria for Mil Sys, Eqpt, & Facils								T							T			
MIL-STD-1521	Tech Rev & Audits for Sys, Eqpt, & Cmptr Progs																		
DOD Handbook																			
DOD-HDBK-248	Gde for App & Talg of Req for Mat Acq																		
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AR 1-1	Planning, Programing and Budgeting														A				
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AR 700-127	Integrated Logistics Support					A									A				
AR 702-3	Army Material Relbl, Avlbl, and Maintainability					A									A				
AR 750-1	Army Matl Maintainability Concepts & Policies					A									A				
AR 1000-1	Basic Policies for Systems Acquisition					A									A				
DARCOM-R 70-9	HF Engineering System Development					A		A	A	A					A			A	
AMC 700-15	Integrated Logistics Support					A													
TRADOC-R 600-4	Integrated Personnel Support					A													
TRADOC PAM 351-4	Job and Task Analysis Handbook							A											
Navy Insts.																			
SECNAV 5000.1	Sys Acq in the Dept of the Navy														N				
OPNAVINST 3960.1	Test and Evaluation									N					N				
NAVAIRINST 3902.10	Lead Sys Command Policies for Human Factors					N		N	N	N					N				
NAVMATINST 3960.6	Plng & Implementation of T&E of New Wpn Sys									N					N				
NAVSEAINST 3900.8	HF in the Naval Sea Systems Command					N				N					N				

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DOD Directives																					N = NAVY
DODD 5000.43	Acquisition Streamlining	T	T	T	T	T	T						T	T	T	T	T				AF = AIR FORCE
DODD 5000.1	Major Systems Acquisitions	T			T																
DODD 5000.2	Major System Acquisition Procedures	T																			
DODD 5000.3	Test and Evaluation	T					T									T					
DODD 5000.19L	Acq. Mgmt. Sys. & Data Requirements																				
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MIL-STD-499	Engineering Management	AF	AF		AF		AF									AF					
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MIL-STD-1388-1	Logistics Support Analysis		T										T			T					
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MIL-STD-1472	HE Dsgn Criteria for Mil Sys, Eqpt, & Facils															T					
MIL-STD-1521	Tech Rev & Audits for Sys, Eqpt, & Cmptr Prgms						AF									AF					
DOD Handbook																					
DOD-HDBK-248	Gde for App & Talg of Req for Mat Acq				T										T						
Army Regs.																					
AR 1-1	Planning, Programing and Budgeting	A																			
AR 15-14	System Acquisition Review Council Procedures	A																			
AR 70-1	Army Research, Development & Acquisition	A																			
AR 70-10	T&E During Development and Acquisition															A					
AR 70-17	System/Program/Project/Product Management	A	A																		
AR 70-55	Mgt of US Army R&D Centers and Labs																				
AR 602-1	Human Factors Engineering Program	A	A																		
AR 700-127	Integrated Logistics Support		A																		
AR 702-3	Army Material Relbl, Avlbl, and Maintainability		A																		
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AR 1000-1	Basic Policies for Systems Acquisition	A	A																		
DARCOM-R 70-9	HF Engineering System Development	A	A	A	A	A	A														
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TRADOC-R 600-4	Integrated Personnel Support	A	A																		
TRADOC PAM 351-4	Job and Task Analysis Handbook															A		A			
Navy Insts.																					
SECNAV 5000.1	Sys Acq in the Dept of the Navy																				
OPNAVINST 3960.1	Test and Evaluation	N														N					
NAVAIRINST 3960.10	Lead Sys Command Policies for Human Factors	N	N																		
NAVMATINST 3960.6	Plng & Implementation of T&E of New Wpn Sys	N														N					
NAVSEAINST 3900.8	HF in the Naval Sea Systems Command	N	N																		

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A.F. Regs.																			
AFR 80-14	Test and Evaluation					AF				AF					AF				
AFR 800-2	Program Management					AF									AF				
AFR 800-3	Engineering for Defense Systems					AF									AF				
AFR 800-8	ILS Program for Systems and Equipment					AF									AF				
AFR 800-12	Acquisition of Support Equipment					AF									AF				
AFR 800-15	HFE and Management					AF				AF					AF				
DIDs																			
DI-H-7051	Human Engineering Program Plan															T			
DI-H-7052	Human Engineering Dynamic Simulation Plan															T			
DI-H-7053	Human Engineering Test Plan															T			
DI-H-7054	Human Engineering System Analysis Report															T			
DI-H-7055	Critical Task Analysis Report															T			
DI-H-7056	HEDAD-O															T			
DI-H-7057	HEDAD-M															T			
DI-H-7058	Human Engineering Test Report															T			
DI-H-7059	Human Engineering Progress Report															T			
Army Guides																			
HEL-TM-7-80	A Concept for Dev HP Specifications																		
HEL-TM-29-76	Guide for Obtaining and Analyzing HP Data in a Materiel Development Project																		
DA Pam 11-25	Life Cycle Sys Mgt Model for Army Systems																		
TECOM Pam 602-1	Man-Materiel Sys Questionnaire & Interview Dsgn																		
HEDGE	HFE Data Guide for Evaluation																		
Navy Guides																			
D180-19476-1	Analyst's Gde for Anal Sects of MIL-H-46855							N											
D180-19476-2	Manager's Gde for Anal Sects of MIL-H-46855							N											N
D180-10006-1	User's Gde for the T&E Sections of MIL-H-46855									N					N				
D180-10006-2	Manager's Gde for the T&E Sect of MIL-H-46855									N					N				
D180-26112-1	User's Gde for the Dsgn Sects of MIL-H-46855								N						N				
D180-26111-1	Mgr's Gde for the Dsgn Sects of MIL-H-46855								N						N				
TP-76-11	HF T&E Manual																		
TP-75-15	HFE Policy & Procedures for T&E of Navy Sys														N				
TP-75-58	Translation of DSARC Milestones into HFE Reqt														N				
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AFAMRL-TR-81-35	Human Engineering Procedures Guide	AF				AF	AF	AF	AF	AF	AF	AF	AF	AF	AF		AF	AF	AF
AFSCP 80-5	Guide for Advanced Development					AF									AF				
ASDP 800-2	Dev of HFE for System/Equipment Programs																		
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A.F. Regs.																				
AFR 80-14	Test and Evaluation	AF	AF																	
AFR 800-2	Program Management	AF	AF													AF				
AFR 800-3	Engineering for Defense Systems	AF	AF		AF															
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AFR 800-12	Acquisition of Support Equipment	AF	AF																	
AFR 800-15	H.F.E. and Mgt.	AF	AF																	
DID																				
DI-H-7051	Human Engineering Program Plan						T	T	T	T	T	T	T	T	T	T	T	T	T	T
DI-H-7052	Human Engineering Dynamic Simulation Plan						T					T	T	T		T	T		T	
DI-H-7053	Human Engineering Test Plan						T					T	T	T		T	T			T
DI-H-7054	Human Engineering System Analysis Report						T				T					T		T		
DI-H-7055	Critical Task Analysis Report						T									T		T		
DI-H-7056	H.E. Design Approach Document-Operator						T									T		T		
DI-H-7057	H.E. Design Approach Document-Maintainer						T									T		T		
DI-H-7058	Human Engineering Test Report						T									T				T
DI-H-7059	Human Engineering Progress Report						T	T	T	T	T	T	T	T		T	T			
Army Guides																				
HEL-TM-7-80	A Concept for Dev. H.P. Specifications																			
HEL-TM-29-76	Gde for Obt and Anal HP Data in a Mat Dev Proj															A				A
DA Pam 11-25	Life Cycle Sys. Mgt. Model for Army Systems				A															
TECOM Pam 602-1	Army Man-Mat Sys Questionnaire & Interview Dsgn															A				A
HEDGE	H.F.E. Data Guide for Evaluation															A				A
Navy Guides																				
D180-19476-1	Analyst's Guide for MIL-H-46855									N	N					N	N	N		
D180-19476-2	Manager's Guide for MIL-H-46855	N														N	N	N		
D180-10006-1	User's Gde for the T&E Sections of MIL-H-46855						N			N						N	N			N
D180-10006-2	Manager's Gde for the T&E Sect of MIL-H-46855	N					N									N	N			N
D180-26112-1	User's Gde for the Dsgn Sects of MIL-H-46855						N									N	N		N	
D180-26111-1	Mgr's Gde for the Dsgn Sects of MIL-H-46855	N					N									N	N		N	
TP-76-11A	HEFTENAM VOL.I DATA Vol.II Sprt Vol.III Mthds & P															N				N
TP-75-15	HFE Policy & Procedures for T&E of Navy Sys															N				N
TP-75-58	Translation of DSARC Milestones into HFE Req															N				N
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AFSCP 80-5	Guide for Advanced Development	AF	AF																	
ASDP 800-2	Dev of HFE FOR System/Equipment Programs																			
AFSCP 800-3	A Guide for Program Management	AF	AF	AF	AF	AF	AF													

APPENDIX C

GENERIC HUMAN ENGINEERING PROGRAM PLAN FOR NEW SHIP AND OTHER MAJOR NAVAL HARDWARE ACQUISITION PROGRAMS

NAVAL SEA SYSTEMS COMMAND
NAVSEA 55W54
WASHINGTON, D.C. 20362
202-692-1591

FOREWORD

This generic Human Engineering Program Plan (HEPP) is provided as a guide to shipyards, naval architects, and others required to submit a HEPP as a part of a ship or other major system design, construction, overhaul, or test program. This Plan contains all the various HE program elements that have appeared in past U.S. Navy ship design and construction contracts which have included an HE requirement. However, each contract will contain its own unique requirements so that the tasks contained in any particular HEPP must be tailored for each specific application. General guidelines for preparing a HEPP may be found in paragraph 3.1.2 of MIL-H-46855 and in the data item description, DI-H-7051.

The HEPP is an important document in any HE program. It must spell out exactly what HE activities will be performed by the Contractor, and how and when these tasks will be completed. The HEPP is the principal yardstick by which both the Contractor and the Navy can assess the Contractor's HE performance during the ship design, construction, and test phases, so it must be prepared with serious thought by personnel knowledgeable of the HE role in the ship design and construction process. Care must be taken to prepare a meaningful plan. A qualified human engineer, experienced in the ship design and construction field, can normally prepare a HEPP in 20-30 pages that provides the necessary detail for all of the required elements in a ship design and construction HE program.

Almost every ship design and construction HE specification will be prepared based in part, or in whole, on the requirements contained in MIL-H-46855, "Human Engineering Requirements for Military Systems, Equipment and Facilities". This specification defines a series of HE tasks that could be completed on any DOD contract and describes how those tasks must be accomplished. Many of the tasks have accompanying Data Item Descriptions (DID's) so that completion of the task results in the submission of a CDRL item.

However, it is not intended or expected that every HE task contained in MIL-H-46855 should be completed on every DOD contract. Rather, the specification is deliberately constructed to allow the DOD procuring agency to pick and choose only those tasks which will be of direct benefit to each contract. As a result, the relationship between MIL-H-46855 and the HEPP for ship design and construction contracts takes one of two basic forms:

1. If the contract is fixed price, the Navy will identify, in the ship specification or statement of work, which of the tasks from Mil-H-46855 must be performed by the Contractor. The HEPP, in turn, must define how and when the Contractor will fulfill the requirements of the specification during the course of the contract.

2. Under a cost plus contract, the Contractor is given much greater leeway in defining which HE tasks he believes are essential to the particular ship. Thus, MIL-H-46855 must be used by the Contractor to: (a) identify which tasks will be completed, and (b) serve as the framework for the HEPP discussion on how and when the selected tasks will be completed.

In addition to the type of contract, the final content of the HEPP will depend primarily on two other factors:

1. The HE requirements specifically identified in the ship specification or statement of work.

2. The point in the design process when HE is first introduced or imposed on the Contractor, i.e., feasibility studies, preliminary, contract, or or detail design and construction.

On the following pages, a generic HEPP is provided together with an explanation for the inclusion of each element in the Plan. As noted earlier, however, each Plan must be tailored to the specific ship contract. Consequently, the Contractor must select from this generic Plan those tasks appropriate for his particular ship contract, then use the information provided herein as a guide in preparing the specific HEPP. The generic plan explains the tasks in the chronological order in which the tasks should be performed.

Having provided the above, a word of caution is now appropriate, not only in the preparation of the HEPP, but in conduct of the HE program in general. The underlying purpose of any HE effort for a ship or major system design and construction is to influence the design of the ship or system, not produce paper. Lengthy studies, wordy progress reports, long HE test reports, etc. are neither warranted nor wanted. Any task included in the HEPP which will not directly contribute to the ship's final configuration from a HE perspective is wasteful and undesirable. Thus, every task included in the HEPP, and the subsequent completion of those tasks during the various design phases, must be oriented toward maximizing the crew's capabilities and the operability of the system so that they can make their best contribution to the overall success of the ship's mission.

EXECUTIVE SUMMARY

The Executive Summary should contain the following:

a. A brief statement as to the extent of the HE program to be covered in the Plan. For example, one might state, "This HEPP covers all HE activities associated with the design, construction, and test of the LXD-99 amphibious ship through delivery to the U.S.Navy". If on the other hand, some limit were placed on the HE program, such as involving HE only in the design of a specific system or particular part of a ship, that should be stated here. An example might be, "This HEPP covers only the design of the operator work station for the XYZ steering control system", or, "This HEPP covers all HE activities associated with the design of the living, messing, office, and work spaces aboard the SBN-100 submarine".

b. A brief explanation of how MIL-H-46855 requirements were tailored for this specific HE program. One can list the sections from MIL-H-46855 that were included in this Plan, or make a statement that MIL-H-46855 was used as a guide in the preparation of the Plan and include the specific sections in a HEPP Appendix. The point is to show the Navy that MIL-H-46855 was considered in the preparation of the Plan. This is extremely important since it provides the Navy with a good indication of the Contractor's knowledge of MIL-H-46855 and how to selectively apply it to a specific contract or other HE program.

c. A list of the HE activities to be accomplished under the Plan. Examples of HE activities include:

    1. Review and sign-off of all arrangement and equipment drawings having man-machine interfaces.
    2. Arrange all operator consoles and work stations.
    3. Complete system analysis reports for the specific systems.
    4. Review specific technical documents, e.g., operator or maintenance manuals.
    5. Design and conduct an HE test program and prepare HE test reports.
    6. Participate in dock and sea trials.
    7. Participate in design review meetings.
    8. Prepare quarterly (or whatever time frame selected) HE progress reports.
    9. Conduct ship checks during construction.
    10. Provide general HE support to Engineers, Designers, and Draftsmen.
    11. HE review and participate in models/mock-ups.

Four things should be noted about item c. First, every separate HE task to be completed should be listed here. Second, the detail shown in the above listing is sufficient to describe the tasks for the Executive Summary.
Third, each task listed must be described in detail in Section 2.0 of the Plan and referenced in the HE schedule. Fourth, the list is not intended to be complete; a knowledgeable HE person can properly tailor the above list, if needed, or add items, as necessary.

d. A brief statement regarding the qualifications of the individuals who will conduct the HE program, where they will be organizationally located in the company, and a general statement regarding the Contractor's philosophy about the integration of HE into the design and construction process. An example of the above might be as follows: "Two persons will be assigned full time to the HE activity. One has 10 years of HE experience in ship design (specific ship experience would be good to include here). The second has twenty years experience in the Navy (cite here any of that experience that would be applicable to the design of the new ship or whatever other hardware the Plan is being prepared for). Both individuals will be assigned to the Chief Engineer (or wherever they may be assigned) and will report directly to the head of that department. XYZ Company is firmly committed to the active participation of HE in all elements of the ship design process and will ensure that HE is included in all man-machine designs on the LXD-99 amphibious ship ".

e. Any other information which is needed to clarify the HE program. For example if the Contractor will use a design agent or subcontractor, then it should be mentioned here briefly how the Contractor will ensure that HE design principles are included in the agent's or subcontractor's activities.

SECTION 1.0 BACKGROUND AND SCOPE

1.1 BACKGROUND. Here the Contractor should describe any pertinent background information specific to this Plan. For example, if the Contractor has performed HE tasks on other new ship contracts (if the Plan is being prepared for a new ship design contract) which influenced the selection of HE tasks on this contract, they should be described here. Or, if the Contractor had participated in the writing of the ship specifications, and had included HE requirements at that time, this should also be mentioned. In summary, this section should contain any background information which the Contractor feels might help explain why the HEPP was prepared the way it was.

1.2 SCOPE. If the HEPP is being prepared in response to a fixed price contract, then it should clearly state that the HE program is only fulfilling those requirements specifically stated in the RFP and/or ship specification. However, if the Contractor believes that other HE tasks should be completed which are not in the RFP/specification, identify these and describe why they should be added to the contract.

If the contract is a cost plus type, and the Contractor has some leeway in defining the HE program, the overall scope of the HE program should be described here, with a brief explanation as to why the specific tasks listed were selected.

Also, in this section mention the role of MIL-STD-1472 in this particular project, as well as any other HE design standards or specifications. For example, will MIL-STD-1472 be used only when it does not conflict with any other specification, and how will such conflicts be resolved? If the needed HE design information is not available in MIL-STD-1472, will some other HE design publication be used, and if so, which ones?

Finally, it is good practice to list the CDRL items that will be furnished in the HE area within the HEPP. If the Contractor proposes to modify any of the CDRL's, that modification should be described here.

In summary, Section 1.0 should accomplish two basic functions:

1. Provide the Navy with any pertinent background by which it can better assess the completeness and appropriateness of the Contractor's HEPP.
2. Provide the Navy with a clear understanding of the magnitude of the Contractor's HE program including the role of MIL-STD-1472 and the deliverables that will be provided.

SECTION 2.0 HE TASKS TO BE PERFORMED

The tasks listed herein have all appeared in past ship design and construction HE programs, but should not be construed as an all inclusive list for a HEPP, since each ship design contract may have its own unique requirements. Tasks 2.1, 2.2, 2.9, 2.11, and 2.12 normally require CDRL's. The remaining tasks have all proven valuable in achieving a good HE program during previous ship design and construction contracts and are strongly recommended for future such contracts.

Section 2.1 SYSTEM ANALYSIS. General guidelines for preparing a system analysis (SA) report are provided in DI-H-7054, and paragraphs 3.2.1 through 3.2.1.2 of MIL-H-46855. SA's are normally prepared early in the design cycle during conceptual, or preliminary or contract design, but special circumstances may require a SA in detail design. Conducting a SA involves identifying the basic functions of a system which must be performed to meet the system objectives. It establishes the conditions under which the functions must be performed, determines the frequency and accuracy required for each function, then determines which functions would best be performed by machines, software, and/or humans. System analyses can become paper intensive and yield minimal practical results in terms of a direct contribution to the ship design if not properly handled. Therefore SA's must only be done to a level of detail sufficient to directly inpact a ship system's design. System analysis studies should be included in a ship design and construction program (and consequently in a HEPP) only if any one of the following conditions exist:

1. They are specifically called for in the RFP or ship specification.
2. New and complex systems are introduced on the ship.
3. Major updates on existing systems, which because of the introduction of new technologies or automation will significantly alter the current man-machine relationship.

Regarding the HEPP, the writeup on SA's should contain three basic pieces of information:

1. The listing of the specific systems on which a system analysis will be performed, and the reason each is being done.
2. The level of detail and format in which the analysis will be completed.
3. The methodology by which the analysis will be conducted, i.e., where will the information come from by which the analysis is made.

2.2 TASK ANALYSIS. Performing a task analysis involves identifying each specific task required to complete a defined function for a specific operator workstation or system. A task analysis is performed to serve as a basis for the design and/or arrangement of a particular workstation and to ensure that human performance requirements do not exceed human capabilities. There are two general categories of task analysis performed during ship design and construction: Gross task analysis and Critical task analysis.

2.2.1 GROSS TASK ANALYSIS (GTA). General guidelines for performing a GTA are provided in paragraphs 3.2.1.3.1 of MIL-H-46855. Basically, a GTA involves reviewing a specific funcion that requires human involvement, documenting the sequence of general tasks required to perform the function, and noting such things as information flow, body movements required, workspace available, environmental conditions, and other considerations that may impact successful completion of the mission. In keeping with the general philosophy of keeping paperwork to a minimum, GTA's should be done only to the detail required to directly contribute to the design effort.

The HEPP should identify all workstations, consoles, and control systems on which the Contractor will perform a GTA. These may be specified in a fixed price contract, or left to the Contractor's discretion in a cost-plus contract, in which case justification for performing each GTA should also be provided in the HEPP. To be useful, a GTA must be done prior to the detail design of the system under consideration, so its results can be incorporated into the final design. Thus, the HEPP should indicate when each GTA is to be performed, and how and when the results will be used. The HEPP should also contain a description of the methodology to be used in performing the GTA; specifically, what will be the inputs to the analysis, how will the analysis be performed and recorded, and how will the results on the analysis be presented.

2.2.2 CRITICAL TASK ANALYSIS (CTA). General guidelines for performing a CTA are provided in paragraph 3.2.1.3.2 of MIL-H-46855 and DI-H-7055. A CTA differs from a GTA in several respects. A CTA is much more detailed analysis of a system function than a GTA, and is usually focused on a specific element of a system function. Finally, a CTA is usually performed on elements of a system that are identified as critical to the completion of the mission under consideration, i.e., if not performed correctly, serious consequences will result. The necessary discussion of CTA's in the HEPP is the same as GTA's above.

2.3 HE REQUIREMENTS FOR VENDORS. The benefit of incorporating HE criteria into a new ship design can sometimes be negated by the lack of such HE requirements in major ship specific vendor supplied hardware, such as propulsion engines, auxiliary boilers, elevators, air compressors, etc. Where a ship specification dictates that the overall ship design adhere to the requirements of MIL-STD-1472, it is understood that this requirement shall include the ship specific vendor supplied hardware. Therefore, the HEPP shall describe how the contractor will meet this obligation. One possible way to achieve this goal is simply to include a general statement in each purchase specification to the effect that, "the hardware shall be designed in compliance with the requirements of MIL-STD-1472". Another approach could be to place specific HE design criteria throughout the purchase specification. Whatever approach is taken, it should be defined in the HEPP. In addition, the contractor should describe how these HE requirements are to be tracked through the contractor's specification preparation, bid solicitation, vendor response package evaluation, vendor selection and hardware acquisition cycle. A proposed list (included as an Appendix) of the hardware items on which the contractor proposes to impose HE, or a description of the criteria on which such a list might be prepared later in the design contract, should be included in the HEPP.

2.4 GENERAL HE SUPPORT TO THE CONTRACTOR's ENGINEERING STAFF. Of all HE tasks likely to be completed on a new ship contract, this is the most difficult to structure and the hardest to cost out, especially on a fixed price contract. Nevertheless, it should be a definitive HE function performed on all new ship design and construction contracts, and shown as a separate HE task in the HEPP. Obviously one cannot predict the exact types of HE inputs that may be requested by the Contractor's engineering staff during a ship design and construction contract. But what the HEPP can contain is the steps the Contractor proposes to take to encourage the use of his HE specialists by the engineers during the design and construction effort. For example, the Contractor can physically and organizationally place the HE function so as to make its interaction with the design engineers more conducive. Another method, is the holding of short training courses by the HE personnel with the engineering staff at the beginning of the design effort to familiarize the engineers with what HE is, and how it can help with the design effort. HE attendance in engineering staff meetings, and a strong show of support for the HE function by the Contractor's management are other ways to integrate the HE function into the daily design activities of the engineering staff. Preparation of a designer's manual by the Contractor's HE personnel, containing the more frequently used HE design standards and criteria, could be provided to each engineer and draftsman as yet another way of providing HE support to the engineering staff. Finally, the HE staff could set aside a certain amount of time each day just to mingle with the engineering personnel to solicit those design problems which could use some HE input. All of these techniques have been used in the past to provide a general HE support to the Contractor's engineering staff. These, or other techniques which the Contractor proposes to use, should be described in the HEPP.

2.5 SHIP DESIGN DRAWING REVIEWS. Review of the detail design engineering drawings completed by the design agent and/or shipyard by a HE specialist is one of the best ways of incorporating HE requirements into the design of a new ship, and thus, it should be an integral part of any HEPP. In preparing the Plan, the following information should be included:

1. A list of the drawings (taken from the master ship drawing list if available and included as an Appendix) that will receive HE review. If these are not available, at least the basic categories of drawing types should be identified. Experience has shown that all arrangement drawings, including those for piping, should be reviewed.
2. A brief description as to how HE will fit in the drawing review cycle, and describing that sign-off by HE will be required before the drawings can be released to production.
3. A statement on how HE will be involved in the review of vendor furnished drawings.
4. A statement describing how recommended design changes resulting from the drawing reviews will be input into the design cycle, and how these inputs will be tracked to ensure they are retained as the drawing goes through engineering revisions.

Retention of the drawings by the HE staff after they have received the HE review is advised, especially if the recommended changes are recorded on those drawings. If the Contractor proposed to follow this practice, note it in the HEPP. Finally, the HEPP should describe the methodology to be used in the HE review of the engineering drawings. Items of interest to the Navy here include the proposed role of the task and/or system analysis studies in the drawing review effort, and the design criteria, i.e., MIL-STD-1472, other HE design manuals, Contractor's HE staff professional judgment, etc., against which the drawings will be judged. The Navy would also like to know how and to what extent the HE reviewers will solicit input from the design engineers before evaluating the design drawings, how safety or maintenance problems identified during the drawing reviews will be transmitted to those responsible within the Contractor's organization, and finally, what general procedure will be followed in completing the drawing reviews. The above requirements may appear to impose a heavy burden on those responsible for preparing the HEPP. In reality, however, a HE specialist with experience in the shipbuilding business should be able to fulfill all of the above requirements easily within three or four pages of text.

2.6 DESIGN REVIEW MEETINGS. Past experience indicates that there are three types of design review meetings of interest to HE. First are the large quarterly progress reviews (QPR's) in which many Contractor and Navy participants gather in singular, and splinter sessions, to review contract progress in many technical and financial areas. HE should be a participant in these QPR's, with the same type of presentation as is made by the other engineering disciplines. The second type of design review meeting is limited to a review of specific systems, or particular pieces of hardware. HE should be an active participant in these sessions provided there is man-machine involvement in the system or hardware under discussion. The third type of design review is that in which only HE is involved. These meetings, involving only Navy and Contractor personnel directly connected with the HE program should be held as often as both sides agree is necessary. The Contractor should spell out in the HEPP which, if not all, of the above type of design review meetings the HE staff will attend.

Section 2.7 MODELS & MOCKUPS. Models and mockups are often called for in a new ship RFP or ship specification for purposes other than HE. Models are commonly constructed for main and auxiliary engine rooms (as well as some of the other machinery spaces), CIC, and Bridge areas, and are used to establish adequate clearances in the equipment arrangements. These models can also be used by the HE professional to verify that adequate clearances exist around machinery for maintenance activities, that adequate visual access exists for large screen displays, that gauge boards and motor controllers are accessible to the full range of user populations, that adequate traffic patterns have been provided and a host of other HE uses. The Contractor's proposed use of models for HE purposes, should be included in the HEPP as a specific HE task. Other useful information would be for what purpose the Contractor plans on using the models in the HE area, specifically how the models will be used, i.e., will the HE staff be able to have items moved on the model to try various configurations or will they only be able to observe what is built for engineering purposes, and how will the HE staff monitor or be kept abreast of changes in the models due to engineering redesigns that could also affect previously established HE design inputs into the model?

Mockups are usually built for: a) specific operator consoles, and b) larger work spaces and in some cases, entire rooms. Mockups can range from simple block structures with very little detail and fidelity, to very detailed structures with total fidelity to the real article. Mockups are often called for in a new ship specification, but not necessarily for HE purposes. However, past ship dedesign experience has clearly shown that if mockups are provided, the principal benefit is for HE purposes. A good design practice is to build a mockup for each operator console on a new ship, using them to establish console shape and arrangement. For this purpose, the mockups need not be dynamic (unless the mockup might be used for training purposes later). Foam-core covering over a light wood frame is usually sufficient for the console structure. Actual replicas of meter and control faces, also mounted on foam-core board and colored with felt tip pens to indicate the red, green, and amber lights on the panel, should also be provided. If the Contractor proposes to use mockups for HE purposes, the HEPP should provide the following information:

1. The identification of the specific consoles, or other systems, that will be mocked up (if these are known).
2. The proposed construction mode (both as to materials and detail).
3. The proposed approach to keeping the mockups current, and for how long in the design cycle.
4. Other uses, such as a training device, for which the mockups might be used.
5. Who will have control of the mockups, i.e., HE, ILS, Engineering, and be responsible for their initial construction and later revisions?

2.8 TECHNICAL DOCUMENT REVIEW. Technical documents such as operator manuals, maintenance manuals, ship information and damage control books, and tech manuals, come in two forms: 1) those prepared by the Contractor, and 2) those prepared by equipment vendors. Normally, the former are prepared by the Contractor's ILS or technical document departments, or by subcontractors who specialize in manual writing, all of whom usually have a background in this area. The latter are normally produced by the equipment manufacturers who may not have the expertise to produce well human engineered manuals. In new ship design projects, the HE specialist can contribute to the document preparation effort by reviewing the publications to ensure that they are properly organized, e.g., the safety section should not be the last chapter, that they are readable, that the visual aids are appropriate and in the proper sequence to impart the maximum information to the reader, and that special caution or warning notes are highlighted and correctly located in the text. Since the volume of manuals produced on a large design project will preclude HE review of all of them, the HE review must be selective. The HEPP should list those manuals that will receive the HE review. In addition, the Plan should describe how the review will be completed, and to whom the recommended changes will be provided.

2.9 HUMAN ENGINEERING DESIGN APPROACH DOCUMENT (HEDAD). There are two types of HEDAD's which may be included in a ship specification: the HEDAD-Operator (DI-H-7056) and HEDAD-Maintainer (DI-H-7057). Further guidance on preparing these documents is found in paragraphs 3.2.1.2, 3.2.1.3, 3.2.1.4, and 3.2.2 of MIL-H-46855. The HEDAD-O describes the layout, detail design, and arrangement of crew station equipment, e.g., a console, specific workstation, etc., or an overall system, e.g., collective protective system, having an operator interface. The HEDAD-M describes the same equipment or system from a maintenance perspective. The HEDAD describes the as-built equipment or system on the ship and is intended to demonstrate that the completed design meets the human performance requirements and human engineering criteria for successful operation or maintenance.

The guidelines for the content of the HEDAD's are well defined in the two DID's but as with all study efforts, must be tailored for each ship contract. For fixed price contracts, the required HEDAD's will be defined in the ship specification. For cost plus contracts, the contractor may have more latitude in selecting those HEDAD's which he feels should be included in the HE effort. HEDAD's are included in a new ship contract for two basic purposes:

1. They describe as-built equipment or systems, thereby giving the Navy the opportunity to assess the adequacy of the contractor's HE efforts toward making specific equipments or systems operable and/or maintainable.
2. They provide the Navy with possible improvements in specific equipments or systems which may be made on later ships, or during ship alterations for the ship on which the HEDAD's were prepared.

In terms of the HEPP, the Contractor should include the following:

a. A list of the equipments or systems on which the HEDAD's will be prepared (especially important on cost plus contracts).
b. The rationale for including the equipments or systems in the HEDAD list (only necessary if the Contractor makes the HEDAD selection).
c. A brief discussion of the proposed methodology for the HEDAD preparation and the specific information which will be provided, i.e., how will the DID's be tailored for the particular ship.

2.10 SHIP CHECKS DURING CONSTRUCTION. Once construction starts, it is imperative that HE personnel make periodic visits to the ship to ensure that changes are not made during the construction phase that would negate the HE design input made in the earlier engineering design efforts. These changes can come about for a variety of reasons, but the most common is due to the field run of pipe, wireways, and other hardware which is left to the discretion of the craftsman installing the material on the ship. Therefore, the inclusion of a ship check task in the HEPP is necessary. Within this task, several items should be addressed including:

1. The proposed frequency of ship visits.
2. The methodology for conducting these visits, i.e., will the checks be conducted by deck level, functional spaces, or random walkthrough, and will the spaces be checked against drawings, or simply observed for flagrant HE violations, etc.
3. The method by which the detected HE problems will be corrected.
4. How detected HE design deficiencies will be corrected, and how this process will change as the ship gets closer to completion.
5. How the requested HE changes resulting from the ship check effort will be tracked to ensure that the changes are made.

2.11 HE TEST PROGRAM. The purpose of any HE test should be to verify that the system under investigation can be safely and effectively operated and maintained by the full range of potential users. HE tests fall in two basic categories:

1. Those in which the test is devised, conducted, and evaluated by HE specialist for HE purposes only, and
2. Those which are designed and conducted by others outside the HE profession, and which HE is involved only as a joint participator and/or monitor.

In new ship design projects, the opportunity to complete category 1 type HE tests is usually limited by time, restricted access to dedicated shipboard equipment, and costs. However, mockups can be used in some cases for these tests. Dynamic mockups may be required for specific systems, although only static mockups are normally built for ship design contracts.

The most frequent opportunity for the conduct of HE tests is through some form of joint participation with the engineering acceptance test program which is required on each new ship contract. Although the preferred method of establishing the validity of a particular design from the HE perspective is via HE specific tests, a HE test program which piggybacks on the ship's engineering accpetance test effort is an acceptable alternative. If a particular system warrants a dedicated HE test, it may be possible to combine it with the engineering test program. Whichever HE test program is selected, it should be in accordance with Paragraph 3.2.3 of Mil-H-46855. The HEPP should address the two main elements of the HE test Program: the HE Test Plan and the HE Test Report.

2.11.1 HE TEST PLAN (HETP). The HETP describes how and when the HE test program will be completed. Although a DID, DI-H-7053, covers the HETP, experience has shown that it usually requires tailoring to be applicable to a new ship design, construction, and test contract. Therefore, the HETP should contain at least the following information:

1. A description of the type of tests that will be conducted. For example, will HE specific tests be completed, and if so, how will they be done, i.e., will mockups be used, or will training simulators or real hardware be the test bed? If the HE test program will rely on joint participation with, or simply observation of, the engineering acceptance tests, the HETP should include:
   a. A list of the engineering acceptance tests which HE will join or monitor. If a list of these tests is not available when the HETP is prepared, a description of the general types of engineering tests for joint participation or monitoring, e.g., operational tests of ship delivered hardware has been used in the past, would be acceptable.
   b. The criteria used in selecting the engineering tests for joint HE participation or monitoring.
   c. The anticipated test subjects, and how they will compare with the projected real user population.
   d. The expected test environment, and how it will compare with the real environment under which the user will operate the equipment.
   e. The control, if any, that the HE personnel will have over the test procedures or conduct.

f. Those responsible within the Contractor's organization for conducting the engineering acceptance tests and a description of how HE coordinates their requirements with that group.

2. The proposed data collection and analysis techniques. These techniques may be as simple as having a HE specialist observe and make notes (for joint participation with the engineering test program) or as sophisticated as automatically recording the test subject's response time and performance errors with a computer which then analyzes the data as well. Often however, sophisticated techniques are not available and only the simpler ones are applicable. This is especially true in new ship contracts. Therefore, the Contractor must make the decision and then explain it in the HETP.

Normally, the HETP is submitted to the Navy for approval approximately 90 days prior to the commencement of the HE test program. However, it must be identified as a task in the HEPP, and a discussion (following the outline given above for the HETP itself) included whereby the Navy can be assured that the Contractor is aware of the need for a HE test program, and basically how he intends to conduct that program.

2.11.2 HE TEST REPORT. A general description of the intended format and content of the HE Test Reports should be presented in the HEPP and later detailed in the HETP. DI-H-7058 outlines the requirements of an HE Test Report, but normally demands much more than is necessary to adequately describe the results of HE ship tests. HE test reports should be prepared as separate short reports covering each HE test as it is completed, with each being 5-10 pages in length and can be submitted either as a part of the HE quarterly progress report or as they are completed by the Contractor. The short, independent reports provide an easy form for Navy review, and provide test results on a near real time basis which gives the Navy an opportunity to act on any identified HE design deficiencies detected during the test.

2.12 HE PROGRESS REPORT (HEPR). The content of the HE progress report should adhere to the requirements of DI-H-7059. Further guidance on preparing a HEPR may be found in paragraphs 1.1, 3.1.2, and 3.3. of MIL-H-46855. Frequency of submission for these reports shall be identified in a fixed-price contract, but quarterly reports are sufficient if left to the Contractor's decision.

SECTION 3.0 MANAGEMENT

The management section of the HEPP should contain at least three basic elements. Each of these is discussed in detail below:

3.1 ORGANIZATION - The location of the HE function within the Contractor's company organization can be very significant in terms of the success HE will have in making a meaningful contribution to the final design and construction of a ship. The HE function must be placed high enough in the organization so that its inputs are not "laundered" through a long chain of command. On past ship contracts, the HE activity has been assigned to a Systems Engineering Department, the Chief Engineer's Office, one of the engineering departments, e.g., Mechanical, and the ILS department. The former two locations were good since it gave HE a voice equal to the other engineering disciplines. The latter two organizational locations were not as good since HE inputs had to pass through several levels of management before being accepted in the final design.

In the HEPP, an organizational chart should be included to show the placement of the HE function, and the reporting chain of command. In addition, some descriptive text describing how the HE personnel will interact with the other engineering groups on a day-to-day basis is necessary. Also a statement should be included in this section to describe how conflicts between the HE design requirements and other engineering needs will be resolved, i.e., who has the final say as to to whether or not a HE requirement will be incorporated.

3.2 ILS, SAFETY, AND HE INTEGRATION. If the Contractor has separate individuals or departments responsible for the three areas, some overlap may occur. Therefore, the HEPP should address this issue by describing how the Contractor proposes to avoid duplication of effort among the three disciplines. In the past, Contractors have physically placed the three groups together to enhance the one-on-one exchange of information and have organizationally required the transfer of detected design problems by one function to the others which might be affected. Hazard Evaluation Reports (HER's) prepared by the Safety group have been reviewed by the HE staff, and safety problems detected by the HE personnel during drawing reviews, tests, or other activities have been reported to the Safety group. However, whatever approach the Contractor selects to ensure a close cooperation among these three groups should be described in the HEPP.

3.3 TRACKING OF HE INPUTS. Establishment of a system to track the HE inputs as they make their way through the design process serves three basic purposes:

1. It keeps the HE inputs from being lost in the design cycle.
2. It provides a permanent record of the HE effort which can be used by the Contractor and Navy to assess the value of the HE effort.
3. It provides items to be corrected on follow ships if not corrected on the present ship.

In creating the tracking system, four basic criteria should be observed:

1. It should be combined with existing data systems and/or existing data forms so as not to create another separate record keeping requirement just for HE.
2. It should involve an absolute minimum of paperwork for all concerned.
3. It should provide a record of each HE design input made, whether that input was accepted or rejected, and if rejected, by whom and for what reason.
4. It does not necessarily have to be a single method but can include several techniques as long as a permanent record remains and is readily accessible.

In the HEPP, the Contractor should describe how he proposes to fulfill the tracking requirement, keeping in mind the above criteria. In past ship contracts, this obligation has been met through a variety of ways including the use of Engineering Change Bulletins (ECB's), retention of marked-up drawings, HE test reports and materials prepared for design review meetings and notes made during ship checks. Whatever techniques are chosen, the Contractor should note the importance of this task and properly address it in the HEPP.

SECTION 4.0 SCHEDULE OF HE TASKS TO BE PERFORMED.

Accurately establishing a schedule for each HE task can be difficult, especially on a project such as a new ship design and construction contract. Therefore, only the major milestones should be shown. If the project is a multiyear contract, the milestones should be shown by year. Further, the HE milestones must be shown in relation to the major design engineering and construction milestones to ensure that the HE inputs will be made in time to influence design. Some of the milestones will be established by the contract, such as for the HE CDRL items. Many however, will be within the purview of the Contractor and will be used for two primary purposes: 1) to allow the Contractor and Navy to assess how well the HE program is doing, and 2) to demonstate that the Contractor realizes the necessity of performing some of the HE tasks in a specific sequence to maximize the benefit of the HE effort. Presentation format for the schedule is open to the Contractor, but "busy" bar charts or other pictorial methods should be avoided.

SECTION 5.0 APPENDIX.

Those items described earlier in this document which were recommended for inclusion in the Appendix plus any other item which the Contractor feels necessary, should be included in the Appendix. However, the content of the Appendix should be kept to a minimum in keeping with the policy of minimizing paperwork.

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1. DOCUMENT NUMBER
DOD-HDBK-763

2. DOCUMENT TITLE
HUMAN ENGINEERING PROCEDURES GUIDE

3a. NAME OF SUBMITTING ORGANIZATION

4. TYPE OF ORGANIZATION *(Mark one)*

☐ VENDOR

☐ USER

☐ MANUFACTURER

☐ OTHER *(Specify)*: ______

b. ADDRESS *(Street, City, State, ZIP Code)*

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

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7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

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