Table of contents

2 General design requirements

This section includes general human factors principles for designing or selecting systems and equipment.

2.1 Basic design elements

■ **2.1.1 Make systems durable.** Systems and equipment shall be sufficiently durable to operate and maintain under the conditions for which it was designed or procured. [Source: Department of Defense (MIL-STD-1472F), 1999]

▫ **2.1.2 Allocate functions appropriately.** Functions should be allocated to equipment or personnel so as to achieve reliable system performance with the needed sensitivity, precision, time, and safety at minimum cost and with the minimum level skills required to maintain and operate the system. [Source: MIL-STD-1472F, 1999]

> **Discussion.** The Automation chapter (Chapter 3) of this document provides information on how to determine which functions are better performed by machines and which functions are better performed by people.

■ **2.1.3 Test with users.** Systems and equipment human factors considerations shall employ early and continuous testing with actual users in a realistic environment. [Source: Ameritech, 1998; Galitz, 1993]

▫ **2.1.4 Make the system reliable.** The system should be reliable, thereby maximizing the availability to the users. [Source: Galitz, 1993]

> **Discussion.** A system does not have to experience a complete shut down to be considered unreliable by the user. A system that is functioning, but performing its intended function poorly may cause the user to consider the system unreliable. For instance, the user may perceive the system as unreliable if it misses alert conditions, provides incomplete information about the operational situation, or performs in a degraded state under certain operational conditions. [Source: Galitz, 1993]

2.2 Simplicity

▪ **2.2.1 Design for simplicity.** The system or equipment design shall be as simple as possible, consistent with the desired human-machine system functions, and compatible with the expected maintenance and operational concepts. [Source: MIL-STD-1472F, 1999]

> **Discussion.** Equipment designed with simplicity in mind is generally more reliable and easier for personnel to maintain and operate. When different designs are compared from a human factors view, the simplest design usually has less potential for human error.

▪ **2.2.2 Minimize training.** Systems and equipment shall be capable of being maintained, operated, and repaired in the planned operational and maintenance environment with minimal training. [Source: MIL-STD-1472F, 1999]

▫ **2.2.3 Make functions obvious.** Systems and equipment should be designed so that basic system functions are obvious to the user. [Source: Martin & Dong, 1999]

> **Discussion.** If the basic functions are obvious to the user, the user will be able to understand the core system tasks with a minimum amount of prior training.

2.3 Consistency

▫ **2.3.1 Make design consistent.** Systems and equipment should be designed to be consistent, appearing, behaving, and responding the same throughout. [Galitz, 1993]

> **Definition. Consistent** means adhering to the same principles with minimal variation. For systems, this entails maintaining a common design philosophy. Consistent design allows users to take general knowledge and skills learned from one system and apply it to other similar systems without extensive learning or training. [Source: CTA, 1996]

> **Example.** An example of a consistent design philosophy would be to use direct manipulation (point-and-click and drag-and-drop of icons) across systems instead of using direct manipulation on one system and command line interface on another system.

□ **2.3.2 Be consistent with user mental model.** To decrease learning or training times, systems should be designed to be consistent with the mental model of the users. [Source: CTA, 1996]

> **Discussion.** The following are some areas that can be exploited to obtain consistency with user mental models in system design:
>
> a. Analogy with real life objects
>
> b. Experience with similar systems
>
> c. Previous operational experience [Source: CTA, 1996]

□ **2.3.3 Minimize inconsistency.** If an occasional departure from consistent design is necessary to support user task performance, designers should minimize the extent of the inconsistency with the rest of the user interface. [Source: CTA, 1996]

2.4 Standardization

■ **2.4.1 Standardize hardware and software.** Hardware and software designs shall be standardized to the degree practical and compatible with system functions and purposes. [Source: MIL-STD-1472F, 1999]

> **Definition. Standardization** refers to common user-interface features across multiple applications.
>
> **Discussion.** Standardized hardware would use consistent fasteners, switches, breakers, and connectors within and across equipment. When software is standardized, applications that address common functions employ the same user dialogs, interfaces, and procedures. Standardization simplifies maintenance procedures and reduces the tools required, the potential for human error, training time, skill requirements, inventory of spares, and documentation. [Source: MIL-STD-1472F, 1999; Department of Defense (MIL-HDBK-759C), 1995]
>
> **Example.** The length of time that it takes the user to mentally process the contents of a screen nearly doubles when the position of the screen elements is varied. [Source: Teitelbaum & Granda, 1983]

■ **2.4.2 Maintain identical interfaces for identical functions.** Equipment with identical functions shall employ identical or similar interfaces. [Source: MIL-STD-1472F, 1999]

■ **2.4.3 Make controls, displays, marking, coding, labeling, and arrangement uniform.** Controls, displays, marking, coding, labeling, and arrangement schemes shall be uniform for common functions of all equipment. [Source: MIL-STD-1472F, 1999]

□ **2.4.4 Make appearance distinctive.** Units of equipment or modules that have different functions should be distinctive in their appearance and identification. [Source: DOE-HDBK-1140, 2001]

□ **2.4.5 Standardize terminology, look, and feel.** Systems and equipment should have standardized terminology, look, and feel. [Source: Avery & Bowser, 1992]

> **Discussion.** Standardized terminology eliminates differences in names assigned to and descriptions of the same functions and features. A standardized look minimizes differences in the appearance of displays based upon different styles. A standardized feel minimizes differences in the actions a user takes to interact with an application. [Source: Galitz, 1993]

■ **2.4.6 Make functionally similar equipment interchangeable.** Equipment that has the same form and function shall be interchangeable throughout a system and related systems. [Source: MIL-STD-1472F, 1999]

■ **2.4.7 Make functionally different equipment non-interchangeable.** If equipment is not interchangeable functionally, it shall not be interchangeable physically. [Source: MIL-STD-1472F, 1999]

2.5 Safety

■ **2.5.1 Incorporate safety factors.** System and equipment design shall incorporate applicable system and personal safety factors that affect human performance including those that minimize human error under normal, degraded, or emergency conditions and under adverse environments. [Source: MIL-STD-1472F, 1999]

> **Discussion.** Specific design criteria on workplace design, personnel safety, and environment, can be found in Chapters 10, 12, and 13 of this document.

■ **2.5.2 Provide a fail-safe design.** A fail-safe design shall be provided for systems in which failure could cause catastrophic damage, injury to personnel, or inadvertent operation of equipment. [Source: MIL-STD-1472F, 1999]

- **2.5.3 Make systems error resistant.** Users shall be protected from making errors to the maximum possible extent. [Source: Martin & Dong, 1999]

   > **Discussion.** To make a system **error resistant** is to make it difficult for a user to make an error. Simplicity in design and the provision of clear information are tools to improve error resistance. Electronic checklists also have the potential to improve error resistance by providing reminders of items that need to be completed. [Source: Billings, 1991]

- **2.5.4 Make systems error tolerant.** Systems should be tolerant of human errors. [Source: Galitz, 1993]

   > **Discussion.** To make a system **error tolerant** is to mitigate the effects of human errors that are committed. Error tolerance can be improved by adding monitoring capabilities. [Source: Billings, 1991]

- **2.5.5 Warn of potentially unsafe actions.** Systems and equipment should warn users before they initiate a task that may result in potentially serious consequences. [Source: Apple Computer Incorporated, 1995]

- **2.5.6 Identify safe and unsafe states and actions.** Systems and equipment shall clearly identify safe and unsafe operating states and actions. [Source: Wallace, Peng, & Ippolito, 1992]

- **2.5.7 Provide emergency procedures for critical systems**. For critical software, systems, or equipment, there shall be a clear, step-by-step description of procedures to be conducted in the event of failure. [Source: Wallace, Peng, & Ippolito, 1992]

- **2.5.8 Provide redundancy.** There shall be redundant means to access systems and equipment that provide a critical function. [Source: Wallace, Peng, & Ippolito, 1992]

- **2.5.9 Design systems to be modular.** Systems and equipment should be modular in design. [Source: Wallace, Peng, & Ippolito, 1992]

   > **Definition.** To be **modular** means to be designed with standardized or uniform components. The advantage of a modular design is that if one component fails, it is easier to replace.

- **2.5.10 Provide warning labels.** Design, location, procedural guidance, and suitable warning labels shall be provided to prevent damage to equipment while it is being handled, installed, operated, or maintained. [Source: MIL-STD-1472F, 1999]

- **2.5.11 Prevent misalignment and improper mounting.** Equipment shall include physical features that prevent improper mounting or alignment, or at least have labels or codes to identify proper mounting and alignment. [Source: MIL-STD-1472F, 1999]

2.6 User-centered perspective

Definition. A **user-centered perspective** involves focusing on the needs and requirements of the end user throughout the design, acquisition, or development process.

▪ **2.6.1 Provide timely and informative feedback.** Systems and equipment shall provide timely and informative feedback to user actions to keep the users informed about what is happening. [Apple Computer Incorporated, 1995]

> **Discussion.** For feedback to be informative, it must be understandable to the users. For example, if a user picks up the phone, the presence of a particular tone indicates that the line is available and ready for use. The change in the tone indicates changes in the availability of the system (e.g., dialing, call placed but waiting for answer, busy).

▫ **2.6.2 Provide predictable results to user actions.** User actions should cause predictable results. [Source: Martin & Dong, 1999]

▫ **2.6.3 Use familiar terms and images.** Systems and equipment should use terms and images familiar to the user. [Source: Martin & Dong, 1999]

▪ **2.6.4 Design within user abilities.** The design of systems, equipment, and facilities shall conform to the capabilities and limitations of the users to operate and maintain it in its operational environment and not exceed user capabilities. [Source: MIL-HDBK-759C, 1995]

▫ **2.6.5 Maximize human performance.** Systems and equipment should be designed to foster effective procedures, work patterns, and personnel safety and health and minimize factors that degrade human performance. [Source: MIL-HDBK-759C, 1995]

▫ **2.6.6 Minimize training requirements.** Systems and equipment should be designed to minimize personnel and training requirements within the limits of time, cost, and performance trade-offs. [Source: MIL-HDBK-759C, 1995]

▫ **2.6.7 Design to meet user requirements**. Systems and equipment should be designed to meet specific user requirements, providing the functionality to meet those requirements. [Source: Avery & Bowser, 1992]

▫ **2.6.8 Minimize user actions.** Systems and equipment should be designed to minimize hand and eye movements, thus maximizing efficiency. [Source: Galitz, 1993]

▫ **2.6.9 Facilitate transfer of skills.** Systems and equipment should be designed to allow skills acquired in one circumstance to be used in another. (Consistency and standardization help to accomplish this.) [Source: Galitz, 1993]

■ **2.6.10 Design for 5th to 95th percentile.** Systems and equipment shall be, at minimum, designed for personnel from the 5th through the 95th percentile levels of the human physical characteristics that represent the user population. [Source: MIL-STD-1472F, 1999]

▫ **2.6.11 Accommodate physical diversity.** Systems and equipment should accommodate the maximum range (so as to address 100%) of the user population. [Source: MIL-STD-1472F, 1999]

> **Discussion.** Systems must be designed to accommodate all of the users. Yet, design guidelines often suggest to accommodate some portion of the demographic database of essential user measurements (such as the 5th through 95th percentile). This approach ostensibly excludes only the extremes of the population.
>
> However, depending upon the source of the demographic database, some significant portion of the user population may be excluded. Also, since body proportions are not linearly correlated, someone who is 5th percentile in height may not be 5th percentile in reach or leg length. Thus, using some portion of the demographic database (5th to 95th percentile) in one dimension may include 90% of the population, but using the 5th to 95th percentile for all body dimensions is likely to exclude much more of the population. Obviously, as the percentile range is extended, significant cost/benefit tradeoffs are incurred.
>
> In some cases, it is not feasible to design for every individual. However, it is necessary to make every reasonable *accommodation* for all users to safely and efficiently perform their tasks. This can be accomplished through a variety of approaches, including conducting appropriate analyses to determine the full range of the user population, innovating designs for adjustability into the system, providing accessories or features that accommodate other users as the need arises, or providing custom modifications.

- **2.6.12 Design to accommodate people with disabilities.**
Systems and equipment shall provide reasonable accommodation for users with disabilities where appropriate. [Source: General Services Administration (Section 508), 2000]

    > **Discussion.** Make a reasonable effort to provide people with disabilities access to and use of systems and equipment that all people can access and use.

- **2.6.13 Provide enough flexibility for different user skill levels.**
Systems and equipment should be flexible enough to accommodate the interaction styles of users with differing skill and experience levels. [Source: Ameritech, 1998]

- **2.6.14 Maximize user subjective satisfaction.** Systems should be designed so that users like the new system or equipment. [Source: Ameritech, 1998]

    > **Discussion.** Users like a system that is well designed because it helps them accomplish their task and is easy to use without causing unnecessary workload.

2.7 Support

- **2.7.1 Provide help.** Help should be available in the event that the user has difficulty operating or maintaining software, systems or equipment. [Source: CTA, 1996]

    > **Discussion.** Help can come in many forms such as a customer support number that can be called for technical assistance, on-line help, and even user manuals.

2.8 Maintenance

- **2.8.1 Design for common tools.** Systems and equipment should be designed to require only common hand tools for maintenance unless specialized tools provide a significant advantage over common hand tools or where required by security considerations. [Source: MIL-HDBK-759C, 1995; MIL-STD-1472F, 1999]

- **2.8.2 Make systems easy to maintain.** Systems and equipment shall be designed so that they can be maintained in the least amount of time, at the lowest cost, and with a minimum expenditure of support resources. [Source: Department of Energy (DOE HFAC1), 1992]

Glossary

Consistent - Consistent means adhering to the same principles with minimal variation.

Modular - To be modular means to be designed with standardized or uniform components.

Standardization - Standardization refers to common user-interface features across multiple applications.

User-centered perspective - A user-centered perspective involves focusing on the needs and requirements of the end user throughout the design, acquisition, or development process.

References

Ameritech Services Incorporated. (1998). *Ameritech character-based interface standards introduction.* Chicago, IL: Ameritech Corporation.

Apple Computer Incorporated. (1995). *Macintosh human interface guidelines*. Reading, MA: Addison-Wesley Publishing Company.

Avery, L. W., & Bowser, S. E. (Eds.). (1992). *Department of Defense human-computer interface style guide (Version 2.0)* (DOE HFDG ATCCS V2.0 also known as DOD HCISG V2). Washington, DC: Defense Information Systems Agency.

Billings, C. E. (1991). *Human –centered aircraft automation: A concept and guidelines*. Moffett Field, CA: National Aeronautics and Space Administration, Ames Research Center.

CTA Incorporated. (1996). *User-interface guidelines* (DSTL-95-033). Greenbelt, MD: Goddard Space Flight Center (Code 520).

Department of Defense. (1995). *Human engineering design guidelines*. (MIL-HDBK-759C). Philadelphia, PA: Navy Publishing and Printing Office.

Department of Defense. (1999). *Design criteria standard-human engineering.* (MIL-STD-1472F). Philadelphia, PA: Navy Publishing and Printing Office.

Department of Energy. (1992). *Human factors engineering design criteria* (DOE-HFAC1). Washington, DC: United States Department of Energy.

Department of Energy. (2001). *Human factors/ergonomics handbook for the design for ease of maintenance.* (DOE-HDBK-1140). Washington, DC: United States Department of Energy.

Galitz, W. O. (1993). *User-interface screen design (3rd edition)*. Wellesley, MA: QED Publishing Group.

General Services Administration. (2000). *Section 508 of the Rehabilitation Act of 1973: Electronic and Information Technology Accessibility Standards*. Washington, DC: Office of Technical and Information Services.

Martin, S. M., & Dong, J. (1999). *IBM Ease of Use. Cluster analysis for web site organization*. Internetworking: The newsletter of the Internet Technical Group v. 2.3.

Teitelbaum, R. & Granda, R. (1983). The effects of positional consistency on searching menus for information. *Proceedings of the CHI '83 Human Factors in Computer Systems.* 150-153.

Wallace, D. R., Peng, W. W., & Ippolito, L. M. (1992). *Software quality assurance: Documentation and reviews* (NISTIR 4909). Gaithersburg, MD: U.S. Department of Commerce Technology Administration, National Institute of Standards and Technology, Computer Systems Laboratory.

Index