Chapter 17: Human Factors Engineering and Safety Principles & Practices

17.0 Human Factors Engineering and System Safety: Principles and Practices

This chapter will serve as an outline for the integration of human factors into activities where safety is a major consideration. The introductory section contains an overview of the FAA human factors process and principles. The remaining sections represent key human factors functions and guidelines that must be accomplished to produce a successful human factors program. The sections offer ways that have proven successful during previously conducted programs to accomplish the integration of human factors into acquisition programs.

The critical impact of human factors on safety is well documented in programs, studies, analyses, and accident and incident investigations. FAA Order 9550.8, Human Factors Policy directs that:

> Human factors shall be systematically integrated into the planning and execution of the functions of all FAA elements and activities associated with system acquisitions and system operations. FAA endeavors shall emphasize human factors considerations to enhance system performance and capitalize upon the relative strengths of people and machines. These considerations shall be integrated at the earliest phases of FAA projects.

Objectives of the human factors approach should be to: a) Conduct the planning, reviewing, prioritization, coordination, generation, and updating of valid and timely human factors information to support agency needs; b) Develop and institutionalize formal procedures that systematically incorporate human factors considerations into agency activities; and, c) Establish and maintain the organizational infrastructure that provides the necessary human factors expertise to agency programs. This chapter will help in that endeavor. Additional information on human factors support and requirements can be obtained from the AUA and AND Human Factors Coordinators or the Office of the Chief Scientific and Technical Advisor for Human Factors, AAR-100, (202) 267-7125.

17.1 FAA Human Factors Process Overview

17.1.1 Definition of Human Factors

Human factors is a multidisciplinary effort to generate and compile information about human capabilities and limitations and apply that information to equipment, systems, software, facilities, procedures, jobs, environments, training, staffing, and personnel management to produce safe, comfortable, and effective human performance.

When human factors is applied early in the acquisition process, it enhances the probability of increased performance, safety, and productivity; decreased lifecycle staffing and training costs; and becomes well-integrated into the program's strategy, planning, cost and schedule baselines, and technical trade-offs. Changes in operational, maintenance or design concepts during the later phases of a project are expensive and entail high-risk program adjustments. Identifying lifecycle costs and human performance components of system operation and maintenance during requirements definition decreases program risks and long-term operations costs.

17.1.2 The Total System Concept

Experience has proven that when people think of a system or project, they tend to focus on the tangibles (e.g., hardware and the software) that are acquired. Individuals often fail to visualize that the "user" (the people who operate and maintain the system) will have different aptitudes, abilities, and training, and will perform under various operating conditions, organizational structures, procedures, equipment configurations, and work scenarios. The total composite of these elements and the human component will determine the safety, performance, and efficiency of the system in the National Airspace System (NAS).

17.1.3 Total System Performance

The probability that the total system will perform correctly, when it is available, is the probability that the hardware/ software will perform correctly, times the probability that the operating environment will not degrade the system operation, times the probability that the user will perform correctly. By defining total system this way, human performance is identified as a component of the system. A system can operate perfectly from an engineering sense in a laboratory or at a demonstration site and then not perform well when it is operated and maintained by the users at a field location. By increasing the probability that the operator can perform the task effectively in the appropriate environment the Total System Performance will increase significantly.

Hardware and software design affects both the accuracy of operator task performance and the amount of time required for each task. Applying human factors principles to the "total system" design will increase performance accuracy, decrease performance time, and enhance safety. Research has shown that designing the system to improve human performance is the most cost-effective and safe solution… especially if it is done early in the acquisition process.

17.1.4 Early Application of Human Factors

In the early phases of system design or development, functions are allocated to hardware, software, or people (or they can be shared). For system and software programs (especially NDI/COTS), a market survey is conducted to reveal what and how candidate systems and software have already made these functional allocations in ways that do or do not enhance total system performance. Identifying human-system performance sensitivities associated with competing vendors/designs lowers technical risks and lifecycle costs (research, engineering, and development; acquisition and development; and operations over the economic life of the system). Since operations risks and costs are often much greater than the costs for research, engineering, and development; early assessment of lifecycle costs and risks has significant benefit to the total program cost and safety. The early development and application of a human factors program is an important key to cost containment and risk reduction. Most lifecycle costs and safety risk components are determined by decisions made during the early phases of the program management process. Early objectives of the human factors program are to ensure that:

- Human-system capabilities and limitations are properly reflected in the system requirements

- Human-system performance characteristics and their associated cost, benefits, and risks assist in deciding among alternatives (especially since lifecycle operation and support costs are often largely dependent upon personnel-related costs)
- Human-system performance and safety risks are appropriately addressed in program baselines

Early in the acquisition program, the investment analysis must identify for each alternative the full range of human factors and interfaces (e.g., cognitive, organizational, physical, functional, environmental) necessary to achieve an acceptable level of performance for operating, maintaining, and supporting the system in concert with meeting the system's functional requirements. The analysis should provide information on what is known and unknown about the human-system performance risks in meeting minimum system performance requirements. Potential human factors/safety issues are listed at Table 17-1.

Table 17-1: Potential Human Factors/Safety Issues

Early in the program, the following issues may need to be assessed:
• **Workload:** Operator and maintainer task performance and workload
• **Training:** Minimized need for operator and maintainer training
• **Functional Design:** Equipment design for simplicity, consistency with the desired human-system interface functions, and compatibility with the expected operation and maintenance concepts
• **CHI:** Standardization of computer-human interface (to address common functions employ similar user dialogues, interfaces, and procedures)
• **Staffing:** Accommodation of constraints and opportunities on staffing levels and organizational structures
• **Safety and Health:** Prevention of operator and maintainer exposure to safety and health hazards
• **Special Skills and Tools:** Considerations to minimize the need for special or unique operator or maintainer skills, abilities, tools, or characteristics
• **Work Space:** Adequacy of work space for personnel and their tools and equipment, and sufficient space for the movements and actions they perform during operational and maintenance tasks under normal, adverse, and emergency conditions
• **Displays and Controls:** Design and arrangement of displays and controls (to be consistent with the operator's and maintainer's natural sequence of operational actions)
• **Information Requirements:** Availability of information needed by the operator and maintainer for a specific task when it is needed and in the appropriate sequence
• **Display Presentation:** Ability of labels, symbols, colors, terms, acronyms, abbreviations, formats, and data fields to be consistent across the display sets, and enhance operator and maintainer performance
• **Visual/Aural Alerts:** Design of visual and auditory alerts (including error messages) to invoke the necessary operator and maintainer response
• **I/O Devices:** Capability of input and output devices and methods for performing the task quickly and accurately, especially critical tasks
• **Communications:** System design considerations to enhance required user communications and teamwork
• **Procedures:** Design of operation and maintenance procedures for simplicity and consistency with the desired human-system interface functions
• **Anthropometrics:** System design accommodation of personnel (e.g., from the 5th through 95th percentile levels of the human physical characteristics) represented in the user population
• **Documentation:** Preparation of user documentation and technical manuals (including any electronic HELP functions) in a suitable format of information presentation, at the appropriate reading level, and with the required degree of technical sophistication and clarity
• **Environment:** Accommodation of environmental factors (including extremes) to which it will be subjected and their effects on human-system performance

17.1.5 The Role of the Human Factors Coordinator

The Human Factors Coordinator (HFC) provides the support for the integration of human factors engineering in the program. The HFC helps to initiate, structure, direct, and monitor the human factors efforts. The HFC serves to identify, define, analyze, and report on human performance and human factors engineering considerations to ensure they are incorporated in investment decisions. Typical human-system performance and human factors engineering studies and analyses conducted, sponsored, or supported by the HFC include requirements analyses, baselines performance studies, trade-off determinations, alternative analyses, lifecycle cost estimates, cost-benefit analyses, risk assessments, supportability assessments, and operational suitability assessments. The HFC helps identify system specific and aggregate technical human factors engineering problems and issues that might otherwise go undetected for their obscurity, complexity, or elaborate inter-relationships. The human performance considerations are developed for staffing levels, operator and maintainer skills, training strategies, human-computer interface, human engineering design features, safety and health issues, and workload and operational performance considerations in procedures and other human-system interfaces. The HFC facilitates the establishment of the necessary tools, techniques, methods, databases, metrics, measures, criteria, and lessons learned to conduct human factors analyses in investment analysis activities. The HFC provides technical quality control of human factors products, participates in special working groups, assists in team reviews, helps prepare documentation, and collaborates on technical exchanges among government and contractor personnel.

Human factors considerations relevant to meeting system performance and functional requirements (and having safety implications) include:

- Human performance (e.g., human capabilities and limitations, workload, function allocation, hardware and software design, decision aids, environmental constraints, and team versus individual performance)
- Training (e.g., length of training, training effectiveness, retraining, training devices and facilities, and embedded training)
- Staffing (e.g., staffing levels, team composition, and organizational structure)
- Personnel selection (e.g., minimum skill levels, special skills, and experience levels)
- Safety and health aspects (e.g., hazardous materials or conditions, system or equipment design, operational or procedural constraints, biomedical influences, protective equipment, and required warnings and alarms).

The HFC provides input to the acquisition program baseline by conducting the following activities:

- Determine the human factors cost, benefit, schedule, and performance baselines for each candidate solution
- Identify the human factors and human performance measures and thresholds to be achieved (e.g., for the equipment, software, environment, support concepts, and configurations expected for the solution)
- Determine the human factors activities to be undertaken during the program, the schedule for conducting them, their relative priority, and the expected costs to be incurred
- Calculate or estimate the relative or absolute benefits of the human factors component of each solution in terms of decision criteria (e.g., cost, schedule, human-system performance)

17.1.6 Major Management Actions

Human factors professionals can assist in applying human factors information related to human resources management, training, safety, health hazards, and human engineering. The human factors process consists of four management actions:

- Manage the human factors program
- Establish human factors requirements
- Conduct human factors integration
- Conduct human factors test and evaluation

17.2 Managing the Human Factors Program

The Human Factors Program establishes the approach for applying human factors engineering to the system being acquired to increase total system performance and reduce developmental and lifecycle costs (especially in the areas of staffing, personnel, operations and training). The Human Factors Program focuses on the human performance produced when the system is operated and maintained in an operational environment by members of the intended target population.

Establishing a Human Factors Program for a given program or project requires focusing on the tasks the humans (operators, maintainers, and support personnel) will perform on the system, and the program activities that must be undertaken to allow early identification and resolution of human performance issues. Figure 17-1 illustrates the steps to be taken in developing the Human Factors Program.

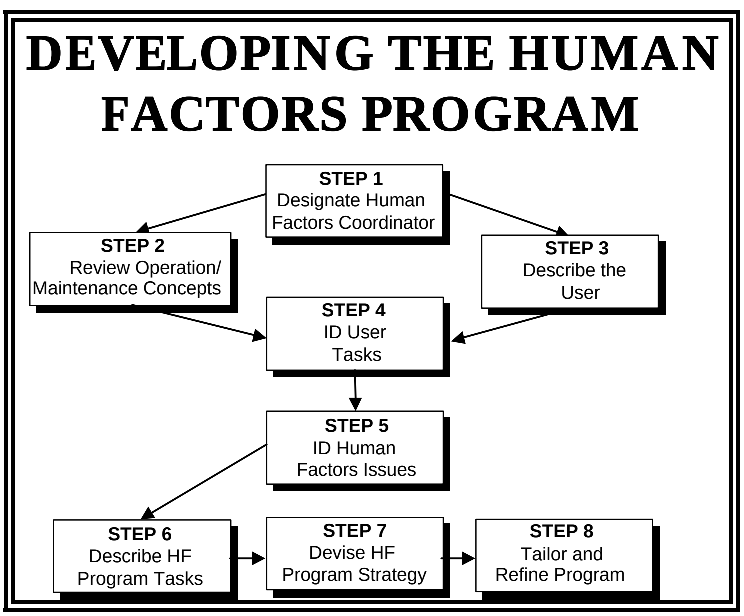


Figure 17-1: Steps in developing a Human Factors Program

Because each project or program is unique in its pace, cost, size, complexity, and human interfaces, the Human Factors Program should be tailored to meet program demands. As the system progresses through the lifecycle phases of the acquisition process, changes will occur. The Human Factors

Program must be structured and maintained to change iteratively with the project. To aid in the management of the Human Factors Program, a Human Factors Working Group may be established.

There is a strong link between the program documentation and the planning, management, and execution of the program. The documentation that supports a program defines the performance requirements and capabilities the program is to meet, the approach to be taken, and the specific tasks and activities that must be performed during design, development, and implementation of the program. Similarly, the human factors inputs to the program documentation accomplish the same result regarding the Human Factors Program. Human factors inputs define human performance requirements and criteria, identify human performance and resource trade-offs, specify human performance thresholds, establish an approach to ensure human performance supports project performance, and define the specific tasks and activities to be conducted.

Without such input, the capabilities and limitations of the designated operators and maintainers will not adequately influence the design, and may result in lower levels of operational suitability, effectiveness, and safety.

17.3 Establish Human Factors Requirements

For human performance and safety considerations to effectively influence the design, project specifications must accommodate the following essential ingredients for all users:

- Staffing constraints
- System operator and maintainer (user) skills
- Training time available and cost limitations for formal, informal, and on-the-job skill development
- Acceptable levels of human and system performance when operated and maintained by members of the target population

Human-system performance considerations are embedded into the project by incorporating human factors requirements in project specifications. The formulation of draft human performance requirements is initiated during the early project phases and continues through implementation of the project.

By identifying and defining human resource and human performance considerations, inputs are provided to the development of project concepts for functional allocation, hardware and software, operations and training, and organizational structure. Through the process of assessing these concepts and the related human resource and human performance trade-offs of various alternatives, the project concepts (e.g., for requirements, design, and implementation) iteratively evolve. This process applies equally to various kinds of projects and program (including developmental, NDI, or COTS acquisitions). The purpose of this process is to place these essential ingredients into the project specifications so that human performance capabilities and limitations will be incorporated in the project in a binding manner.

17.3.1 Project Specifications

From a human performance perspective, the project specification will have the most significant impact on system design and safety. It states the technical and mission performance requirements for a system as an entity, allocates requirements to functional areas, documents design constraints, and defines the interfaces between or among the functional areas. To achieve the design objective in a manner that results in a safe, efficient, usable system for the lowest possible expenditure of resources, the human performance constraints and requirements need to be placed into the system specification.

17.3.2 Generate Human Factors Requirements in a Statement of Work

In simple terms, the Statement of Work (SOW) identifies the work the sponsor wants the contractor to perform, the CDRL specifies the data to be provided to the sponsor for a specific contract, and the DID specifies the format and content of the data to be submitted to the Sponsor. The objective of the human factors effort is to integrate all elements of the project involving human performance and safety, and to influence project design so as to optimize total system effectiveness. The objective of this human factors task is to translate these human performance design and integration activities to the contractor as clear, unambiguous requirements in a contractually binding way. Human factors contractual requirements, through the SOW, CDRLs, and DIDs, are the critical elements to achieve design and development conformance.

A good SOW starts with an understanding of what the sponsor wants the contractor to do. The starting point for determining human factors requirements for inclusion in the SOW is a review of human factors requirements in the early project documentation (such as requirements documents, program baselines, and program plans) to identify human factors issues that must be resolved, and tasks and analyses that must be conducted by the contractor to ensure that human performance goals are met.

Essential human factors elements that must be addressed by the requirements in the SOW include:

- Limits to the skill level and characteristics of operator, maintainer, and support personnel
- Maximum acceptable training burden
- Minimum acceptable performance of critical tasks
- Acceptable staffing limits
- System safety and health hazards

The contractor's response to these requirements will result in a comprehensive human factors program for the system that defines the management and technical aspects of the effort. The response should also address the scheduling of key events and their timing in relation to other system engineering activities. The contractor's program must demonstrate how it effectively integrates human factors with their design and development process.

The scope and level of effort to be applied to the various human factors tasks and activities must be tailored to suit the type of system being acquired and the phase of development. The SOW should describe the specific task or activity required and the associated data deliverable. Human factors reviews and demonstrations should be planned and conducted to coordinate and verify that requirements are being met. The contractor should convincingly indicate how human performance data would influence system lifecycle design and support.

17.3.3 Human Factors in Data Item Descriptions

A Data Item Description (DID) describes the format and content of the data that is to be provided to the Sponsor as required by the SOW and CRDL. The DID should be tailored to require only those items that are pertinent to the project being acquired, and what is necessary to allow the human factors engineer sufficient information to assess the quality and suitability of the contractor's human factors effort. The Human Factors Coordinator should prepare a list of human factors-related DIDs applicable to the project being acquired and provide them for inclusion in the SOW.

17.3.4 Human Factors in Contract Data Requirements Lists

The purpose of the CDRL is to describe all of the items that are required to be delivered under the terms of the contract. The Human Factors Coordinator should review the CDRL to ensure the proper timing of submission of the data and that the appropriate distribution is indicated. The Human Factors Coordinator should recommend approval or rejection of the delivered product.

17.3.5 Human Factors in Source Selections

Human factors criteria must be developed to support source selections conducted in any phase. Since it is difficult to enforce compliance after a contract is awarded if vendor capabilities are inadequate, offerors must demonstrate the ability to incorporate human factors design criteria and guidelines into their system design and engineering before contract award. The Sponsor incorporates human factors requirements in the Screening Information Request (SIR), which includes appropriate weighting in the proposal evaluation criteria. Offerors show they understand the requirements by making human factors commitments in their proposals. The offerors must demonstrate comprehension of and the ability to comply with the total system performance concept as well as their ability to integrate human considerations into system design and development. The human factors practitioner, having provided input to the source selection plan, helps determine how well offerors have met the human factors selection criteria. Representation of human factors expertise on source selection team or panel(s) will provide the capability to adequately assess the human factors aspects of proposals.

17.4 Conduct human factors integration

The integration function (such as in system engineering activities) is the translation of operational requirements into design, development, and implementation of concepts and requirements. The Human Factors Coordinator assists the sponsor's and contractor's system engineering effort by integrating human factors within the project development and management process. Identifying the human performance and safety boundaries, risks, trade-offs, and opportunities of the system engineering options and alternatives does this. A human engineering effort (which may directly affect safety) is conducted to:

- Develop or improve human interfaces of the system,
- Achieve required effectiveness of human performance during system operation, maintenance, and support, and
- Make economical demands upon personnel resources, skills, training, and costs.

System engineering is an interdisciplinary approach to evolve and verify an integrated and lifecycle-balanced set of system product and process solutions that satisfy customer needs. The Human Factors Coordinator assists in the system engineering task by contributing information related to design enhancements, safety features, automation impacts, human-system performance trade-offs, ease of use, and workload. The Human Factors Coordinator also assists in identifying potential task overloading or skill creep for system operators and maintainers. Where user teams or operator juries and representatives participate in achieving an operational viewpoint to design, the human factors engineer complements the effort to ensure performance data represents more than individual preferences. Optimally, the Human Factors Coordinator participates fully in system engineering design decisions.

While the actual design and development work may be completed by either the sponsor or the contractor, the Human Factors Coordinator (in conjunction with the Human Factors Working Group) provides close, continuous direction throughout the process. To accomplish this, the Human Factors Coordinator reviews all documentation for human performance impacts that will affect total system performance and exercises his or her responsibility by participating in technical meetings and system engineering design reviews.

The human engineer actively participates in four major interrelated areas of system engineering:

- Planning
- Analysis
- Design and Development
- Test and Evaluation

17.4.1 Human Engineering in Planning

Human engineering planning is performed to ensure effective and efficient support of the system engineering effort for human performance and human resource considerations. Human engineering program planning includes the human factors tasks to be performed, human engineering milestones, level of effort, methods to be used, design concepts to be utilized, and the test and evaluation program, in terms of an integrated effort within the total project.

The human engineering planning effort specifies the documentation requirements and assists in the coordination with other program activities. Sponsor and contractor documentation provides traceability from initially identifying human engineering requirements during analysis and/or system engineering, through implementing such requirements during design and development, to verifying that these requirements have been met during test and evaluation. The efforts performed to fulfill the human engineering requirements must be coordinated with, but not duplicate, efforts performed by other system engineering functions.

17.4.2 Human Engineering in System Analysis

To support system analysis, the functions that must be performed by the system in achieving its objective(s) within specified mission environments are analyzed for their human factors implications and alternatives. Human engineering principles and criteria are applied to specify human-system performance requirements for system operation, maintenance and support functions and to allocate system functions to automated operation and maintenance, manual operation and maintenance, or some combination thereof. Essential activities related to system analysis include: functional analysis, functional allocation, design configuration, and task analysis.

17.4.3 Human Engineering in Detail Design

During detail design, the human engineering requirements are converted into detail engineering design features. Design of the equipment should satisfy human-system performance requirements and meet the applicable human engineering design criteria. The human factors engineer participates in design reviews and engineering change proposals for those items having a human interface. Essential products to be reviewed related to detail design include: hardware design and interfaces, tests and studies, drawings and representations, environmental conditions, procedures, software, technical documentation.

17.4.4 Human Engineering in Test and Evaluation

The Sponsor and contractor establish and conduct a test and evaluation program that addresses human factors to:

- Ensure fulfillment of the applicable human performance and safety requirements;
- Demonstrate conformance of system, equipment, and facility design to human engineering design criteria;
- Confirm compliance with system performance and safety requirements where human performance is a system performance determinant;
- Secure quantitative measures of system and safety performance which are a function of the human interaction with equipment; and
- Determine whether undesirable design or procedural features have been introduced.

The fact that the above may occur at various stages in system development should not preclude a final human engineering verification of the complete system.

17.4.5 Human Engineering Coordination

Coordinating the Human Factors and other activities (such as integrated logistics support activities) takes active and continuous communication. There are many opportunities to plan requirements, collect data, and share information, especially in the areas of maintenance staffing, training, training support, and personnel skills. Coordination will result in program cost savings or cost avoidance by eliminating redundancy and will strengthen the planning, analysis, design, and testing for both programs during all phases of the process.

17.5 Conduct Human Factors Test and Evaluation

Testing is performed to assess the operational effectiveness, suitability, and safety of the products to meet system requirements. The purpose of human factors in project testing is to produce evidence of the degree to which the total system can be operated and maintained by members of the target population in an operational environment. If the total system exhibits performance deficiencies when operated or maintained by members of the target population, the testing should produce human factors causal information.

Human factors planning for test and evaluation (T&E) activities is initiated early in the project management process. Specific human factors-related T&E tasks and activities are subsequently identified in the project/program planning documentation. The conduct of the human factors T&E is integrated with the system T&E program, which is largely performed during program implementation. Key principles for addressing human factors requirements in system testing are:

- Coordinate human factors test planning early in the program.
- Measure human performance of critical tasks during testing in terms of time, accuracy, and operational performance.
- Leverage human factors data collection by integrating efforts with system performance data collection.
- Make recommendations for human factors design and implementation changes and human performance improvements.

Providing human factors in system testing entails an early start and a continuous process. Figure 17-2 illustrates the flow of this process.

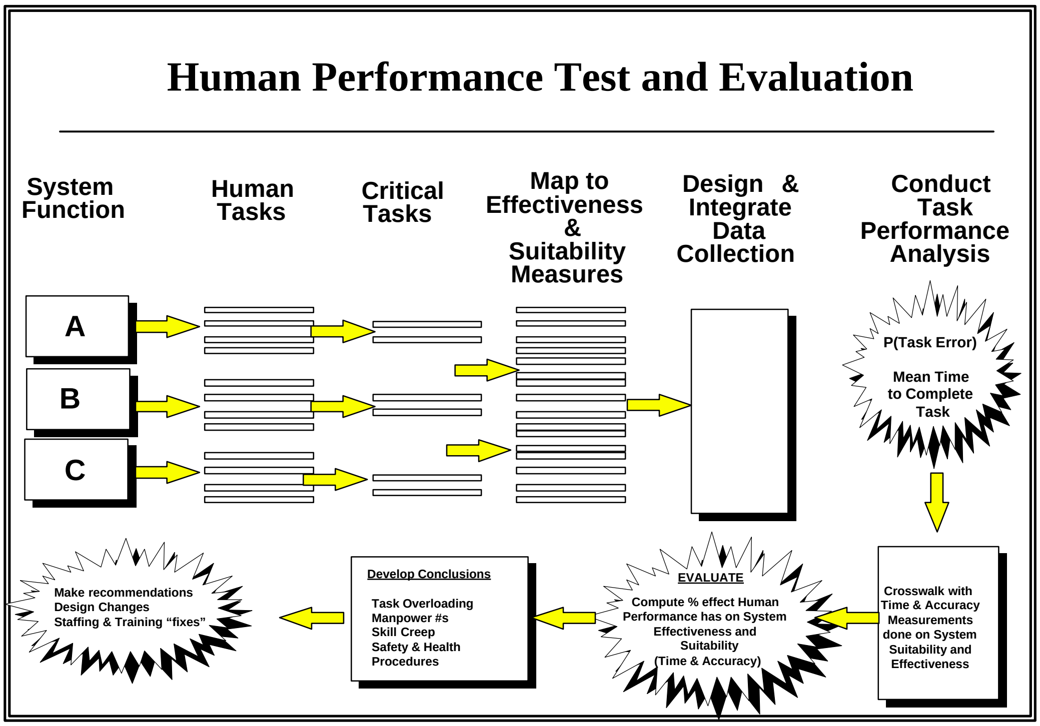


Figure 17-2: Process for providing human factors in system testing

Human engineering testing is incorporated into the project test and evaluation program and is integrated into engineering design and development tests, demonstrations, acceptance tests, fielding and other implementation assessments. Compliance with human engineering requirements should be tested as early as possible. Human engineering findings from design reviews, mockup inspections, demonstrations, and other early engineering tests should be used in planning and conducting later tests. Human engineering test planning is directed toward verifying that the system can be operated, maintained, and supported by user personnel in its intended operational environment.

Human engineering test planning should also consider data needed or to be provided by operational test and evaluation. Test planning includes 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. Human engineering portions of tests include:

- Performance of task or mission;
- Critical tasks;
- Representative samples of non-critical, scheduled and unscheduled maintenance tasks;
- Personnel who are representative of the range of the intended user populations;
- Proposed job aids, new equipment training programs; training equipment, and special support equipment;
- Collection of task performance data in actual operational environments;
- Identification of discrepancies between required and obtained task performance; and
- Criteria for acceptable performance.

Unfavorable outcomes occurring during test and evaluation are subjected to a human engineering review to differentiate between failures of the equipment alone, failures resulting from human-system incompatibilities and failures due to human error. Human-system incompatibilities and human errors occurring in the performance of critical tasks are analyzed to determine the reason for their occurrence and to propose corrective action(s).

17.6 Human Factors in System-to-System Interfaces

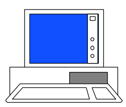
While the scope of human factors considerations for the development of acquisition product is obviously broad and complex, the application of human factors for the integration of systems within the National Airspace System is exponentially more complicated. Even beyond the increased scope of human factors demonstrated by Figure 17-3, maintaining the coordination, communication, situational awareness, and common understanding in the dynamic and interactive NAS demands sophisticated approaches to the research and engineering of the human component of system-to-system interfaces.

For example, *'Free Flight'* as described by the RTCA Task Force 3, provides a concept that suggests placing more responsibility on flight crews to maintain safe separation from other aircraft in the NAS. This idea could potentially shift aircraft separation responsibility from controllers to flight crews creating a '*shared separation*' authority environment. The guiding principle of the Free Flight concept is to provide benefits to users and providers. Some of the benefits include improved safety through enhanced conflict detection and resolution capabilities, more flexibility to manage flight operations, greater predictability of the NAS, and better decision-making tools for air traffic controllers and pilots. The major benefit anticipated for users is greater freedom to choose efficient routes and altitudes, resulting in savings on fuel and operating costs. To exercise these benefits, there may be a need to supply traffic information to flight crews, and develop operating methods and tools for both the air and ground to assure safety. While there have been studies done on new tools developed to display traffic information in the cockpit (with its conflict alerting logic) and to support in controller decisions, investigating how the tools might (safely) work together in a shared separation environment requires considerable exploration and analysis.

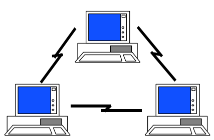
An experiment intended to provide an examination of the effect of shared separation authority on flight operations when both air and ground have enhanced traffic and conflict alerting systems would necessarily emphasize identifying and evaluating the human factors impact. Such an evaluation would require detailed knowledge about how safety, human-system integration, and system-to-system performance are affected in the following broad areas:

- How automation should be used and how it should not be used
- How to balance the benefits of automation with the requirement for human authority and responsibility
- What information and feedback operators need to stay aware, in control, and able to intervene into the new or automated process
- Which are the best methods for selecting, training, and evaluating operators and teams in the context of the advanced systems and the changing environment
- What policies and procedures will ensure the appropriate use of the new automation and effective human performance and team coordination
- What formats and interfaces will best support the operator and team performance
- How to ensure the operators of the interacting systems maintain coordination with each other to maintain and enhance safety and efficiency during all operational activities
- What procedures are necessary to ensure that the appropriate information is applied during all stages of the development of the new automation applications and operations
- How physiological, psychological, and cultural factors such as fatigue, duty cycles, and concepts of authority affect operator performance, and what standards and measures need to be applied to ensure safety and efficiency
- What methods, materials, and configurations to apply to the new systems and operations that will reduce risks and ensure safety and efficiency during normal, abnormal, and emergency situations.

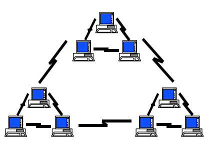
Many compromises in safety that lead to errors, accidents, or incidents can be attributed to unforeseen effects of how new technologies, new operational procedures, and changing organizations affect the human-system and system-to-system interface. Only through the rigorous exploration of these inter-relationships, can the safety of the NAS be ensured.



Products that accommodate human interfaces:
- Detailed displays & controls
- Screen layout and design
- User inputs & commands; information processing
- Physical and cognitive demands
- Product usability



Systems that accommodate human-system interfaces:
- Workstation ergonomics
- Decision aiding; training & procedure development
- Individual workload; job design
- Product-product compatibility
- System usability



A system of systems that accommodates multi-system human requirements:
- Organizational structures; staffing levels
- Communication; coordination; team workload & performance
- Training strategies and resource requirements
- System-system compatibility
- NAS usability

Figure 17-3: The complexity of human factors increases in system-to-system interfaces

17.7 Human Factors Engineering and Safety Guidelines

Human factors integration in the development and management of a project is a complex one because of the scope of the human factors considerations, the pervasiveness of human performance issues, and the difficulty in quantifying performance parameters especially early in the process. However, if given the proper resources and discipline, the process has proven to be successful in lowering lifecycle costs, improving overall system safety and performance, and reducing program technical risks. The human factors engineering process encompasses efforts related to the design, development, manufacturing, verification, deployment, operations, support, and disposal of system products and processes. Overarching principles include those that adhere to the summary guidelines and principles of Table 17-2. Some key human factors references that may be useful to the practitioner are listed in Table 17-3.

Table 17-2: Overarching Human Factors Guidelines/Principles

Overarching Human Factors Principles

1. Honor The User (The user defines requirements – but only in a structured, data-driven way.)
2. To Err Is Human (People are not machines; machines are not perfect; design the interface to tolerate errors of both.)
3. Human Factors Is Not Free (Plan the resources for human factors program support.)
4. Human Factors Requires Experts (The application of human factors engineering is neither easy, nor common sense -- except in retrospect of an incident or accident or poor design; co-locate human factors resources near the project/program teams they serve.)
5. People Are the Same; Individuals Are Different (Design for people sameness & tolerance of measured differences, especially in their skill and performance.)
6. Early Operator and Maintainer Decisions Drive Safety and Lifecycle Support Costs (Identify early in the program development process a requirement to subject every product to an "Out-of-Box" human factors study.)
7. Operator and Maintainer Skill Is a Function of Aptitude and Training (Training is part of the system engineering and safety performance package.)
8. Performance Is Measured in Terms of Time and Accuracy (Performance is a matter of degree -- quantitatively and qualitatively determined; test for human performance early and often.)
9. Task Safety & Performance Are Determined by the Design (Designs can improve or detract from task safety and performance.)
10. Operator and Maintainer Performance Affect System Performance (How people use the system IS the measure of the system's capabilities and risks.)

Table 17-3: Key Human Factors References

- FAA Order 9550.8, Human Factors Policy (October 1993)
- FAA Human Factors Design Guide (January 1996)
- MIL-STD-1472F, DOD Design Criteria Standard: Human Engineering (23 August 1999)
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