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Human Engineering - Principles and Practices

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HEB1-A

Human Engineering - Principles and Practices

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December 2005

TechAmerica
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Many member of the G-45 Committee, the DoD HFE TAG Standardization sub TAG, and other interested individuals helped in the preparation of this document. Members of the G-45 Committee who made significant contributions are listed below. It is not possible to include everyone who assisted in the development of this Bulletin. To each person who contributed, the members of the GEIA G-45 Human Factors Committee extend their thanks.

Mr. Louis Adams	Lockheed Martin Aeronautics, Fort Worth
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Preface

Human Engineering Bulletin – 1 (HEB-1) is not a textbook, nor is it in competition with any other published US document. It is unique on at least two other levels as well, in that : 1) it is the *only* human factors (HF) document to have survived transition from a Military Specification to Standard then to a Handbook, and now, to an industry non-government standard (NGS) Bulletin, and 2) it is the only complete Program Planning and Implementation tool for Human Factors, Ergonomics and Safety practitioners accepted across ALL military services, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA).

Since its last publication, HEB-1 has had many technical improvements. It now requires a Human Engineer to be 'qualified' in human engineering (HE), have continuity on the program, and have sign-off responsibility for the HE of the finished product (including software and training). HEB-1 was expanded with principles and practices for personnel safety, life-support, escape, and recovery. This revision now carries the user through the material acquisition phases, from product definition to disposal, including, for the first time, issues about abort and accident-investigation procedures, and it does all this according to its time-tested US military environment process legacy.

I had the unique and exciting opportunity to work with the initial document (MIL-H-46855, 1968) and a majority of the 'crew' involved with its evolution into this Bulletin, a keystone of our human factors culture. Historic perspective—not meant to be in competition with the foregoing Acknowledgment—demands recognition of the professionalism and tenacity of certain key Department of Defense Human Factors Engineering Technical Advisory Group (DoD HFE TAG) members under the tutelage of Jerry Chaikin, chairman of the Human Factors Standardization Steering Committee (HFSSC), the lead DoD HF standardization agency assigned to the US Army in 1968. Since there is no way to include all of the contributors to this work, I am using the HFSSC session, chaired by Mr. Chaikin, that met jointly with the DoD HFE TAG in 1977 for a snapshot of the original players. The list includes Test and Evaluation (T&E) SubTAG chair, Dr. Norm Lane (USN), along with Dr. Joe Birt, Cy Crites, and Jean Ring (US Air Force), Drs. Jim Geddie and John Miles (US Army), and Dr. William Moroney and Steve Merriman (US Navy), who all had a hand in initiating the task analysis process and the Qualitative and Quantitative Personnel Requirements Information (QQPRI) procedure. The accuracy of the solid paper trail over the years leading to HEB-1 was due to Mr. Chaikin, who carried the cause of countless government standards and specifications in general, and especially MIL-H-46855, the predecessor to this Bulletin. Without Jerry's devotion and support for over a quarter of a century, we would not have this formal, coherent HE document today!

This Preface is the result of many iterations with some of my friends mentioned in the Acknowledgment, those noted above, and four of my favorite HF educators: Drs. Newton C. Ellis, Jerry Krueger, Dick Pew, and Harry Wolbers. Please excuse me if I accidentally omitted anyone from this group of HF practitioners.

By virtue of its acceptance across such a vast 'worst-case' (stress-wise) military environment, HEB-1 is also the one ideal, seminal, baseline Program Planning and Implementation reference for any HF curriculum within any University setting—whether couched within Engineering or Psychology. While useful in the University, it is critically needed on *real* programs, even those in the civilian sector and on consumer products. Customers *must* impose HEB-1 on contractors who *must* then impose it upon their subcontractors (along with the appropriate data items). Although no longer *designed* to include the vagaries of research or conceptual development since implementation of acquisition reform, HEB-1 is a user-friendly 'yardstick' with which to generate the plan for any real product using human beings in the loop, or—with reverse engineering—evaluate a product for its effectiveness.

Respectfully submitted,
Dr. Mark M. Brauer, PE & CSP
Emeritus Member, U.S. DoD HFE TAG

Foreword

This Government Electronics & Information Technology Association (GEIA) Bulletin was prepared by its G-45 Committee under the guidance of both government and industry members of the Department of Defense Human Factors Engineering Technical Advisory Group (DoD HFE TAG).

The purpose is to issue a Human Engineering Best Practices document in support of the DoD's acquisition reform as expressed in Department of Defense Directive (DoDD) 5000.1 [1] , Department of Defense Instruction (DoDI) 5000.2 [2], and the Defense Acquisition Guidebook [3].

This document is based on the cancelled MIL-H-46855, which was originally a consolidation of one Army, one Air Force, and two Navy specifications first issued in February 1968. In May 1994, following a re-definition of the term *standard*, MIL-H-46855B was revised and converted to a military standard, MIL-STD-46855. In January 1996, as part of standardization reform, MIL-STD-46855 was redesignated as MIL-HDBK-46855, *Human Engineering Guidelines for Military Systems, Equipment, and Facilities*. Because MIL-HDBK-46855 and its companion guideline, DoD-HDBK-763, were now both handbooks, it was decided to consolidate them into a new handbook: MIL-HDBK-46855, *Human Engineering Program, Process, and Procedures*. This document was used to guide DoD and contractor program managers and practitioners regarding analysis, design, and test aspects of the human engineering program.

This bulletin is based upon Section 4 of MIL-HDBK-46855A (May 1999) [4]. It has been edited to address both government and industry needs, and to include a list of, and links to, current Data Item Descriptions (DIDs) developed at the DoD and by the Federal Aviation Administration (FAA).
A list of acronyms used in the document and the terms they represent is provided in Annex A. A list of documents that give more information is provided in Annex B.

1 Scope

This Engineering Bulletin and its annexes provide guidance on the application of Human Engineering principles and practices to the analysis, design, development, testing, fielding, support, accident investigation, and training for military and commercial products throughout their intended life cycles.

2 General Guidelines

2.1 Application and nature of work

Human Engineering (HE) should be applied during pre-development, development, and acquisition of commercial and military systems, equipment, and facilities to integrate humans effectively into the design of the system. An HE effort should be provided to:

* develop or improve all human interfaces of the system;
* achieve required effectiveness of human performance during system operation, maintenance, support, control, and transport;
* make economical demands upon personnel resources, skills, training, and costs; and
* improve human performance to maximize system performance.
* effect safe, efficient life support, escape, search and recovery of personnel.

The HE effort should include, but not necessarily be limited to, active participation in the following three major interrelated areas of system development.

2.1.1 Analysis

Starting with a mission analysis developed from a baseline concept of operations and operational scenario, the functions that must be performed by the system in achieving its mission objectives should be identified and described. These functions should be analyzed to determine their best allocation to personnel, hardware, software, or combinations thereof. Allocated functions should be further dissected to define the specific tasks that must be performed to accomplish the functions. Each task should be analyzed to determine the human performance parameters; the system, equipment, and software capabilities; and the tactical/environmental conditions under which the tasks will be conducted. Task parameters should be quantified where possible, and should be expressed in a form that permits effectiveness studies of the human-system interfaces in relation to the total system operation. HE high-risk areas should be identified as part of the analysis. Analyses should be updated as required to remain current with the design effort.

2.1.2 Design and development

HE should be applied to the design and development of the system hardware, software, procedures, work environments, and facilities associated with the system functions that require personnel interaction. This HE effort should convert the mission, system, and task analysis data into (a) detailed design and (b) development plans to create a human-system interface that will operate within human performance capabilities, meet system functional requirements, and accomplish mission objectives. The HE design of a system should also take into account any requirements to interoperate with other systems and untrained personnel.

The HE program should be executed by experienced HE practitioner(s). As appropriate consistent with the acquisition strategy and nature of the program, the responsible HE practitioner should have sign off authority for those portions of the program's design and development that have a human interface.

2.1.3 Test and evaluation (T&E)

T&E should be conducted to validate and verify that commercial and military systems, equipment, and facilities can be operated and maintained in its intended operational environment, within the intended users' performance capabilities.

2.2 HE program planning

HE activities are described in a Human Engineering Program Plan (HEPP). The HEPP should be in accordance with the system specification, and should include the following elements: tasks to be performed, HE milestones, level of effort, methods to be used, design concepts to be used, and the T&E program. The HEPP components must be part of an integrated effort within the total project, and must be coordinated with related program disciplines.

2.3 Risk management

Risk management procedures should be planned and implemented for the entire life cycle of the system. Human performance and HE design criteria issues that involve potential technical, cost, or schedule risks should be identified, analyzed, and prioritized as early as possible to establish provisions for eliminating the associated risks or reducing them to acceptable levels. Such provisions should be implemented and monitored during the HE program. HE should participate in defining the criteria for system acceptance to achieve operational suitability. Risk management should:

* identify potential cost, schedule, design, and performance risks that result from design aspects of human-system integration;
* quantify such risks and their impacts on cost, schedule, and performance;
* evaluate and define the sensitivity of such risks to HE design;
* identify alternative solutions to moderate- and high-risk HE problems and define the associated risks of each alternative;
* take actions to avoid, minimize, control, or accept each HE risk.

* document the identified risks, their impact, and the actions taken; and
* ensure that human performance/design risk is an element of management awareness/control specification requirements.

2.4 Reviews

2.4.1 Major technical reviews

HE practitioners should participate in the major technical reviews, as applicable to the acquisition phases indicated, which include:

* Analysis of Alternatives
* System Requirements Review
* System Design Review
* Preliminary Design Review (PDR)
* Critical Design Review (CDR)
* System Verification Review

HE practitioners should also participate in other important technical activities that further HE efforts (e.g., mission analysis, and test and evaluation planning).

2.4.2 Subsystem reviews

HE practitioners should also participate in subsystem reviews, including, where applicable, software specification, test readiness, and functional reviews (e.g., support, training, systems engineering, test, and manufacturing reviews).

2.5 Cognizance and coordination

The HE program should be integrated into the total system program. In particular, HE should be coordinated with systems engineering, software engineering, RAM (reliability, availability, and maintainability), system safety, survivability/vulnerability, facilities engineering, Integrated Logistic Support (ILS) and Logistics Support Analysis (LSA), and other HE-related functions, including biomedical, life support, personnel survivability, habitability, personnel, and training functions. (See International Standards Organization (ISO) 13407 [5] for information on a human-centered design process for interactive systems). HE data should be provided for incorporation into Logistic Management Information (LMI). The HE effort should utilize the LMI reports as source data where possible. The HE portion of any analysis, design, or T&E program should be conducted under the direct cognizance of qualified HE practitioners assigned HE responsibility by the contractor.

2.6 Data

2.6.1 Traceability

Contractor documentation should provide traceability from initial identification of HE requirements during analysis or system engineering, through implementation of such requirements during design and development, to verification that these requirements have been met during T&E of approved hardware, software, and procedures.

2.6.2 Access

All data, such as plans, analyses, design review results, drawings, checklists, design and test notes, and other supporting background documents reflecting HE actions and decision rationale, should be maintained at the contractor's facilities and made available to the customer for meetings, reviews, audits, demonstrations, tests and evaluations, and related functions.

2.7 Subcontractors and suppliers

The prime contractor should ensure that tasks and products obtained from subcontractors and suppliers conform to relevant HE principles and practices herein. Continuous and open communications between the HE practitioners at the prime and subcontractor/supplier locations are essential.

2.8 Nonduplication

The efforts performed to apply the HE principles and practices specified herein should be coordinated with, but should not duplicate, efforts performed to fulfill other contractual program tasks. Necessary extensions or transformations of the results of other efforts for use in the HE program are not considered duplication.

2.9 Early application of Human Engineering

During the early stages of acquisition, a market survey may reveal how candidate hardware and software will contribute to enhancing total system performance. Human-system performance sensitivities associated with competing designs should be identified in order to reduce technical risks and life cycle costs (e.g., research, engineering, design, and operations over the economic life of the system). Since operational costs are often much greater than acquisition costs, life cycle costs should be assessed early in the program. Early program decisions shall consider operator and maintainer capabilities and limitations to avoid expensive training, staffing, or redesigns. Guidance on the human engineering aspects of maintainability can be found in MIL-HDBK-470.

3 Detailed Guidelines

3.1 Analysis

Requirements analysis should be developed from a baseline mission scenario. Analysis should include application of HE methods as follows.

3.1.1 Definition and allocation of system functions

The functions that must be performed by the system in achieving its objective(s) within specified mission environments should be analyzed. HE principles and criteria should be applied to specify human-system performance requirements for system operation, maintenance, and control functions, and to allocate system functions to automated operation/maintenance, manual operation/maintenance, or some combination thereof. Function allocation is an iterative process continued until the level of detail appropriate for the level of system definition is reached.

3.1.1.1 Information flow and processing analysis

Analyses should be performed to determine the basic information flow and processing required to accomplish the system objective. These analyses should include decisions and operations without assuming any specific machine implementation or predetermined level of human involvement.

3.1.1.2 Estimates of potential operator/maintainer processing capabilities

Plausible human roles in the system (e.g., operator, maintainer, programmer, decision-maker, communicator, or monitor) should be identified. Estimates of processing capability in terms of workload, accuracy, rate, and time delay should be prepared for each potential operator/maintainer information-processing function. Comparable estimates of equipment capability should also be made. These estimates should be used initially in determining the allocation of functions and should later be refined at appropriate times for use in defining operator/maintainer information requirements and control, display, and communication requirements. In addition, estimates should be made of how implementing or not implementing HE design recommendations is likely to affect these capabilities. Results from studies in accordance with 0 may be used as supportive inputs for these estimates.

3.1.1.3 Allocation of functions

From projected operator/maintainer performance data, estimated cost data, and known constraints, analyses and tradeoff studies should be conducted to determine which system functions should be hardware implemented, software controlled, or performed by the human operator/maintainer. Allocation of functions should consider the mission-performance risks of making an incorrect decision for each alternative being evaluated. Designs should provide adequate decision support to minimize situations where human decisions are made under conditions of uncertainty, time stress, or workload stress. The possibility of influencing human or equipment capabilities through personnel selection and training as well as through equipment and procedure design should be considered. The costs of personnel selection and training should be considered in trade studies and cost-benefit analyses.

3.1.2 Equipment and software selection

HE principles and criteria should be applied along with all other design requirements to identify and select the particular equipment and Commercial-off-the-Shelf (COTS) software to be operated, maintained, or controlled by personnel. The selected design configuration should reflect HE inputs, based on supporting data, to satisfy the functional and technical design requirements and to ensure that the equipment will meet applicable design criteria, such as MIL-STD-1472 and style guides as appropriate.

3.1.3 Analysis of tasks and workload

HE principles and criteria should be applied to analyses of tasks and workload. These analyses should also be provided as basic information for developing preliminary manning levels; equipment procedures; and skill, training, and communication requirements; and as inputs to Logistics Support Analysis, as applicable. All analyses of tasks should use the task taxonomy expressed in MIL-HDBK-1908 [6].

3.1.3.1 Analysis of tasks

Analyses of tasks should be conducted and should provide one of the bases for making conceptual design decisions. For example, task analyses should be considered in determining, before hardware fabrication, whether system performance and maintenance requirements can be met by the combination of anticipated hardware, software, and personnel, and in ensuring that human performance requirements do not exceed human capabilities. Time requirements for tasks should be evaluated for task duration versus time availability, task sequencing, and task simultaneity. Task requirements should be evaluated, as applicable, for accuracy, precision, completeness, and the effects of task feedback and error tolerance/error recovery on performance. These analyses should also consider effects of sustained/continuous operations on human performance. Tasks identified during HE analyses that require performance of critical tasks, reflect possible unsafe practices, or show the potential for improvements in operating efficiency should be further analyzed for redesign.

3.1.3.2 Analysis of critical tasks

Further analysis of critical tasks should identify the:

* information required by the operator/maintainer, including cues for task initiation,
* information available to operator/maintainer,
* evaluation process,
* decision reached after evaluation,
* action taken,
* body movements required by the action taken,
* workspace envelope required by the action taken,
* workspace available,
* location and condition of the work environment,

* frequency and tolerances of action,
* time base,
* feedback informing the operator/maintainer of the adequacy of the action taken or the failure to take an action,
* tools and equipment required, and their timely availability,
* number of personnel required, their specialties, and their experience,
* job aids, training, or references required, and their timely availability,
* communications required, including type of communication, channel clarity, and available channel capacity,
* special hazards involved,
* required or typical operator interactions when more than one crewmember is involved,
* performance limits of personnel, and
* operational limits of hardware and software.

The analysis should be performed for all affected missions and phases, including degraded modes of operation. Each critical task should be analyzed to a level sufficient to identify operator/maintainer problem areas that can adversely affect mission accomplishment and to evaluate proposed corrective action.

3.1.3.3 Workload analysis

Operator and maintainer (individual and team) workload analyses should be performed and compared with performance criteria. To avoid overloading or underloading, the degree to which demands of any task or group of tasks tax the attention, capacities, and capabilities of system personnel (individually and as a team) and thus affect performance should be evaluated. Sensory, cognitive, and physiological limitations should be considered, as applicable. The workload analyses should define operational sequences and task times. Preliminary workload estimates should correlate mission segments with crew tasks for each task component (visual, auditory, motor, and cognitive) specified in terms of time, workload, mental effort, and psychological stress. A workload estimate for each crewmember should be defined in a fashion permitting individual and team workload to be related to mission segment(s).

3.1.3.4 Corrective action

Human-system interface design incompatibilities and excessive skill/physical requirements identified by analysis of tasks, analysis of critical tasks, or workload analysis should be corrected by changing the design or restructuring the tasks to ensure that degraded human performance does not result in degraded system performance.

3.1.3.5 Timeliness and availability

Analyses of tasks should be modified as required to remain current with the design effort and should be available to the customer.

3.1.4 Preliminary system and subsystem design

HE principles and criteria should be applied to system and subsystem designs and should be reflected in design criteria documents, specifications, functional flow diagrams, system and subsystem schematics and block diagrams, interface control drawings, overall layout drawings, and related applicable drawings provided in compliance with contract data requirements. The preliminary system and subsystem configuration and arrangements should satisfy human-system performance requirements and comply with applicable HE design criteria, such as MIL-STD-1472 [7].

3.2 HE in design and development

During design and development, the HE inputs made by implementing the results of analyses described in 3.1 through 3.1.4, as well as other appropriate HE inputs, should be converted into detailed engineering design features. Design of the equipment should satisfy human-system performance requirements and meet applicable HE design criteria such as, MIL-STD-1472. HE testing of the system or equipment should be considered during design and should include such factors as verifying proper operation, defining need for maintenance, and allocating adequate space for test personnel to perform their tasks. HE provisions in the equipment should be evaluated for adequacy during design reviews. HE practitioners assigned early HE responsibilities by the contractor should maintain design continuity and participate in design reviews and engineering change proposal reviews of all equipment end items that involve the human-system interface.

3.2.1 Experiments, tests, and studies

The contractor should conduct experiments, tests (including dynamic simulation and software prototyping), and studies to resolve HE and life support problems specific to the system. Experiments, tests, and studies should be performed with actual users in the actual user environment (or in a realistic simulation thereof) to validate design goals and system performance, including potentially hazardous emergency procedures. These experiments, tests, and studies should be accomplished as early as possible and reiterated as the design matures, so that their results may be incorporated in equipment design and, if necessary, used to revise initial function allocations. Any significant HE or life support problem deemed resolvable only by a major experiment, test, or study effort should be brought to the attention of the customer; this notification should include the estimated effect on the system if the problem is not resolved. To avoid duplication of effort, the applicability and utility of existing HE and other relevant data bases (e.g., general literature, research reports, and study reports) should be determined before initiating major efforts. For guidance on HE T&E methods and tools, see Chapter 8 of MIL-HDBK-46855.

3.2.2 Computer models, three-dimensional mockups, and scale models

3.2.2.1 Computer models

When it is cost effective, three-dimensional computer models, rapid prototyping, and computer-aided design/computer-aided manufacturing (CAD/CAM) methods should be used to develop the design of equipment for which human performance will be a determinant of operational performance and maintenance effectiveness. Computer models should be able to provide a suitable range of body sizes, clothing, and postures for evaluating proposed designs and design changes in terms of compatibility with whole-body fit and access; finger, hand, arm, foot, leg, and other access and reach; visual field; and strength. Computer models should not be used for compliance testing of human performance and HE design. When used for predictive purposes, such models should produce accurate and empirically repeatable, valid outputs. Computer models, simulations, rapid prototyping outputs, and CAD/CAM designs and analyses should be accessible to the customer and should, as applicable, be available during technical meetings and design reviews to facilitate concurrent engineering.

3.2.2.2 Three-dimensional mockups

At the earliest practical point in the development program and well before fabrication of system prototypes, full-scale three-dimensional mockups of equipment involving critical human performance should be constructed. The mockups should be constructed sufficiently early to ensure that results of HE evaluations can influence design. The mockups should be no more elaborate or expensive than is essential to represent those aspects of the human-system interface to be evaluated. These mockups should provide a basis for resolving operational and maintenance access, workspace, and related HE problems, and for incorporating solutions into system design. In those design areas that involve critical human performance and for which human performance measurements are necessary, development of functional mockups should be considered. The mockups should be available for inspection as determined by the customer. (Disposition of mockups after they have served the purposes of the contract will be stipulated by the customer.)

3.2.2.3 Scale models

Scale models may be used to supplement three-dimensional computer models, rapid prototyping, CAD/CAM, or mockup methods, but should not be substituted for mockups unless such substitution provides equivalent, valid, repeatable, and accurate information in a cost-effective and timely manner.

3.2.3 Dynamic mockups

Dynamic mockups, also known as engineering simulators (full-scale physical models that simulate functions), may be used when static three-dimensional mockups are inadequate for assessing human performance in the design of complex systems. These mockups may be used to:

* evaluate operator procedures and equipment/operator interfaces, and identify any potentially unsafe procedures and unacceptable workload demands;
* evaluate the non-mechanical aspects of a design, such as control dynamics, communications, information, electronic displays, and display formats;
* emulate user-system performance to derive estimates of performance for alternate design configurations and cost-effectiveness evaluations of variable manpower, personnel, and training parameters;
* evaluate biomedical and environmental considerations; and

* validate that the proposed design is suitable for operational use.

While the simulation equipment is intended for use as a design tool, its design should consider the opportunity to transition the technology to subsequent training simulators.

3.2.4 Engineering drawings

HE principles and criteria should be reflected by the engineering drawings and CAD representations to ensure that the final product can be used and maintained effectively, efficiently, economically, reliably, and safely. The following drawings are included: system layout, panel layout, control, communication system, individual equipment design drawings, and other drawings depicting equipment important to system operation and maintenance by human operators. The design, as reflected by such drawings, should comply with applicable HE design criteria such as that found in MIL-STD-1472. HE practitioners assigned HE responsibility by the contractor should review layouts and drawings for all designs with potential impact on human performance or the human-system interface and should identify for corrective action those designs that may induce human error or be unsafe (see sign-off authority, Para. 2.1.2).

3.2.5 Work environment, crew station, and facilities design

HE principles and criteria should be applied to detailed design of work environments, crew stations, and facilities to be used by system personnel. Drawings, specifications, and other documentation of work environments, crew stations, and facilities should reflect compliance with HE requirements and with applicable HE design criteria such as MIL-STD-1472. The design of work environments, crew stations, and facilities that affect human performance under normal, unusual, and emergency conditions should incorporate at least the following, where applicable:

* provisions for addressing the effects of atmospheric conditions, such as composition, volume, pressure and control for decompression, temperature, humidity, and air flow,
* provisions for minimizing the effects of weather and climate, such as rain, hail, snow, ice, and mud; and arctic, desert, and tropical conditions,
* provisions for minimizing the effects of positive and negative acceleration forces, including linear, angular, and radial,
* protection from physical and performance effects of acoustic noise (steady state and impulse), vibration, and impact forces,
* provisions for maintaining human performance during weightlessness,
* provisions for minimizing disorientation,
* adequate space for personnel, their movement, and their equipment,
* adequate physical, visual, and auditory interfaces between personnel and their equipment, including provision for proper eye position in relation to display surfaces, controls, and external visual areas,
* safe and efficient walkways, stairways, platforms, and inclines,
* provisions for minimizing physiological stresses,
* provisions for minimizing psychological stresses,

* provisions for minimizing physical fatigue,
* allowance for the effects of clothing and personal protective equipment, such as full and partial pressure suits, fuel handler suits, body armor, chemical/biological clothing and equipment, cold weather clothing, and temperature-regulated clothing,
* equipment-handling provisions, including remote handling provisions and tools when materiel and environment require them,
* provisions for safe and error-proof equipment installations,
* protection from chemical, biological, toxicological, radiological, thermal, mechanical, electrical, electromagnetic, and directed energy (e.g., laser) hazards,
* optimum illumination commensurate with anticipated visual tasks,
* appropriate sustenance and storage equipment (e.g., oxygen, water, and food), and provision for refuse management,
* crew safety protective restraints (shoulder, lap, and leg restraint systems; inertia reels; and similar items) appropriate to mission phase and their operability compatible with control, display, and PPE utilization, and
* adequate space, clearance, and layout for normal ingress/egress and emergency escape from hatches, crew workstations and aircraft crew stations.

3.2.6 HE in performance and design specifications

The provisions of performance, design, and procurement specifications prepared by the contractor should invoke applicable HE design criteria such as MIL-STD-1472.

3.2.7 Procedure development

Based upon the human performance functions and tasks identified by HE analyses, the contractor should apply HE principles and criteria to the development of procedures for operating, maintaining, or otherwise using the system equipment. HE is applied to procedure development to ensure that the human functions and tasks identified through HE analysis are organized and sequenced for efficiency, safety, and reliability; to provide inputs to the Logistics Support Analysis where required; and to provide inputs to the development of operational, training, and technical publications. The development of procedures should minimize training, and consider the possible culturally diverse nature of the operational, maintenance, and support population.

3.2.8 Software development

The contractor should apply HE principles to software architecture and design in those systems where software determines part of the human interface. Software that affects controls and displays should be evaluated for its impact on the human-system interface. Automated system functions that require human monitoring or intervention should be considered part of the human-system interface. Multifunction controls and displays that vary in function depending on system software should also be considered part of the human-system interface.

3.2.9 Style Guides and Standards

The contractor should use a style guide in the development of software user interfaces to define the general principles and specific rules that guide the design of individual components. A style guide can be based on an already-existing commercial or military style guide (e.g., Microsoft Windows or Common Desktop Environment (CDE) Motif) or be developed for specialized interfaces using tailored conventions. Using a style guide provides HE practitioners and the software developers with a set of guidelines that will assist in developing a consistent user interface.

3.2.10 Manuals

HE should be applied to the development of operation, maintenance, and training manuals (electronic or hard-copy) to ensure thoroughness, technical accuracy, suitable format of information presentation, appropriate reading level, appropriate level of technical sophistication, clarity, and suitable quality of illustrations.

3.3 HE in test and evaluation

The contractor should establish and conduct a T&E program to:

* demonstrate conformance of system, equipment, and facility design to HE design criteria;
* confirm compliance with system performance requirements where personnel performance is a system performance determinant;
* secure quantitative measures of system performance that are a function of the human interaction with equipment; and
* determine whether undesirable design or procedural features have been introduced.

Maximum use should be made of the data collected from experiments, tests, and studies (see 3.2.1). Both qualitative and quantitative data can be used to support HE efforts in the T&E process. The fact that these functions may occur at various stages in system, subsystem, or equipment development should not preclude final HE verification of the complete system. Both operator and maintainer normal, emergency, and degraded mode tasks should be performed as described in approved test plans during the final system test.

3.3.1 Planning

HE testing using certified operational software should be incorporated into the system T&E program and should be integrated into engineering design and development tests, contractor demonstrations, flight tests, acceptance tests, and other development tests. Compliance with HE requirements should be tested as early as possible. HE findings from design reviews, mockup inspections, demonstrations, and other early engineering tests should be used in planning and conducting later tests. HE test planning should be directed toward verifying that the system can be operated, maintained, supported, and controlled by user personnel in its intended operational environment, including emergency and degraded modes. HE test planning should also consider data needed from or to be provided by operational T&E. Test planning should include methods of testing (e.g., use of checklists, data sheets, test participant descriptors, questionnaires, operating procedures, and test procedures), schedules, quantitative measures, test criteria, and reporting processes.

3.3.2 Implementation

Planned HE T&E should be implemented upon approval by the customer. Test documentation (e.g., checklists, data sheets, test participant descriptors, questionnaires, operating procedures, and test procedures) should be available at the test site. HE portions of all tests should include the following:

* performance of mission or work, or a simulation thereof if actual performance is not possible;
* critical tasks;
* a representative sample of non-critical scheduled and unscheduled maintenance tasks that do not duplicate the tasks selected for the maintainability demonstration;
* proposed job aids, new equipment training programs, training equipment, and special support equipment;
* use of personnel who are: representative of the range of the intended user populations in terms of skills, size, and strength; wearing suitable garments and equipment appropriate to the tasks; and approved by the customer (use of personnel from the intended user population is preferred);
* collection of task performance data in actual operational environments, or in simulated environments if collection in the actual operating environment is not possible;
* identification of discrepancies between required and obtained task performance; and
* criteria for acceptable performance or rejection of the test.

3.3.3 Failure and error analysis

All failures occurring during T&E should be subjected to an HE review to differentiate among failures of equipment alone, failures resulting from human-system incompatibilities, and failures due to human error. Human errors occurring in the performance of critical tasks during T&E should be analyzed to determine the reason for their occurrence. The contractor should identify to the customer those design characteristics or procedures that may contribute substantially to human error and should propose corrective action.

3.4 HE in Abort and Accident Investigations

HE practitioners should continue to participate in the system life cycle after CDR, such that their technical acumen may be tapped in abort and accident investigations, as applicable to the system. Guidelines for this activity should be established. While it is intended to be pervasive, these guidelines must grow qualitatively and quantitatively as HE practitioners develop a better understanding of their roles in relationship to the other well-established national and international accident analysis and investigative bodies.

4 Human Engineering Data Item Descriptions (DIDs)

For data to be produced and delivered, the description of the work effort must be in the Statement of Work (SOW). The description, format and content of the data product may be provided in a DID. The DID, if provided, must be listed on a Contract Data Requirements List (CDRL), or other officially sanctioned list of contracted work products. Although DID format and content are not mandatory unless imposed by the customer, the use of DIDs helps ensure consistency across contracts and between contractors. The HE practitioner should tailor a DID to require only those items that are pertinent to the system being acquired, and necessary to assess the quality and suitability of the contractor's HE effort. A representative sample of HE DIDs that have been developed by the DoD and the FAA are listed below. A copy of these DIDs can be found at: http://dtica.dtic.mil/hftag/hfs_docs.html

Department of Defense:

* DI-HFAC-80742B, Human Engineering Simulation Concept
* DI-HFAC-80746A, Human Engineering Design Approach Document – Operator (HEDAD-O)
* DI-HFAC-80747B, Human Engineering Design Approach Document – Maintainer (HEDAD-M)
* DI-HFAC-80938A, Noise Measurement Report
* DI-HFAC-81399A, Critical Task Analysis Report

Federal Aviation Administration:

* FAA-HF-001, Human Engineering Program Plan
* FAA-HF-002, Human Engineering Design Approach Document–Operator (HEDAD-O)
* FAA-HF-003, Human Engineering Design Approach Document–Maintainer (HEDAD-M)
* FAA-HF-004, Critical Task Analysis Report
* FAA-HF-005, Human Engineering Simulation Concept

5 The Future of HEB1

It is envisioned that HEB-1, like its earliest predecessor Military Specification, will be a living document with future versions satisfying additional needs as technology advances. Future versions of HEB-1 will contain:

a. A visual definitions of temporal (time line) needs, illustrating critical program phases or actions chronologically in a typical life cycle (inverted bathtub curve).

b. A description of a typical mission profile or scenario (roller coaster curve).

c. An illustration of the myriad instantaneous operational input, output, feedback, and firewall needs for a crew under stress (stimulus-organism-response model).

d. A discussion of HE considerations during the disposal of a system or component, and.

e. A standardized process and taxonomy for HE participation in abort and accident investigations.

6 Terms and Definitions

For the purposes of this bulletin, the following terms and definitions apply.

6.1 acquisition reform: An ongoing series of initiatives sponsored by the Office of the Secretary of Defense to streamline and tailor the acquisition process.

6.2 analysis of tasks: See Task Analysis.

6.3 commercial-off-the-shelf (COTS): A product or service that has been developed for sale, lease, or license to the general public and is currently available at a fair market value.

6.4 contract data requirements list (CDRL): The standard format for identifying potential data requirements in a solicitation, and deliverable data items in a contract.

6.5 critical task: A task requiring human performance which, if not accomplished in accordance with system requirements, will most likely have adverse effects on cost, system reliability, efficiency, effectiveness, or safety. A task is also considered critical whenever equipment design characteristics demand human performance that approaches the limits of human capabilities.

6.6 **customer:** The internal and/or external users of the system being designed/developed. For the purposes of this bulletin, the customer generally refers to the integrated product team (internal) or to the acquisition office or commercial entity (external) that has contracted for human engineering support services.

6.7 **data item description (DID):** A completed document that defines the data requirements of a contract. The document specifically defines the data content, format, and intended use.

6.8 **environment:** The aggregate of all the conditions and influences including physical location and operating characteristics of surrounding equipment and occupants, including temperature, humidity, and contaminants or surrounding air; operational procedures, acceleration, shock, vibration, and radiation.

6.9 **human-computer interface:** See User-Computer Interface.

6.10 **human engineering:** The application of knowledge about human capabilities and limitations to system or equipment design and development to achieve efficient, effective, and safe system performance at minimum cost and manpower, skill, and training demands. Human engineering assures that the system or equipment design, required human tasks, and work environment are compatible with the sensory, perceptual, mental, and physical attributes of the personnel who will operate, maintain, control, and support it.

6.11 **human engineering design criteria:** Stated limits on design to achieve the objectives of human engineering.

6.12 **human factors:** A body of scientific facts about human characteristics. The term covers all biomedical and psychosocial considerations; it includes, but is not limited to, principles and applications in the areas of human engineering, personnel selection, training, life support, job performance aids, and human performance evaluation.

6.13 **human performance:** A measure of human functions and action in a specified environment, reflecting the ability of actual users and maintainers to meet the system's performance standards, including reliability and maintainability, under the conditions in which the system will be employed.

6.14 **human-system integration (HSI):** A comprehensive management and technical strategy to ensure that human performance; the burden design imposes on manpower, personnel, and training; and safety and health aspects are considered throughout system design and development.

6.15 **lesson learned:** A proven experience of value in the conduct of future programs. It is normally a conclusion drawn from evaluation of feedback information or from analysis of the performance resulting from technical and management functional activities. A lesson learned is usually recorded and eventually incorporated, where applicable, in regulations, technical manuals, specifications, standards, or handbooks.

6.16 **life cycle:** All phases of the system's life including design, research, development, test and evaluation, production, deployment, operations and support, and disposal.

6.17 **MIL-HDBK-46855A:** *Human Engineering Program Process and Procedures* provides human engineering program tasks, procedures and preferred practices, and methods for application to system acquisition. The program tasks outline the work to be accomplished by a contractor or subcontractor in conducting an HE effort integrated with the total system engineering and development effort.

6.18 **MIL-STD-1472:** *Human Engineering*, establishes general human engineering design criteria for military systems, subsystems, equipment, and facilities.

6.19 **nondevelopmental item (NDI):** An item that has been previously developed for use by federal, state, local, or a foreign government, and no further development is required.

6.20 **non-government standard:** A standardization document developed by a private sector association, organization, or technical society which plans, develops, establishes, or coordinates standards, specifications, handbooks, or related documents.

6.21 **operational effectiveness:** The degree to which a product accomplishes its mission when used by representative personnel in the expected operational environment.

6.22 **operational suitability:** The degree to which a product intended for field use satisfies its availability, compatibility, transportability, interoperability, reliability, maintainability, safety, human factors, logistics supportability, documentation, personnel, and training requirements.

6.23 **risk:** A measure of the inability of a system to achieve program objectives within defined cost and schedule constraints. Risk has two components: the probability (or likelihood) of failing to achieve particular performance, schedule, or cost objectives; and the consequences of failing to achieve these objectives.

6.24 **risk management:** The practice of controlling the risk drivers that adversely affect the program. It includes the process of identifying, analyzing, and tracking risk drivers; assessing the likelihood of their occurrence and their consequences; defining risk-mitigation plans; and performing continuous assessments to determine how risks change during the life of the program.

6.25 **style guide:** A document that describes the general principles and specific rules for the design (look) and interaction with (feel) of a software user interface. A style guide typically includes information and options on a range of topics, e.g., the layout and location of windows; the organization of material; the size and style of fonts; the use of color, flashing and other coding dimensions; icons and symbology; the type of