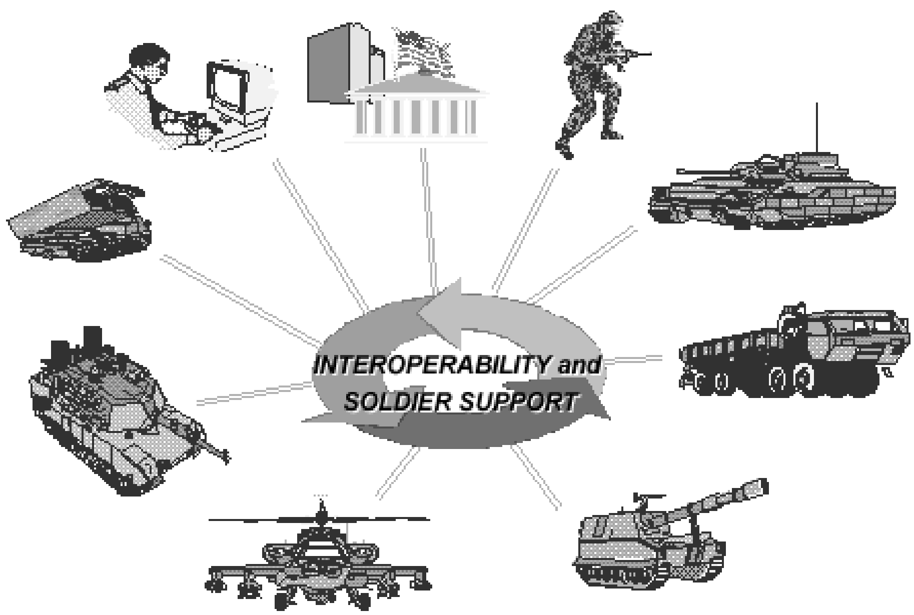
U. S. Army Weapon Systems Human-Computer Interface Style Guide



Version 3

December 1999

U.S. Army Weapon Systems Human-Computer Interface (WSHCI) Style Guide

Larry W. Avery
Thomas F. Sanquist
Peter A. O'Mara
Anthony P. Shepard
Daniel T. Donohoo

Version 3
December 1999

Prepared by

The Pacific Northwest National Laboratory
Richland, WA

Prepared for

Department of the Army
Office of the Director of Information Systems for
Command, Control, Communications, and Computers

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

FOREWORD

A stated goal of the U.S. Army has been the standardization of the human computer interfaces (HCIs) of its systems. Some of the tools being used to accomplish this standardization are HCI design guidelines and style guides. Currently, the Army is employing a number of HCI design guidance documents. These include the *Department of Defense (DoD) HCI Style Guide*, and the *User Interface Specifications for the Defense Information Infrastructure (DII)*. While these style guides provide good guidance for the command, control, communications, computers, and intelligence (C4I) domain, they do not necessarily represent the more unique requirements of the Army's real time and near-real time (RT/NRT) weapon systems. The Office of the Director of Information for Command, Control, Communications, and Computers (DISC4), in conjunction with the Weapon Systems Technical Architecture Working Group (WSTAWG), recognized this need as part of their activities to revise the *Army Technical Architecture (ATA)*, now termed the *Joint Technical Architecture - Army (JTA-A)*. To address this need, DISC4 tasked the Pacific Northwest National Laboratory (PNNL)[1] to develop an Army weapon systems unique HCI style guide, which resulted in the *Weapon Systems Human-Computer Interface (WSHCI) Style Guide Version 1*. Based on feedback from the user community, DISC4 further tasked PNNL to revise Version 1 and publish Version 2. In 1999, DISC4 again tasked PNNL to revise the *WSHCI* and publish Version 3. This document provides that revision.

The purpose of this document is to provide HCI design guidance for the RT/NRT domain across the weapon system subdomains of ground vehicle systems, aviation systems, missile systems, soldier systems, and munition systems. Each subdomain should customize and extend this guidance by developing their domain-specific style guides, which will be used to guide the development of future systems within their subdomains.

This document was developed through a comprehensive review of the open literature and domain system documentation. In addition, iterative reviews and input from a specially organized working group composed of representatives from each of the Army weapon system subdomains were used to tailor the contents to their requirements. This document is meant to be a living document that will be updated at intervals based on new research and the emerging maturity of the subdomain style guides.

---

1 Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle under Contract DE-AC06-76RLO 1830.

Copies of this document can be obtained from DISC4 at the following address:

Office of the Director of Information Systems for Command, Control,
Communications, and Computers
Attn: SAIS-ADM (Mr. Don Routten)
Pentagon
Washington, DC 20310
(703) 614-0514

Copies can also be downloaded from the following Websites:

http://arch-disc4.army.mil/hci/html/hci.htm

http://www.pnl.gov/wshciweb

The authors would like to thank all the people who participated in the development of this document. The *WSHCI Style Guide* was developed through the combined efforts of the following organizations:

- DISC4
- PNNL
- WSTAWG
- The *Weapon Systems HCI Style Guide* Working Group
- Monterey Technologies, Incorporated.

The Working Group was particularly critical to the success of this effort through their valuable insights into the requirements of each subdomain as well as their extraordinary efforts to review and comment on drafts of the document. The authors would also like to thank those many organizations and people who provided documents for inclusion in the literature review.

Points of contact for each of the Army weapon system subdomains are as follows:

Ground Vehicles	PM Ground Systems Integration SFAE-GCSS-W-GSI Warren, MI 48397-5000 810-574-6720 or DSN 786-6720
Soldier Systems	PM Soldier SSCPM-LW 10401 Totten Road Suite 21 Fort Belvoir, VA 22060 703-704-3858 or DSN 654-3858
Aviation	CMDR, USA AMCOM ATTN: AMSAM-AR-ESC Bldg 5681 Redstone Arsenal, AL 35898-5000 205-313-4858
Missile	PEO-Missile Defense SFAE-AMD-TSD-EA P.O. Box 1500 Huntsville, AL 35807-3801 205-955-1062
Munition	DSA Director of Aircraft, Armament, and Small Arms AMSTA-LC-CS Rock Island, IL 61299-6000 301-782-0677
	APEO Ground Combat and Support Systems SFAE-GCSS-PM Picatinny Arsenal, NJ 07806-5000 973-724-7115

This page intentionally left blank.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1.0 INTRODUCTION

1.1 BACKGROUND

The U.S. Army has long recognized the importance of the human in overall system effectiveness through its emphasis on human factors engineering (HFE) in system design and evaluation. As the complexity of systems entering the Army inventory has increased, so has the complexity of the interface between the operator and the machine. This has led to an increased potential for work overload on the operator, increased chances for human error, and a corresponding potential decrease in overall system effectiveness. This is particularly true where the system relies on computers. Effective design of the human-computer interface (HCI) has become critical to system success.

Designing an effective HCI focuses on achieving three major goals:

- Design an HCI that meets the user’s operational needs.

- Ensure that the HCI has been designed to maximize human and system performance and to minimize human error.

- Standardize HCI design.

Some of the tools to achieve these goals include design guidelines documents, standards, and style guides. The U.S. Department of Defense (DoD) has published a number of guidelines documents and style guides that address the design of the HCI for military systems. These documents include, but are not limited to, the following:

- *DoD HCI Style Guide* (U.S. DoD 1995)

- *User Interface Specification for the Defense Information Infrastructure (DII)* (U.S. DoD 1999a)

- *Human Factors Design Guidelines for the U.S. Army Tactical Command and Control System (ATCCS) Soldier-Machine Interface* (U.S. Army 1992).

These documents provide human factors design guidance, starting from the *DoD HCI Style Guide*, which contains general, high-level design guidelines, down through successive levels of tailoring and specificity. Each of these documents, while being comprehensive, is more appropriate to command, control, communications, computers, and intelligence (C4I) systems that use extensive windowing, are deployed in buildings, ships, shelters and tents, and do not require almost instantaneous decision-making. What these documents do not address well are the unique requirements of real time and near-real time (RT/NRT) systems, such as the weapon systems domain, and particularly RT/NRT systems from the following subdomains:

- **Aviation Systems** - This subdomain is responsible for developing aircraft systems to support a variety of military missions, including attack, reconnaissance/security, utility, cargo and special operations. These missions encompass various environmental factors that can impact aircrew performance and HCI design, with the task environment characterized as being: information-intensive, dynamic, time-constrained, and imposing severe consequences for error. High vibration, ambient noise, restricted visibility, and limited cockpit real estate for controls and displays are additional factors to be considered with aviation systems.

- **Ground Vehicle Systems** - This subdomain is composed of the following elements: tanks, infantry fighting vehicles, engineering vehicles with processor-based mission controls/sensors, howitzers, mortar systems, and chemical/biological systems with processor-based mission controls/sensors.

- **Missile Systems** - This subdomain encompasses rocket and missile systems used in diverse Battlefield Functional Areas including Air and Missile Defense, Fire Support, Close Combat, and Special Operations. The diversity of missions that rocket and missile systems must perform induces a variety of system solutions including shoulder-fired missiles, line-of-sight direct fire missiles and rockets, non-line-of-sight indirect fire missiles and rockets, and air and missile defense systems. Broadly, missile systems may be described by subsystem elements as consisting of: 1) missile, 2) launcher, 3) C3I (including fire control or battle management), and 4) sensor.

- **Soldier Systems** - This subdomain is responsible for developing integrated soldier systems. These soldier systems integrate target location, target identification, target acquisition, enhanced survivability, navigation, position location, enhanced mobility and command and control into a system worn or carried by a soldier in performance of their duties.

- **Munition Systems** – This subdomain encompasses non-mobile, transportable, weapon systems which include, but are not limited to, munitions and munitions integrated with combat sensors, control stations, and the supporting combat communication systems with their repeaters and gateways. The Munitions Systems subdomain includes any system or subsystem containing an explosive warhead (such as dumb, smart, and precision bombs, or mines and artillery shells) or non-lethal deterrent and that detects, classifies, identifies, intercepts, and destroys or negates the effectiveness of the enemy.

The following style guide has been developed to provide guidance more appropriate to RT/NRT systems and the weapon systems domain.

1.2 OBJECTIVE

The objective of this style guide, the *Weapon Systems Human Computer Interface (WSHCI) Style Guide*, is to provide design guidelines that can be used to design the HCI for RT/NRT systems. These guidelines are meant to:

- Provide HCI design guidance–focusing in look and behavior–that will assist in designing weapon systems to optimize human-system effectiveness and reduce human workload and error.
- Complement and extend those guidelines contained in the *DoD HCI Style Guide* (U.S. DoD 1995).
- Address guidelines that are applicable across most or all of the RT/NRT subdomains.
- Provide a starting point for developing subdomain-specific style guides that will further the goal of standardization.

These guidelines are intended to be a living document. The guidelines will be revised, depending on the emergence of more focused subdomain HCI style guides as well as future research.

1.3 USE OF THIS DOCUMENT

Effective system design for the user can only be accomplished if HFE is involved early in the design process. There is a well-established and documented set of processes and methodologies for applying HFE in the design process, for example in MIL-HDBK-46855, *Human Engineering Requirements for Military Systems, Equipment, and Facilities* (U.S. DoD 1996b). These processes and methodologies will not be repeated in this document. Most germane to this document are the processes of user-centered design and style guide tailoring.

1.3.1 User-Centered Design

User-centered design is an approach for design that focuses on improving system usability through iterative design and significant user involvement. Figure 1.1 provides an illustration of the user-centered design process.

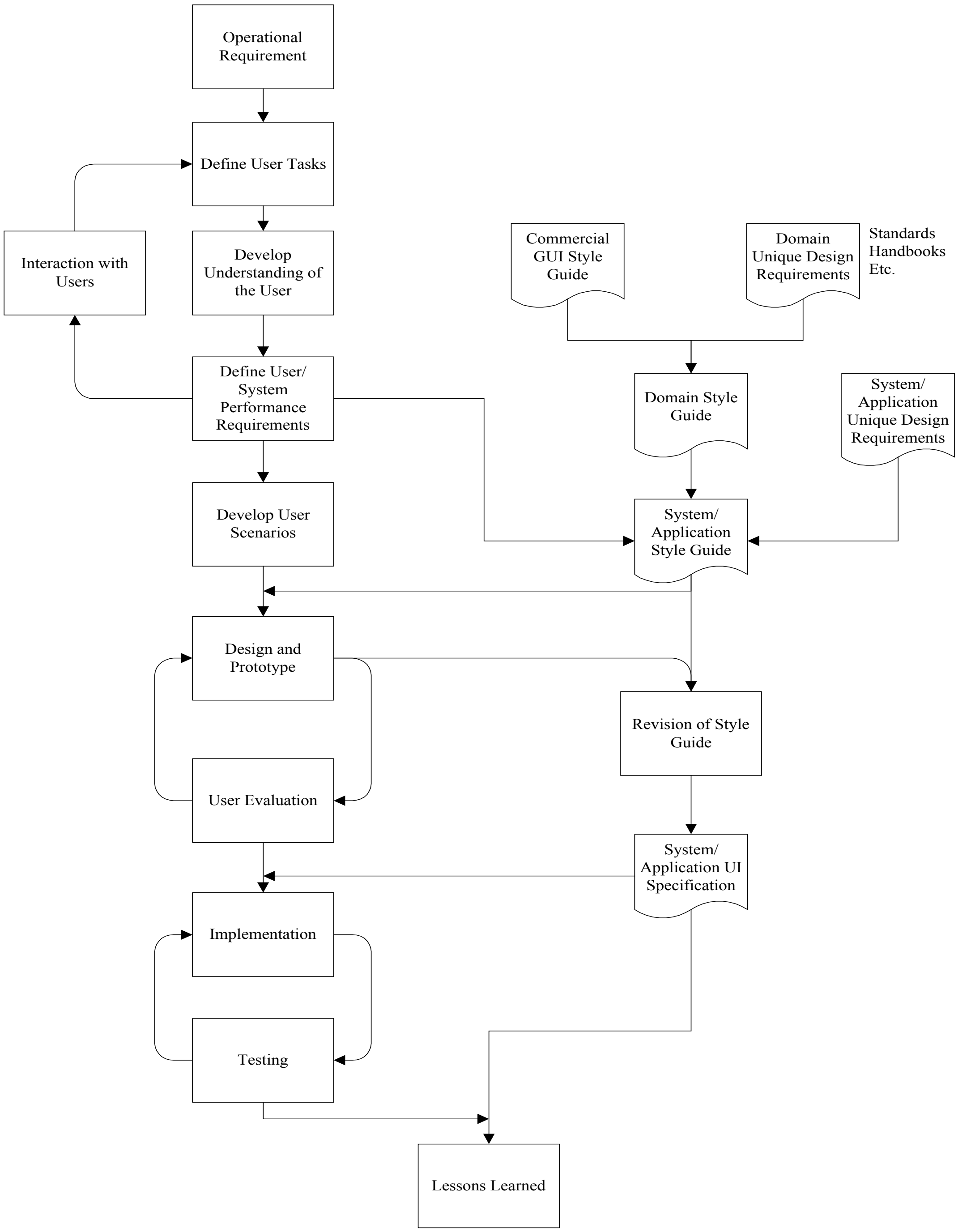


Figure 1.1 User-Centered Design and Style Guide Development Process

The four key principles of user-centered design are (adapted from Gould 1988):

- **Early and continual focus on users**. Focus on the users from the beginning. Follow this by continually contacting users to understand their requirements and capabilities.
- **Integrated design**. Develop all aspects of design that address usability in parallel and under one focus. Integrate usability design with overall system design.
- **Early and continual user testing**. Involve the user from the beginning and continuously. This early involvement is key in evaluating the design concepts and emerging prototypes.
- **Iterative design**. Modify the system/application design iteratively based on the results of user testing.

1.3.2 Application to Weapon Systems Development

The application of user centered design to the development of weapon systems may vary somewhat depending on the type of acquisition strategy being pursued, but the basic premise is consistent with the process outlined in Figure 1.1. Users, as well as qualified human factors and usability specialists, need to be involved in the full acquisition process, from requirements development through post-fielding lessons learned data collection. Currently, there are few DOD documents that define how the user-centered design process should be applied to weapon system development. MIL-HDBK-46855 (DoD 1996b) and MIL-HDBK-763 (DoD 1987) provide some guidance on human factors design processes and procedures, but do not necessarily reflect the current DoD acquisition environment. Although it is currently beyond the scope of this document to provide user-centered design processes for weapon system development, user interface designs should be based on operator tasks to ensure optimum system performance (Armstrong and Steinberg, 1998).

1.3.3 Style Guides

A key part of user-centered design for the HCI is the development of style guides. An HCI style guide is a document that specifies design rules and guidelines for the look and behavior of the user interaction with a software application or a family of software applications. The goal of a style guide is to improve human performance and reduce training requirements by ensuring consistent and usable design of the HCI across software modules, applications, and systems. The style guide represents "what" user interfaces should do in terms of appearance and behavior, and can be used to derive HCI design specifications that define "how" the rules are implemented in the HCI application code.

A style guide differs from a handbook or a user interface specification. Handbooks are typically documents that provide broad design guidance, including both design guidelines and design methodology. Style guides tailor the guidance contained in a handbook to provide more specificity for the design of an application, system, or family of systems. A user interface specification further tailors the guidance contained in a style guide and provides specific design rules for an application or system. Figure 1.1 provides an illustration of this tailoring process as part of user-centered design. Table 1.1 provides an illustration of the varying levels of specificity for design guidance contained in these various documents.

Table 1.1 Example of Levels of Specificity Between Handbooks, Domain Style Guides, and User-Interface Specifications

Document Type	Example Guidance Statement
Style Guide/Handbook	Format the display of hierarchical menus, dialog boxes, and pop-up windows such that options that actually accomplish control entries can be distinguished from those that merely branch to other menu frames.
Domain Style Guide	Provide a visual indication when a menu option will take the operator to a submenu. For example, use an arrowhead to indicate a cascading menu or three ellipses to indicate a pop-up menu.
User-Interface Specification	Menu options that lead to a cascading menu shall be indicated by an arrow placed to the right of the option label on the multifunction or soft key.

1.3.4 Use of the WSHCI Style Guide

The *WSHCI Style Guide* is, in reality, a set of design guidelines, not a style guide as defined in paragraph 1.3.2. The *WSHCI Style Guide* should be used as a starting point for developing subdomain- and system-specific style guides. The relevant guidance from the *WSHCI Style Guide* should be expanded with subdomain-specific requirements and tailored to meet the requirements of the subdomain. Figure 1.2 illustrates this process. Subdomain style guides will become annexes to the *WSHCI Style Guide* as they are completed and approved.

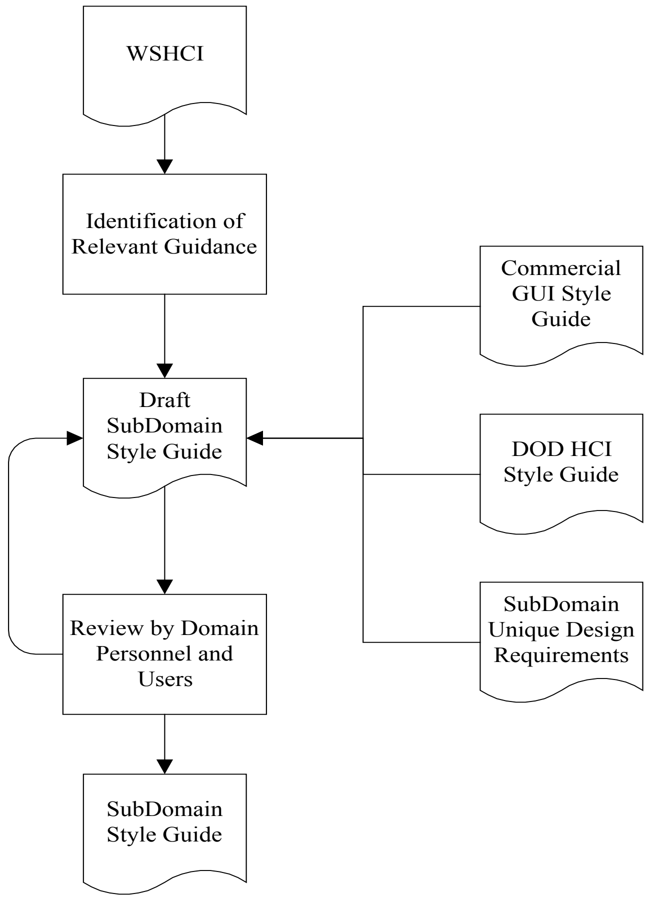


Figure 1.2 Process for Developing a Subdomain-Specific Style Guide from the *WSHCI Style Guide*

1.4 ORGANIZATION

The remainder of the body of this document is organized into the following sections:

- 2.0 - Real Time and Near-Real Time Systems
- 3.0 - General Guidelines
- 4.0 - General Guidelines for Input Devices
- 5.0 - General Guidelines for Displays
- 6.0 - Touch Screen Design
- 7.0 - Helmet-Mounted Displays
- 8.0 - Head-Up Displays
- 9.0 - Auditory Human-Computer Interaction
- 10.0 - Interactive Control
- 11.0 - Screen Design
- 12.0 - Coding
- Appendix A - Acronyms
- Appendix B - References
- Appendix C – Glossary
- Index.

2.0 REAL TIME AND NEAR-REAL TIME SYSTEMS

The objectives of this section are to provide designers with an understanding of real time and near-real time systems, the environments in which they are employed, and some of the high-level considerations that should be used to guide the design of their HCIs.

2.1 DEFINITIONS

Currently, no definitions for real time (RT) systems and near-real time (NRT) systems are approved for use by the U.S. Army. Joint Publication 1-02 (U.S. DoD 1994) provides jointly approved definitions for the terms "Real Time" and "Near-Real Time" that focus solely on electromagnetic signal transmission characteristics. However, when these terms are used as modifiers to describe systems, the resulting definitions are imprecise and ambiguous.

The definition of time, when utilized in the context of RT/NRT systems, can be considered from three viewpoints:

- Time, as a criterion for usability, considers the system response time to user input and the time required by a user to perform a task.
- Time, as a part of information, considers system data as a function of time in the decision process, where "stale" data may result in an incorrect decision.
- Time, in relation to timeliness, relates to overall demands on either the system, the user, or both.

The consensus among users is that RT/NRT systems and C4I systems are different. This differentiation can be made based on the deterministic nature of RT/NRT systems and the asynchronous nature of C4I systems. The general concurrence is, however, that another major differentiating factor is whether or not a system performs time-critical operational functions. Because no definitions are approved for army-wide use, and because "time-critical" is relative, systems are categorized as either RT/NRT or C4I based on domain perspectives and opinions of users. As a direct result, no clear agreement can be obtained from the user population as to which systems constitute the true RT/NRT system baseline.

To identify appropriate systems to use for "baseline characterization," the following working definition of RT/NRT systems was used in constructing the *WSHCI Style Guide*:

> "RT/NRT Systems - Systems where little or no delay exists between the time an event occurs and the time it is presented to the user; and where there is an operational requirement for the user to quickly recognize this presentation, comprehend its significance, and determine and execute appropriate action(s)."

While there are subtle technical differences between an RT and an NRT system, based on the above definition, there is no perceived difference to the user. Therefore, RT and NRT systems will be treated as one type of system in this document.

2.2 REAL TIME AND NEAR-REAL TIME SYSTEM CHARACTERIZATION

RT/NRT systems may exist in their own right or as components of C4I systems. As a general rule, RT/NRT systems or components exhibit the following characteristics that further distinguish them from C4I systems:

- **Time-Critical Operational Function Orientation**. RT/NRT systems or components are designed to perform operational functions where time-critical user responses are essential to mission accomplishment. Definitions for "time-critical" vary across domains.

- **High-Stress Decision Environment**. RT/NRT systems or components are often found in environments where users must make decisions and take actions when the penalty for incorrect or improper responses can be severe, e.g., mid-air collision, failure to intercept an inbound missile, failure to take evasive action, etc. The outcome of an incorrect decision may include serious injury or death for the user or for individuals at other locations. Often these decisions must be made in time competition with other equally important decisions.

- **Situational Awareness**. RT/NRT systems or components are generally designed to provide users with immediate situational awareness of rapidly changing events and often include position location information (PLI) or related information, i.e., two-dimensional (2-D)/three-dimensional (3-D) location, vector data, relative bearing, etc., as a major system focus. This information is usually computed by the system or component, based on input received from externally focused sensors.

- **Context Sensitivity of Information**. A critical aspect of RT/NRT systems is that information displayed must be context-sensitive to the task or mission currently being performed to ensure awareness of and focus on the mission in a rapidly changing environment.

2.3 SYSTEM OPERATIONAL ENVIRONMENTS

As is the case with C4I systems, RT/NRT systems can potentially exist at all unit echelons and can be designed for use in a variety of possible environments. In general, emerging RT/NRT systems are being inserted into increasingly hostile operational environments. The impact of unfriendly environmental conditions on operator-system interactions can yield significant overall degradation in operational performance and must be accommodated during system design. Because RT/NRT systems are time-critical by nature, the effects of the operational environment can be particularly important.

Some of the more significant conditions for consideration in RT/NRT system design are:

- **Shock and Vibration.** Shock and vibration effects on the operator, such as those associated with moving vehicles (ground and aircraft) and impulse shock due to firing weapons, can make it difficult for operators to comprehend visually presented data and to execute appropriate control actions on displays. Refer to Section 10.4 in the *Engineering Data Compendium Human Perception and Performance* (Boff and Lincoln 1988) for a discussion on the impact of vibration on human performance. Also, operators in these environments may be required to use one hand for stability inside the moving platform and, because of this, may only be able to interact with system controls with a single hand.

- **High-Decibel Noise.** High-decibel noise, such as that associated with some aircraft, large vehicles, and the general combat environment, can make it difficult for operators to notice audible cues, alerts, and alarms.

- **Variable Ambient Lighting.** Variable ambient lighting conditions can make it difficult for operators to quickly focus–and therefore comprehend–visually presented data. This is particularly pronounced in environments where the operator is exposed to rapidly fluctuating lighting conditions, such as bright sunlight followed by shadow.

- **Physically Constrained Work Areas.** Physically constrained work areas, such as those found inside vehicle crew compartments, can make it difficult for operators to observe system displays and to interact with system controls. In addition, physically constrained areas can impact the size and number of controls and displays.

- **Nuclear, Biological, and Chemical (NBC) Environments.** Operating a system while wearing NBC clothing can make it difficult to view displays, hear audible signals, communicate verbally, and operate controls. In addition, sustained operation in NBC environments can lead to heat stress and other physiological degradation of operator performance.

- **Temperature Extremes.** Operation in extreme heat or extreme cold can impact both operator and system performance. Military personnel, in particular, are susceptible to performance degradation in temperature-extreme environments and while wearing cold weather clothing.

- **Dirt, Dust, and Humidity.** Dirty, dusty, and humid environments can impact both operator and system performance. These conditions can cause difficulties in reading, in operating equipment, and in reducing reliability of equipment.

- **Survivability.** Designing a system to survive conditions such as electromagnetic interference (EMI), electromagnetic pulse (EMP), crashworthiness, and ballistic protection can impact system weights and sizes.

- **Open Hatch Operations.** Operating systems in an open hatch mode can cause additional display illumination requirements for visibility and readability, which must be accommodated without compromising anti-detection requirements. Additionally, open-hatch operations will create a noisier workspace and may also yield requirements for remoted controls and displays.

- **Portability.** In dismounted operations, systems must be carried by the operator in addition to their normal load. Weight, comfort, battery life, and compatibility with other equipment are critical design issues

3.0 GENERAL GUIDELINES

The following section provides general guidelines for the design of HCIs for RT/NRT weapon systems.

3.1 APPROPRIATE USE OF COMPUTERS

Design the computer-enhanced system to increase system effectiveness and reduce operator workload by allocating functionality appropriately between the human and the computer. Operators possess certain inherent skills and attributes that make them superior to automation for certain types of tasks. The following are general types of tasks that are more appropriate for operators:

- Flexible time-critical decision-making, for example, to engage or not to engage a target, or in some cases to modify existing automated rules of engagement during tactical operations
- Complex pattern recognition, for example, determining whether the target is a friend or foe, or recognizing subtle changes to a dynamic engagement operation
- Decision-making under time-critical and uncertain conditions, for example, deciding which is the best sensor and/or weapon to use
- Communications where voice inflection is critical.

Computers are capable of providing information and assistance to the operator for some of these tasks but are not the best choice for final responses. For mission-critical tasks that fall within these categories, use computers to monitor and signal state changes. However, ensure that the operator will always make the final input. For non-mission-critical tasks, permit the operator to determine whether to let the computer make the decision. (Parasuraman 1987; U.S. Army 1995f, 1995g; WSSG Working Group 1996)

3.2 RT/NRT DESIGN GOALS

Consider in the development of RT/NRT systems the following high-level design goals, presented in no order of priority:

a. Minimize requirements for the operator to focus on the internal system environment and maximize the focus on the external environment or threat.

b. Minimize cursor travel requirements across and between displays or windows on a display.

c. Minimize switching visual focus between different displays during a procedure or windows on a display.

d. Minimize the use of color, except where it enhances performance.

e. Minimize the number of steps within a procedure.

f. Minimize the amount of required display manipulation such as screen adjustment, window sizing, window placement, and window manipulation.

g. Minimize the frequency and significance of operator error.

h. Minimize the requirement for operator memory recall.

i. Maximize the distribution of both physical and cognitive workload for individual operators and between crew members.

j. Maximize the availability and speed of feedback, and keep the operator informed about system processing.

k. Maximize the use of error recovery.

l. Maximize the use of similar procedures.

m. Maximize the relevance of human-computer dialogue to the operator's job.

n. Maximize the use of standard and consistent human-computer dialogue.

o. Maximize the use of preset, templated, and automated setup procedures.

p. Minimize the display of information not directly relevant to the immediate decision the operator must make.

q. Maximize, for crew-served systems, the ability of the crew to directly share information and control functions between crewstations.

r. Minimize the number of times the operator’s hands need to leave vehicle controls.

s. Maximize system safety.

(Obermayer and Campbell 1994; WSSG Working Group 1996, 1997)

3.3 DESIGN FOR CREW TASKS

3.3.1 Design for Simultaneous Complex Task Performance

Design the human-to-system interaction, when complex tasks must be performed simultaneously, for crew performance rather than for individual performance. This limits situations where operator performance is degraded because operators must perform simultaneous complex tasks, such as piloting a vehicle while concurrently recognizing and acting on target acquisition data. (Dominessy et al. 1991)

3.3.2 Design for Shared and Redundant Functionality

When crew can share functionality, with the control being exclusive to one crew member, provide the following:

a. A visual indication of who has control.

b. The capability for an override of any lock-out of control functionality, when one crew member may have to take over control for another injured crew member. Ensure that the override is communicated prior to its occurrence to preclude inappropriate override.

(WSSG Working Group 1996)

3.4 DESIGN TO HUMAN LIMITATIONS

Design the user interface for RT/NRT systems such that it does not overload user cognitive processing, perception, decision-making, and manipulation. A design that considers the limitations in human sensory, perceptual, and cognitive abilities helps avoid over-stressing the operator. Designing to human limitations is particularly important for decision support systems. (U.S. Army 1995g; Heinecke 1993; Walrath 1989)

3.5 MISSION-CRITICAL FUNCTIONS

3.5.1 Access to Mission-Critical Functions

Provide direct access to mission-critical functions to minimize the number of choices during time and mission-critical phases of operation. This can be accomplished by separating the mission-critical functions from the non-mission-critical functions, and designing the HCI so that mission-critical options are made through dedicated controls, menu options at the top of a menu list, or input focus directed to the critical options. (U.S. Army 1995g)

3.5.2 Mission-Critical Function Execution

Design the HCI so that the number of actions required to initiate a mission-critical function is minimized, while ensuring that inadvertent activation is prevented. (U.S. Army 1995g; Site Visit to U.S. Army Tank-Automotive Research, Development, and Engineering Center [TARDEC] 1996; WSSG Working Group 1997)

3.5.3 Redundant Methods for Execution of Mission-Critical Functions

Provide the operator with redundant methods to execute mission-critical functions, for example, a pointing device and a touch screen. One of the redundant methods should be the primary input method. Ensure that it is obvious to the operator which method is primary and which is secondary. (U.S. Army 1995g; Site Visit TARDEC 1996)

3.6 RETAINING CONTROL

Ensure that the operator retains control of the system so that system status, e.g., target engaged or location, is always known and the operator has final determination of system actions. (U.S. Army 1995g)

3.7 CONTROLS AND DISPLAYS

3.7.1 Control Input Data Feedback

Design the system so that the operator receives clear, unambiguous, and rapid feedback for control data being entered and that any data displayed do not mislead the operator with regard to nomenclature, units of measure, sequence of task steps, or time phasing. (General Dynamics 1986)

3.7.2 Control and Display Compatibility with Operator Skill Levels

Ensure that the design of controls and displays is compatible with the appropriate operator skill levels as well as tailorable for differing skill levels, e.g., novices versus experienced users. (General Dynamics 1986; WSSG Working Group 1996, 1997)

3.7.3 Control and Display Relationships

Ensure that control and display relationships, including control and display objects on a screen, are straightforward and obvious to the operator and that control actions are simple and direct. (General Dynamics 1986; WSSG Working Group 1997)

3.7.3.1 Relationship

Ensure that the relationship of a control to its corresponding display or displayed object is apparent and unambiguous by:

- Location adjacent to associated displays
- Proximity, similarity of groupings, coding, labeling, or similar techniques.

(U.S. DoD 1996a)

3.7.3.2 Functional Grouping

Design functionally related controls and displays so that they are located in proximity to one another, arranged in functional groups. Design controls related to a specific task so that they are located close to one another to maximize proximity compatibility. (U.S. DoD 1996a; Wickens and Carswell 1995)

3.7.3.3 Consistency

Ensure that the location of recurring functional groups and individual items is consistent from panel to panel and, for multifunction displays, from screen to screen. (U.S. DoD 1996a)

3.7.3.4 Simultaneous Use

Ensure that, when the operator must monitor a display concurrently with the manipulation of a related control, the display is located in the primary visual zone. See Figure 3.1. (U.S. DoD 1996a)

3.7.3.5 Minimization of Eye Focus Shifts

Design the operator-system interface to minimize visual shifts between displays and controls—as well as displays and displays—that require the eye to refocus. (WSSG Working Group 1996)

3.7.4 Multifunction Displays

3.7.4.1 Use

Consider providing multifunction displays (MFDs), where appropriate, that allow access to the system functionality, rather than dedicated displays. This reduces the number of physical controls and displays required where control panel surface is limited. (U.S. Army 1995g)

3.7.4.2 Redundancy

When using MFDs, provide redundancy to ensure that system safety is not compromised. For example, provide hardwired controls for critical safety functions, or provide the ability to send display input to another display device in the event of display failure. (WSSG Working Group 1997)

3.7.4.3 Design

Design MFDs in accordance with the relevant guidance contained in Sections 4.0, “General Guidelines for Input Devices,” 5.0, “General Guidelines for Displays,” 6.0, “Touch Screen Design,” 8.0, “Head-Up Displays,” and 9.0, “Auditory Human-Computer Interaction.”

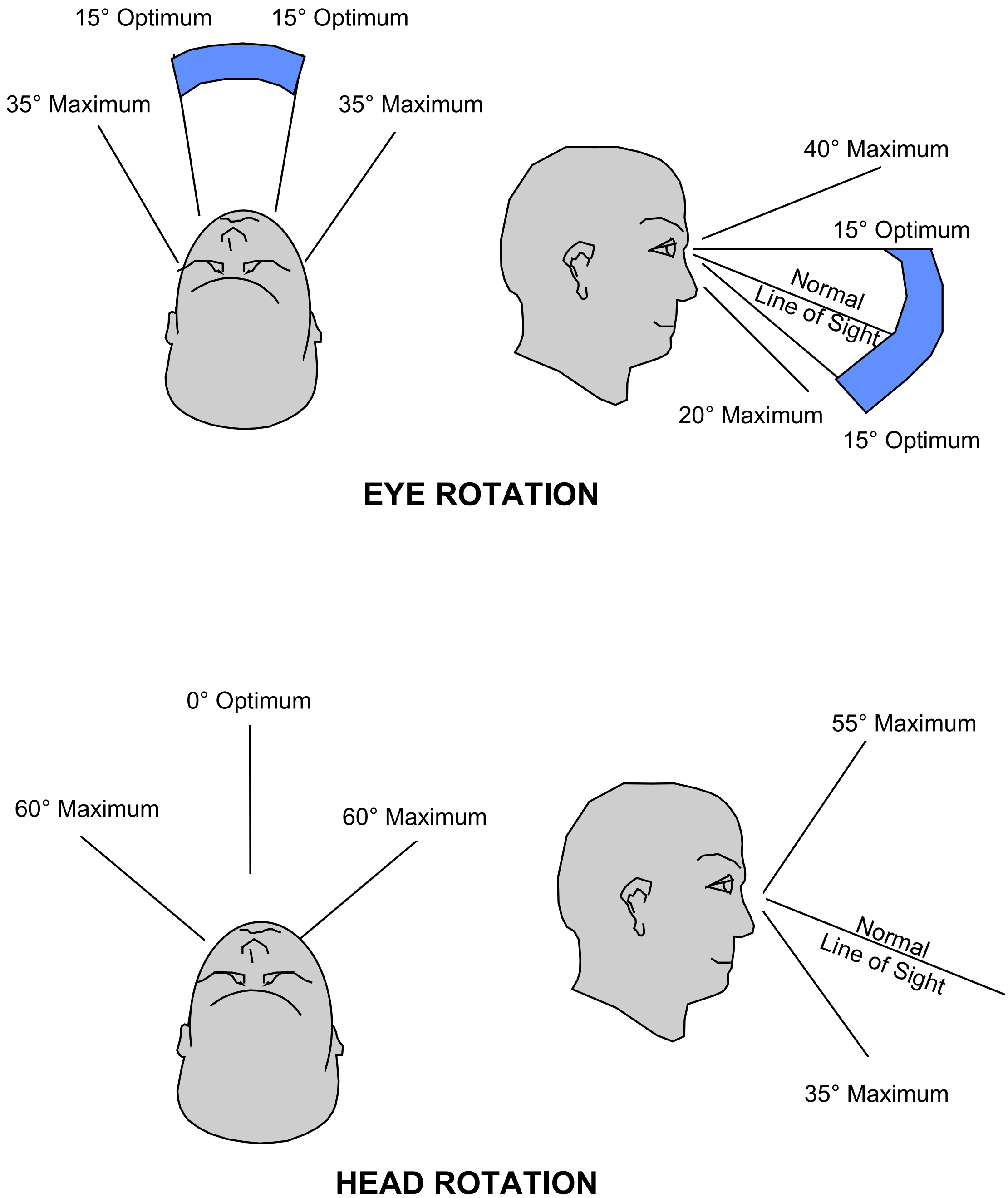


Figure 3.1 Illustration of the Primary Visual Zone

Adapted from MIL-STD-1472E (U.S. DoD 1996a)

3.7.5 Design for Left and Right Dominance

Consider, when designing the controls and displays for some types of weapon systems, that operators may be either left- or right-handed or eye dominant. (WSSG Working Group 1996)

3.8 DESIGN FOR MULTIPLE CREWSTATIONS

Ensure that the design of the HCI, where there are multiple crewstations in an RT/NRT system, provides consistent input and output methods among individual crewstations within a platform. For example, the HCI for a vehicle control workstation should be similar to that for weapons control, where the functionality lends itself to similar crewstation designs. See Figure 3.2 for an illustration. (General Dynamics 1986)

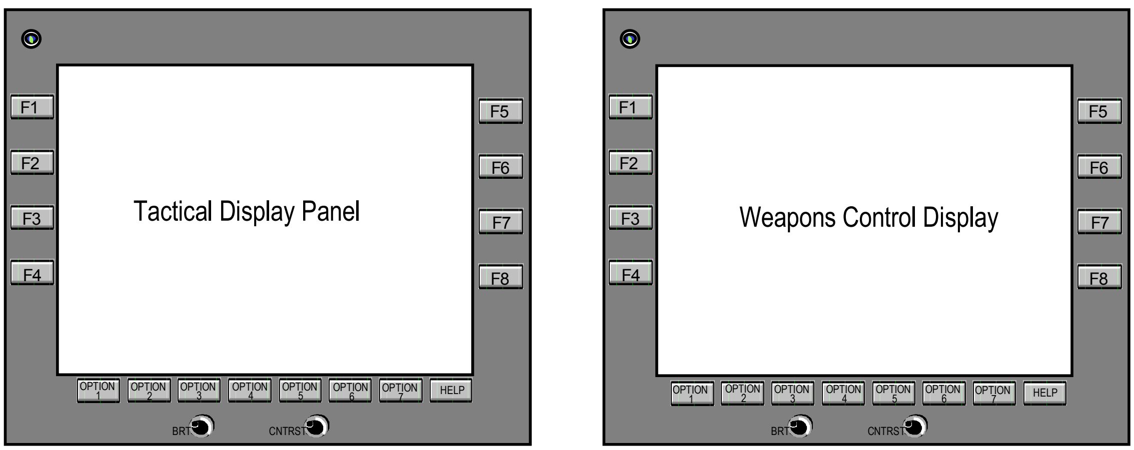


Figure 3.2 Illustration of Consistent Input and Output Methods Among Crewstations

3.9 SYSTEM SETUP PRIOR TO MISSION START

Design the system to allow mission-related data and functions to be loaded and set up prior to the start of the mission, thereby minimizing the need for data input during real-time operations. For example, methods such as autofilling databases or data-entry templates could be used. Ensure that the design allows modification of the data to reflect changes in the mission situation. (U.S. Army 1995f; WSSG Working Group 1996, 1997)

3.10 USE OF MNEMONICS

Ensure that the HCI design minimizes the use of mnemonics, codes, special or long sequences of actions, or special instructions—except for emergency instructions. (General Dynamics 1986)

3.11 DISPLAY RESPONSE TIMES

Ensure that display response times, e.g., latency, update rates are minimized and consistent with operational requirements. (General Dynamics 1986; WSSG Working Group 1997)

3.12 MESSAGING

3.12.1 Message Queue

Design message queues such that:

a. The capability is provided for the operator to sort messages by time, type, author, or other way that better meets an operational need for message display. (Osga et al. 1995; WSSG Working Group 1996)

b. Incoming messages are queued by priority and time of receipt. (Osga et al. 1995; WSSG Working Group 1996)

c. The capability is provided for the operator to quickly view summary information on the messages. (Osga et al. 1995; WSSG Working Group 1996)

d. An indication is provided of which messages have been accessed and which have not. (Osga et al. 1995; WSSG Working Group 1996)

e. If not all messages can be viewed simultaneously, a summary number of critical messages in the queue are displayed. (Steinberg et al. 1994)

f. Critical messages are not covered by a number of less significant messages. (Steinberg et al. 1994)

3.12.2 Automatic Verification of Message Format and Content

Provide automated processes to verify message formats and content, and allow the operator to verify that messages have been sent and received. (Osga et al. 1995)

3.12.3 Message Received Alert

Provide a means for alerting operators of the receipt of high-priority messages by means of alerting tones or audible signals, visual indications in the primary viewing zone, tactile methods, or a combination of methods. Provide a less obtrusive alerting mechanism for lower-priority messages. When using a visual indication, ensure that it does not appear in the primary viewing zone when the operator must use that zone to place or align a weapon reticle on a target. (Osga et al. 1995; WSSG Working Group 1996)

3.12.4 Message Management

Provide the operator with the capability to manage messages in the queue through reviewing, editing, and deleting functions. Where possible and appropriate, provide automatic message processing and display to minimize operator interaction with the messaging system. (WSSG Working Group 1996)

3.13 DECISION SUPPORT SYSTEM DESIGN

Design decision support systems for RT/NRT systems to:

a. Allow the operator to monitor the on-going system processes, to facilitate intervention when necessary.

b. Be consistent with the operator's expectations and mental model of the battle management process and the tactical problem at hand.

(Alexander et al. 1994)

3.14 DESIGN FOR EMERGENCY SHUTDOWN AND RECOVERY

Design RT/NRT systems to provide for system emergency shutdown, initiated by either the operator or the system. System-initiated emergency shutdown should provide a warning indicating the source or event initiating the shutdown and should allow confirmation of shutdown actions. Emergency shutdown should preserve system configuration information and data to facilitate recovery. (WSSG Working Group 1996)

3.15 ERROR TOLERANCE

Design RT/NRT systems to be tolerant of operator errors. (WSSG Working Group 1997)

3.15.1 Identification of Errors

Ensure that errors can be easily identified and corrected before they propagate through the system. (Cardosi and Murphy 1995; Bailey 1982)

3.15.2 Assisting Error Detection

Design the RT/NRT system to assist the operator in detecting critical errors. (Cardosi and Murphy 1995)

3.15.3 Error Recovery

Design the RT/NRT system so that operators can easily recover from errors. (Cardosi and Murphy 1995)

This page intentionally left blank.

4.0 GENERAL GUIDELINES FOR INPUT DEVICES

The types of input devices utilized in RT/NRT systems vary depending on how and where the system is employed. Systems employed in aviation or ground vehicle platforms, which are affected by vibration and limited workspace, tend to make use of touch screens, keypads, and pointing devices. Systems deployed in shelters such as air defense systems, which have more workspace and are not operated "on the move," tend to employ full standard alphanumeric keyboard layout (QWERTY) keyboards and track balls, as well as other technology. Soldier systems tend to employ unique keypads and cursor control devices attached to the operator's body. Guidance for the physical design of keyboards, track balls, and other input devices can be found in the following references:

- *DoD HCI Style Guide* (U.S. DoD 1995)
- *User Interface Specification for the Defense Information Infrastructure (DII)* (U.S. DoD 1999a)
- Section 11.4 of the *Handbook of Human Factors* (Greenstein and Arnaut 1987).

This section addresses general considerations in selecting input devices, as well as guidelines for function keys. Design guidelines for touch screens and speech recognition systems can be found in Sections 6.0, "Touch Screen Design," and 9.0, "Auditory Human-Computer Interaction," respectively.

4.1 GENERAL DESIGN CONSIDERATIONS

4.1.1 Input Device for Operation on the Move

Where appropriate, design input devices used in RT/NRT systems for vehicle control, fire control, and command and control so that they can be used effectively by the operator while on the move, either in a vehicle or when dismounted. (WSSG Working Group 1996)

4.1.1.1 Design for Hands-on Vehicle Control Operation

Consider that the operator's hands may need to stay on the primary vehicle control when designing an input device for a vehicle where the system will be operated on the move. (Site visit TARDEC 1996; Jones and Parrish 1990)

4.1.1.2 Use of a Thumb Controller

Consider using a thumb controller mounted on the vehicle control stick, when the system must be operated by a pilot/driver while on the move. The thumb controller provides good performance compared to other types of devices, e.g., touch panel, multifunction control throttle, and stick. (Jones and Parrish 1990)

4.1.1.3 Bump Switch Use

Consider using "bump" switches in vehicles for accessing input areas on a display rather than having to scroll the cursor. Bump switches allow the operator to tab from input area to input area while maintaining hands-on control of the vehicle. Bump switches minimize errors due to vibration and shock. (Site visit TARDEC 1996)

4.1.1.4 Two-Handed Controller Use

Consider using a two-handed controller when the operator must perform a compensatory tracking task in a moving vehicle. This controller may allow the operator to attenuate the effects of vibration on tracking accuracy. See Figure 4.1 for an illustration of a two-handed controller. (Sharkey et al. 1995)

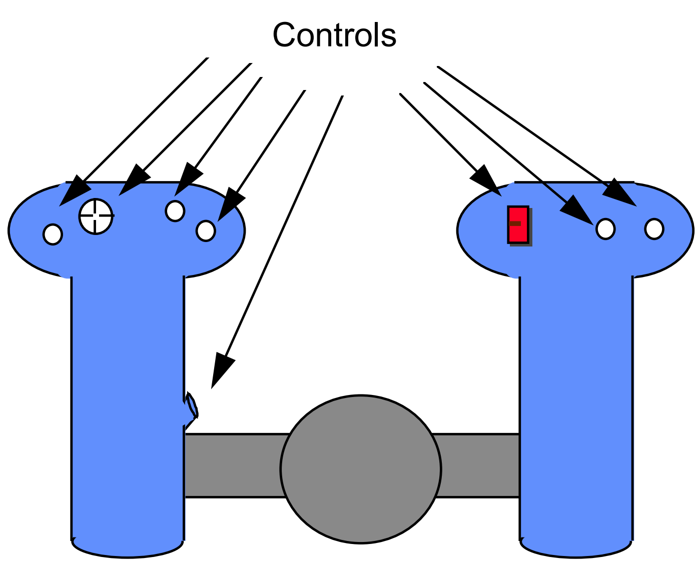


Figure 4.1 Illustration of a Two-Handed Controller*

* *Figure 4.1 was rendered from a Cadillac Hand Control Unit schematic.* (Sharkey et al. 1995)

4.1.2 Dual Input Device Capability

Provide, where possible, at least a dual input device capability, such as a pointing device and a keyboard. (Obermayer and Campbell 1994)

4.1.3 Use of Joysticks in RT/NRT Systems

Consider the following when planning on the use of a joystick as an input device for an RT/NRT system where operation will occur in a vibrating environment. Data suggest that force control (isometric) joysticks, while potentially more sensitive to vibration in the performance of some types of tracking tasks, provide better performance than the displacement joystick (isotonic). Ideally, a joystick should include properties of both, such as a small-deflection, low-stiffness stick. (Ribot et al. 1986; Boff and Lincoln 1988)

4.1.4 Control Sensitivity

Consider the following guidelines in designing the sensitivity of controls (i.e., gain) for RT/NRT systems. Keep in mind that control sensitivity must be consistent with required operator response times.

a. Use lower control sensitivity for RT/NRT systems where operators must operate in environments containing vibration. The lower control sensitivity should not negatively impact use while the operators are wearing gloves (cold weather, mission-oriented protective posture [MOPP], or fire retardant). (Boff and Lincoln 1988; WSSG Working Group 1996)

b. Provide the operator with the ability to control cursor response to pointing device movement, by setting the velocity-sensitive gain. This enables better control, depending on the task needs. Ensure that the operator cannot set the sensitivity to the 'off' position. (Obermayer and Campbell 1994; WSSG Working Group 1996)

4.1.5 Cursor Control

4.1.5.1 Cursor Control Velocity for Isometric Pointing Device

Consider, when using an isometric pointing device, that the requirements for cursor movement velocity in response to applied force on the pointing device vary for a gross positioning task versus a fine positioning task. Gross positioning tasks generally require faster cursor velocity changes at low levels of force, whereas fine positioning tasks require lower cursor velocity changes at low levels of force. The designer must make trade-offs to provide for the best operator performance.

The following ranges are recommended for velocity to force:

a. Minimum velocity gain of 146 pixels per second (pix/s) at a force of 1.75 pounds (lb).

b. Maximum velocity gain of 486 pix/s at a force of 3.0 lb.

(Doyal et al. 1995; Rauch 1988)

4.1.5.2 Cursor Movement Using a Track Ball

Locate on-screen buttons, widgets, and other selection objects close enough to each other to prevent the user from having to make more than one stroke on a track ball to move the cursor to a new selection on the screen. Research studies on using a track ball have demonstrated that there is a performance degradation when a user is required to take more than one stroke on the ball. (MacKenzie 1992, 1994)

4.1.5.3 Cursor Processing Delays

Keep cursor movement processing delays to a minimum. Data suggest that delays should be 75 milliseconds (ms) or less for best operator performance, and that delays higher than 120 ms may be perceived by the user as unacceptable. (Basile 1990)

4.1.6 Direct Manipulation Keypads and Keyboards

Design keypads and keyboards that are visually represented on a display screen where input is performed by a pointing device in accordance with the guidance contained in Paragraph 6.3, "Touch Screen Keyboards." (WSSG Working Group 1996)

4.1.7 Appropriate Hand Access to Controls

Locate controls, where one hand will be used consistently for input, to ensure that the operator does not have to cross hands or arms to use them. (WSSG Working Group 1996)

4.2 FUNCTION KEY DESIGN

There are three basic types of function keys: fixed function, multifunction, and soft keys. Fixed function keys, as their name implies, are dedicated to controlling single functions. The label for the function is on or adjacent to the control and non-variant. Multifunction keys, also called programmable or variable function keys, control a number of functions depending on the system mode or state. The label indicating the current function is variable and displayed on, or adjacent to, the control. Soft keys are a variation of a multifunction key where the label for the control is on a display screen and mimics a function key. Soft keys are typically depicted on the screen display as keyboard keys or buttons with bezels. However, on devices such as touch screens, the label itself may serve as the control.

4.2.1 General

4.2.1.1 Use of Function Keys

Consider using function keys as shortcuts for frequently used actions and for operations where speed is critical. (U.S. DoD 1995)

4.2.1.2 Assigning Functions to Keys

Associate function keys with just one function, where possible. Where keys are associated with more than one function, ensure that the current associated action is clearly evident to the user. (U.S. DoD 1995)

4.2.1.3 Disabling Inactive Function Keys

Automatically disable function keys that have no current function. For multifunction and soft keys, provide a visual indication of the key's functional status. For example, if no function is currently available to a certain key, that key should be grayed out or blank. (U.S. DoD 1995; U.S. Army 1995g)

4.2.1.4 Feedback for Inappropriate Key Activation

Provide visual, audible, and/or tactual feedback to a operator who tries to use an inappropriate or unavailable function key. (Mitchell and Kysor 1992)

4.2.1.5 Positive Indication of Activation

Ensure that function keys provide a positive indication of activation, such as tactile, aural, and/or visual feedback. (General Dynamics 1986)

4.2.1.6 Momentary Visual Feedback

Ensure that when the effects of the activation are momentary, the visual feedback is momentary as well, i.e., feedback occurs and then disappears. (U.S. Army 1995g)

4.2.1.7 Lock/Latch Visual Feedback

When the effects are to lock/latch a condition, ensure that the feedback lasts as long as the condition is locked. (U.S. Army 1995g)

4.2.1.8 Function Key Design for Operation on the Move

Design function keys so that vibration from operating on the move does not cause inadvertent repeated activation of a function key or, for that matter, any other touch input device. (Mitchell and Kysor 1992)

4.2.1.9 Function Key Labeling

Ensure that function keys have appropriate contextual labels that represent the operator's missions and tasks. (WSSG Working Group 1996)

4.2.2 Fixed Function Keys

4.2.2.1 Use of Fixed Function Keys

Use fixed function keys:

- For time-critical, error-critical, or frequently used control inputs.
- For functions that are continuously available regardless of mode.
- For control functions that are limited in number or discrete.
- For functions that require immediate application where menu selection is inappropriate.
- When space is at a premium. For example, lighted legend switches can integrate switch, legend, and illumination.

(General Dynamics 1986)

4.2.2.2 Design of Fixed Function Keys

Design fixed function keys in accordance with the appropriate sections of the *DoD HCI* Style *Guide* (U.S. DoD 1995).

4.2.2.3 Reassignment of Functions

When a fixed function key has been assigned a given function, do not reassign that function to another key. For example, if the far right key has been assigned the Help function in one application or module, do not assign the Help function to another key for a different application or module. (General Dynamics 1986)

4.2.3 Multifunction (Programmable) Keys

4.2.3.1 Use of Multifunction Keys

Use multifunction keys when:

- Total number of functions cannot be conveniently handled by dedicated pushbuttons.
- Control input requirements vary significantly for different modes of operation.

(General Dynamics 1986)

4.2.3.2 Multifunction Key Feedback

Provide the operator with tactile feedback when selecting a multifunction key. Once the function being selected activates, there should be visual feedback, such as the label changing to inverse video. (U.S. Army 1995g)

4.2.3.3 Visibility of Unavailable Function Key Options

When a function/option is not currently available through a multifunction key, either gray it out or ensure that it is not visible to the operator. (General Dynamics 1986)

4.2.4 Soft Keys

4.2.4.1 Use of Soft Keys

Consider using soft function keys where other input devices are not available or where redundant input modes are required. The general guidelines discussed elsewhere in this section for fixed and multifunction keys apply to soft function keys. (U.S. DoD 1995)

4.2.4.2 Soft Key Design

Design soft keys such that they are located near and/or adjacent to their respective function keys. Soft keys should maintain the same spatial orientation as their respective function keys. Figure 4.2 presents an illustration of soft keys. (U.S. DoD 1995)

4.2.4.3 Redundant Activation of Soft Key Function

Ensure that the operator is able to activate the function represented by the soft key by using the function key as well as by other redundant means, such as a track ball, keypad, or keyboard. (U.S. DoD 1995)

4.2.4.4 Indicating Active and Inactive Soft Keys

Indicate the subsets of active and inactive function keys in some visible way, such as using different gray scales for the soft key labels. See Figure 4.3 for an example. (U.S. DoD 1995)

4.2.4.5 Easy Return to Default Functions

Where functions assigned to soft keys are changed, provide an easy method for returning to the default assignments and to the previous level in a multilevel system, such as dedicated keys for return to previous and return to default. (U.S. DoD 1995; WSSG Working Group 1996)

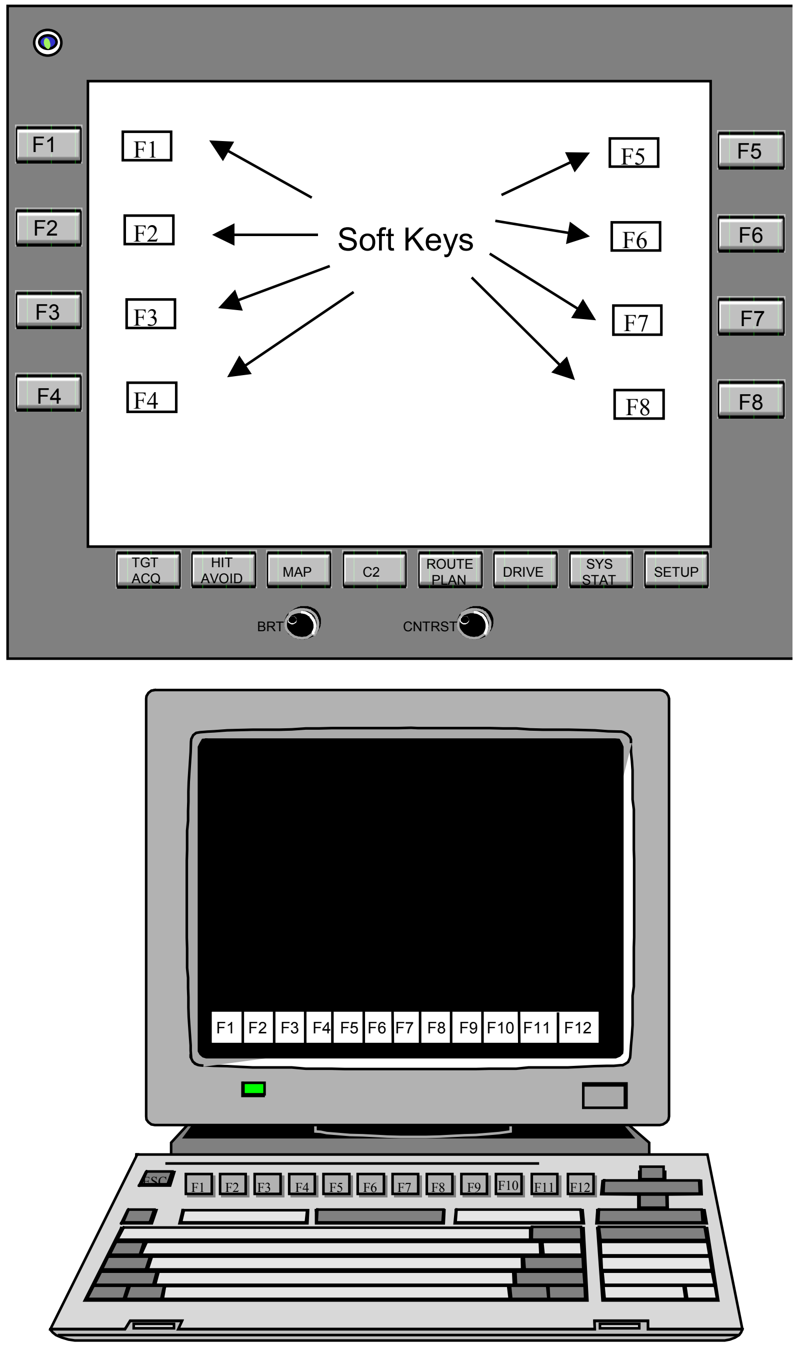


Figure 4.2 Illustration of Soft Keys

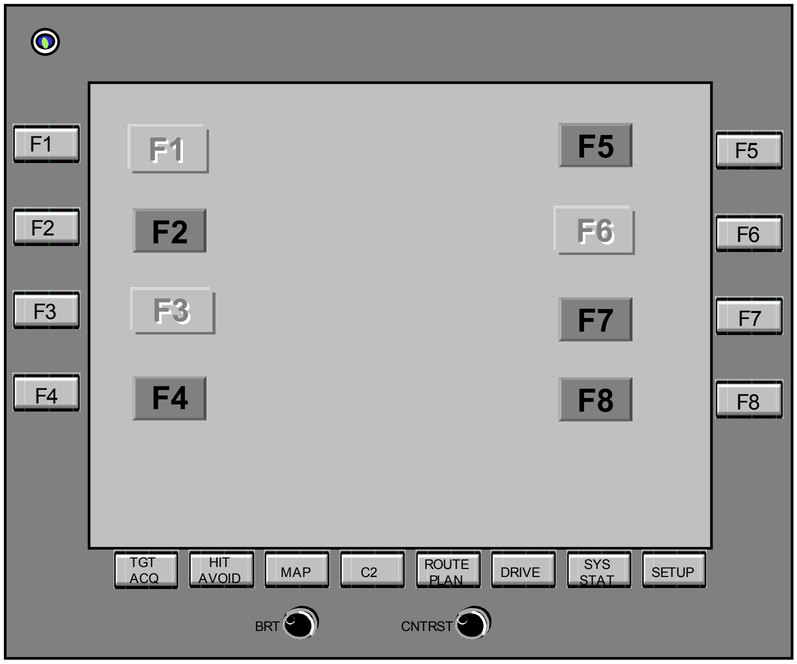


Figure 4.3 Example of Graying Out Inactive Keys

5.0 GENERAL GUIDELINES FOR DISPLAYS

5.1 GENERAL

5.1.1 General Display Design for RT/NRT Systems

Design displays for RT/NRT systems to conform to these general guidelines:

a. Present information in such a way that any failure or malfunction in the display or its circuitry will be immediately obvious.

b. Group displays functionally or sequentially, so the operator can use them more easily.

c. Ensure that all displays are properly illuminated, coded, and functionally labeled—including symbols.

d. Ensure that controls and displays are located in the same visual area.

e. Ensure that failure in the display does not cause failure in the associated equipment.

f. Display graphics to the resolution required for the mission. Excess graphics may blur in vibrating environments.

g. Ensure that the operator can easily view displays with minimum head or eye movement.

h. Display information in the appropriate sequence for the mission or task currently being performed.

i. Consider the impact on readability of display screen electromagnetic interference (EMI) protection devices (e.g., mesh).

j. Ensure that displays viewed by multiple crew members are readable and color coding appears uniform from all expected viewing angles.

(General Dynamics 1986; WSSG Working Group 1996, 1997)

5.1.2 Information Proximity Compatibility

Use the proximity compatibility principle when organizing information on the display.

Consider the following:

a. Use color in multifunction displays to facilitate focused attention recall of those variables that are uniquely colored in the display. (Andre and Wickens 1989)

b. Use physical space as the predominant factor in the perceived organization of an information display. (Andre and Wickens 1989)

c. Locate information and controls required to perform a specific task in the same window, if possible, when using windows. (WSSG Working Group 1997)

5.1.3 Stimulus/Central Processing/Response Compatibility

The principle of stimulus/central processing/response compatibility implies the following: the designer ensures that the display format used is congruent with the response modality required of the task, either verbal or spatial. Specify the central processing resources for a task to determine the optimal assignment of presentation (visual or auditory). Consider the following:

a. Place spatial information to the left of verbal information to ensure visual field compatibility. (Wickens 1984a)

b. Use verbal-auditory input for the task depending on verbal working memory. (Wickens 1984a; Wickens 1992)

c. Use graphics or analog pictures for tasks that demand spatial working memory. (Wickens 1992)

d. Use redundant verbal-spatial format when displaying instructions for users. A redundant information format provides for individual differences among users and flexibility to present instructions in the most relevant mode. (Wickens 1992)

5.1.4 Cues for Detecting Changes in Vehicle Attitude

Provide visual cues, such as color shading or patterns, when operators must detect changes in attitude from a display. Provide pitch lines and numbers where exact information is required. (Reising et al. 1994)

5.1.5 Alerting Display

Ensure that alerting displays clearly indicate the urgency of the message and whether that message requires a response from the operator. Also ensure that symbology used for alerting conforms to the general criteria contained in Paragraph 12.6, "Symbology." (Osga et al. 1995)

5.1.6 Selection of Alerting Methods

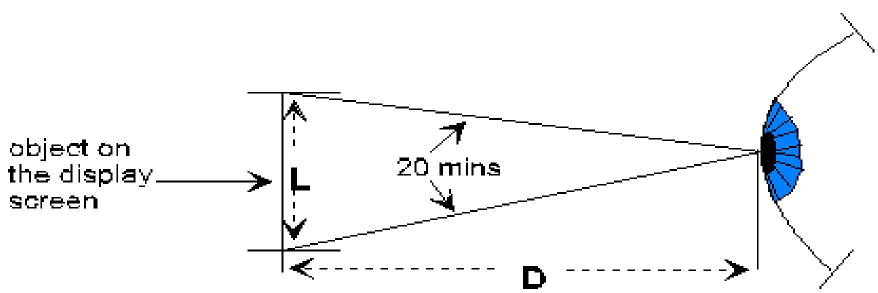
Ensure that the method(s) used to alert the operator, which can potentially disrupt the operator's current task to process the alert, are contingent upon the urgency of the alert and the need to disrupt the ongoing operator task. The methods used should not conflict with existing signals in the system environment and should not compromise survivability requirements. (Calantropio and Campbell 1994; WSSG Working Group 1996)

5.1.7 Character Size

Ensure that character size for displayed information conforms to the following format, though provisions should be made in the design for vibration induced by vehicle or operator movement:

a. Alphanumeric characters should subtend a minimum of 15 minutes of visual arc and complex shapes such as symbology subtend a minimum of 20 minutes of visual arc. Figure 5.1 illustrates how this is calculated. Symbology should be appropriately sized upward for vibrating environments. (WSSG Working Group 1996; U.S. DoD 1981, 1996a)

b. Alphanumeric character size for displays mounted in shelters should be 1/200 of the viewing distance. (Obermayer and Campbell 1994; U.S. DoD 1995)



$$\text{Visual Angle (Min.)} = \frac{(57.3)\,(60)L}{D}$$

where L = size of the object, and D = distance from the eye to the object.

Figure 5.1 Illustration of How to Calculate Visual Angle

5.1.8 Font Style for Legibility

Design fonts to promote the legibility of alphanumeric characters. Legibility is defined as the attribute of alphanumeric characters that makes it possible for each character to be identifiable from others. The legibility of an alphanumeric character depends on such features as character size, stroke width, form of characters, contrast, and illumination. Characteristics of alphanumeric characters that lead to legibility are contained as follows in Table 5.1.

Table 5.1 Characteristics of Alphanumeric Characters Contributing to Legibility

Characteristic	Minimum	Maximum	Preferred
Character Size	16 min*	45 min*	20-22 min*
Stroke width	1:6 - 1:8 black on white 1:8 - 1:10 white on black		
Height to Width	2:3 to 1:1		
Contrast	No difference with respect to black on white versus white on black		
Character Form	Sans Serif		

*Minutes of visual angle as defined in Figure 5.1.

(McCormack 1970; ANSI HFS 100-1988 1988)

5.1.9 Integration of Display Design

Ensure that the design of a display is integrated into the total system design and is not just an "add-on." (Newman and Haworth 1994)

5.2 DISPLAY LIGHTING

Requirements for display lighting may vary among subdomains. Tailor the following guidance, as required, to meet the users' needs.

5.2.1 Display Luminance and Contrast

5.2.1.1 Display Luminance

Ensure that the display luminance of all information is such that the data are distinguishable in all daytime and nighttime lighting conditions.

a. Ensure that displays to be used in direct light are readable in a combined environment consisting of up to 10,000 footCandle (fC) diffuse illumination and specular reflection of up to 2000 footLamberts (fL) glare source.

b. During night operations, display lighting should provide the operator with a capability to rapidly and accurately obtain required display information with unaided vision.

c. Ensure that display lighting does not have an adverse effect on external unaided night vision or, when required, on the operator's capability to obtain required information external to the vehicle while employing night vision goggles (NVGs).

(U.S. Army 1995e; U.S. DoD 1988)

5.2.1.2 Display Contrast

Ensure that the contrast of all displayed information is adequate for visibility in illumination environments ranging from total darkness to high ambient, e.g., 10,000 fC. Contrast is defined as the relationship of the brightness of the displayed information to the brightness of the immediate background surrounding the displayed information. See Table 5.2 for the recommended contrast levels.

Table 5.2 Recommended Display Contrast Levels for RT/NRT Systems

Type of Information	Required contrast (C_L and C_I)*
Numeric Only	>1.5
Alphanumeric	>2.0
Graphic Symbols	>3.0
Video Worst case ambient condition Otherwise	 ≥4.66, to make at least six √2 gray scale ratio shades visible ("off" counts as one) ≥10.3, to make at least eight √2 gray scale ratio shades visible under other than worst case ambient conditions

*Notes:

1. For numeric and alphanumeric information, the above ratios assume a character height (h) of 0.2 inches and 0.12h ≤stroke width (SW) ≤0.2h. For other character heights and stroke widths, multiply the required contrast by 0.2/h for 0.1≤h≤0.3 and by 0.12h/SW for 0.01h ≤SW ≤0.12h.
2. The character height criteria above assumes a viewing distance of less than 30 inches. No character height should be less than 0.1 inch.
3. The OFF/BACKGROUND ratio should be ≤0.25 for all displays, and ≤0.1 for any display where unlighted elements could provide false information.
4. Definitions:

   C_L = the ON/BACKGROUND contrast of a lighted or activated display for display image element

   C_I = the ON/OFF contrast of a display image element

   C_{UL} = the OFF/BACKGROUND contrast of an unlighted or deactivated display image element

   √ = square root

(U.S. Army 1995e; U.S. DoD 1988)

5.2.1.3 Display Luminance and Contrast Change

Ensure that the display luminance and contrast do not change more than plus or minus 20% when changing display from one type of information display to another, e.g., from a map display to a video display. No random bright flashes should occur during this switching. (U.S. Army 1995e)

5.2.2 Display Brightness Adjustability

Design displays so that the display brightness is operator-adjustable from "Off" to maximum brightness, to allow for reading over the full range of ambient lighting conditions, typically from total darkness to 10,000 fC. (U.S. Army 1995e, 1995f)

5.2.3 Brightness of Illuminated Indicators

Ensure that the brightness of illuminated indicators, e.g., simple indicators or transilluminated displays, conforms to the following:

a. Brightness is at least 10% greater than the immediate surface on which they are mounted.

b. When a two-level indicator is used, the difference between the two levels of brightness should be approximately 2:1.

c. Where glare must be reduced, the luminance of transilluminated displays should not exceed 300% of the surrounding luminance.

(General Dynamics 1986)

5.2.4 Luminance Compatibility with Ambient Illumination

Ensure that the luminance (brightness) of displays is compatible with the expected range of ambient illuminances associated with mission operation and/or servicing and maintenance of the system and equipment. Consider the following factors when determining luminance levels:

a. **Within-Display Contrast** (i.e., contrast between light ON vs. OFF modes). Provide two-level contrast if the display requires a dormant luminance to read an identifying label, plus an active luminance increase to indicate functioning mode.

b. **Display/Surround Contrast** (i.e., contrast between the illuminated indicator and its immediate panel surface). Compensate for the effects of ambient reflection on either the display or surround surface by increased display luminance, surround surface modification, use of filters, use of shields, or other methods. The contrast ratio should be as near 90% as is practicable.

c. **Operator Visual-Adaptation**. Ensure that display luminance is compatible with the operator's requirement to detect low-level signals or targets in the external visual environment, to perceive faint signals on a cathode ray tube (CRT), and/or to read red- or blue-lighted instruments provided for nighttime operation. A line brightness of 100 fC is required under normal ambient light levels. Display luminance should also be compatible with night vision devices.

d. **Conspicuity and Attention-Demand Requirements**. Ensure that the luminance of alerting signals provides the required alerting to ensure that the operator will not miss a critical warning, caution, or advisory message. Luminance of alerts should not compromise system survivability criteria by increasing the chances of detection by the threat.

e. **Distraction**. Ensure that luminance levels do not dazzle or otherwise distract the operator in a manner that could be detrimental to safe, efficient system operation.

(General Dynamics 1986; WSSG Working Group 1996)

5.3 IMPACT OF VIBRATION ON READABILITY

Design displays—and the associated information presented on the displays—to accommodate the effects of vibration, where required. Consider that under 10 hertz (Hz) vibration, readability is least affected when the operator and display device are vibrating at the same or similar frequencies. (Viveash et al. 1994; Moseley and Griffin 1986; Boff and Lincoln 1988)

6.0 TOUCH SCREEN DESIGN

Touch screens offer operators a method of interacting with a system through the intuitive mechanism of pointing with their fingers, and combine both input and visual feedback devices into one unit. Input can be accomplished, depending on the technology, through initial contact with the screen or through lift-off (removal) of the finger or touching device. If lift-off is used, the initial touch selects the control, and lift-off activates the function. Touch screens are easy to learn, space-efficient, and generally durable with respect to high-volume usage. However, they generally yield a reduction in image brightness and may introduce special positioning requirements due to ergonomics. In addition, there are some limitations regarding their use for RT/NRT weapon systems. These limitations include the loss of display screen surface to accommodate the on-screen control objects, difficulties in control activation in a moving vehicle, and the frequent requirement for the operator to be wearing gloves of some type. When touch screens are used, they should comply with the following guidelines. (WSSG Working Group 1997)

6.1 GENERAL GUIDELINES

6.1.1 Touch Screen Use

Consider using touch screen input devices where:

a. Data entry is limited.

b. Flexibility of layout or language is required.

c. Display and input device will be in a confined area.

(Plaisant 1991; WSSG Working Group 1996, 1997)

6.1.2 Touch Screen Use Limitations

a. Be aware of the potential fatigue factor associated with frequent use of a touch screen. (Plaisant 1991; WSSG Working Group 1996)

b. Do not use touch panel input exclusively when control entries must be made by the vehicle pilot/driver while on the move. This may cause operators to take their hands off the control stick and/or move forward, possibly causing poor vehicle handling performance and potential accidents. (Jones and Parrish 1990)

c. Be aware that using touch screens may cause the operator’s hand or arm to obscure critical information on the screen. (WSSG Working Group 1997)

6.1.3 Operational Environment and Touch Screens

Consider the operational environment when designing applications for RT/NRT systems that may use a touch screen. Many operational environments may have dust, oil, and hydraulic fluid present, which may adversely affect the performance of the touch screen. (Site visit to General Dynamics Land Systems Division 1996)

6.1.4 Touch Screen Application Development

When building application screens, keep firmly in mind that they will be used for touch screens. There are distinctive differences in interaction when using a touch screen as opposed to some other pointing device. Perform frequent testing of the developing application using touch interaction technology rather than pointing device technology. (Humphry 1994; WSSG Working Group 1996)

6.1.5 Inadvertent Activation Protection

Provide a method that will preclude inadvertent activation due to casual touching. (Humphry 1994)

6.1.6 Touch Screen Control Object Interaction

6.1.6.1 Cursor Movement for Lift-off Activation

Cause the cursor to relocate onto the on-screen control with the initial touch, where activation of the control object is performed by lift-off (removing the finger from the control surface). This should cause the control to be selected, unless safety or critical mission requirements are associated with the control. (U.S. Army 1996b)

6.1.6.2 Lift-off and Control Object Selection

Ensure that no selection takes place if the operator’s finger slides off the control before removing it from the screen surface, when activation is performed by lift-off. However, the cursor should either remain on the last control touched or, if safety or critical mission considerations are associated with the control, return to a default position. (U.S. Army 1996b)

6.1.6.3 Visual Feedback for Control Object Selection and Activation

Provide visual feedback to the operator when a touch screen control object has been touched. The feedback should be visually different for selection and subsequent activation of the function, such as when the finger is removed to activate. See

Figure 6.1 for an illustration. (Site visit to General Dynamics Land Systems Division 1996)

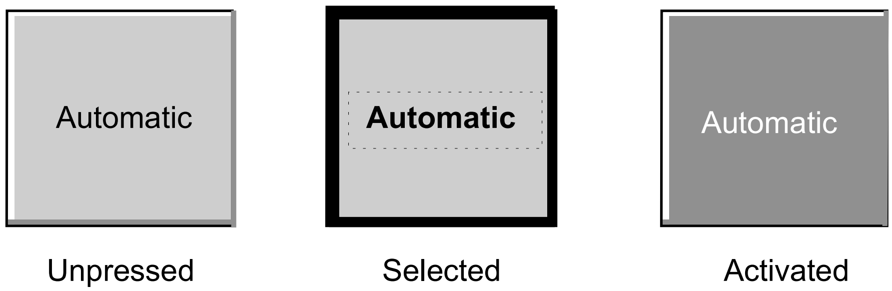


Figure 6.1 Illustration of Visual Feedback for Touch Screen Control Objects

6.1.6.4 Layout of Touch Screens

Organize touch screen input buttons such that critical information is not covered when the operator reaches across the display to activate a control. (WSSG Working Group 1997)

6.1.7 Hardwiring of Critical Safety Controls

Consider using hardwired controls rather than touch screens for critical safety input. (Humphry 1994)

6.1.8 Touch Screens and Autocompletion Capability

Design touch screens through which the operator must perform frequent and complex data entry with an autocompletion capability to reduce keystrokes, fatigue, and errors. The operator should have the capability to confirm the autocompletion as well as edit it. Autocompletion is where data fields are automatically filled in by the system from a database based on partial information supplied by the operator. (Gould 1989)

6.1.9 Touch Force Required for Piezoelectric and Resistance Touch Screens

Ensure that touch force is low for touch screens using technologies such as resistance and piezoelectric to reduce fatigue. In general, resistance for these types of touch screens should be similar to that for alphanumeric keyboards. See Table 6.1. (Gungl 1989; U.S. DoD 1996a)

Table 6.1 Recommended Resistance for Touch Screen Control Activation

	Numeric	Alphanumeric	Dual Function
Minimum	3.5 oz	0.9 oz	0.9 oz
Maximum	14.0 oz	5.3 oz	5.3 oz

6.1.10 Window Input Focus with Touch Screens

Where using multiple windows with touch screens, design windows such that they become active and ready to receive input when touched. (U.S. Army 1996b)

6.2 CONTROL OBJECT DESIGN

Input through a touch screen is accomplished by contact with an on-screen control object (also referred to as a target). A control object is composed of the icon, symbol, or text that identifies the control, as well as a touch zone surrounding the object. The touch zone encompasses the object and the area around the object in which action is enabled. In general, these touch screen control objects are like hardwired legend switches and should conform to the relevant design criteria from MIL-STD-1472E (U.S. DoD 1996a).

(WSSG Working Group 1997)

6.2.1 Control Object Size

6.2.1.1 Control Object Size

Design touch screen control objects to be a minimum of 0.79 inches square. For systems where the operator will be operating the touch screen in vibrating environments or while wearing gloves (NBC, cold weather, fire retardant), the control objects should be 1 inch square. See Figure 6.2 for an illustration. Smaller control objects may be used when the operator can adjust finger location and lift to activate. (Benel and Stanton 1987; Plaisant 1991; Humphry 1994; U.S. Army 1996b)

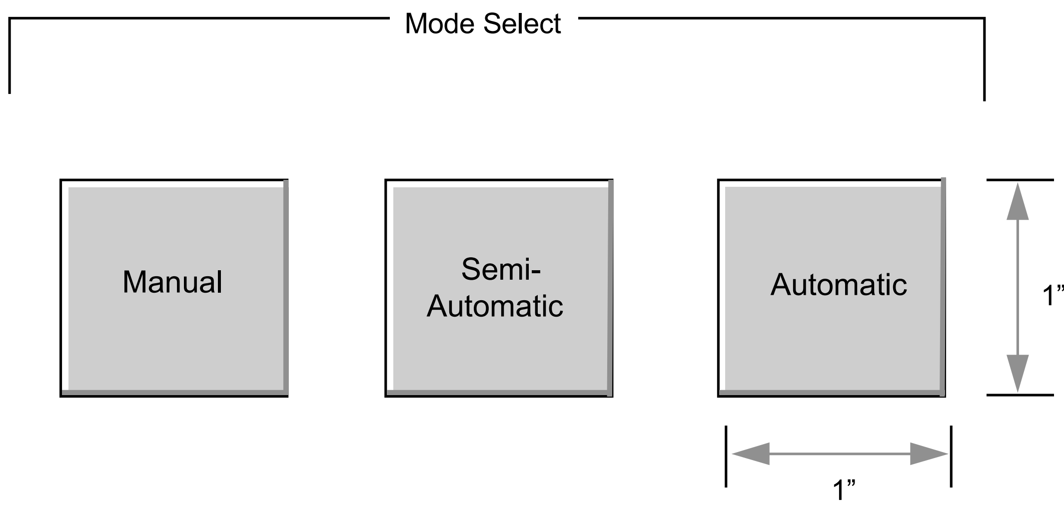


Figure 6.2 Touch Screen Control Object Size

6.2.1.2 Touch Zone Size Relative to Visual Control Object Size

Design touch zones larger than their associated visual control object, as illustrated in Figure 6.3. This compensates for the fact that operators tend to touch below an object, for possible misregistration between the video and touch screens, for wearing of gloves, and for sloppy touching. (Gould 1989; Humphry 1994)

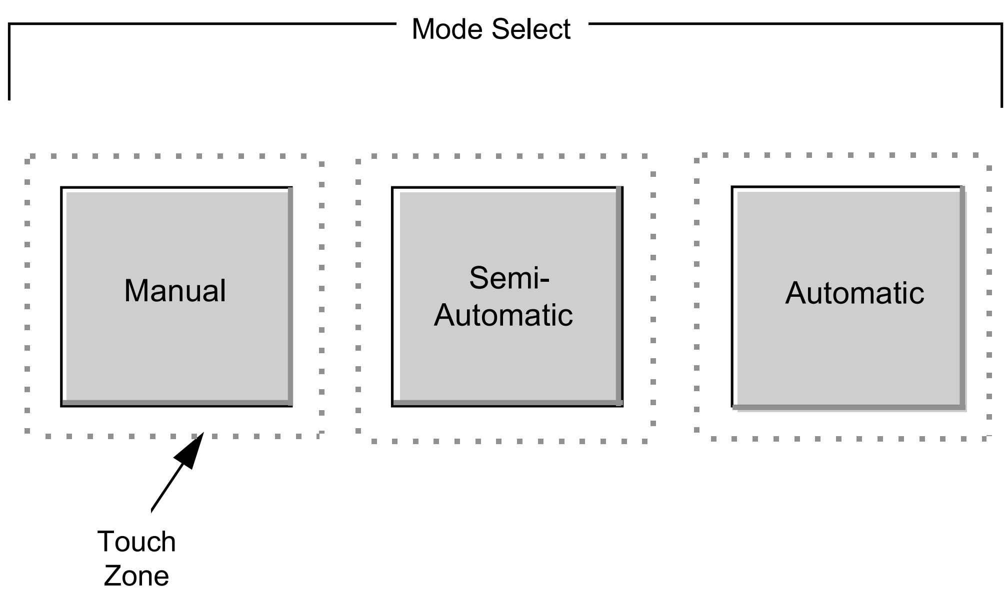


Figure 6.3 Illustration of Touch Zone Size

6.2.2 Control Object Separation

Separate touch screen control objects from each other and from the edge of the display by at least 0.125 inches, and ensure that there is no overlapping of touch zones. (U.S. Army 1996b)

6.3 TOUCH SCREEN KEYBOARDS

6.3.1 Numeric Data Entry Keyboard for Touch Screens

Use a standard numeric keypad rather than a QWERTY keyboard layout when entering numeric data with a touch screen. (Coleman et al. 1991)

6.3.2 Alphanumeric Data Entry Keyboard for Touch Screens

Use standard or modified QWERTY keyboard layouts rather than an alphabetic keyboard layout when entering alphanumeric data with a touch screen. (Coleman et al. 1991) However, the designer should be aware that some task dependencies indicate modifying this guideline. For example, if speed and accuracy of data entry are most important, a QWERTY style keyboard will provide the best performance. If accuracy is more important than speed, an alphabetic keyboard may provide better accuracy but at a cost in terms of speed. (MacKenzie et al. 1994)

7.0 HELMET-MOUNTED DISPLAYS

Helmet-Mounted Displays (HMDs) are small, high-resolution displays that can replace Head-Down Displays (HDDs) and offer new methods of presenting visual information to individuals on the battlefield. HMD systems project images in front of the wearer's eyes. The images are focused at a distance variable from 50 cm to infinity, depending on the application. Images cover about 20% of the immediate field of view (FOV), but remain transparent for the direct view (normally 10%). Image transparency can be modified on user demand, and a large unobstructed peripheral view is maintained. The emphasis of HMDs is to provide information to people where ordinary direct view displays are either inappropriate or impractical. The following guidelines should be used to guide HMD design, though the designer should keep in mind that achieving the users' requirements is the most critical factor to consider in designing an HMD. These guidelines are directed primarily at the capability for HMDs to display information and not necessarily at see-through capability.

7.1 GENERAL

7.1.1 HMD Design for Situational Assessment

For situational assessment, consider using an HMD to:

a. Slave sensors and weapons to the helmet line of sight (LOS).

b. Display combat and critical vehicle/system status information.

(Adam 1992)

7.1.2 Use of Opaque Monocular HMDs

Consider using an opaque monocular HMD, where the HMD symbology and information will be viewed against an additional layer of panel-mounted display information, e.g., tactical maps or detailed text displays. An opaque monocular HMD will reduce distracting clutter. (U.S. Army 1995g)

7.1.3 Design of Attitude Information Display for HMDs

When designing the HMD to include attitude information, consider presenting attitude information with respect to the vehicle body-axis (non-conformal) rather than real world (conformal). Research indicates that a non-conformal presentation for attitude information provides better human performance. If conformal displays are used, ensure that the designer is aware that conformal displays may be difficult to interpret and confusing because of the symbology motion caused by vehicle and head movements. (Jones et al. 1992; WSSG Working Group 1996)

7.1.4 Multi-Image HMD Design

Multi-image HMDs provide integrated visual input from multiple sources, such as a forward-looking infrared (FLIR) and a night vision sensor. When designing a multi-image source HMD, consider the following guidelines for minimizing potential negative impact on the user's performance:

a. FOV of a minimum of 40 degrees.

b. Center of gravity and weight that minimizes risk of injury and fatigue.

c. Real-world transmission greater than 70%.

d. One design for both day and night use.

e. Symbology contrast greater than 1.2 in daylight without using a visor.

f. Night vision goggles (NVG) gain greater than 2000.

g. Compatible with required NBC equipment.

h. Latency of image update relative to the real world.

Consider night vision integrity from the outset when designing a multi-image HMD system, taking into account all possible failure modes that might endanger the operator and system through the loss of night vision.

(Bull 1992; WSSG Working Group 1996)

7.1.5 Potential Interference Sources for HMD Tracking Systems

Consider the following potential interference sources when designing an HMD for an RT/NRT tracking system application:

a. Rotor chop/sun modulation.

b. Reflections/IR energy sources.

c. Limited motion box/helmet surface integrity.

d. Presence of cockpit/vehicle metal/changing metal location/magnetic fields.

(Ferrin 1991)

7.1.6 Image Processors for Infrared (IR)/Low Light Television (LLTV) Image Fusion

Consider the following when designing suitable image processors for infrared/low light television (IR/LLTV) image fusion used for viewing tasks on HMDs:

a. Defined obstacle edges are the most important requirement for vehicle navigation tasks.

b. High contrast enhancement, absence of blur, and good picture stability have to be achieved for visual recognition or identification of targets.

c. Good uniformity of the picture background is important for small target visual detection.

(Balzarotti et al. 1994)

7.1.7 HMD Movement

Be aware that the HMD display can move through a large angle. If improperly implemented, this can lead to incorrect control inputs or aggravated spatial disorientation. (Newman and Haworth 1994)

7.1.8 Potential Reduced Situational Awareness

Consider, when designing HMDs, that there is a potential for this display to compete with the outside world for the operator's attention, leading to reduced situational awareness. As a result, the operator may miss cues and other information from the environment. (National Research Council [NRC] 1997)

7.1.9 Minimization of Occlusion of Environmental Sensing

Minimize occlusion of normal (visual and auditory) sensing of the environment, and enhance sensory input only when needed (e.g., NVG). (NRC 1997)

7.1.10 Minimization of Cognitive Load

Minimize the cognitive load on the operator induced by the HMD by:

a. Providing integrated information.

b. Providing easy user input of information.

c. Minimizing memory requirements.

d. Reducing extraneous information.

e. Simplifying formats.

f. Minimizing tasks performed with the HMD.

g. Presenting information in a task-oriented sequence or grouping.

h. Providing information in the needed format.

(NRC 1997)

7.1.11 Use of Cueing for Situational Awareness Enhancement

Enhance situational awareness by providing salient cueing to direct the operator's attention to the most important information being displayed. (NRC 1997)

7.2 BINOCULAR HMD DESIGN

7.2.1 Use of Binocular HMD Design

Consider using binocular stereo displays where operators are required to follow a displayed pathway using an HMD. Stereopsis can improve tracking performance, though it may reduce the attention users apply to monitoring tasks. (Williams and Parrish 1990)

7.2.2 Partial Binocular-Overlap Imagery

Consider the following when designing partial binocular-overlap imagery for HMDs:

a. **Luminance Roll-Off**. Eliminate the unnatural high-contrast edge.

b. **Eye Assignments**. Increase binocular correspondence of the HMD with the natural world.

c. **Contour Lines**. Compensate for the unnatural continuity of binocular/monocular imagery and the black surrounding surface.

d. **Binocular Overlap**. Use a binocular overlap of at least 40 degrees to reduce image breakup effects and eye discomfort, when using partially overlapping monocular images to increase the field of view for NVGs.

Partial binocular-overlap, illustrated in Figure 7.1, is where an HMD presents the user with a central binocular image flanked by monocular images.

(Melzer and Moffitt 1991; Alam et al. 1995)

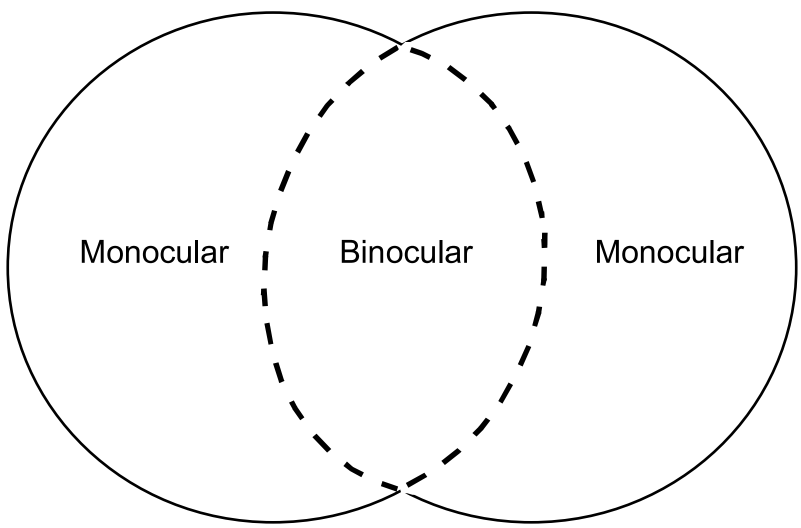


Figure 7.1 Illustration of Partial Binocular-Overlap

7.2.3 Adjustability

Consider providing operators with the ability to adjust image disparity to produce the best depth effect for the individual user of an HMD, as well as to adjust the diopter. (WSSG Working Group 1996)

7.2.4 Binocular HMD for Combined Day and Night Usage

Consider using binocular HMDs for combined day and night operations. Binocular HMDs offer advantages over monocular systems when designing for day and night operations. They provide superior contrast sensitivity, perceptual threshold, and visual acuity, and prevent binocular rivalry between the eyes. (Leger et al. 1993)

7.2.5 Design for Maximum Binocular Visual Capabilities

Consider using converging axes sensors when presenting images to each eye, where maximum binocular visual capabilities are required. With converging axes sensors, each sensor is angled in towards the other. Converging axes sensors should:

a. Where possible, control sensor orientation by eye movements.

b. Use two integrated sensors to provide an extra margin of safety when using binocular HMDs.

(Leger et al. 1993)

7.2.6 Display of Symbology to Both Eyes

Ensure that HMDs are capable of displaying symbology to both eyes for binocular applications. (Leger et al. 1993)

7.2.7 Bi-Ocular Versus Binocular HMD Use

Consider the use of bi-ocular instead of binocular displays in HMDs where stereoscopic depth judgments are not critical. Bi-ocular displays present each eye with an identical image. (Rushton et al. 1994)

7.3 MONOCULAR HMD DESIGN

7.3.1 Use of Monocular HMDs

Use monocular HMDs when the operator needs one eye for real-world viewing and stereo-optic presentation is not required.

7.3.2 Monocular HMD Use for Night Operations

Although monocular HMDs may be used for daytime operations, use monocular HMDs for night operations carefully. Whereas some data indicate that they preserve night vision adaptation in one eye (Lippert 1990), they may cause binocular rivalry for night video displays and are therefore undesirable at night. (Bohm and Schranner 1990; Bull 1990; Storey et al. 1994)

7.4 HMD OPTICS DESIGN

7.4.1 Optic Coatings

Consider the impact of optic coatings in the design process. Optic coatings should not significantly change outside world coloration. Specifically, white, red, green, and blue colors should be discernible. Where there may be an impact on color, such as that created when using laser protection coatings, consider this impact during the design to ensure that operator performance is not compromised. (Storey et al. 1994; WSSG Working Group 1996)

7.4.2 Adjustment of HMD Optics

Provide control over optics adjustment during operations, specifically interpupillary distance (IPD), eye relief, and vertical positioning. A 28-34 mm eye relief has been found to be acceptable, depending on overall system design. (Storey et al. 1994)

7.4.3 HMD Optics Transmissivity

Consider the following in designing HMD optics transmissivity:

a. For night use, provide a minimum of 30% transmissivity where direct vision is not important and vision of a HUD or vehicle instrumentation is required. However, 50% to 70% transmissivity is preferred. Night is defined as the period from End Evening Nautical Twilight (EENT) to Beginning Morning Nautical Twilight (BMNT).

b. For day use, provide 70% to 80% transmissivity to avoid reducing target detection performance.

(Bull 1990; Storey et al. 1994)

7.5 FIELD OF VIEW

There are arguments against the use of NVG HMDs because of their narrow FOV, which can block the operator’s use of peripheral vision cues (Newman and Haworth 1994). Search time increases significantly as the size of the FOV becomes smaller. Some research indicates that the size of the FOV affects the ability to acquire spatial information of one's surroundings. Consider the following paragraphs for the design of HMD FOV. (Venturino and Kunze 1989)

7.5.1 Field of View Size

Design the HMD with the following FOV:

a. **Minimum FOV** - 30 degrees. This is most appropriate for day-optimized and video sensor HMDs. (Storey et al. 1994)

b. **Desired minimum FOV** - 40 degrees. (Bohm and Schranner 1990; Bull 1990; Leger et al. 1993; Storey et al. 1994)

c. **NVG FOV** – 32 degrees for tasks such as targeting and sighting, 40 degrees for general tasks such as patrolling, surveillance, and vehicle operations. A 60 degree FOV provides little benefit in performance for their cost in weight and size. (ARL-HRED 1996)

7.5.2 Devices to HMDs

Consider, when widening the operator's FOV by slaving a sensor device such as a FLIR to the LOS of the HMD, that time lags between the operator's head movement and the display of the sensor output can seriously impair the ability to derive control-oriented information from the visual field. The operator may tend to minimize head rotations, which diminishes the wide-angle coverage provided by the slaving system, thereby impairing search performance and spatial orientation. (Grunwald et al. 1991)

7.5.3 Location of Display Symbology in the FOV

Keep symbology display within the central 25 to 27 degrees of the display FOV to preclude eye strain but be careful not to over-clutter the central part of the display, which can degrade viewing of the outside world. (Storey et al. 1994; WSSG Working Group 1996)

7.5.4 Resolution

Ensure that the resolution of HMDs optimizes human visual performance for the task being performed. Many factors can contribute to visual performance, including the following:

7.5.4.1 Line Width for Viewing Tasks

For day use, design an HMD to provide a minimum display resolution of 1 milliradian line width as well as appropriate distance between lines. At night, higher resolutions may be required to make full use of FLIR capabilities. (Bohm and Schranner 1990; Bull 1990)

7.5.4.2 Design for Spatial Resolution Tasks

When designing an HMD for spatial resolution tasks, use a high-resolution display (e.g., 640 x 480) for the best operator performance. (Sharkey et al. 1995)

7.5.5 Image Brightness

Design HMDs for daytime use with a minimum contrast ratio of 1:2; preferably 1.3:1. At night, brightness should be adjustable to allow viewing of the display without loss of night vision (about 3 footLamberts) and without compromising survivability. (Bull 1990; WSSG Working Group 1996)

7.5.6 Shades of Gray

Design monochromatic HMD displays to provide a minimum of 6 shades of gray for alphanumeric and graphical information. If possible, design the HMD display to support 9 to 10 shades of gray for viewing more complex sensor data. (Bohm and Schranner 1990; Honeywell Technology Center 1995)

7.6 PHYSICAL DESIGN OF HMDs

7.6.1 General

Ensure that HMD designs:

a. Are comfortable and do not restrict head movements.

b. Do not otherwise compromise safety, e.g., impact and penetration protection, eye and hearing protection.

(Cameron 1994; Storey et al. 1994; Honeywell Technology Center 1995; WSSG Working Group 1996)

7.6.2 Weight

Actual weight of HMDs will be driven by mission requirements. Consider the following in the design of HMDs:

a. Ideal weight is between 3.5 lb. and 3.99 lb. or less to reduce operator fatigue. (Perry et al. 1993; Burley and LaRussa 1990)

b. Night-equipped HMDs, which will weigh more than day HMDs due to additional optics, should weigh less than 4.5 lb. (Cameron 1994)

c. Total head-supported weight (e.g., helmet, HMD, etc.) should be less than 5.3 lb., because operator performance is degraded in vibrating environments after 1 hour with greater weights. (Storey et al. 1994)

7.6.3 HMD Weight Distribution

7.6.3.1 Weight Distribution

Ensure that weight distribution of an HMD does not cause significant out-of-balance conditions with respect to the neck pivot point. (Cameron 1994)

7.6.3.2 Mass and Center of Gravity

Ensure that the mass and center of gravity of HMDs do not cause fatigue or head mobility problems. Ideally, the mass should be centered low on the helmet, near the head pivot point. (Leger et al. 1993; Newman and Haworth 1994; Honeywell Technology Center 1995)

7.6.4 HMD Visor and Optical Configuration Design

Use the following guidelines to aid design when visors are used on HMDs. Not all HMDs use visors.

7.6.4.1 Visor Orientation and Curvature

Ensure that the visor's orientation and curvature:

a. Reflect the light projected from the optical assembly to the operator's eye.

b. Keep the size of the solution envelope as small as possible, in order to keep to a minimum the limitations on operator's head movements in restricted space.

(Gilboa 1991)

7.6.4.2 Curvature and Eye Relief Values

In general, when visors are used, design the HMD with appropriate curvature and eye relief values. (Gilboa 1991)

7.6.4.3 Handedness and HMD Visors

Where visors are used on HMDs, ensure that visors are operable with either hand. (Cameron 1994)

7.6.5 HMD Design for Safety

Consider the following safety concerns when designing an HMD:

a. Design the HMD used for daytime operations so that it does not obstruct the operator's view of the outside scene. Otherwise, the HMD can have an impact on the operator's ability to safely perform tasks. Ensure that, if one eye is obstructed, the other has a clear view. (Bull 1990)

b. Note that some types of display devices require high voltage to operate. The cables required to conduct this high voltage to the helmets may create a safety issue. (Honeywell Technology Center 1995)

c. Ensure that cables running to the helmet have a quick disconnect. (Honeywell Technology Center 1995)

d. If possible, design the HMD such that no part is located on or near the top of the helmet, to preclude damage due to impact on hatches or other parts of crew compartments. (Honeywell Technology Center 1995)

e. Eliminate cables, snaps, etc. from snagging or interfering with other equipment or crew operations. (WSSG Working Group 1996)

7.6.6 Minimization of Soldier Distraction

Design should minimize distracting operator attention by allowing the removal of the sensor, displacement of the display out of the line of sight, or in other ways to ensure a clear view of the outside environment. (NRC 1997)

7.6.7 Design for Dismounted Operations

Consider the following when designing HMDs for dismounted operations:

a. There is no support for the head or body in dismounted operations to compensate for weight and center of gravity.

b. Dismounted users must move and take cover rapidly.

c. There will be a significant number of posture changes, including partial crouches, while moving fast. The weight distribution must accommodate these postural changes without risk of injury or inducing fatigue.

(NRC 1997)

7.6.8 Helmet Movement Impact on Optics

Where using electro-optical systems, consider that the helmet should not be free to move on the wearer's head. If this is unavoidable, ensure that the helmet can be resettled quickly and easily. (NRC 1997)

7.7 VIBRATION AND HMDs

7.7.1 Design for Vibrating Environments

Design HMDs with the understanding that vibration may be present in the operator's environment. In particular, human task performance on tracking tasks is the worst at 4 Hz. (Sharkey et al. 1995)

7.7.2 Attenuation of Head Motion

If HMDs are used in vehicles, include engineering features that attenuate head motion in the 4 Hz range, particularly if the seating position requires head support. This will improve tracking performance and reduce the chances of motion sickness. (Sharkey et al. 1995)

7.7.3 Adaptive Filtering

When using adaptive filtering to estimate head motion due to platform accelerations, consider using complementary filtering methods. These methods have been effective in compensating for the image stabilization error due to sampling delays of HMD position and orientation measurements. The complementary filtering method combines the measurements of the head position and orientation system with measurements of the angular acceleration of the head. (Merhav and Velger 1991)

8.0 HEAD-UP DISPLAYS

Head-Up Displays (HUD) are fixed displays mounted at the top of aircraft and ground vehicle instrument panels. Computer-generated information is projected onto a vehicle's windscreen or other reflective surface and, as the operator looks through the glass, both the scene in front of the vehicle and the HUD-projected information are viewed. This arrangement allows the operator to see important information without having to look down at the instrument panel. When HUDs have integrated sensors, synthetic images of objects can be displayed, allowing operators to "see" objects that may not be visible to their unaided eyes.

The following guidelines can be used to aid in the development and implementation of HUDs in aircraft and ground vehicles. Designers of HUDs need to be aware of the differences between aircraft usage and ground vehicle usage. Ground vehicles have dense and varied arrays of obstacles in the backgrounds, whereas aircraft have relatively stable backgrounds with less complexity (Ward et al. 1994). Additional information may be found in the following documents:

- *Improvement of Head-Up Display Standards, Volume 1: Head-Up Display Design Guide* (Newman 1987)
- *Human Factors Aspects of Using Head-Up Displays in Automobiles: A Review of the Literature* (Gish and Staplin 1995)
- *Head-Up Displays for Automotive Applications* (Harrison 1994).

8.1 GENERAL

8.1.1 HUD Advantages over Head-Down Display (HDD)

Consider the advantages of HUDs over HDDs. In general, the advantages of a HUD over an HDD are the reduction of eye movement and the reduction of eye refocusing, as well as improved precision aiming. (Knoll and Konig 1992; Inuzuka et al. 1991; WSSG Working Group 1997)

8.1.2 Minimization of Presented Information

Minimize the information presented on a HUD to reduce clutter and to avoid restricting the visibility of objects in the real world—typically the far domain. (Newman and Haworth 1994)

8.1.3 Use of Multiple Cues

Use multiple cues, such as size and color/gray scale coding, with 2-D or 3-D HUDs to improve spatial-perceptual performance. (Reising and Mazur 1990)

8.1.4 Perceptual Segregation of Near and Far Domain Cues

If a task requires that the operator focus exclusively on cues in either the near or far domains when using a HUD, maximize the perceptual segregation of the two domains. If cues are required in both domains, be aware that the HUD may interfere with processing information from the far domain and lead to task fixation to the detriment of other concurrent tasks, such as piloting or driving. (McCann et al. 1993)

8.1.5 Depth Cues

Consider using depth cues such as stereo 3-D, aerial perspective (symbol becomes more gray or less bright with depth), and familiar object size to improve operator performance, for example, improving the speed and accuracy in determining locations of friendly, enemy, and unknown aircraft. (Mazur and Reising 1990; WSSG Working Group 1997)

8.1.6 3-D Cues

Consider using 3-D HUD displays if depth perception is required and monocular depth cues are not available when presenting information. Monocular cues provide perceived depth perception for one eye through linear perspective, interposition, familiar object size, etc. (Reising and Mazur 1990; WSSG Working Group 1997)

8.1.7 Compatibility with HDD

Design HUDs to display information that is compatible with HDDs. This will ensure consistency of operation within the system. (Newman 1987)

8.1.8 Nonreflectivity of HUDs

Ensure that HUDs are designed to be nonreflective to the outside world, to reduce any external visual signature. (WSSG Working Group 1996)

8.1.9 Placement of HUDs

Place HUDs as close as possible to the horizontal center position and eye level relative to the operator. This enhances user performance. (Okabayashi et al. 1989; WSSG Working Group 1996)

8.1.10 Information Projection with HUD Systems

Design HUDs so that the information is projected against the least complex visual field. HUDs designed for ground vehicles should be projected down towards the roadway, which has a less complex visual field. For aircraft, where the general background is less complex, design HUDs so the visual field is projected higher. (Ward et al. 1994)

8.2 SYMBOLOGY FOR HUDs

8.2.1 Use of HDD Symbology

Use caution when designing symbols for HUDs that mimic head-down displays, because they can result in cluttered displays or cause confusion regarding control techniques. (Newman and Haworth 1994)

8.2.2 Information Origin Certainty

Design symbols and information presented on a HUD to ensure that operators have no uncertainty about the origin of the information being displayed. (Newman and Haworth 1994)

8.2.3 Overuse of Non-Conformal Symbology

Avoid overusing non-conformal symbology on HUDs. Non-conformal symbology refers to symbology that is not consistent with its far domain analog, e.g., symbology that is consistent with the vehicle body orientation rather than the horizon orientation. The design goal to reduce operator scanning can be neutralized or defeated by too much clutter from non-conformal symbology. (Wickens and Long 1994)

8.2.4 Declutter Capability

Provide the operator with the capability to declutter the symbology and/or information displayed on a HUD. (Newman 1987)

8.3 USE OF COLOR IN HUDs

Use color sparingly in HUDs. Trade-offs must be made by the designer in terms of costs versus a potential minimal performance enhancement. Although operators like color subjectively, color appears to have little positive impact on performance when using HUDs. (Dudfield 1991)

8.3.1 Color and HUD Coatings

Be aware when using color that coatings used on HUDs, such as those used to reduce reflectivity, may have an impact on the perception of color. (WSSG Working Group 1996)

8.3.2 Color Control and HUD Background

Provide the operator with the capability to change the color codes and contrast to adjust for varying backgrounds. (WSSG Working Group 1996)

8.4 FIELD OF VIEW

Design the FOV for HUDs as wide and as tall as possible, depending on the vehicle. Ground vehicles need wide FOVs, whereas aircraft need wide and high FOVs. Consider the following:

a. In general, the suggested minimum total FOV of a HUD for aviation systems should be 25 to 30 degrees azimuth and 22 to 25 degrees elevation.

b. Data are more sparse for ground systems. In general, many of the commercial HUDs being used in automobiles have a much narrower FOV, due in part to cost considerations as well as the minimal information being displayed. The FOV for ground vehicle HUDs should be designed to meet system and user requirements.

(Newman 1987; Harrison 1994; Wisely 1994; Gish and Staplin 1995)

8.5 RASTER IMAGE DESIGN

8.5.1 Visual Raster Image Contrast and Refresh

Present visual raster images (i.e., video images) used in HUDs using a high raster image-to-background contrast ratio and appropriate refresh rates. (Todd et al. 1995)

8.5.2 HUD Raster Image Luminance

Ensure that HUD raster image luminance is approximately 50% of the forward scene luminance. If the HUD is restricted to observation of familiar terrain, such as a runway or roadway, with high-contrast edges, center line, and markings, the luminance level should be about 15% of the forward scene luminance. (Lloyd and Reinhart 1993)

8.6 DYNAMIC RESPONSE

Design HUDs so that symbology and other displayed information are stable.

8.6.1 Flicker

Ensure that symbols show no discernible flicker. (Newman 1987)

8.6.2 Jitter

Ensure that symbols have no discernible jitter. Jitter is considered motion at frequencies above 0.25 Hz. (Newman 1987)

8.7 HUD AND FLIR IMAGES

When using forward looking infrared (FLIR) images on a HUD, consider the following guidelines.

8.7.1 FLIR and Night Vision Goggles

When the operator will be viewing FLIR images on a HUD concurrently with use of night vision goggles (NVGs), either provide a mechanism to turn off the NVGs, or use NVGs that allow vision of the HUD directly through the NVG (straight through) rather than having the image presented indirectly through combiner lenses (folded-optic). Data suggest that viewing the FLIR image through the folded-optic NVGs can be confusing to the operator. (Evans 1991)

8.7.2 FLIR and HUD Symbology

Consider, when designing systems to display FLIR images on HUDs, providing a dark border around white HUD symbols. FLIR images can sometimes be presented as dark “hot-zones” on a white “cool-zone” background. This may make it difficult to see the HUD symbology. (Evans 1991)

This page intentionally left blank.

9.0 AUDITORY HUMAN-COMPUTER INTERACTION

This section addresses interactions between weapon systems and users through non-verbal acoustic signals and speech interaction. In this context, signals include devices such as alarms and other non-verbal auditory presentations that convey information through their tonal, intensity, or spatial characteristics. Speech technologies include speech and speaker recognition, speech synthesis and digitized voice. The intent of these technologies is to facilitate linguistic communications between users and machines when the use of hands and eyes is constrained due to other task-related requirements. Speech interfaces are also useful when users do not understand system interfaces and input devices or when users lack certain written language skills.

Designers of auditory signals and speech communications devices must be cognizant of factors that can degrade the subjective intelligibility of acoustic signals. Some of these, such as background noise and degraded user and communications capabilities, might be particularly important under conditions in which RT/NRT systems are likely to be used. In addition, designers need to be aware that there are differences between the presentation of auditory signals through loudspeakers compared to headsets.

9.1 GENERAL

9.1.1 Limits to the Number of Auditory Signals

Although a large number of auditory signals can be learned, use no more than six immediate action signals and two attention signals to minimize learning and training requirements. This assumes that distinct temporal and spectral patterns are used, perceived urgency of warnings matches their priority, and warning sounds are followed by keyword speech warnings. (General Dynamics 1986; NRC 1997; WSSG Working Group 1999)

9.1.2 Selection of Auditory Displays

Note that three basic types of auditory signals can be used for auditory displays: periodic tones, non-periodic complex sounds, and speech. Table 9.1 provides an illustration of the utility of each of these signal types for different functions, though this guidance is most appropriate for single signal presentation. The designer will need to consider trade-offs when designing for a complex auditory environment. (WSSG Working Group 1999)

Table 9.1 Guidance for Selection of Audio Signals Based on Function

	Types of Signal		
Function	**Tones (Periodic)**	**Complex Sounds (Non-Periodic)**	**Speech**
Quantitative indication	**POOR** Maximum of 5 to 6 tones absolutely recognizable.	**POOR** Interpolation between signals inaccurate.	**GOOD** Minimum time and error in obtaining exact value in terms compatible with response.
Qualitative indication	**POOR-TO-FAIR** Difficult to judge approximate value and direction of deviation from null setting unless presented in close temporal sequence.	**POOR** Difficult to judge approximate deviation from desired value.	**GOOD** Information concerning displacement, direction, and rate presented in form compatible with required response.
Status indication	**GOOD** Start and stop timing. Continuous information where rate of change of input is low.	**GOOD** Especially suitable for irregularly occurring signals (e.g., alarm signals).	**POOR** Inefficient: more easily masked; problem of repeatability.
Tracking	**FAIR** Null position easily monitored; problem of signal-response compatibility.	**POOR** Required qualitative indications difficult to provide.	**GOOD** Meaning intrinsic in signal.
General	Good for automatic communication of limited information. Meaning must be learned. Easily generated.	Some sounds available with common meaning(e.g., fire bell). Easily generated.	Most effective for rapid (but not automatic) communication of complex, multidimensional information. Meaning intrinsic in signal and context when standardized. Minimum of new learning required.

Adapted from National Research Council 1997

9.1.3 Operator Request for Repeat of Signal

Provide the operator with the capability to request a repeat of the nonverbal or verbal auditory signal. (Obermayer and Campbell 1994)

9.1.4 Redundant Cues for Auditory Signals

Ensure that auditory display signals are always accompanied by a redundant visual indication. (Obermayer and Campbell 1994; U.S. Army 1995g)

9.1.5 Redundant Cues for Visual Signals

Use auditory cues to augment visual cues for out-of-tolerance conditions, when operators are monitoring rather than actively controlling automated actions. (Wickens and Kessel 1979)

9.1.6 Timing of Tones and Voice Signals

When using tones concurrently with voice annunciation, begin both simultaneously, with the tone terminating 1 second after the voice annunciation. (U.S. Army 1995g)

9.1.7 Lack of Data Transmission Interference

Ensure that digital data transmission does not interfere with voice communication or auditory signals and is not masked by background noise. (U.S. Army 1993)

9.1.8 Speech Intelligibility

Design systems that use speech presentations to provide a degree of speech intelligibility consistent with listening conditions, user characteristics, and mission requirements.

9.1.8.1 Intelligibility Criteria

Design RT/NRT systems so that they meet the speech intelligibility criteria in Table 9.2. (U.S. DoD 1996a)

Table 9.2 Intelligibility Criteria for Voice Communications Systems

Communications Requirement	Score		
	PB*	**MRT****	**AI*****
Exceptionally high intelligibility; separate syllables understood	90%	97%	0.7
Normal acceptable intelligibility; about 98% of sentences correctly heard; single digits understood	75%	91%	0.5
Minimally acceptable intelligibility; about 90% sentences correctly heard (not acceptable for operational equipment)	43%	75%	0.3

* Phonetically balanced
** Modified rhyme test
*** Articulation index
(Adapted from MIL-STD-1472E [U.S. DoD 1996a])

9.1.8.2 Testing Requirements

When very high degrees of intelligibility are required, test systems using the target word sets (i.e., words the user is expected to understand when using an application that includes speech output) and one of the following methods: phonetically balanced monosyllabic word intelligibility methods as outlined in ANSI S3.2-1989[R1995] (ANSI 1995) and the articulation index described in ANSI S3.5-1969[R1986] (ANSI 1986). For less stringent requirements, use modified rhyme testing or similar methods. (U.S. DoD 1981)

9.1.8.3 Use of Prerecorded Speech

Consider using prerecorded speech rather than synthesized speech when high degrees of intelligibility are required. (Streeter 1988)

9.1.9 Avoiding Masking of Auditory Signals

Avoid potential masking of one auditory signal by another through:

a. Considering how multiple auditory alarms and warnings will interact with each other. (Stuart 1995)

b. Ensuring that multiple auditory alarms and warnings are outside the critical masking band. (Stuart 1995)

c. Maintaining adequate spatial separation between different sound sources. (Stuart 1995)

d. Providing the ability to emphasize some signals and de-emphasize other signals based on priority. (WSSG Working Group 1999)

9.1.10 Use of Auditory Interfaces

Use auditory displays for interfaces that do not usually get direct visual attention from the user or where visual interaction is not possible. (Hindus et al. 1995; Stuart 1995)

9.1.11 Active Noise Reduction

In high ambient noise environments, use active noise reduction (ANR). In ANR two microphones are used to try to compensate for noise environments. One picks up the speaker's voice and one picks up the ambient noise. The input from the second is used to cancel out the noise, thereby enhancing the speaker's input. (Takahashi, et al. 1995; WSSG Working Group 1999).

9.1.12 Use of a Common Lexicon

When using speech for signaling, use words from a lexicon familiar to the target audience to reduce cognitive demands for recognition of the signal. (Companion and Epp 1997)

9.2 NONVERBAL SIGNALS

9.2.1 Use of Nonverbal Auditory Signals

Use nonverbal auditory signals for applications when their immediate discrimination is not critical to personnel safety or system performance. Ensure that nonverbal auditory signals are intuitive in nature. Limit the number of nonverbal signals to ensure rapid and correct interpretation by the operator under mission conditions. (Obermayer and Campbell 1994; WSSG Working Group 1996)

9.2.2 Control of Auditory Signal

Provide the operator with the capability to control or disable the audio signal volume. However, consider the following:

a. Do not allow the disabling of mission and safety critical signals.

b. Design the volume control to ensure that the operator cannot inadvertently decrease the volume level to where it is inaudible.

c. Ensure that the volume control allows adjustment of the signal to compensate for noisy environments, but does not exceed the noise limits set in MIL-STD-1472E (U.S. DoD 1996a) and MIL-STD-882C (U.S. DOD 1996c).

(Obermayer and Campbell 1994; U.S. Army 1995g; WSSG Working Group 1996)

9.2.3 Auditory Signals - Tonal Display Design

Design tonal displays according to the following guidelines:

9.2.3.1 Pitch

Design pitch of warning sounds to be between 150-1000 hertz (Hz). (NRC 1997)

9.2.3.2 Frequency Components

Include at least 4 dominant frequency components within the first 10 harmonics of signals. This will help minimize masking effects, as well as pitch and quality changes during masking, and maximize the number of distinctive signals that can be generated. (NRC 1997)

9.2.3.3 Harmonic Spectra

Ensure that signals have harmonic rather than inharmonic spectra.

a. **Lower priority** - most energy in the 1st five harmonics.

b. **Higher priority** - energy in 6 to 10 harmonics.

c. **High priority** - can make distinctive by adding a small number of inharmonic components.

(NRC 1997)

9.2.3.4 Frequency Range

Restrict frequency range to within 500-5000 Hz, with the dominant ones within 1000-4000 Hz. (NRC 1997)

9.2.4 Selection of Tonal Frequencies for Background Noise

Select tonal frequencies with minimal noise masking when background noise is present. Ensure that the major concentration of energy is between 250 and 2500 Hz. (General Dynamics 1986)

9.2.5 Signal Modulation

To demand attention, modulate the signal to give intermittent beeps or to make the pitch rise and fall at a rate of about 1 to 3 cycles per second. (General Dynamics 1986)

9.2.6 Temporal Form and Shape of Auditory Displays

Temporal form and shape are important factors in detectability of, coding of, and listener reaction to auditory displays. Consider the following in designing temporal form and shape:

a. Near-optimum envelope parameters are a minimum of 100 milliseconds (ms) duration, 25 ms rise and fall time, and quarter sine shaping.

b. Onset rates should be less than 1 decibels (dB)/ms, with final level falling below 90 dB.

c. Use a variety of temporal patterns in order to minimize confusion.

d. Code urgency or priority with pulse rate, i.e., high pulse rate for high priority.

(NRC 1997)

9.3 SPEECH OUTPUT

9.3.1 When to Use Speech Output

Consider using speech output when the:

a. Message is short, simple and will not need to be referred to again.

b. Message calls for immediate action.

c. Inappropriate for a visual display.

d. Task requires continuous physical movement by the operator.

(Cowley, Miles and Jones 1990)

9.3.2 Synchronization of Speech and Visual Warnings

Ensure that synthetic speech warnings used in conjunction with visual warnings are synchronized. (Hansen and Bou-Ghazale 1995)

9.3.3 Vowel Versus Consonant Sounds in High Noise Environments

In high noise environments, design speech output systems so that vowel sound levels are higher than the background noise and consonants are detectable. (NRC 1997)

9.3.4 Polysyllabic Versus Monosyllabic Words

In designing speech output systems, consider that polysyllabic words are more intelligible than monosyllabic words, as are word sentences over words in isolation. (NRC 1997)

9.3.5 Speech Output in Alarm Handling

a. Use speech and text simultaneously to provide fault diagnostic information in alarm displays.

b. Do not use speech alone as a means to provide alarm information – fault correction will be impaired.

(Stanton and Baber 1997)

9.4 3-D AUDITORY LOCALIZATION

3-D auditory localization refers to providing auditory cues that assist the operator in orienting towards the physical location of a source. For example, auditory cues might be used to indicate the direction of a threat.

9.4.1 Use of 3-D Auditory Localization

Consider using 3-D localization of the auditory signal to cue the operator on the direction from which a target or signal is coming, or to help localize where the operator needs to focus attention. When using 3-D localization through headsets, include a mechanism for tracking the operators' head location with respect to the task being performed to ensure appropriate orientation of the 3-D signal. (Begault 1993; U.S. Army 1995g; Elias 1996; WSSG Working Group 1997, 1999)

9.4.2 3-D Auditory Localization and Stimulus-Response Compatibility

Consider using 3-D localization to maximize Stimulus-Response Compatibility (SCR). This is accomplished by matching 3-D localization representative of spatial processing when a manual response is required and non-directional audio when a verbal response is required. For example, where selection of a button is required when an alert condition occurs, consider using 3-D localization to draw user attention to the location of the button. (Wickens, Sandry, and Vidulich, 1983, Wickens, 1984b)

9.4.3 Auditory Preview

If implementing auditory preview for targets not yet in the visual field, ensure that the perceived velocity of the auditory signal is either consistent with or proceeds the target's approach to the visual field. Do not allow the auditory signal to lag behind the target. Auditory preview consists of an auditory signal that indicates to a operator the direction and approaching speed of a target that is not yet visible to the eye, either through a display or naked eye. (Elias 1995)

9.5 SPEECH RECOGNITION

The two basic types of speech recognition systems are: speaker-dependent and speaker-independent. Speaker-independent approaches are designed to accommodate differences in individual speech patterns. Most commercial products in this category are trained to respond to a relatively smaller collection of words and phrases. Examples in this category include telephone order entry and dialing assistance applications and simple speech-actuated control devices. Improvements in speech recognition technology will result in more robust speaker-independent applications but, at the present time, these technologies tend to be more limited than speaker-dependent approaches.

The designer should keep in mind that weapon system aural environments include very adverse conditions for implementing speech recognition. This includes poor signal to noise ratios, very variable background noise conditions, and significant stress on the speaker - causing voice pattern changes. These conditions can make it very difficult to achieve high recognition accuracy.

9.5.1 General Design Considerations for Speech Recognition

Consider the following when designing a speech recognition system:

a. Prior to deciding whether to implement a speech recognition element into a weapon system, perform a thorough analysis of the costs and benefits of this technology. Among the questions that need to be considered are the following:

   - What are the benefits of using speech versus other means of interaction, e.g. does it support operator performance? (Steeneken 1996)

   - What functions and/or tasks are to be mediated using speech recognition? (Steeneken 1996)

   - Who are the speakers(s)? This includes determining if there will be multiple users or a single user, and intellectual level of the users. (Steeneken 1996)

   - What are the benefits versus costs of implementing speech recognition? (Steeneken 1996)

   - Does the speech recognition system map to the task and is it appropriate to the corresponding visual user interface. (WSSG Working Group 1999)

b. Ensure that the design includes the voice transducer in the speech recognition system. Because the direction of the incoming speech signal and the distance between the source and the microphone determine the quality of the signal captured, designers need to include the voice transducer in the speech recognition system design.

c. For all systems—and in particular those that must be trained to a specific speaker's voice (enrollment)—consider the potential effects of within-speaker variability. Factors that can cause changes in speech include physical and physiological characteristics of the speaker, voice quality, rate of speaking, prosody (i.e., accenting different syllables and words), and degraded modes, such as wearing MOPP equipment, etc.

d. Design speech systems to degrade gracefully when operating under unusual conditions, and consider methods for automatically adapting system characteristics to changing conditions, such as vibration and background noise, and new human speakers.

e. When designing systems for use by native and non-native speakers, consider the possible effects of dialects and multiple word pronunciations on the accuracy of speech recognition

f. Limit vocabulary size to what is required for the tasks. Provide a means for detecting out-of-vocabulary or low certainty words or phrases and alerting the user when the meanings are not clearly understood by the system. Do not require complete sentences and allow for multi-grammar design where certain words are not recognized by the system based on user, task, or mode of operation. Consider that the use of a standard military lexicon that includes vocabulary specific to the target audience will significantly improve the accuracy of speech recognition.

g. When using an isolated word recognition system, improve recognition by using keyword spotting. In keyword spotting, the system is trained/designed to recognize certain keywords that are embedded in redundant utterances of conversational speech and in noisy speech. This improves performance for spontaneous speech. Spontaneous speech is different from the read speech typically used for system training in that a number of other "speech events" are embedded in the signal. These events include false starts, interjections (i.e., "uh"), disfluencies, and out-of-vocabulary words. (Lee and Rabiner 1995; Takahashi, et al. 1995).

h. Note that acoustic mismatches between the actual environment and the environment used for training the system can degrade performance. This can be a significant problem for RT/NRT applications because of the number of variables that can affect the acoustic environment.

i. Note that microphones used in tactical environments may have a limited frequency range and peak clip inflections and other aspects of speech. (WSSG Working Group 1996)

j. Provide the ability for the operator to disable speech recognition systems for some operational modes, such as those that require silence. (WSSG Working Group 1999)

9.5.2 Use of Automatic Speech Recognition Systems

Use automatic speech recognition (ASR) only where:

a. The resulting action is not mission critical.

b. An alternative control system is available.

(Coueffin et al. 1983)

9.5.3 Speech Recognition Interaction with Other Primary Tasks

Consider the possible ramifications on other tasks when selecting speech recognition systems. While data suggest that concurrent use of speech recognition with a primary visual task, i.e., piloting or driving may degrade performance on the primary task, these possible limitations should be balanced against the potential benefits when operators must use their vision and hands for other tasks. (Dudfield 1991)

9.5.4 Environmental Impact on Speech Recognition

In the design, consider the environmental impact on speech recognition. When considering the implementation of a speech recognition system in an RT/NRT system, designers should be aware that the operational environment may contain high levels of noise and vibration, require speech through a mask, and induce stress in the operator, thus changing voice characteristics and making speech recognition systems less reliable. (Gordon 1990; U.S. Army 1995g; Site visit General Dynamics Land Systems Division 1996; WSSG Working Group 1997)

9.5.5 Whispered Speech

Consider, in designing speech recognition for direct voice input (DVI) for RT/NRT systems, that the system may need to respond accurately using a microphone mounted in the workspace to whispered speech through a respirator or MOPP mask or due to whispered modes of operation. (Hughes and King 1989; WSSG Working Group 1997, 1999)

9.5.6 Fail-Safe Protocols

Use fail-safe protocols in the design of DVI systems that will preclude potential catastrophic results from errors in speech recognition. (Hughes and King 1989)

9.5.7 Redundant or Alternate Means for Input

Ensure that speech recognition used for data input or command entry always has a redundant or alternate means for input. (Osga et al. 1995)

9.5.8 Interference and Speech Recognition

Ensure that activated speech recognition systems do not interfere with other communications systems. Likewise, ensure that other communications systems do not interfere with the speech recognition system. In particular, ensure that a voice recognition system does not accept computer speech output as a command. (U.S. Army 1995g; WSSG Working Group 1996, 1999)

9.5.9 Push-to-Talk Control

Consider providing the operator with a push-to-talk button or other suitable type of control when using a speech recognition system when this supports task performance. (U.S. Army 1995g)

9.5.10 Location of Microphones

Design the microphone location to fit the combat mission. In general, use headset-mounted microphones for speech recognition input devices in RT/NRT systems where appropriate to the task and combat mission. (Smolders et al. 1994)

9.5.11 Training ASR Users

Consider, when designing speaker-dependent ASR systems, that training the user is just as important as training the voice recognizer. Data indicate that:

a. Visual feedback can help the user control both spoken vocabulary and, to some degree, syntax. (Nunn 1989)

b. Daily enrollment of the user improves overall system performance. However, complex daily enrollment procedures may not be operationally acceptable. (Smyth 1991)

9.5.12 Dialog Design for Speech Recognition Systems

A variety of dialog styles are available for speech recognition systems, as with CRT-based human-computer interfaces. This section provides a number of guidelines for dialog design that address different aspects of user experience and type of tasks performed.

9.5.12.1 Structured Dialog Design

Use structured dialogs in the design of speech recognition systems. Structured dialogue is preferred by users - both novice and expert - and can increase the success of speaker independent systems. This will also minimize the effects of disfluency (i.e., pauses, self-corrections). (Kamm 1994; Oviatt 1996).

9.5.12.2 Use of System Prompts or Dialogs

Guide the user by using system prompts or a system dialog (linguistic convergence) when systems require isolated word recognition, or where the pace of continuous speech must be constrained to meet system capabilities. (Cole et al. 1996)

9.5.12.3 Design of Prompts

When designing prompting dialogs for ASR systems, consider opening the prompt with a question, followed by a pause to encourage barge-in from experienced users, followed by an options list for less experienced users. This will result in more accurate and shorter transactions. (Brems, et al. 1995)

9.5.12.4 Vocabulary Selection for Constrained Speech

When using a constrained vocabulary for speech control, select vocabulary words that are appropriate to the user's perception of the task. This will reduce the memory demand and improve the user's ability to recall the appropriate command. (Baber and Noyes 1996)

9.5.12.5 End of Dialog Feedback

Include an explicit indication that a verbal dialog between the human and the system has been completed, analogous to the disappearance of a pop-up dialog window in a Graphical User Interface (GUI). This is particularly important when not using explicit prompting of user input. Some type of indication from the system when a subdialog is finished, such as a "what now" response from the system will ensure that the user remains aware of the need for some type of input. (Yankelovich, et al. 1995; Spiegel, et al. 1997)

9.5.12.6 Pacing of Dialog

To improve the overall pacing of the dialog, consider including the following in the design:

- Barge-in that allows the user to respond before the end of the system verbal prompt/response.
- User control of the pace of dialog, allowing them to speed up or slow down the pace.
- Keypad or other manual control device short-cuts for common functions to all applications using speech recognition.

(Yankelovich, et al. 1995)

9.5.12.7 Dialog Feedback

When possible and appropriate, provide immediate and continuous visual feedback of operator utterances for speech recognition systems. Once an utterance is completed, the system should then execute the command. (Hatazaki, et al. 1994)

9.5.12.8 Dialog Types and Modes

a. Use directive dialog mode for novice users – in this mode the computer has complete dialogue control. (Smith 1994)

b. Use passive mode for expert users – here the user has complete dialogue control. (Smith 1994)

c. Use suggestive and declarative mode for complex problem solving situations that require computer guidance, e.g., relying on large databases for targeting information. In declarative mode, the user has dialogue control but the computer is free to make relevant comments in response to the user. In suggestive mode, the computer has dialogue control, but allows interruptions by the user. (Smith 1994)

d. Use structured dialogue for tasks in which guidance and user perception of closure is required. (Oviatt, et al. 1994)

9.5.12.9 Alternative Input Modes for Spatial Locations

Provide alternative input modes for indicating spatial locations in an automated speech recognition system, as in working with maps. For example, users may employ ambiguous terms when referring to map locations, such as “there” – however, by using a pointing device or touch screen to point to a location, the spoken input can be disambiguated. (Oviatt 1996)

9.6 AUDITORY ICONS AND EARCONS

Emerging auditory interfaces include the use of auditory icons and earcons. Auditory icons consist of sounds drawn from the everyday user environment that are mapped to analogous computer events. For example, arming a weapon might be represented by the sound of cocking a pistol. Related categories of events can be represented by variations of a particular class of sound. This is called parameterising. For example, a series of related sounds could be used to represent target detection, acquisition, and lock on. As with the design of visual icons, the users should be involved in selecting meaningful auditory icons.

Earcons are abstract, synthetic musical tones used to create auditory messages. Earcons use varying rhythms, melodies, and timbres to create short tunes that are mapped to information such as status and feedback. In some cases, earcons are arbitrarily mapped, therefore they may require the operator to memorize them. In other cases they may be analogous to the intonation and rhythm of the equivalent spoken message. Earcons can be simple or compound. Compound earcons consist of earcons for multiple operations, such as weapon and arm, that are combined to provide a more complex message. They can be presented serially or in parallel.

When using auditory icons and earcons, ensure that auditory icons and earcons do not interfere with other auditory alerts or verbal communications. For more information on auditory icons and earcons, please refer to the 1997 article by Gaver (Gaver 1997).

9.6.1 General

Use sound, such as auditory icons and earcons, to provide feedback that might otherwise be missed by visual monitoring, particularly for large-screen, high-resolution, multiple monitor interfaces. (Brewster 1998)

9.6.2 Auditory Icons

9.6.2.1 Auditory Icon Enhancement of Visual Warnings

To improve user response to critical visual warnings, consider providing a visual display combined with an auditory display consisting of an auditory icon. Auditory icons may enhance human performance better than standard auditory signals. (Haas 1998; Belz, et al. 1998)

9.6.2.2 When to Use Auditory Icons

Use auditory icons when they can be easily mapped to user interface objects or computer actions (e.g., ensure an appropriate metaphor). If this is not possible, earcons may be more appropriate. (Gaver 1997)

9.6.2.3 Use of Auditory Icons with Visual Cues

To maximize their effectiveness, accompany auditory icons with an appropriate visual cue. Where appropriate, provide the operator with the ability to acknowledge the auditory icon and maintain the primary visual indication. (Gaver 1997; WSSG Working Group 1999)

9.6.2.4 Sound Selection

Select sounds to portray analogous computer events that are meaningful, interpretable, and intuitively complement and/or supplement their accompanying visual indications. (Gaver 1989, 1997)

9.6.2.5 Suitability of Auditory Icons for Frequent Events

Avoid the use of auditory icons for events of little consequence that occur frequently. (Gaver 1997)

9.6.2.6 Avoiding Masking with Multiple Auditory Icons

When using multiple auditory icons, reduce the chances of having one mask another by the following:

a. Spread sounds evenly across the frequencies being used. See paragraph 9.1.9.

b. Use repetitive streams of sounds, rather than continuous sounds, which will maximize the chances of other sounds being heard during gaps.

(Gaver 1997)

9.6.2.7 Use of Parameterized Auditory Icons

Use parameterized auditory icons when presenting information that needs to convey detailed, dimensional data. (Gaver 1993)

9.6.2.8 Operator Control of Auditory Icons

Provide operators with the ability to turn off individual sounds for non-critical auditory icons. (Gaver and Smith 1990)

9.6.2.9 Operator Involvement in Auditory Icon Design

Involve the operator in the design of auditory icons to ensure that they have the same meaning to all operators. This is particularly important since different operators may interpret sounds differently based on their backgrounds. (Gaver and Smith 1990)

9.6.3 Earcons

9.6.3.1 Use of Earcons for Enhancement of Precision Tasks

Consider using acoustic feedback in the form of earcons where visual search and data entry tasks require precision. This may reduce response time and mental workload. (Brewster 1997)

9.6.3.2 Limitations in Use of Earcons

When employing earcons in weapon systems, consider the following:

a. Earcons tend to be arbitrary, requiring user learning without the benefit of prior experience. (Gaver 1997)

b. Musical phrases may not integrate well with a weapon system operational environment. (Gaver 1997)

c. Earcons tend to be of long duration. For RT/NRT systems, a long duration during engagement may conflict with the need to take immediate action. (Gaver 1997; Brewster, Wright and Edwards 1993)

9.6.3.3 Design of Sequential Earcons

When playing earcons one after another, use a gap (at least 0.1 seconds) between each earcon so users can tell where one finishes and the other starts. (Brewster, Wright, and Edwards 1993)

9.6.3.4 Use of Earcons with Menus

When using extensive menuing in graphical user interfacess, consider using earcons to provide feedback on correct or incorrect selection of a menu option. Earcons can be used to indicate the following:

a. Cursor slipping off a menu – use a loss of continuous auditory signal indicating that a menu has been selected and displayed.

b. Cursor drift from a selection - use a change in tone where each menu option has an alternating tonal signal.

c. Release of pointing device selector over a menu option divider – use no auditory signal.

d. Selection of an incorrect option - use a discordant sound.

(Brewster and Crease 1999)

9.7 SONIFICATION AND DATA

Sonification Auralisationis the process of representing numerical data, or other types of data, by non-verbal sounds. Data auralisation is a more complex form of sonification that is used to help in the perception of complex, frequently multidimensional data. In both of these methods, the sounds mapped to that data might be single tones or continuous streams of sounds. Changes in the sounds reflect changes in the data. Sonar and a Geiger counter are examples of sonification. Potential uses for sonification with weapon systems include representing changes in a target being tracked or own unit location status relative to other units.

9.7.1 Advantages to Using Sonification

Using sonification as a display modality has the following advantages:

a. Auditory perception is very sensitive to temporal characteristics or changes in sound over time. Humans can easily detect small changes in frequency of continuous signals. Therefore, sonification is useful for comprehending or monitoring complex temporal data or data that is embedded in other, more static signals.

b. Perception of sound does not require the user to be visually oriented to the source, making sonification a good modality where the visual system is already fully occupied with a task.

(Kramer et al. 1997)

9.7.2 Limitations to Data and Sound Mapping

Consider the following when using sonification in weapon systems:

a. Do not map data linearly to sound dimensions that are heard logarithmically.

b. Do not use sonification for complex presentations where multiple tones must be presented for serial processing. This can quickly overwhelm the operator.

(Gaver 1997)

9.7.3 Use of Sonification

Use sonification where the need to move the eyes to acquire information is risky and a potential bottleneck for human performance. (Barrass and Kramer 1999)

10.0 INTERACTIVE CONTROL

Interaction between the computer and the user is performed through a two-way communication process, where the user inputs commands and the computer responds to the input. This is referred to as interactive control. Interactive control of a system occurs through a give-and-take of command and response between the user and the computer, called a "dialog." The following are basic principles for designing a good human-computer dialog:

- Strive for consistent design across terminology, menus, command structure, and other aspects of design for all applications.
- Enable the use of shortcuts for experienced users, thus improving operator acceptance and overall system performance.
- Offer rapid and informative feedback for all operator actions.
- Design dialogs to yield closure. The operator will then feel a sense of accomplishment and control, and will know when to go on to the next task.
- Offer simple error-handling, both by system error-checking and ease in correcting an identified error.
- Allow easy reversal of actions through error tolerance and easy error recovery.
- Enable the operator to feel in control of the interaction with the system.
- Reduce short-term memory load on the user by using intuitive displays, interactive sequences, sufficient training, and on-line helps and tutorials.

The following section discusses guidelines for interactive control for RT/NRT systems.

10.1 GENERAL

10.1.1 Minimizing Data Entry

Use selection lists, default values, hot keys, or other methods to minimize alphanumeric data entry, and to speed the execution of frequently used and critical actions. (Osga et al. 1995; U.S. Army 1995f)

10.1.2 Use of Default Values

When message fields or forms need to be completed, provide as much data as possible from the system as default values and/or autofill from the database. (U.S. Army 1996d)

10.1.3 Early Indication for Visual Detection

Provide advance or early approximate location information, when visual detection is an important task. Display information consistently in the same location. (Fallesen 1985; WSSG Working Group 1996)

10.1.4 Operator Control of Processes

Provide the operator with the capability to control, interrupt, or terminate processes. When this is not possible, ensure that the application/system informs the operator of a change in status. (Osga et al. 1995; U.S. Army 1995e; WSSG Working Group 1996)

10.1.5 Operator Selection of Displayed Information

Consider providing the operator with a means to determine the types of information to be displayed for a given set of operational conditions. For weapon systems, this is more of a decluttering capability than a tailoring capability. The degree of declutter capability provided to the operator should be subdomain-defined. (Hair and Pickslay 1993; WSSG Working Group 1996)

10.1.6 Design for Information Security

Standards governing the design of information security for Army systems are provided in Section 6 of the *Joint Technical Architecture - Army* (U.S. Army 1999). Guidelines for designing log-on screens for RT/NRT systems are described in the *DoD HCI Style Guide* (U.S. DoD 1995).

Some guidelines for the design of log-off procedures are presented below. Not all RT/NRT systems will require log-off, and each domain should specify the log-on and log-off methods that are most operationally appropriate.

10.1.6.1 Operator Initiated Log-Off

Ensure that log-off for real-time systems is initiated by a operator, not by the system. (WSSG Working Group 1996)

10.1.6.2 Prompting to Save Data

Prompt operators when logging off to save or not to save any new or changed data. (Obermayer and Campbell 1994)

10.1.6.3 Confirmation of Log-Off

Require the operator, if log-off is required from an RT/NRT system, to confirm the log-off action to ensure that it does not occur inadvertently. (WSSG Working Group 1996)

10.1.6.4 Local Area Network (LAN) Log-off

Ensure that, when multiple workstations connected to a LAN within a shelter or vehicle will be affected by log-off of a single workstation, each affected workstation will receive a warning. (Obermayer and Campbell 1994)

10.1.7 Dedicated Return to Previous or Top Level

Provide, in multilayered systems, dedicated function keys or other means for returning to the main menu or top level, as well as for returning to the previous level. When returning to the next level or main menu, ensure that the operator is prompted to save changes, if appropriate. (U.S. Army 1995a; WSSG Working Group 1996)

10.1.8 Multiple Page Displays

When designing multiple page displays, consider the following:

a. Provide dedicated display keys for “Page Up” and “Page Down,” when designing multiple page displays that require using function keys.

b. When a operator is at the top or bottom page, the corresponding “Page Up” or “Page Down” key should be disabled.

c. Provide an auditory alert or visual indication, i.e., graying out the corresponding key, that the user is trying to move beyond the available range of pages.

(U.S. Army 1996b)

10.1.9 Prompt to Save Changes

Ensure that the system prompts the operator to save changes prior to closing a file or terminating a process. In a system that does not support multiple windows, prompt the operator to save changes to the current option before closing it and opening a new option. (McCann et al. 1993)

10.1.10 Hybrid Graphical User Interfaces (GUIs)

Avoid the use of hybrid GUIs. A hybrid GUI is a GUI composed of tool kit components from more than one user interface style. An example of a hybrid GUI would be one that uses tool kit components from both Motif™ and MS Windows™. In addition, graphical and character-based application user interface styles should not be mixed within an application. (U.S. Army 1997)

10.2 TRANSACTION SELECTION

Transaction selection refers to the control actions and computer logic that initiate transactions (interchanges) between computers and users.

10.2.1 Limited Hierarchical Levels

Limit hierarchical levels to three when used in an operational sequence or task unless more are absolutely required operationally. (General Dynamics 1986; WSSG Working Group 1999)

10.2.2 Consistent Display and Control Formats Within Levels

Ensure display and control formats are consistent within levels. (General Dynamics 1986)

10.2.3 Control of Information Update Rates

Allow the operator to control the rate at which some display information is updated, when appropriate in an RT/NRT system. The types of information that lend themselves to user-controlled update rates include distance traveled and altitude, which should be controlled by algorithms based on rate of change, and network status based on pings. The types of information that do not lend themselves to user-selected update rates include enemy unit location and range, own and friendly unit location, and weapon systems status when engaged. The designer needs to be extremely careful in implementing user-selected update rates because the update rate requirements for information may be very situational-dependent. (Obermayer and Campbell 1994; Osga et al. 1995; WSSG Working Group 1997)

10.2.4 Tailoring Information Flow and Control Actions

Tailor the information flow and control actions to those specific to the operator's operational needs at that moment. For example, when in combat mode, the displays, controls, and available information should support only that mode. (General Dynamics 1986)

10.2.5 Display of Control Options

When a operator must select control options from a discrete list of alternatives, display the list at the time the selection must be made, rather than requiring the operator to try to remember the alternatives. For example, control options could be selected from a pop-up list box or a pull-down menu. (General Dynamics 1986)

10.2.6 Availability of Necessary Information

Make all necessary information available to the operator at the time an action is to be performed. (General Dynamics 1986)

10.3 ERROR MANAGEMENT AND FEEDBACK

10.3.1 Error Management

10.3.1.1 Confirmation of Destructive Entries

Ensure that operators can confirm control entries that may be hazardous, destructive, cause extensive changes in databases or system operations, or that cannot otherwise be undone. (General Dynamics 1986; Obermayer and Campbell 1994; Osga et al. 1995; U.S. Army 1995c, 1995e)

10.3.1.2 Indication of Error Conditions

Ensure that the system provides a clear indication and explanation of error conditions.

a. Do not overtly display noncritical errors, because they may distract the operator from the primary operational task.

b. Ensure that error descriptions indicate the cause of the error. Where feasible and appropriate, suggest corrective actions.

c. Where feasible and appropriate, provide troubleshooting guidance, corrective actions, or alternate or work-around solutions. Subsequently, provide feedback of troubleshooting and corrective actions.

(Osga et al. 1995; WSSG Working Group 1996, 1997, 1999)

10.3.1.3 Undo Function

Where appropriate for a RT/NRT system, provide the operator with the capability to reverse or undo the effects of the last edit action, as well as previous actions. (Obermayer and Campbell 1994;WSSG Working Group 1996, 1997)

10.3.1.4 Consistent Error Message Location

Display error messages in a consistent location. (WSSG Working Group 1996)

10.3.1.5 Error Message Dialog Box Location

Locate an error message dialog box, when used, close to the source of the error without obscuring it. (Obermayer and Campbell 1994)

10.3.2 Feedback

10.3.2.1 General Guidelines for Feedback

Provide feedback to the operator, as necessary, to supply system status information. The following general guidelines apply to feedback for RT/NRT systems. Additional guidance for systems using significant windowing can be found in the *UI Specification for the DII.* (U.S. DoD 1999a)

a. Provide periodic feedback to indicate normal system operation when system functioning requires the operator to stand by.

b. Present positive indication to the operator concerning the outcome of the process and requirements for subsequent operator action, when a control process or sequence is completed or aborted by the system.

c. Provide a means to cue the operator to the mode in which the system is currently operating, when the system has multiple modes of operation.

d. Highlight the displayed item when it is selected to indicate acknowledgment by the system.

(General Dynamics 1986)

10.3.2.2 Warning of Time to Complete Action

Ensure that the application warns the operator when a selected action will require more time to complete than would be normally expected, and provide the operator with the capability to cancel the requested action. (Osga et al. 1995)

10.3.2.3 System-Busy Indication

Ensure that a visual indication of "system-busy" is displayed when results of the operator-requested action cannot be displayed immediately. This visual indication should occur within 0.1 seconds from the time the action was requested. If the delay will be longer than 5 seconds, ensure that the application provides an indication that processing is taking place. (Obermayer and Campbell 1994; Osga et al. 1995)

10.3.2.4 Feedback of Input Acceptance

Provide operators with visual feedback on whether a control action, data entry, or other input has been accepted or not accepted by the system. This feedback should occur within a minimum of 5-50 milliseconds (ms) and no more than 200 ms (0.2 seconds). When input is rejected, the feedback should indicate why and what corrective action is required. (U.S. Army 1995e; U.S. DoD 1995)

10.3.2.5 Error Feedback Timing

Provide error feedback, such as feedback for an invalid action, to the operator within 2 seconds of the time the system detected the error. (Obermayer and Campbell 1994)

10.3.2.6 Critical Information Availability

Alert the operator when critical information becomes available or changes occur in an inactive or minimized (iconified) window. For windows or applications that are temporarily frozen for command processing, ensure that the system provides an immediate indication to operators, allowing them to return to automatic updating. Once the display is unfrozen, the system should indicate the information that has changed. (Obermayer and Campbell 1994)

10.3.2.7 Loss of Critical Signal Input

Provide a visual indication when a tracking system loses the target track or other critical signal input. This is particularly important for systems that rely on sensor input and predictive algorithms. (U.S. Army 1995g; WSSG Working Group 1997)

10.3.2.8 Auto-Tracking

Provide a visual indication that auto-tracking is engaged. For systems where the operator can employ an auto-tracking and/or coasting feature, such as a target tracking and engagement system, ensure that visual indications are evident when that feature is engaged.

10.4 CURSOR

10.4.1 General

10.4.1.1 Cursor Pointer Shape

Vary the cursor pointer shape to provide the operator with visual feedback, depending on the functionality being accessed or system mode. See Figure 10.1 for an illustration. (Obermayer and Campbell 1994; U.S. Army 1995e, 1995g)

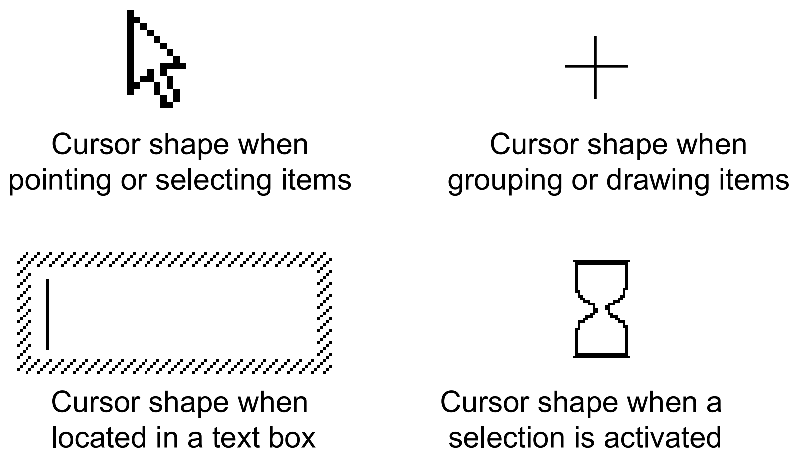


Figure 10.1 Illustration of Pointer Shape Used for Visual Feedback of Cursor Function

10.4.1.2 Hot Spot

Ensure that the cursor hot spot "feels" obvious. For example, although an arrowhead pointer is made up of individual pixels, only the topmost pixel is the hot spot. See Figure 10.2. (Fowler and Stanwick 1995)

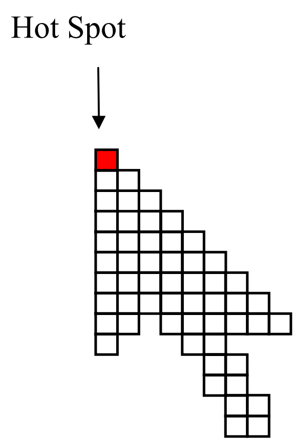


Figure 10.2 Example of Hot Spot

10.4.1.3 Cursor Visibility

Ensure that the cursor is constantly visible on the display. Consider the following design principles in maintaining cursor visibility:

a. Ensure that the cursor changes shade, color, or intensity as required to remain visible while superimposed on menu selections, buttons, icons, or other screen features. (U.S. Army 1995e)

b. Provide the operator with the capability to either enlarge the size of the cursor to aid in locating it against the background, or to bring the cursor to a single home position. (Obermayer and Campbell 1994)

c. Ensure that the cursor is constrained from moving off the screen. (Obermayer and Campbell 1994; U.S. Army 1995e)

10.4.1.4 Cursor Movement

Provide the following, where appropriate, for cursor movement:

a. Smooth movement in any X and Y direction.

b. Ability for auto-increment or step function movements for some modes, such as movement between grids on a map.

(WSSG Working Group 1996)

10.4.2 Redundant Methods for Cursor Movement

Provide a redundant capability to a pointing device for cursor movement or other primary means of cursor control. For example, keyboard arrow keys can be a backup method of cursor control. (U.S. Army 1996b)

10.4.3 Targeting Reticle

10.4.3.1 Composition of Targeting Reticles

Ensure that targeting reticles are composed of both light and dark pixels to ensure visibility when superimposed on both light and dark backgrounds. (U.S. Army 1995g)

10.4.3.2 Targeting Reticle Center

Ensure that targeting reticles include a dot or other visual indication in the center to represent impact point. This visual indication should not obscure the visibility of the target. (U.S. Army 1995g; WSSG Working Group 1996)

10.4.4 Cursor Location

10.4.4.1 Cursors and Multiple Screens

Ensure that the cursor appears in only one screen at a time for systems using multiple display screens on separate display devices. (Obermayer and Campbell 1994)

10.4.4.2 Discrete and Analog Cursor Location

Ensure that the cursor is appropriately located in the window. For systems using windows with discrete cursors, when the window opens, always locate the cursor in the upper left corner. For systems employing windows with analog cursors, locate the cursor in the middle of the window when it first opens. (U.S. Army 1996a, 1996b)

10.4.4.3 Location of Cursor for Option Selection

Design menus so the cursor is automatically placed on the most likely option to be selected. If there is no likely option, ensure that the cursor is automatically placed at the top of the option list. (Site visit to TARDEC 1996; WSSG Working Group 1996)

10.5 DIRECT MANIPULATION

Direct manipulation is an interaction technique that allows the user to control computer interaction by acting directly on objects such as windows, buttons, or icons on-screen. When using a GUI, these objects are organized using metaphors and visual representations of real-life objects from the user's task environment. Using a computer, the user interacts directly with a graphical representation of a physical object to complete a task and has the sensation of working directly with or manipulating these objects.

Direct manipulation user interfaces contain the following three characteristics:

- Continuous representation of the object of interest to the user

- Physical actions or labeled button presses, instead of complex syntax and command names
- Rapid incremental and reversible operations whose impacts on the object of interest are immediately visible.

The designer must ensure that, when used, direct manipulation satisfies these three requirements. Additional guidance on direct manipulation can be found in the *DoD HCI Style Guide* (U.S. DoD 1995) and the *UI Specification for the DII* (U.S. DoD 1999a).

10.5.1 Object Design

Object design elements consist of icons, control widgets, and menu options. When designing such objects, consider the guidance on touch screen control objects design in Section 6.0 of this document, "Touch Screen Design," as well as the guidance contained in the *DoD HCI Style Guide.* (U.S. DoD 1995)

10.5.1.1 Design of Controls for Task Performance Facilitation

Design the controls so they facilitate task performance. For example, scales with sliders may be used for quick but approximate actions, whereas spinners or arrow buttons may be used for precise entries. (Osga et al. 1995)

10.5.1.2 Object Selection Area Size

Ensure the selection area for icons, menu options, and object selection is as large as possible and consistent in size throughout the application/system. The selection size may vary if using an adaptive cursor technology such as proximity hooking. (Osga et al. 1995; U.S. Army 1995e)

10.5.1.3 Pushbutton Labels

Design pushbutton labels so they are terse and unambiguous. Action buttons should describe the results of the action. See Figure 10.3 for examples. (Obermayer and Campbell 1994)

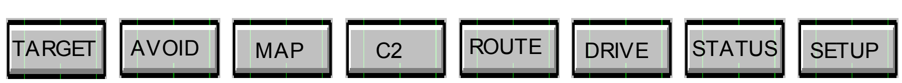


Figure 10.3 Examples of Pushbutton Labels

10.5.1.4 Defaulting to Destructive Options

Do not default to an option that represents a potential destructive action. (Osga et al. 1995)

10.5.1.5 Indication of Functional or Nonfunctional Options

Ensure that functional or enabled buttons or options are visually distinct from disabled or nonfunctional options and buttons. For example, nonfunctional options could be grayed out. (U.S. Army 1995d)

10.5.2 Option Selection

10.5.2.1 Location of Selection Points

Design RT/NRT display screens, where possible, so that selection options are located close to one another. This will reduce the time required to reach and select objects per Fitts Law. (Card et al. 1983)

10.5.2.2 Proximity Selection of Objects and Options

Consider designing the system so objects and symbols are selected through proximity of the pointer/cursor rather than requiring the pointer to be placed on the object. When using proximity highlighting, ensure that the highlighted symbol is different than the selected symbol. (Osga et al. 1995; WSSG Working Group 1997)

10.5.2.3 Option Selection Sensitivity to Vibration

Ensure that, when designing option selection using a pointing device, the selection method is not sensitive to the inherent vibration in some RT/NRT systems, thus avoiding inadvertently selecting an object or initiating an action. (U.S. Army 1995e)

10.5.2.4 Movement to Foreground of Selected Object

Ensure that, when an object or icon is selected, i.e., receives focus or is hooked, it moves to the foreground to guarantee that it is unobscured. (Obermayer and Campbell 1994)

10.5.2.5 Indication of Action Taken

Provide a positive visual indication to the operator once an action is taken with a symbol or object, such as having the object remain highlighted. (Obermayer and Campbell 1994)

10.5.3 Click and Point Versus Click and Drag

Consider, when designing direct manipulation interfaces, that a click-and-drag interface such as that used to scroll a window takes more time when compared to point and click. For RT/NRT system functions where response time is critical, using point and click to page through multiple windows/pages may be preferred to scrolling a window. (MacKenzie 1994; Steinberg et al. 1994; U.S. DoD 1995)

10.6 MENU DESIGN

More detailed guidelines for designing menus are included in the *DoD HCI Style Guide* (U.S. DoD 1995).

10.6.1 Format of Menus

10.6.1.1 Organization of Menus

Consider organizing menus around subsystems or operational modes, with each subsystem or mode functionality accessed from a top-level menu option. (U.S. Army 1996b)

10.6.1.2 Multipage Menu Design

Design multipage menus so a operator does not have to scroll a display to access all the options. If options extend beyond the immediate display, break up the options and allow access through paging, cascading, or pop-up boxes. Pop-up boxes should not overlap critical information such as alerts messages or system status areas. (Site visit to General Dynamics Land Systems Division 1996; WSSG Working Group 1996)

10.6.1.3 Number of Menu Options

Design menus so that options per menu do not exceed 10, and preferably no more than 3 to 5. (Obermayer and Campbell 1994; U.S. Army 1995g)

10.6.1.4 Indication of Option Selection

Highlight the option when the cursor rests on a menu option in an RT/NRT system. See Figure 10.4. (U.S. Army 1995e)

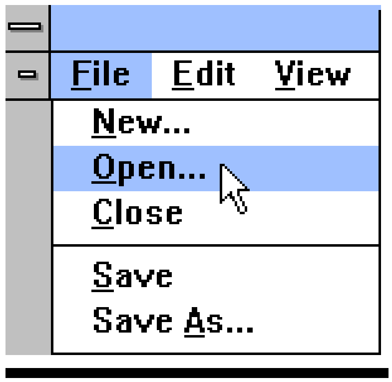


Figure 10.4 Illustration of How a Menu Option Should be Highlighted

10.6.1.5 Indication of Unavailable Menu Options

Visually indicate inactive or unavailable options by dimming or graying out the option. If appropriate, hide unavailable options. (U.S. Army 1995a, 1995b, 1995e; WSSG Working Group 1996)

10.6.1.6 Organization of Options

Organize menu options as follows:

a. Group and arrange options logically within a group according to frequency of use, with the most frequently used options at the top of the menu structure. (Obermayer and Campbell 1994; U.S. Army 1995e)

b. Organize options alphabetically or numerically, if there is no apparent organization based on logical groups or frequency of use. (Obermayer and Campbell 1994)

c. Organize similar options on different menus consistently. (Obermayer and Campbell 1994)

10.6.1.7 Location of Infrequently Used or Destructive Options

Locate less frequently used or potentially destructive options at the end of a menu structure. (Obermayer and Campbell 1994; U.S. Army 1995e)

10.6.2 Return to the Top or Next Level

Provide the capability for the operator to cancel out of any menu and return to the top level, or to the previous level, with one action. (U.S. Army 1996b; WSSG Working Group 1996)

10.6.3 Visual Distinction Between Selected and Non-Selected Options

Provide a visual distinction between selected and non-selected menu options, for example, highlighting or underlining selected options. (General Dynamics 1986)

10.6.4 Menu Navigation

10.6.4.1 Indication of Submenus

Provide a visual indication when a menu option will take the operator to a submenu. For example, use an arrowhead to indicate a cascading menu or three ellipses to indicate a pop-up menu. See Figure 10.5 for an illustration. (U.S. Army 1995d)

10.6.4.2 Hierarchical Location Indicators

Ensure that the system provides a constant indication of the operator's current place within a hierarchical task or operational sequence, as well as provides navigational aids to help operators identify where they are in a hierarchical menu structure. See Figure 10.6 for an illustration. (General Dynamics 1986; Site visit to General Dynamics Land Systems Division 1996)

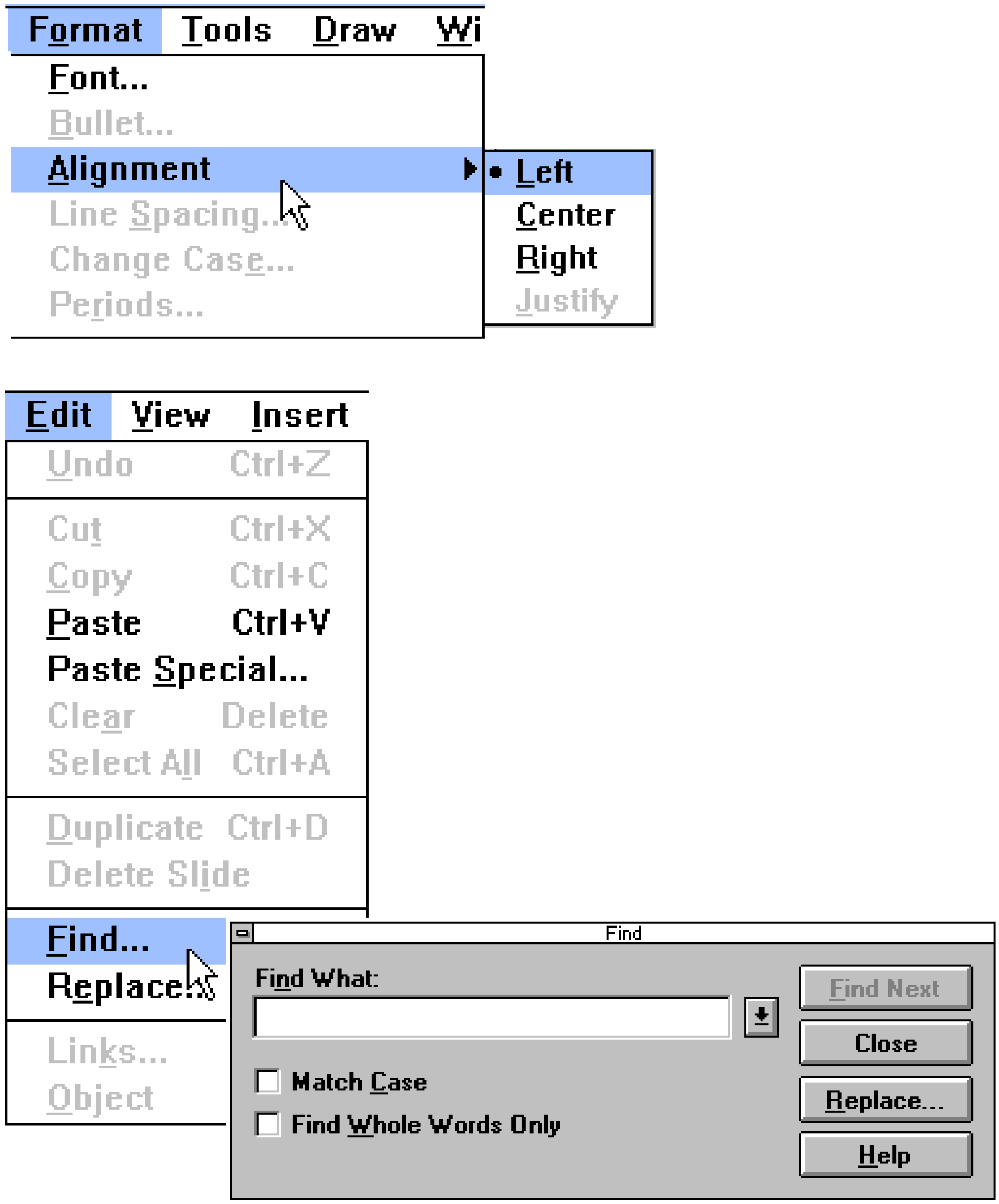
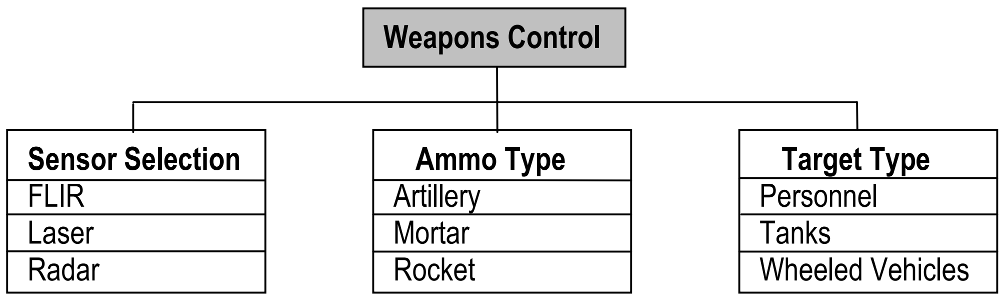
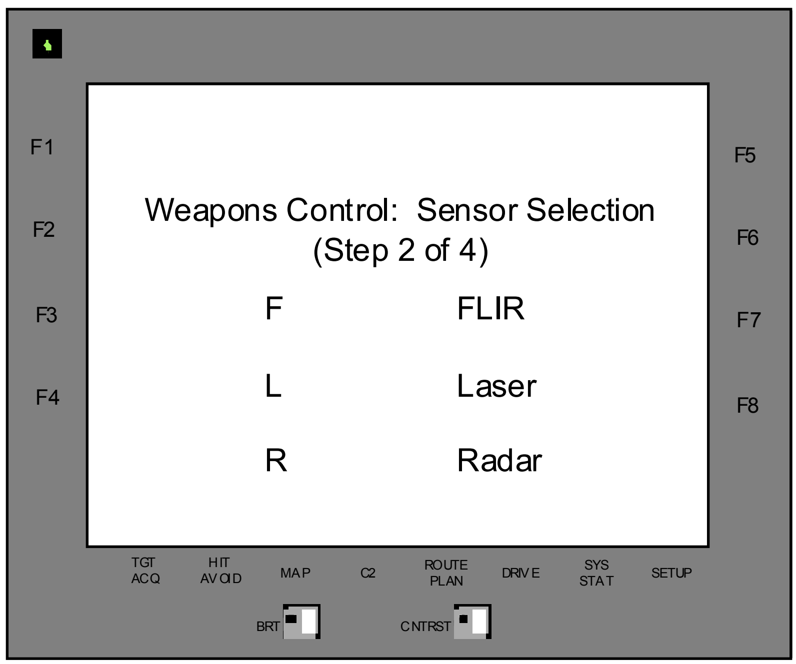


Figure 10.5 Illustration of Visual Indication of Submenu



Menu Map



Screen Navigation Indication

Figure 10.6 Illustration of Two Types of Menu Navigation Aids

10.6.4.3 Menu Control Using Keyboards

Provide the following where keyboards can be used to control menu selection:

a. If only the menu bar is active, ensure that the right keyboard arrow moves the option selection cursor to the next option at the right, and the left arrow moves it to the left. If the cursor is at the end of a menu, movement of the cursor should wrap to the beginning of the menu bar.

b. Ensure that the down arrow causes the menu option list to drop down and the first option to be highlighted.

c. If the menu option list is already dropped, ensure that the down arrow moves the cursor to advance to the next item on the list. If the cursor is located at the end of the list, it should then wrap to the top.

(WSSG Working Group 1996)

This page intentionally left blank.

11.0 SCREEN DESIGN

11.1 GENERAL

Screen design includes the arrangement and presentation of information displayed on an output device. Screen design requirements are unique for each system and subdomain of systems—ground, aviation, missile, soldier, and munition—depending on the system's primary function. The designer needs to understand the primary function of the system being developed to provide an effective screen design. For RT/NRT systems, the designer needs to keep in mind that screen design must support the operator's need to make immediate decisions regarding the displayed information, and that the display device may be small, as well as subject to vibration, variable lighting, and extreme environments.

The designer should also incorporate the following general principles of Human Factors Engineering (HFE) into the screen design, regardless of the system function:

- Guide the organization of information by these basic principles of perception:
  - **Proximity**. The human perception system tries to organize objects into groups if they are near each other in space.
  - **Similarity**. Objects are perceived as a group or set if they visually share common properties, such as size, color, orientation in space, or brightness.
  - **Closure**. The human visual perception system tries to complete the figure and establish meaningful wholes. The incomplete object or symbol may be seen as complete or whole.
  - **Balance**. Humans prefer stability in the perceived visual environment. The presentation of materials at right angles and in vertical or horizontal groupings is easier to look at than curved or angled visual images.
- Improve user performance by implementing the following screen features:
  - Simple, well-organized presentation
  - Orderly, clutter-free appearance
  - Information present in expected locations
  - Plain, simple language
  - Simple way to move through the system
  - Clear representation of interrelationships.

- Design display formats to group data items on the basis of some logical principle, considering trade-offs derived from task analysis.

- Design screens to minimize eye and cursor movement requirements within the overall design. The goal to minimize eye and cursor movement must be considered within general task considerations, with logical trade-offs taken into account. (U.S. DoD 1995)

- Display only the information that is essential to mission performance.

- Display information only as accurately as the operator's decisions and control actions require. For example, do not provide numerical information to decimal places beyond which the operator needs to make a decision.

- Present data in the most direct, simple, understandable, and usable form possible.

- Arrange information on displays so the operator can locate and identify them easily, without unnecessary searching.

Use the following guidelines to develop the design of screens for RT/NRT systems.

11.1.1 Grouping by Proximity or Other Cues

Group elements and data by proximity or other cues such as color, where integration of screen elements and data are required. Where multifunction displays are used, consider the location of the multifunction keys in designing the screens. (Andre and Wickens 1989; WSSG Working Group 1996)

11.1.2 Presentation of Alerting Information

Present alerts for noncritical information in the operator’s peripheral field of vision to reduce foveal information load, but ensure that it is still within the primary visual field. The fovea is the portion of the retina used for acute vision. (U.S. DoD 1981; Walrath 1994; WSSG Working Group 1996)

11.1.3 Key Features Protection

Ensure that key display features, such as main menu bars and critical warnings or other messages, are not movable or resizable and that they cannot be covered by other windows. (Osga et al. 1995)

11.1.4 Location of Most Important Information

In general, design screens with the most important task information located in the upper left corner of the screen, unless another arrangement is more operationally logical. Set apart critical information visually from other information. (Osga et al. 1995)

11.1.5 Status Message Area

Provide a dedicated status message area to be located consistently throughout the application. The recommended location is the bottom of the display. Do not use this status message area for critical warnings. (U.S. Army 1995g; WSSG Working Group 1996)

11.1.6 Weapon and Sensor Systems Orientation

Provide an indication of the orientation of the weapon or sensor, for weapon and sensor systems where the direction of the weapon or sensor can vary. Figure 11.1 provides an illustration. (U.S. Army 1995g; WSSG Working Group 1996)

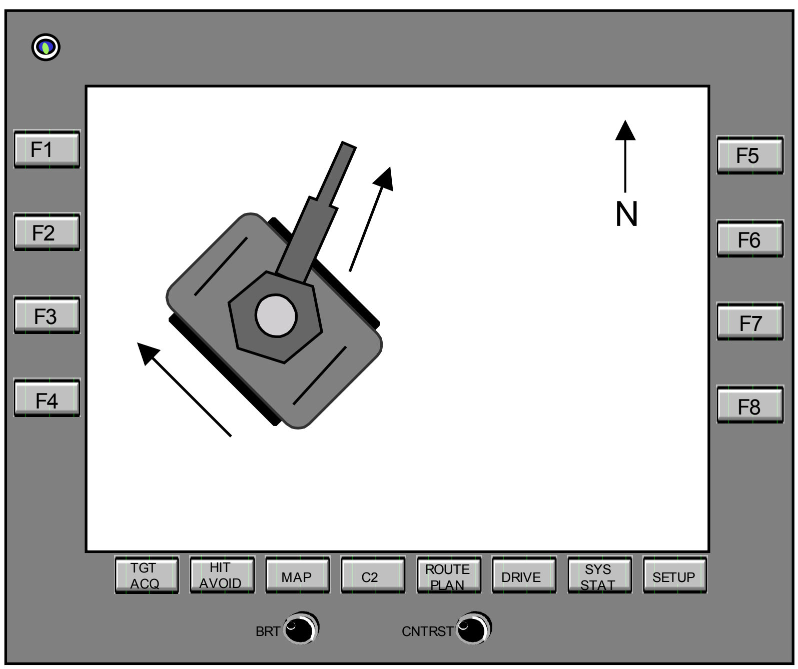


Figure 11.1 Illustration of Weapon/Sensor Orientation

11.1.7 Multipage Information Display

Display the total number of pages and the current page number, when more than one page of information is provided, e.g., Page 2 of 3. (U.S. Army 1996b)

11.1.8 Consistent Appearance for Similar Controls and Screen Elements

Ensure that controls and other screen elements with the same function have the same appearance. (Osga et al. 1995)

11.1.9 Screen Elements Identification by Appearance

Clearly identify controls and other screen elements by their appearance. See Figure 11.2 for examples. (Osga et al. 1995)

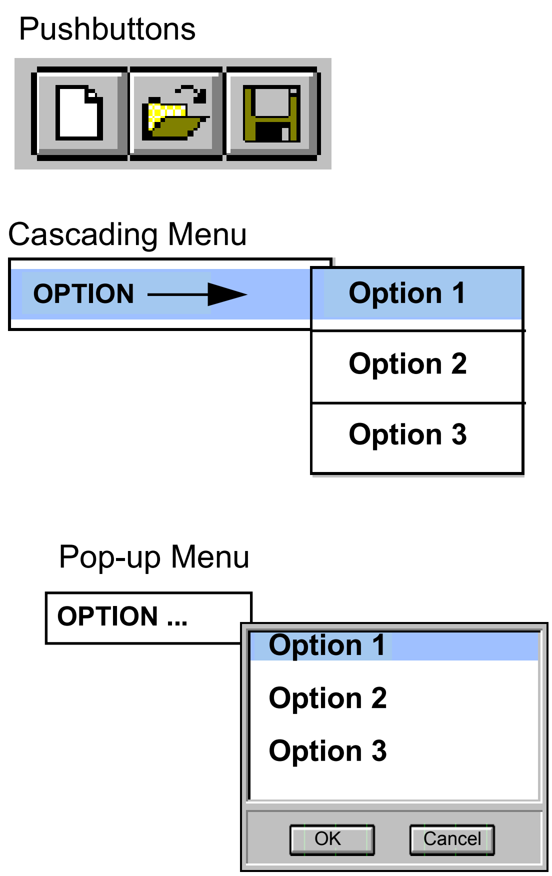


Figure 11.2 Examples of Visually Identifiable Controls and Screen Elements

11.1.10 Fire Control Information Location

Provide fire control information, for example, ready-to-fire indication, range, or interrogation status, close to the targeting reticle. See Figure 11.3 for an example. (U.S. Army 1995g)

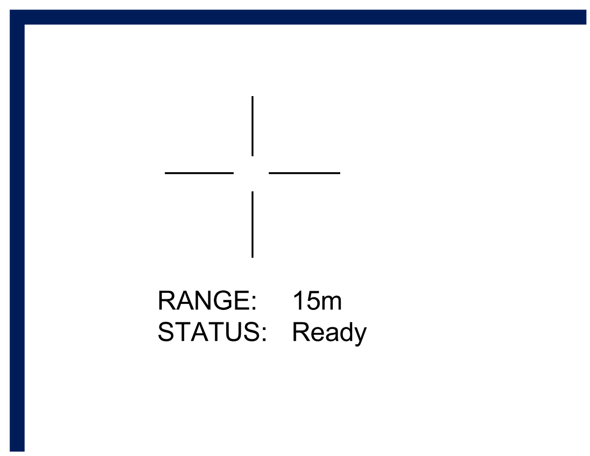


Figure 11.3 Example of Fire Control Information Placement Relative to the Reticle

11.1.11 Separation of Screen Elements for Focused Attention

Separate screen elements spatially or by using other cues, for those tasks that require focused attention. (U.S. Army 1995g)

11.1.12 Perspective Displays

Consider the use of perspective displays, rather than 2-D displays, only when it will improve operator performance of the mission and is appropriate to the task. Perspective displays provide depth representation on a 2-D surface. (WSSG Working Group 1996)

11.2 WINDOW DESIGN

Carefully consider the use of windowing for RT/NRT systems because of potential limitations in display size and processing power, as well as the potential for vibration or variable lighting. Windows should be designed to meet system performance and user requirements. Where extensive windowing is used, designers should follow the guidance contained in the *DoD HCI Style Guide* (U.S. DoD 1995) and the *User Interface Specification for the Defense*

Information Infrastructure (U.S. DoD 1999a), unless there is a compelling operational reason for these documents to not be applicable.

11.2.1 Fixed Window Design

Unless there is a compelling operational requirement, design windows for RT/NRT systems so that they are fixed regions and not resizable, movable, or multilayered so that they require forward and backward movement. (U.S. Army 1996e)

11.2.2 Window Appearance

11.2.2.1 Identification of Window Controls

Ensure that window controls are identifiable based solely on their appearance. All controls with the same function should have the identical appearance. (Obermayer and Campbell 1994)

11.2.2.2 Window Titles

Ensure that windows have descriptive titles centered at the top. (U.S. Army 1996a)

11.2.2.3 Consistent Design of Windows Performing the Same Tasks

Design windows performing the same basic task to look and behave in the same way. (Obermayer and Campbell 1994)

11.2.3 Multifunction Key Context Definition

Ensure that the multifunction key that has opened a window retains its visual indication of activation, e.g., highlighted, to provide window context to the operator. (U.S. Army 1996a)

11.2.4 Window Control

11.2.4.1 Maintenance of Overwritten Background Information

Ensure that, when a window is opened on top of existing information on a screen, the existing or “background” information is not lost, but saved and redisplayed when the top window is moved or closed. (U.S. Army 1994)

11.2.4.2 Closing a Window and Associated Subwindows

Ensure that closing a primary window (parent) causes all subwindows (children) associated with that window to close. (U.S. Army 1994)

11.2.4.3 Location of Window Opened with Multifunction Key

When opening a window using a multifunction key, design this feature such that the window appears close to the multifunction key that opened it. See Figure 11.4. (U.S. Army 1996a)

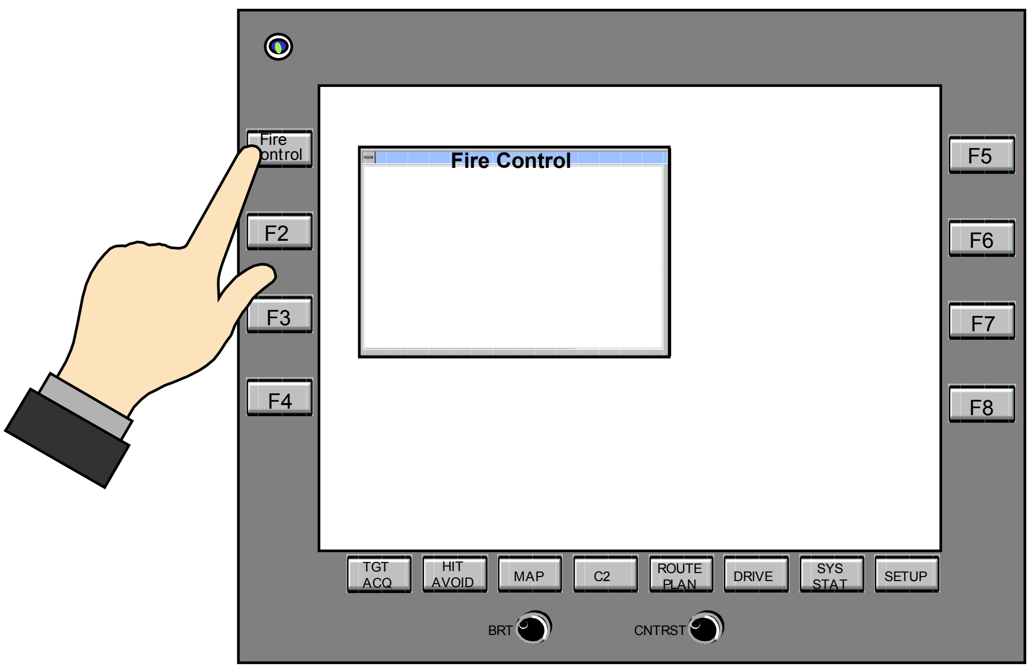


Figure 11.4 Illustration of Window Location when Opened by a Multifunction Key

11.2.4.4 Covering (Occluding) of Critical Screen Information

Ensure that pull-down or pop-up menus, as well as windows, do not occlude critical screen information, such as message alert areas. (WSSG Working Group 1996)

11.2.4.5 Context Sensitive Windowing Hierarchy

Provide the user with a navigational route through the window/menu hierarchy, whereby the flow of each thread through the hierarchical structure is a logical sequence of end-to-end processes accomplishing a real-world task. These processes are created from sub-tasks or elemental steps that, when performed sequentially in stepwise fashion, complete a task sequentially from beginning to end. The ideal structure of the hierarchy would be where only a single window/menu is needed for the completion of a task or sub-task. (WSSG Working Group 1996)

11.2.5 Window Dialog

11.2.5.1 Single Selection Pop-up Windows

Consider using single selection pop-up windows when the operator must select only one option from a list. Selecting the option through a single activation control such as touch button, enter key, or other pointing device will cause the option to be implemented and the window to close. (U.S. Army 1996a) See Figure 11.5 for an example.

The design of single selection windows should ensure that:

a. the current or default selection is highlighted when the window opens. See Figure 11.6 for an example. (U.S. Army 1996a)

b. the selection button, if a soft key, remains highlighted until its associated window disappears. (U.S. Army 1996e)

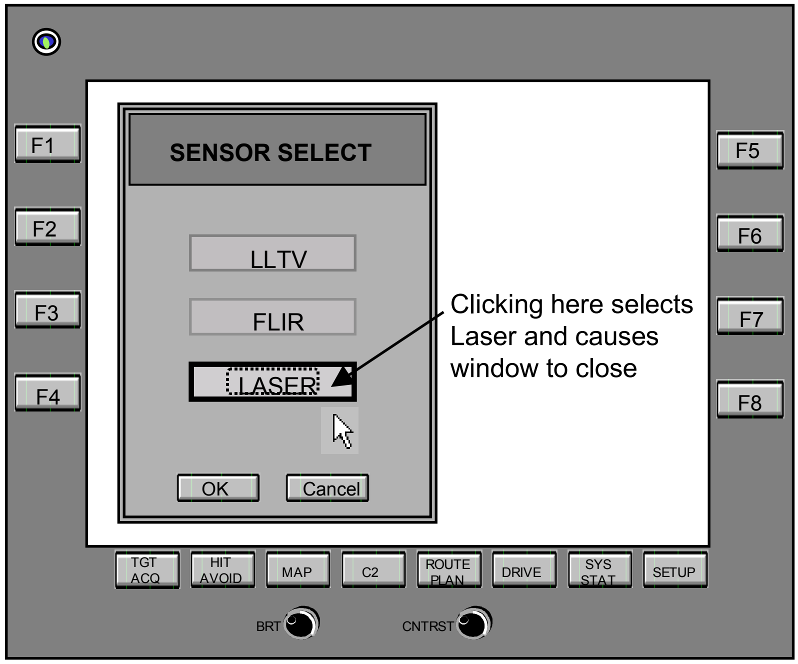


Figure 11.5 Example of a Single Selection Pop-Up Window

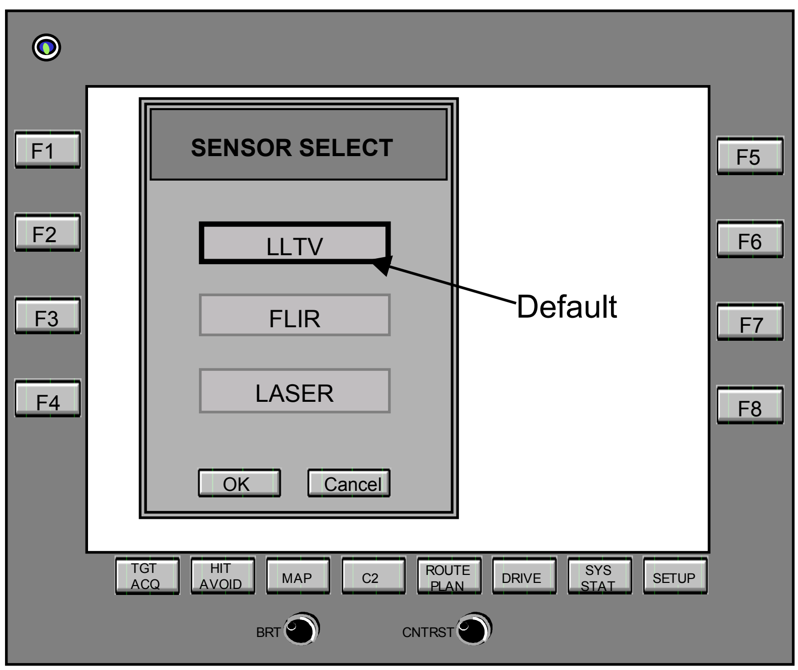


Figure 11.6 Example of Current or Default Selection on Single Selection Pop-Up Windows

11.2.5.2 Multiple Selection Pop-Up Window

Provide a multiple-selection pop-up window, when the operator needs to select more than one option from a list. See Figure 11.7 for an example. (U.S. Army 1996a)

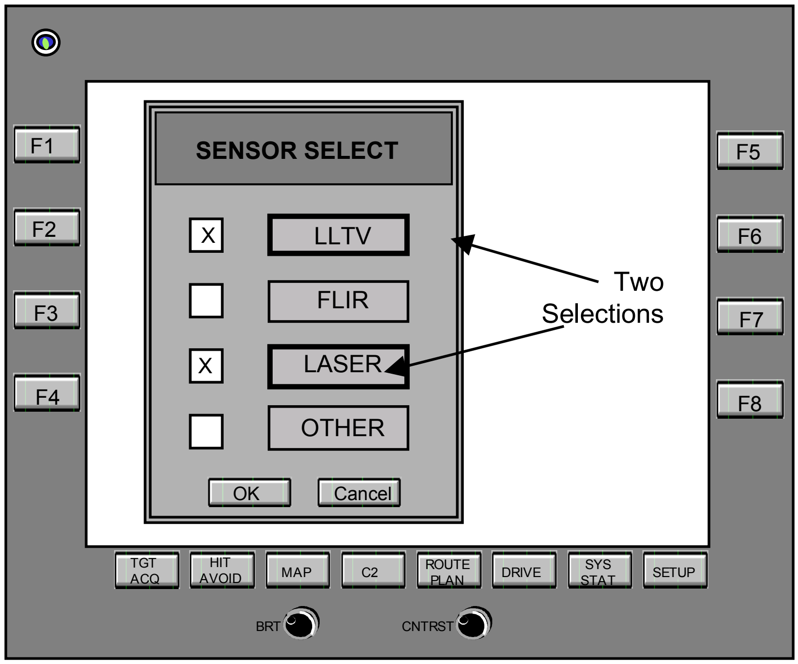


Figure 11.7 Example of a Multiple-Selection Pop-Up Window

Multiple selection pop-up windows should be designed so that:

a. at least the default or the previously selected option is highlighted when a multiple-selection pop-up window opens. The operator can then highlight, thereby select, additional options. Activation can be performed through an "OK" or "DONE" button. (U.S. Army 1996a)

b. check boxes, if used, are placed to the left of each option. (U.S. Army 1996e)

c. for check boxes, an X or check in the box indicates it is selected. (U.S. Army 1996e)

d. OK and Cancel Buttons are at the bottom of the window, with OK being on the left and Cancel on the right. (U.S. Army 1996e)

e. OK indicates acceptance of the options and closes the window. (U.S. Army 1996e)

11.2.5.3 Window Input Focus

Ensure that the default window input focus is "explicit." Windows have input focus when they are active, meaning they are ready to accept command or data input. There are two types of input focus models for windows: explicit and implicit. Explicit is where the user takes an overt action to move input focus, such as activating a trackball control when the cursor has been moved into the window. Implicit focus is when the window becomes active as soon as the cursor is moved into the window. (U.S. DoD 1999a) When a window has been opened that requires the operator to make a selection, it should have sole input focus, though information behind it may still be visible. (U.S. Army 1996e)

11.2.5.4 Indicating Window Input Focus

Visually indicate input focus by a change in either the window frame, if it has one, or in the window title. See Figure 11.8 for an example. (U.S. Army 1995d)

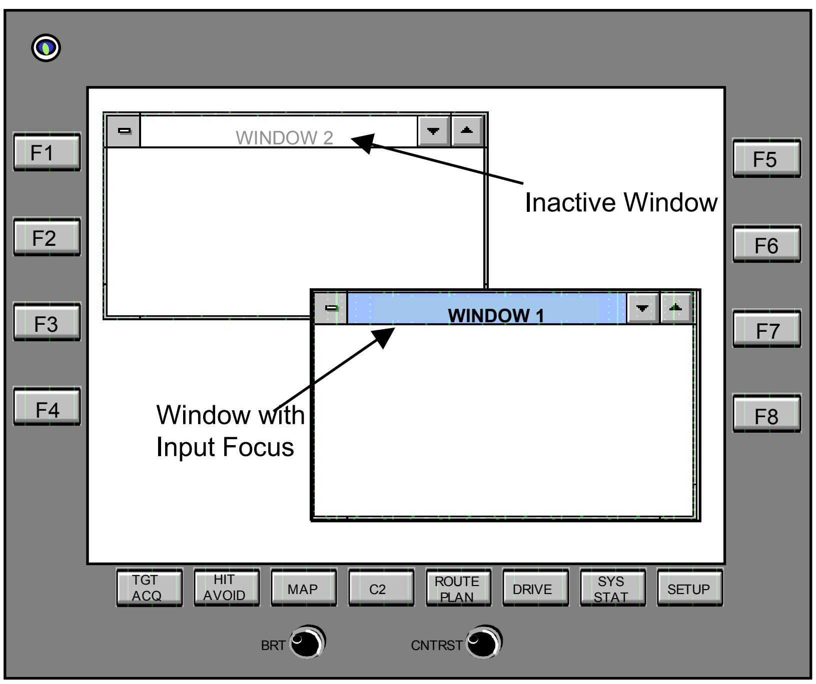


Figure 11.8 Illustration of How To Visually Indicate Input Focus

11.2.5.5 Include All Required Information Within a Window

Where possible to maintain an efficient and effective user interface, include all information necessary to complete the task within a window. (Osga et al. 1995)

11.2.6 Multiple Layers of Windows

Design an RT/NRT system that uses multiple layers of windows using the following principles. Ensure that:

a. non-critical windows cannot be moved or resized such that they obscure critical screen areas, e.g., message alert areas or other critical windows.

b. windows containing critical information cannot be closed without confirmation by the user.

c. critical windows cannot be moved off the screen.

d. critical windows move to the top (or front), or an indication is provided to the operator when critical events occur with the information being displayed or controlled from that window. Ensure that this does not disrupt on-going user tasks.

e. users can display an open window map that indicates which windows are currently open, and that allows the user to navigate to any open window.

f. return to the home screen is performed through one operator action, though this action should require confirmation by the user.

g. windows have a default location for appearance on the screen.

11.2.7 Dialog Box Design

11.2.7.1 General Design

Design dialog boxes so that they:

a. follow the guidance in found in the *DoD HCI Style Guide* (U.S. DoD 1995).

b. have input focus.

c. contain all selectable functions for that dialog.

d. are centered in primary area of user attention on the screen.

e. highlight the default option with the cursor.

f. include OK and Cancel buttons, with the OK being on the left.

(U.S. Army 1996e)

11.2.7.2 Dialog Box Default

When appropriate for the operational task, include a default pushbutton in dialog boxes that represents the most frequently selected option or that is most appropriate for the current situation. (Osga et al. 1995)

11.3 TEXT AND DATA PRESENTATION

11.3.1 Information Requirements for the Content of Displays

11.3.1.1 Content

Strictly limit the information displayed to the operator operating an RT/NRT system to that which is necessary for performing specific actions, monitoring a situation, or making decisions or assessments. (General Dynamics 1986)

11.3.1.2 Precision

Display information only to the level of precision that is operationally meaningful and useful to the operator. For example, if the operator uses distance data to the nearest kilometer, do not provide data down to the meter. (General Dynamics 1986)

11.3.1.3 Format

Present information to the operator in a directly usable form to minimize the requirements for actions such as transposing, computing, interpolating, and converting units. (General Dynamics 1986)

11.3.1.4 Combining Operator and Maintainer Information

Do not combine operator and maintainer information in a single display unless the information in terms of content and format lends itself to being combined. (General Dynamics 1986)

11.3.2 Text/Data Display

11.3.2.1 Entry/Edit Text Display

Ensure that text that can be entered or edited is in a text field and is visually distinctive from labels or uneditable text. See Figure 11.9 for an example. (Obermayer and Campbell 1994)

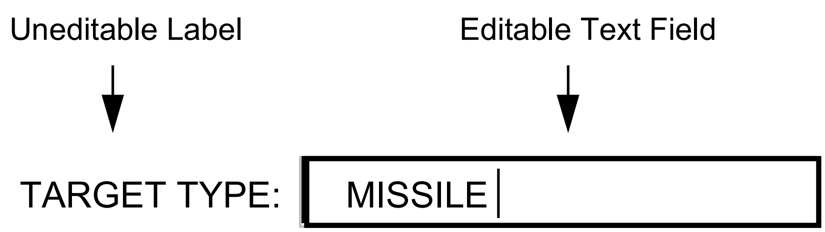


Figure 11.9 Illustration of Editable and Uneditable Text Fields

11.3.2.2 Use of Leading Zeros

Minimize the requirement for leading zeros for numeric data. Leading zeros may be used for some types of data, such as time and mils. (Obermayer and Campbell 1994; WSSG Working Group 1996)

11.3.2.3 Use of Delimiters for Strings of Data

Delimit long strings of data with spaces, commas, or slashes—if these strings must be displayed. (Obermayer and Campbell 1994)

11.3.2.4 Justification of Data

Left-justify alphabetic data, right-justify numeric data, and justify by decimal point numeric data with decimal points, as illustrated in Figure 11.10. (Obermayer and Campbell 1994)

Poor	Good
Washington DC Cars People	Washington DC Cars People
400 4210 39111	400 4210 39111
1.5 10.36 1.365	1.500 10.360 1.365

Figure 11.10 Illustration of How Data Should Be Justified

11.3.2.5 Use of Delimiters for Rows and Columns

Insert a blank line, if the display contains many rows and columns, after every third to fifth row, and insert three spaces between every column to facilitate scanning by operators. (Obermayer and Campbell 1994)

11.3.2.6 Grouping Columnar Data

Indicate grouping of data within a column by blank space between the columns or by a separator line. (Obermayer and Campbell 1994)

11.3.2.7 Separation of Columns

Clearly separate each column of data from other columns by a minimum of three spaces. (Obermayer and Campbell 1994)

11.3.2.8 Headings for Columns and Rows

Ensure that data presented in columnar or tabular format have a heading describing the type of data. (Obermayer and Campbell 1994)

11.3.2.9 Presentation of Likelihood of Outcome Information

Display items, when presenting information in terms of likelihood of an outcome, either in rank-order or present only the highest likely item. Do not include the absolute likelihood ratings. See Figure 11.11 for an example. (Dunkelberger 1995)

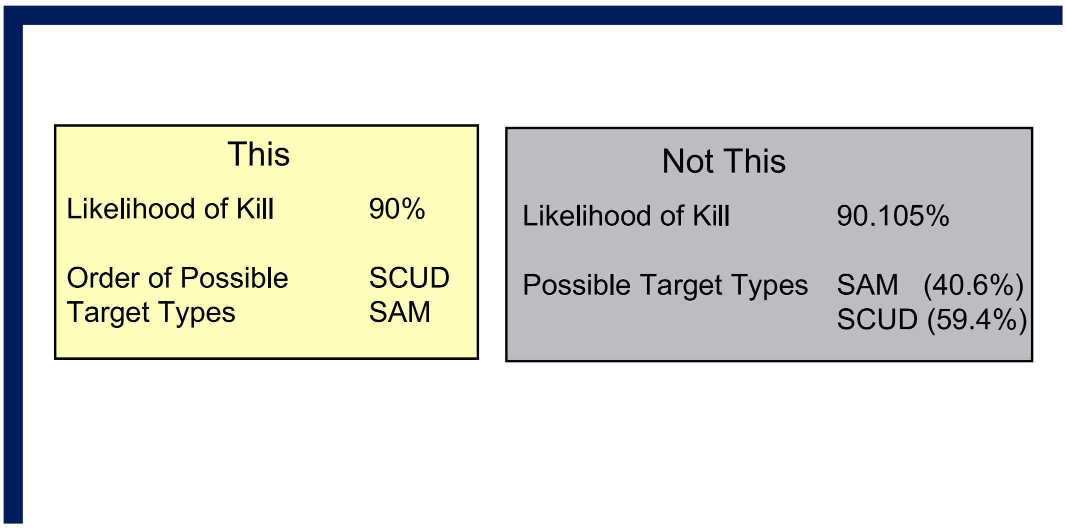


Figure 11.11 Example of How to Present Likelihood of Outcome Data

11.3.3 Text/Data Entry

11.3.3.1 Autofilling of Critical Messages

Design all critical messages, where possible, so that as many fields as possible are autofilled from on-board sensors, databases, or other means, to reduce the need for data entry by the operator. Provide the operator with the ability to accept and edit autofilled information. (Site visit to TARDEC 1996; WSSG Working Group 1996)

11.3.3.2 Cues for of Data

Provide the operator a cue to indicate when a field has been filled, if the system uses autocompletion to automatically complete data entry based on partial operator input. (Gould et al. 1990)

11.3.3.3 Use of Insert Mode

Use the insert mode as the default rather than the overwrite (replace) mode as the data entry default. If the operator has the capability to change from insert to overwrite mode, ensure that the current mode is indicated. (Obermayer and Campbell 1994; WSSG Working Group 1996)

11.4 GRAPHICS

11.4.1 Map Graphics

In general, map graphics for RT/NRT systems should conform to the guidance contained in the appropriate sections of the *DoD HCI Style Guide* (U.S. DoD 1995). Additional guidance for RT/NRT systems is as follows.

11.4.1.1 Scrolling

Ensure that maps allow the user to scroll horizontally (left to right), vertically (top to bottom), and diagonally. Where feasible, provide the capability for the map to scroll automatically to follow vehicle or operator progress. (U.S. Army 1995f; WSSG Working Group 1996)

Other scrolling design considerations include the following:

a. Provide an indication to the operator of critical information being displayed in an area of a scrolled map window that is not currently being displayed on the screen. (WSSG Working Group 1996)

b. Consider designing object movement such that, when a force transducer, pointing device, or equivalent of a joystick is causing movement (i.e., of a map), graphics viewing is moved either proportional to force or time in position. For example, if a force transducer is pressed harder or held down in a position to cause viewing of a map from lower to upper areas, the view rate would move from one viewing area per second to three viewing areas per second. (WSSG Working Group 1996)

11.4.1.2 Panning

Provide the operator with the capability to view all areas beyond a display frame by providing a fixed "window" or frame that can be panned in any direction. Consider the following:

a. Select the panning capability, either discrete or continuous, based on the crew member's specific task requirements. Continuous panning capability is preferable to discrete for most tasks, but discrete may be used if the crew member cannot pan smoothly or needs to rapidly "jump" to specific locations or areas of interest.

b. Ensure that display framing is consistently implemented for panning operations throughout the interface design, so the operator can either conceive the display frame as a window moving over a fixed array of data or conceive data as moving behind a fixed display frame.

c. During panning operations, provide some graphic indication of the current position relative to the overall display.

d. During panning operations, provide a means for rapidly returning to the origin.

e. Ensure that framing functions perform integrally so that panning and/or zooming will affect all displayed data in the same way.

f. When a zooming or panning option is provided, provide a method that allows the operator to select a given position on the display page to become the center for the zooming or panning operation.

g. If graphical display pages can be customized through options such as panning, zooming, and decluttering, provide a method for the operator to return to a default display configuration.

(Smith and Mosier 1986; U.S. DoD 1995; WSSG Working Group 1997)

11.4.1.3 Zooming

Design map displays for real-time systems so there will be a compensating shift in the size of the symbology, labels, and other map features when users zoom the coverage area. When zooming out, this would include an aggregation of symbols to reduce visual clutter. (Obermayer and Campbell 1994; WSSG Working Group 1997)

11.4.1.4 Modification of Map Overlays

Ensure that operators can modify the contents of a map overlay by adding, deleting, editing, or relocating labels and symbols. (Obermayer and Campbell 1994)

11.4.1.5 Adjustment of Background Intensity

Ensure that the operator can adjust the background intensity of a map to fade out selected portions without losing all map features. Background intensity refers to the map saturation rather than the background lighting. (Obermayer and Campbell 1994; WSSG Working Group 1997)

11.4.1.6 Calculations of Range, Bearing, Position, and Map Datum

Ensure that range, bearing, position, and map datum (scale and coordinate measurements) calculations reflect the degree of accuracy appropriate to the scale of the displayed map. (Obermayer and Campbell 1994)

11.4.1.7 Querying Symbols

Provide the capability to query symbols for more information. The operator should be able to place the cursor on the symbol and select to bring up an information box next to the symbol. See Figure 11.12 for an illustration. (U.S. Army 1995f)

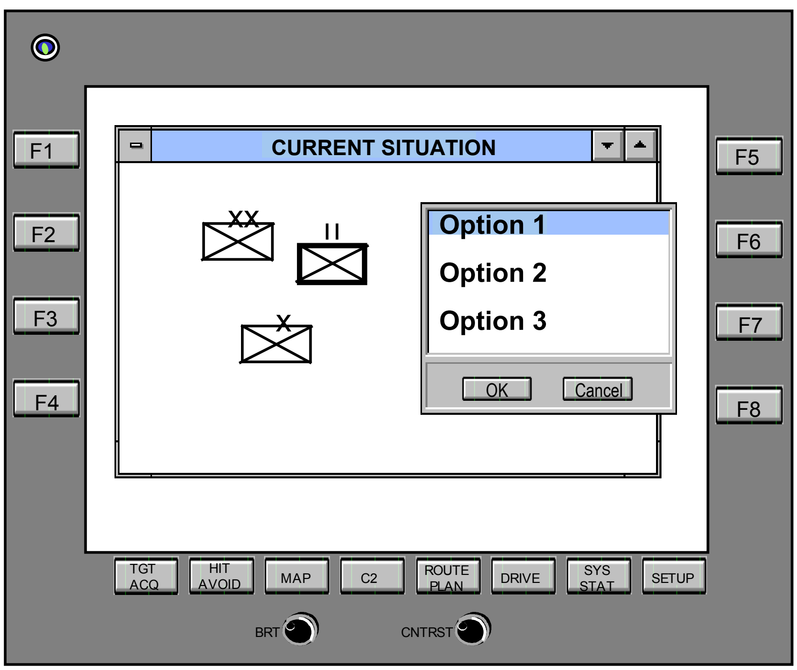


Figure 11.12 Illustration of Querying Symbols on a Map Display

11.4.1.8 Map Graphic and Overlay Control Functionality

Provide the following control functionality for map graphics and overlays:

a. **Scale** - Allow either zooming or stepped scaling of maps and overlays.

b. **Orient** - Allow orientation of a map and overlay to either north or system primary operational axis, e.g., vehicle heading, azimuth of fire, etc. Map labeling should remain oriented to the user position.

c. **Home** - Allow a return of the map or overlay view so that it is centered on a designated home position, such as the user's own position.

d. **Declutter** - Allow declutter of noncritical information off the map or overlay graphic.

(U.S. Army 1995f; U.S. Army 1996a)

11.4.1.9 Map Symbology

Design map symbology in accordance with the standards cited in the *Joint Technical Architecture - Army* (U.S. Army 1999), as well as *Operational Terms and Graphics,* U.S. Army Field Manual 101-5-1 (U.S. Army 1980). See Section 12.6, "Symbology," for more information on symbology. (U.S. Army 1995f)

11.4.1.10 Shades of Gray (Gray Scale)

Select steps in a gray scale that produce shades of gray resulting in just noticeable differences that are spaced at perceptually equal intervals (rather than equal steps of luminance or gamma-corrected CRT voltage). There is no universally accepted number of shades of gray for the application. The number of gray shades that should be used for an application is based on the task and the brightness range in the image. It has been estimated that about 30 gray levels can be visually distinctive on a CRT or photographic print, while only 8 levels can be reliably produced on color-matrix displays. Data from experiments with human observers indicate that approximately 200 just noticeable differences can be seen for targets on a highly luminous surround, indicating that eight bits or 256 levels may be the usable maximum number of steps for a gray scale. The maximum number of shades of gray can be achieved with a background of moderate luminance, when compared with a black or white background. (Carter 1993, 1997)

11.4.2 Presentation Graphics

Design presentation graphics in accordance with the appropriate section of the *DoD HCI Style Guide* (U.S. DoD 1995).

This page intentionally left blank.

12.0 Coding

Coding information on a display, as any design attribute for RT/NRT systems, requires that the designer be aware of HCI design constraints. These constraints include the need for quick recognition of the coded information, as well as the potential impact of vibration and variable ambient lighting.

12.1 GENERAL

12.1.1 Coding of Time-Critical Information

Use bolding, brightness, shape, color, or other coding techniques to focus the operator's attention on time-critical information and changes in the state of the system. (Obermayer and Campbell 1994; General Dynamics 1986; Osga et al. 1995)

12.1.2 Code Consistency and Meaningfulness

Use consistent, meaningful codes that do not reduce legibility or increase transmission time. (General Dynamics 1986)

12.2 BRIGHTNESS CODING

12.2.1 Use of Brightness Coding

Use brightness coding only to differentiate between an item of information and adjacent information. (General Dynamics 1986)

12.2.2 Levels of Brightness Coding

Use no more than three levels of brightness coding, with each level separated from the nearest brightness level by at least a 2:1 ratio. (General Dynamics 1986)

12.3 FLASH CODING

12.3.1 Use of Flash Coding

Consider using flash coding only to display information urgently requiring the operator's attention, such as mission-critical events or emergency conditions. Do not flash text or text background. Instead, flash an icon or border, or display a focus area associated with and adjacent to the text. (Obermayer and Campbell 1994; General Dynamics 1986; Osga et al. 1995; U.S. DoD 1999a; U.S. DoD 1995)

12.3.2 Flash Rates

Use no more than two flash rates. (Obermayer and Campbell 1994; General Dynamics 1986)

12.3.3 Rate of Flashing

Ensure that flash rates are between 3 and 5 hertz when one flash rate is used. When two are used, ensure that the second flash rate is less than 2 hertz. (General Dynamics 1986; U.S. DoD 1981; U.S. DoD 1996a)

12.3.4 Acknowledgment of Flash Coding

Ensure that operators can acknowledge the causal event and suppress (i.e., terminate) the flashing. (Obermayer and Campbell 1994)

12.4 PATTERN AND LOCATION CODING

Consider the use of pattern and location coding to reduce search times. Pattern coding should be used only if the display size and resolution permit distinction of patterns. (General Dynamics 1986)

12.5 COLOR CODING

The following paragraphs provide some guidance on the use of color coding. When selecting colors for use, the designer should consider the potential of impaired color discrimination if the user is wearing laser protective eyewear or is colorblind. Additional information on the use of color coding may be found in the *DoD HCI Style Guide* (U.S. DoD 1995).

12.5.1 Use of Color Coding

Use color coding to differentiate among classes of information in complex, dense, or critical displays—in particular, for complex computer-generated symbology. (Ellman and Carlton 1993; Melzer and Moffitt 1992; General Dynamics 1986)

12.5.2 Color Codes for Alerts and Warnings

Ensure that color codes for alerts and warnings conform to the color usage in Table 12.1, which is based on existing human factors standards and population stereotypes. When a night vision imaging system (NVIS) will be used to read color coded displays, refer to Table 12.2.

Table 12.1 Color Code Meanings

Color	Meaning
Red	critical system nonoperational/failure, warnings
Yellow	degraded operation, warnings, priority information, cautions
Green	good/fully operational, informational, routine, advisory
White	inactive, no data.

(U.S. Army 1995d; U.S. DoD 1981)

Table 12.2 Color Coding for Night Vision Imaging Systems (NVIS)

Signal	Color Code
Warning	NVIS Red (Class B) or NVIS Yellow (Class A).
Caution	NVIS yellow (Class B) or NVIS Green (Class A).
Advisory	NVIS Green (Class A)

(U.S. DoD 1991)

12.5.3 Color Codes and Population Stereotypes

Ensure that color codes are consistent with population stereotypes and are limited to a small number that have adequate size, brightness, and color contrast. (Melzer and Moffitt 1992)

12.5.4 Minimal Use of Color for Quick Response

Minimize the use of color when quick and accurate responses by the operator are important. (Osga et al. 1995)

12.5.5 Color Code Redundancy

Use color coding with an additional, redundant coding mechanism, such as shape. Color should be the secondary code, not the primary one. (Site visit to TARDEC 1996; General Dynamics 1986; Osga et al. 1995)

12.5.6 Use of Color Cueing in Display Design

Consider using color cueing for providing an additional alerting function to symbology located in the peripheral areas of a display that must be monitored by the operator. Color increases detection and decreases extraneous detection of information change. Color cueing information that must be monitored can also aid in tracking performance. (Williams and Parrish 1990)

12.5.7 Label Background Color Changes to Indicate Off-Normal Conditions

Consider using color changes of text label backgrounds to indicate off-normal conditions only when:

- The label text is constant,
- There is an additional icon or object associated with the text,
- The conditions being indicated are critical to mission success,
- The operators know the meaning of the text based on location on the display, and
- The user can acknowledge the off-normal condition which reverts the text background to the standard color but maintains the color change of the associated icon or object.

Data suggest that this may improve a real-time weapon system operator’s time to recognize that there is an off-normal condition that needs immediate attention. (Schafer Corporation 1998)

12.6 SYMBOLOGY

Symbology refers to pictorial representations of information. Typically, symbols only display information and are not used as controls. Control input is performed through icons; see Paragraph 12.7. Symbology should be designed in collaboration with the user population to ensure that it is meaningful and does not violate population stereotypes. When designing symbology, as well as icons for RT/NRT systems, consider the following:

a. Ensure that each piece of symbology adds value to the display, providing essential information for a specific task in such a manner that it reduces operator workload.

b. Ensure that operators are cued in a clear, unambiguous manner to system limitations and that they are automatically provided with the information necessary to execute appropriate procedures.

c. Do not allow previous designs to limit innovation in symbology design by using symbols that are currently being used but may not be very appropriate or meaningful. Rather, ensure that symbology design is driven by a detailed system and mission analysis, to include a thorough operational/simulation evaluation based on mission representative tasks. However, consider any similar symbols already provided to the operator by other display systems. If classes of information are to be represented by a symbol, the symbol should be the same throughout all applications and the system to preclude the operator from having to memorize multiple symbols for the same information.

d. Conduct developmental testing in the design mission environment.

e. Ensure that operators have the capability to declutter a display when required. Declutter means being able to designate sets of symbols or symbol decorations to not be displayed.

f. Ensure that designers consider using hot symbols to provide quick access while reducing display clutter. Hot symbols allow the operator to select a symbol to quickly display additional information about that symbol.

g. Ensure that symbol size subtends a minimum of 20 minutes of arc (see Section 5.1.7).

(Garman et al. 1994; WSSG Working Group 1996; WSSG Working Group 1997)

12.6.1 Use of Symbology

Use symbol coding to enhance information assimilation from data displays, to separate classes of objects from their background, and for search and identification tasks. (General Dynamics 1986; Osga et al. 1995)

12.6.2 Contribution of Symbology to Primary Display Objectives

Add symbology only if it measurably contributes to the primary objectives of the display, improves the performance of the operator-system, or reduces operator workload. (Bailey 1994)

12.6.3 Symbols as Analogs for Coded Events or Elements

When symbols are used for coding, ensure that they are analogs of the event or system element they represent and are well known to the expected users. (General Dynamics 1986; Osga et al. 1995)

12.6.4 RT/NRT Symbology Standards

Ensure that the general design of symbology for RT/NRT systems is consistent with the symbology standards identified in the *Joint Technical Architecture (U.S. DoD 1999c)* and the *Joint Technical Architecture - Army* (U.S. Army 1999). For unique design requirements for Army engagement operations symbology, refer to Annex 1, published under a different cover.

12.6.5 Use of Graphics and Colors with Symbols

12.6.5.1 General

Consider the use of graphics and color to increase the informational content of symbols, in particular, to aid in the visual classification of:

a. Asset location.

b. Track/target awareness.

c. Filtering out low-priority background information.

d. Highlighting threats or potential threats.

e. Classifying tracks for database management.

f. Highlighting weapons deployment and employment.

(Osga and Keating 1994; Kirkpatrick et al. 1992)

12.6.5.2 Symbol Background Contrast

Consider the following in designing symbol background contrast:

a. **Symbol Luminance:** Maximize symbol luminance to obtain a higher symbol/background luminance contrast. (Van Orden and Benoit 1994)

b. **Background Luminance Levels:** Select intermediate luminance levels for symbol backgrounds. (Osga 1992; Crawford, Toms, and Wilson 1991)

c. **Symbol/background Contrast:** Set Symbol/background contrast to be at least 40%. (Van Orden and Benoit 1994)

d. **Symbol Color Fill:** Use block-filled symbols, as they result in better performance when compared to stroke-written symbols. (Van Orden and Benoit 1994; Osga 1992)

e. **Symbol Backgrounds:** Use achromatic display backgrounds with medium luminance for color symbols. The use of achromatic backgrounds minimizes the effect of color induction and permits the use of larger pallet of color in the display. Color values of intermediate luminance (e.g., medium or dark gray) have been shown to be the best choice as a background for colored symbols. (Van Orden and Benoit 1994; Osga 1992; Osga 1995)

f. **Symbol/Background Color Contrast:** Ensure that the color difference between symbol and background is a minimum of 40 delta E units as calculated using the CIE LU'V' color chromaticity coordinates corrected for small symbol sizes. (Van Orden and Benoit 1994)

12.6.5.3 Use of Color Filled Symbols

Consider, when designing symbology, that color filled symbols may enhance human performance over color outlined or monochrome symbols. Keep in mind that there may be conditions, such as when symbols are cluttered together, when color filled symbols may hinder the operator's ability to differentiate multiple symbols. (Kirkpatrick et al. 1992; WSSG Working Group 1999)

12.6.5.4 Colored Symbols on Colored Backgrounds

Where colored symbols will be used on colored backgrounds of similar chromaticities, ensure that:

a. The difference between the symbol and the background is greater than .01 CIE/UCS to enhance recognition of the symbol.

b. Display luminance is approximately 19 cd/m^2 for blue symbols on a blue background.

c. Display luminance is approximately 56-58 cd/m^2 for red on red and green on green.

(Crawford, Toms, and Wilson 1991)

12.6.6 Size Coding

Ensure that, if size coding is used with symbology, the larger symbol is at least 1 1/2 times the size of the smaller symbol. There should be no more than three size levels. (General Dynamics 1986; U.S. DoD 1981)

12.6.7 Multiple Coding Variables

Use multiple coding variables in symbology to facilitate information coding. If used, ensure that they are consistent with MIL-STD-2525B (U.S. DoD 1999b; Osga and Keating 1994)

12.6.8 Symbology Overlaid on Video

Consider the readability of symbology overlaid on a video background. Methods for enhancing readability of symbology include the following:

a. Use occlusion zones to “black out” video where symbology is displayed.

b. Use different colors for video and symbology.

c. Use separate brightness controls for video and symbology.

(WSSG Working Group 1996)

12.6.9 Improving Symbol Recognition

Consider, when designing symbols, that recognition performance may be improved by either enhancing the size or color coding of the critical symbol feature such as a gun barrel. See Figure 12.1 for an illustration. (Barthelmy, Mazur, and Reising 1990)

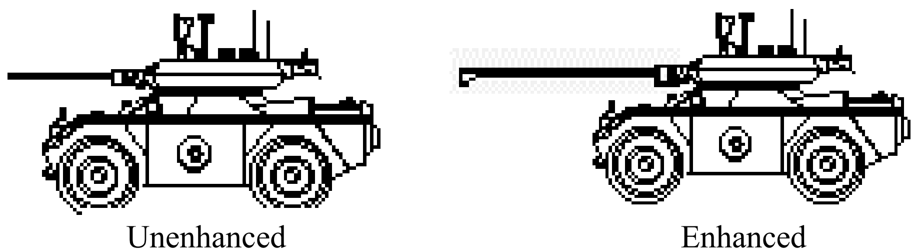


Figure 12.1 Illustration of Enhanced Size of Critical Symbol Feature for Recognition

12.6.10 Visual Symbol Design Guidelines

In designing symbols, consider that good symbols will have the properties of good figures as defined by human perceptual characteristics. These include:

a. Symbols should be symmetric.

b. Symbols should be convex.

c. Symbols should have a relatively small area relative to the background on which they are displayed.

d. Symbols should have a vertical or horizontal orientation rather than a diagonally orientation.

(Duncanson 1994)

12.7 ICON DESIGN

Icons are pictographic symbols that represent objects, concepts, processes, applications, or data. The icon is made up of a symbol or graphic that provides visual representation, together with the coded instructions to execute an associated action. Consistency, clarity, simplicity, and familiarity are the basic principles for designing icons and symbols used in a graphical user interface. Users should be significantly involved in the icon design. (Fowler and Stanwick 1995; Galitz 1994; Gittins 1986; Lewis and Fallesen 1989; Lodding 1983; Marcus 1992; Nolan 1989)

The following paragraphs provide very high-level guidance on the design of icons for RT/NRT systems. Refer to the *DoD HCI Style Guide* (U.S. DoD 1995) for more detailed information.

12.7.1 Icon Usage

Consider using icons to start an application or action, or to indicate the importance of a message (Fowler and Stanwick 1995; Weinschenk and Yeo 1995). Design icons to be general enough to allow the user to understand and use them across applications. Also ensure that the icon can be used in all expected operational environments and while wearing night vision devices. For example, if the icon will be used in blackout conditions, it should be visible under red lighting. (Marcus 1984; MacGregor and Lee 1988; Lewis and Fallesen 1989; Galitz 1994; Fowler and Stanwick 1995)

12.7.2 Icon Design Principles

Use the following principles to guide the design of icons. Also see Paragraph 12.6 for general symbology design guidelines that are applicable to icons.

12.7.2.1 Icon Meaning

Ensure that icons are familiar and have intrinsic meaning for the user, and that the function associated with an icon is obvious. (Lodding 1983; Lewis and Fallesen 1989; Galitz 1994)

12.7.2.2 Icon Function

Design icons to represent a single function, where possible, since multiple functions for a single icon may confuse the user. (Rogers 1989)

12.7.2.3 Consistency

Design consistent command icons across all DoD applications, e.g., a common set of icons for command and utility functions within tactical/operational applications. (U.S. DoD 1995; MacGregor and Lee 1988; Lewis and Fallesen 1989)

12.7.2.4 Appearance

Use a common set of graphic features in icon design to improve the user's ability to recognize and associate icons with their meanings. Large objects, bold lines, and simple areas are recommended. Also use a single presentation style for an icon set. See Figure 12.2. (Neurath 1980; Wood and Wood 1987; MacGregor and Lee 1988; Lewis and Fallesen 1989; Marcus 1992; Galitz 1994; Marcus et al. 1995)

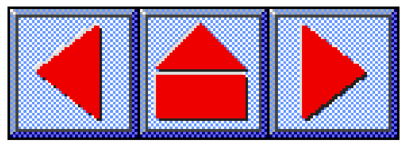


Figure 12.2 Example of a Single Icon Set

12.7.2.5 Standardization

Always use standardized icons to inform the user of risk or danger factors. (Wood and Wood 1987)

12.7.3 Icon Shape

12.7.3.1 Familiarity

Ensure that the icon shape is familiar to the user. Icons should include only enough detail for reliable recognition. (Lodding 1983; Gittins 1986; Lewis and Fallesen 1989; Galitz 1994; Weinschenk and Yeo 1995)

12.7.3.2 Uniqueness

Design unrelated icons to have unique shapes. This will assist the user in learning their meanings. Limit the number of unique icon shapes to 20 per screen. (Wood and Wood 1987; Lewis and Fallesen 1989; Galitz 1994)

12.7.3.3 Function

Ensure that the icon shape indicates its function. Use mirrored shapes to represent opposite functions/modes. See Figure 12.3. (Marcus 1984; Lewis and Fallesen 1989; Rosenstein and Weitzman 1990; Marcus 1992; Galitz 1994; Fowler and Stanwick 1995)

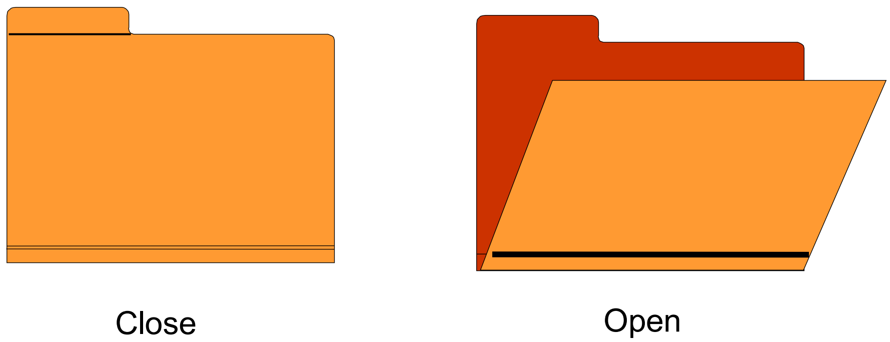


Figure 12.3 Example of Mirrored Icons

12.7.4 Icon Size

Ensure that icons are large enough for functions to be easily recognized. Do not use symbol or graphic size as a coding mechanism. Keep scales constant when enlarging or reducing the size of icons. (Neurath 1980; Marcus 1984; Lewis and Fallesen 1989; Galitz 1994; Fowler and Stanwick 1995)

a. Ensure that icons are no smaller than 45 minutes of visual angle, as calculated in Section 5.0, "General Guidelines for Displays." (Galitz 1994; Fowler and Stanwick 1995)

b. Use no more that three sizes of icons for an operational system. (Lewis and Fallesen 1989; Galitz 1994; Fowler and Stanwick 1995)

12.7.5 Icon Color

Design icons as black and white objects rather than color objects, because icons should be equally usable in black and white, and in color. Although color should be used for coding only as a supplement to other methods, ensure the user knows and understands the color code. (Tullis 1981; Gittins 1986; Lewis and Fallesen 1989; Fowler and Stanwick 1995; Weinschenk and Yeo 1995)

12.7.5.1 Number of Colors to Use

Limit the colors used to five or fewer, including black, white, and/or gray. Also limit colors to a carefully chosen set, and use them consistently across content areas and different display media. Ensure that the same color is not used on too many items. (Marcus 1984; Marcus 1992; Galitz 1994; Weinschenk and Yeo 1995)

12.7.5.2 Background Color

Use background colors that are dissimilar from the icon color. (Weinschenk and Yeo 1995; Galitz 1994)

12.7.6 Icon Boundary Lines

Ensure that icon boundary lines or borders are solid, closed, and of consistent line weight. Design icon borders such that they have high contrast with the screen background and smooth corners. Do *not* put a box around an icon, because this can impair visual discrimination. (Gittins 1986; Lewis and Fallesen 1989; Nolan 1989)

12.7.7 Icon Labeling

a. When an icon represents a class of items or functions, provide a text label for each icon. Labels assist the user in identifying the icon's precise function. Therefore, for emphasis and information, keep the textual material simple, and highlight the label when an icon is selected. (Smith and Magee 1980; Shneiderman 1982; Ziegler and Fahnrich 1988; Lewis and Fallesen 1989)

b. Place the icon label underneath the icon. If labels are not used, ensure that the user can query the system for a definition of the icon. (Smith and Magee 1980; Shneiderman 1982; Ziegler and Fahnrich 1988; Lewis and Fallesen 1989; Galitz 1994)

12.7.8 Hot Zone

The hot zone is the part of the icon that enables an assigned action. Ensure that the hot zone is as large as possible. The hot zone usually encompasses the entire area of the icon, including the label. See Figure 12.4. (Fowler and Stanwick 1995)

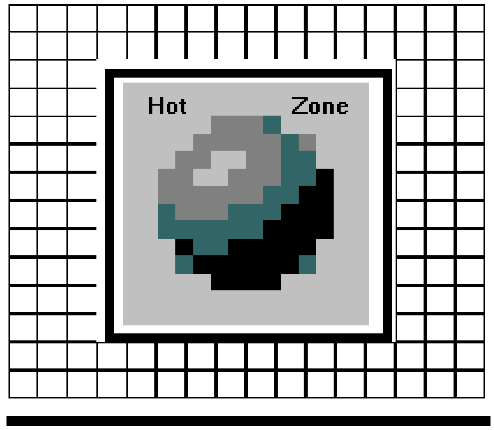


Figure 12.4 Example of Hot Zone

APPENDIX A - ACRONYMS

AI	articulation index
ASR	automatic speech recognition
ATCCS	(U.S.) Army Tactical Command and Control System
ATA	Army Technical Architecture
BMNT	Beginning Morning Nautical Twilight
CIE	Commission Internationale de L'Eclairage
C4I	command, control, communications, computers, and intelligence
CRT	cathode ray tube
dB	decibel(s)
DII	Defense Information Infrastructure
DISC4	Director of Information for Command, Control, Communications, and Computers
DoD	(U.S.) Department of Defense
DVI	Direct Voice Input
EENT	End Evening Nautical Twilight
EMI	electromagnetic interference
EMP	electromagnetic pulse
fC	footCandle
fL	footLambert
FLIR	forward looking infrared
FOV	field of view
GUI	graphical user interface

HCI	human-computer interface
HDD	head-down display
HFE	human factors engineering
HMD	helmet-mounted display
HUD	head-up display
Hz	hertz
IPD	interpupillary distance
IR	infrared
JTA	Joint Technical Architecture
JTA-A	Joint Technical Architecture - Army
LAN	local area network
LCD	liquid crystal display
LED	light emitting diode
LLTV	low light television
LOS	line of sight
MFD	multifunction display
mm	millimeter
MOPP	mission-oriented protective posture
MRT	modified rhyme test
ms	millisecond
NBC	nuclear, biological, and chemical
NRT	near-real time
NVG	night vision goggles

NVIS	night vision imaging system
PB	phonetically balanced
PLI	position location information
PNNL	Pacific Northwest National Laboratory
QWERTY	standard alphanumeric keyboard layout
RGB	red, green, blue
RT	real time
TAFIM	Technical Architecture Framework for Information Management
TARDEC	U.S. Army Tank-Automotive Research, Development, and Engineering Center
3-D	three-dimensional
2-D	two-dimensional
UCS	Uniform-Chromaticity-Scale
UI	user interface
WSHCI	(U.S. Army) Weapon Systems Human Computer Interface (Style Guide)
WSTAWG	Weapon Systems Technical Architecture Working Group

This page intentionally left blank.

APPENDIX B - REFERENCES

Adam, E.C. 1992. "Tactical cockpits - the coming revolution." *High-Resolution Displays and Projection Systems, SPIE Imaging Science and Technology Proceedings, San Jose, CA,* Feb. 11-12, 1992.

Alam, M.S., Karim, M.A., Zheng, S.H., and Iftekharuddin, K.M. Dec. 1995. "Field-of-view overlap effects in helmet-mounted night-vision systems." *Microwave and Optical Technology Letters,* ISSN 0895-2477.

Alexander, S., Koehler, J., Stolzy, J., and Andre, M. 1994. "Mission management system architecture for cooperating air vehicles." *Proceedings of the IEEE 1994 National Aerospace and Electronics Conference, NAECON,* May 23-27, 1994.

American National Standards Institute (ANSI). 1988. *American national standard for human factors engineering of visual display terminal workstations.* ANSI/HFS Standard No. 100-1988, The Human Factors Society, Inc., Santa Monica, California.

American National Standards Institute (ANSI). 1995. *Method for measuring the intelligibility of speech over communications system*. ANSI S3.2-1989 (R1995), New York.

American National Standards Institute (ANSI). 1986. *Methods for the calculation of the articulation index*. ANSI S3.5-1969 (R1986), New York.

Andre, A.D., and Wickens, C.D. Oct. 1989. *Proximity compatibility and information display: The effects of space and color on the analysis of aircraft stall conditions*. U.S. Army. Army Human Engineering Laboratory, Aberdeen Proving Ground, MD. DTIC Report Number: ADA214488.

Armstrong, S., Steinberg, R. 1998. "Advocating User-Centered Software Design," *CSERIAC Gateway*, Volume IX, Number 4.

Baber, C. and Noyes, T. 1996. "ASR in adverse environments." *Human Factor,* 38(1):142-155.

Bailey, R.E. 1994. "HUD lessons-learned for HMD development." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 5-7, 1994.

Bailey, R.W. 1982. *Human performance engineering: A guide for system designers*. New Jersey: Prentice-Hall, Inc.

Balzarotti, G., Fiori, L., and Malfagia, R. 1994. "Presentation of IR pictures on helmet mounted displays." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 5-7, 1994.

Barrass, S. and Kramer, G. Jan. 1999. "Using sonification." *Multimedia Systems,* vol.7, no.1, pp. 23-31.

Barthelemy, K., Mazur, K., and Reising, J. 1990. "Color coding and size enhancements of switch symbol critical features." *Proceedings of the Human Factors Society 34th Annual Meeting – Orlando, FL.*

Basile, S.D. 1990. *Cursor positioning performance as a function of delay between trackmarble movement and cursor motion.* U.S. Navy. Naval Underwater Systems Center, New London Lab. DTIC Report Number: ADA-228182.

Begault, D. Dec. 1993. "Head-up auditory displays for traffic collision avoidance system advisories: A preliminary investigation." *Human Factors*, 35(4):707-717.

Belz, S., Robinson, G., and Casali, J. 1998. "Auditory icons as impending collision warning signals in commercial motor vehicles." *Proceedings of the HFES 42nd Annual Meeting,* pp. 1127-1131.

Benel, R.A., and Stanton, B.C. 1987. "Optimal size and spacing of touch screen input areas." Eds. Bullinger, H.J., Shackel, B., and Kornwachs, K. *Proceedings of the Second IFIP Conference, Stuttgart, West Germany,* Sep. 1-4, 1987.

Boff, K.R., and Lincoln, J.E., eds. 1988. *Engineering data compendium human perception and performance*. Harry G. Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio.

Bohm, H.D.V., and Schranner, R. 1990. "Requirements of an HMS/D for a night-flying helicopter." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 16-20, 1990.

Brems, D., Rabin, M., and Waggett, J. 1995. "Using natural language conventions in the user interface design of automated speech recognition systems." *Human Factors*, 37(2):265-282.

Brewster, S. 1998. "Using earcons to improve the usability of a graphics package." *People and Computers XIII. Proceedings of HCI*, pp. 287-302.

Brewster, S. and Crease, M**.** 1999. “Correcting Menu Usability Problems with Sound.” *Behaviour and Information Technology*, 18(3), pp. 165-177.

Brewster, S., Wright, P., and Edwards, A. 1993. “Evaluation of earcons for use in auditory human-computer interfaces.” *Conference Proceedings on Human Factors in Computing Systems*. Pub. by ACM, New York, NY, pp. 222-227.

Brewster, S.A. 1997. “Using non-speech sound to overcome information overload.” *Displays,* 17(3-4):179-89.

Bull, G.C. 1990. “Helmet display options - a route map.” *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 16-20, 1990.

Bull, G.C. 1992. “Helmet mounted display with multiple image sources.” *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 21-22, 1992.

Burley, J.R., II, and LaRussa, J.A. 1990. “Full-color wide-field-of-view holographic helmet-mounted display for pilot/vehicle interface development and human factors studies.” *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 16-20, 1990.

Calantropio, F.P., and Campbell, N.L. 1994. *Alert presentation model ver. 3.1 for the advanced tomahawk weapon control system*. U.S. Navy, Naval Command, Control, and Ocean Surveillance Center. Jun. 1, 1994.

Cameron, A.A. Apr. 1994. “24 hour helmet-mounted display.” *Displays*, ISSN 0141-9382.

Card, S.K., Moran, T.P., and Newell, A. 1983. *Psychology of human-computer interaction*. Lawrence Erlbaum Associates.

Cardosi, K.M., and Murphy, E.D., eds. 1995. *Human factors in the design and evaluation of air traffic control systems*. Cambridge, MA: U.S. Department of Transportation.

Carter, R. 1993. “Gray scale and achromatic color difference.” *Journal of the Optical Society of America*, 10(6):1380-1391.

Carter, R. 1997. “Gray-scale perceptions calculated: Optimum display background luminance.” *Applied Optics*, 36(8):1705-1717.

Cole, R.A., Mariani, J., Uszkoreit, H., Zaenen, A., and Zue, V. 1996. *Survey of the state of the art in human language technology*. National Science Foundation European Commission.

Coleman, M.F., Loring, B.A., and Wiklund, M.E. 1991. "User performance on typing tasks involving reduced-size, touch screen keyboards." *Vehicle Navigation and Information Systems Conference Proceedings, Dearborn, MI,* Oct. 20-23, 1991.

Companion, M.A. and Epp, D. G. 1997. *Application of speech recognition to the land warrior soldier computer interface*. Hughes Defense Systems.

Coueffin, R.E., and Hancock, H.A.R. 1983. *Speech recognition systems and their military applications.* Royal Military Coll. of Science, Shrivenham (England).

Cowley, C, Miles, C. and Jones, D. 1990. "The incorporation of synthetic speech into the human-computer interface." *Contemporary Ergonomics 1990, Proceedings of the Ergonomics Society Annual Conference*. E.J. Lovesey (Ed.), pp. 438-444.

Crawford, R., Toms, M., and Wilson, D. 1991. "Effects of display luminance on the recognition of color symbols on similar color backgrounds." *Proceedings of the Human Factors Society 35th Annual Meeting,* v. 2, pp. 1466-70.

Dominessy, M.E., Lukas, J.H., Malkin, F.J., Monty, R.A., et al. 1991. "Effect of information display formats on helicopter pilot's target acquisition and flying performance." *Military Psychology,* ISSN 0899-5605.

Doyal, J.A., Irvin, G.E., and Ramer, D.P. 1995. "Performance-based evaluation of B-2 cursor system gain functions for use on navigational update and targeting tasks." *IEEE National Aerospace and Electronics Conference, Dayton, OH*, v. 1, pp. 566-573. May 22-26, 1995.

Dudfield, H.J. 1991. "Colour head-up displays: Help or hindrance?" *Proceedings of the Human Factors Society 35th Annual Meeting, San Francisco, CA,* Sep. 2-6, 1991.

Duncanson, J. 1994. *Visual and auditory symbols: A literature review*. DOT/FAA/CT-TN94/37.

Dunkelberger, K.A. 1995. "Fuzzy logic approach to vulnerability assessment." *Proceedings of the SPIE - The International Society for Optical Engineering Applications of Fuzzy Logic Technology II.* Orlando, FL. Apr. 19-21, 1995.

Elias, B. 1995. "Dynamic auditory preview for visually guided target aiming." *Proceedings of the HFES 39th Annual Meeting*, pp. 1415-1419.

Elias, B. 1996. "The effects of spatial auditory preview on dynamic visual search performance." *Proceedings of the HFES 40th Annual Meeting,* pp. 1227-1231.

Ellman, A., and Carlton, M. 1993. *Deep Space Network (DSN), Network Operations Control Center (NOCC) computer-human interfaces.* National Aeronautics and Space Administration. Mar. 1, 1993.

Evans, L. 1991. "Fixed wing night attack EO integration and sensor fusion." *Helmet Mounted Displays and Night Vision Goggles, Pensacola, FL, AGARD Conference Proceedings*; Vol. 517, pp. 1-1 through pp. 1-5. DTIC Report Number: ADA246 925. May 2, 1991.

Fallesen, J.J. 1985. *Information analysis of the short-range air defense fire unit*. U.S. Army. Human Engineering Lab., Aberdeen Proving Ground, MD.

Ferrin, F.J. 1991. "Survey of helmet tracking technologies." *Proceedings of the SPIE - The International Society for Optical Engineering, San Jose, CA,* Feb. 26-28, 1991.

Fowler, S.L., and Stanwick, V.R. 1995. *GUI style guide*. Cambridge, Massachusetts, AP Professional, Imprint of Academic Press, Inc.

Galitz, W.O. 1994. *It's time to clean your windows*. New York, John Wiley & Sons, Inc.

Garman, P.J., Trang, J.A., Garman, P.J., and Trang, J.A. 1994. "In your face -- The pilot's/tester's perspective on HMD symbology." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL.* Apr. 5-7, 1994.

Gaver, W.W. 1997. "Auditory interfaces." In *Handbook of Human-Computer Interaction 2nd Edition*, edited by Helander, M.N.G., Landauer, T.K., et al., Amsterdam, the Netherlands, pp. 1021-1024.

Gaver, W.W. 1989. "Sonicfinder: An interface that uses auditory icons." *Human-Computer Interaction,* 4(1):67-94.

Gaver, W.W. 1993. "Synthesizing auditory icons." *Conference Proceedings on Human Factors in Computing Systems,* Pub. by ACM, New York, NY, pp. 228-235.

Gaver, W.W., Smith, R.B. 1990. "Auditory icons in large-scale collaborative environments." *Human-Computer Interaction*, pp. 735-740.

General Dynamics-Land Systems Division. 1986. *Human factors and system safety design guide, block improved abrams tank program, M1A1E2 configuration*. General Dynamics. Contract DAAE07-86-C-R125.

Gilboa, P. 1991. "Designing the right visor." *Proceedings of the SPIE - The International Society for Optical Engineering, San Jose, CA,* Feb. 26-28, 1991.

Gish, K.W., and Staplin, L. 1995. *Human factors aspects of using head up displays in automobiles: A review of the literature.* Office of Crash Avoidance Research, National Highway Traffic Safety Administration.

Gittins, D. 1986. "Icon-based human-computer interaction." *International Journal of Man-Machine Studies.* ISSN: 0020-7373.

Gordon, D.F. 1990. "Voice recognition and systems activation for aircrew and weapon system interaction." *IEEE National Aerospace and Electronics Conference, Dayton, OH,* pp. 744-748. May 21-25, 1990.

Gould, J.D. 1989. "Using touchscreen for simple tasks." *Tech Report No: RC 14434 (#64616).* Yorktown Heights, NY: IBM, T. J. Watson Research Center.

Gould, J.D. 1988. "How to design usable systems" *in Handbook of Human-Computer Interaction*, ed. M. Helander, pp. 757-789. Elsevier Science Publishers B. V., Amsterdam.

Gould, J.D., Greene, S.L., Boies, S.J., Meluson, A., et al. Apr. 1990. "Using touchscreen for simple tasks." *Interacting with Computers*, ISSN 0953-5438.

Greenstein, J.S., and Arnaut, L.Y. 1987. "Human factors aspects of manual computer input devices." In *Handbook of Human Factors*, ed. by G. Salvendy, pp. 1450-1489, A. Wiley-Interscience Publications.

Grunwald, A.J., Kohn, S., and Merhav, S.J. 1991. "Visual field information in nap-of-the-earth flight by teleoperated helmet-mounted displays." Large-screen-projection, avionic, and helmet-mounted displays*. Proceedings of the SPIE - The International Society for Optical Engineering, San Jose, CA.* pp. 132-53. Feb. 26-28, 1991.

Gungl, K.P. 1989. "Computer interface and touch sensitive screens." *VLSI and Microelectronic Applications in Intelligent Peripherals and their Interconnection Networks, Hamburg, West Germany,* May 8-12, 1989.

Haas, E. 1998. "Can 3-D auditory warnings enhance helicopter cockpit safety?" *Proceedings of the HFES 42nd Annual Meeting,* pp. 111-1121.

Hair, D.C., and Pickslay, K. 1993. "Critiquing in real time systems." *Working Notes of the AAAI-93 Workshop on Expert Critiquing Systems*.

Hansen, J.H.L., and Bou-Ghazale, S.E. 1995. "Robust speech recognition training via duration and spectral-based stress token generation." *IEEE Transactions on Speech and Audio Processing*, ISSN 1063-6676.

Harrison, A. 1994. *Head-up displays for automotive applications.* University of Michigan, Transportation Research Institute.

Hatazaki, K., Ehsani, F., Noguchi, J., and Watanabe, T. 1994 "Speech dialogue system based on simultaneous understanding." *Speech Communication,* 15(3-4):323-330.

Heinecke, A.M. 1993. "Software ergonomics for real-time systems." *VCHCI '93 Fin de Siecle Proceedings, Vienna, Austria,* Sep. 20-22, 1993.

Hindus, D., Arons, B., Stifelman, L., Gaver, B., et al. 1995. "Designing auditory interactions for PDAs." *UIST (User Interface Software and Technology): Proceedings of the ACM Symposium*. ACM, New York, NY, pp. 143-146.

Honeywell Technology Center. 1995. *Combat vehicle crew helmet-mounted display (CVCHMD), Final Report A001.* U.S. Army Soldier Systems Command, Natick RD&E Center, Advanced Systems Concepts Directorate. Nov. 8, 1995.

Hughes, R.D. and King, R.A. 1989. "Comparison of the performance of 'normal' and 'whispered' speech with simple time encoded digital speech (TES) direct voice input (DVI) systems in a tactical military environment." *Eurospeech, Paris, France*, pp. 417-20. Sep. 26-28, 1989.

Humphry, J.A. 1994. "Touch screens: The simple way to interact with complex systems." *I&SO*, ISSN 0746-2395.

Inuzuka, Y., Osumi, Y., and Shinkai, H. 1991. "Visibility of head up display (HUD) for automobiles." *Proceedings of the Human Factors Society 35th Annual Meeting, San Francisco, CA,* Sep. 2-6, 1991.

Jones, D.R., Abbott, T.S., and Burley, J.R., II. 1992. "Evaluation of conformal and body-axis attitude information for spatial awareness." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 21-22, 1992.

Jones, D., and Parrish, RV. 1990. *Simulator comparison of thumball, thumb switch, and touch screen input concepts for interaction with a large screen cockpit display format*. National Aeronautics and Space Administration.

Kamm, C. 1994. "User interfaces for voice applications." In Roe, D.B. and Wilpon, J.G. (Eds.) *Voice Communications Between Humans and Machines*. National Academy of Sciences, Washington, D.C., pp. 422-444.

Kirkpatrick, M., Dutra, L., Lyons, R., Osga, G., et al. 1992. "Tactical symbology standards." *Proceedings of the Human Factors Society 36th Annual Meeting. Innovations for Interactions,* pp. 1087-91, vol.2.

Knoll, P.M., and Konig, W.H. 1992. "Advanced integrated driver information systems." *Measurement and Control*, ISSN 0020-2940.

Kramer, G., Walker, B., Bargar, R., Barrass, et al. 1997. *Sonification report: Status of the field and research agenda*. Prepared by the International Community for Auditory Display for National Science Foundation.

Lee, C.L., and Rabiner, L.R. 1995. "Directions in automatic speech recognition." *NTT Review*, ISSN 0915-2334.

Leger, A., Roumes, C., Gardelle, C., Cursolle, J.P., et al. 1993. "Binocular HMD for fixed-wing aircraft: A trade-off approach." *Proceedings of the SPIE - The International Society for Optical Engineering, Munich, Germany,* Jun. 23-24, 1993.

Lewis, H.V., and Fallesen, J.J. 1989. *Human factors guidelines for command and control systems: Battlefield and decision graphics guidelines*. Interim report, Oct 86-Sep 88. Alexandria, VA: Army Research Inst. for the Behavioral and Social Sciences.

Lippert, T.M. 1990. "Fundamental monocular/binocular HMD human factors." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 19-20, 1990.

Lloyd, C.J.C., and Reinhart, W.F. 1993. "Requirements for HUD raster image modulation in daylight." *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, Seattle, WA,* Oct. 11-15, 1993.

Lodding, K.N. Feb. 1983. "Iconic interfacing." *IEEE Computer Graphics and Applications.* ISSN: 0272-1716.

MacGregor, J.M., and Lee, E.S. 1988. "Feature matching approach to the retrieval of graphical information." *Behaviour & Information Technology.* ISSN: 0144-929X, 457-465. Oct.-Dec. 1988.

MacKenzie, I.S. 1994. "Comparison of input devices in elemental pointing and dragging tasks." *Proceedings of the Computer Machinery SIG - Computer Human Interface Proceedings*.

MacKenzie, I.S. 1992. "Fitts law as a research and design tool in human-computer interaction." *Human-Computer Interaction,* Volume 7.

MacKenzie, I.S., Nonnecke, B., Riddersma, S., McQueen, C., et al. 1994. "Alphanumeric entry on pen-based computers." *International Journal of Human-Computer Studies,* 41, pp. 775-792.

Marcus, A. 1984. "Corporate identity for iconic interface design: The graphic design perspective." *International Journal of Man-Machine Studies*. ISSN: 0020-7373.

Marcus, A. 1992. *Graphic design for electronic documents and user interfaces*. New York, ACM Press.

Marcus, A., Smilonich, N., and Thompson, L. 1995. *Cross-GUI handbook*. Reading, MA, Addison-Wesley Publishing Company.

Mazur, K.M., and Reising, J.M. 1990. "Relative effectiveness of three visual depth cues in a dynamic air situation display." *Proceedings of the Human Factors Society 34th Annual Meeting, Orlando, FL,* Oct. 7-12, 1990.

McCann, R.S., Lynch, J., Foyle, D.C., and Johnston, J.C. 1993. "Modelling attentional effects with head-up displays." *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, Seattle, WA,* Oct. 11-15, 1993.

McCormack, E.J. 1970. *Human factors engineering.* McGraw-Hill Book Company, New York.

Melzer, J.E., and Moffitt, K.W. 1992. "Color helmet display for the military cockpit." *Proceedings IEEE/AIAA 11th Digital Avionics Systems Conference, Seattle, WA,* Oct. 5-8, 1992.

Melzer, J.E., and Moffitt, K.W. 1991. "Ecological approach to partial binocular-overlap." *Proceedings of the SPIE - The International Society for Optical Engineering, San Jose, CA,* Feb. 26-28, 1991.

Merhav, S., and Velger, M. 1991. "Compensating sampling errors in stabilizing helmet-mounted displays using auxiliary acceleration measurements." *Journal of Guidance, Control, and Dynamics*, ISSN 0731-5090. Sep.-Oct. 1991.

Mitchell, D.K., and Kysor, K.P. 1992. "Preliminary evaluation of the prototype tactical computerized interactive display," Technical Note 2-92, U.S. Army Human Engineering Laboratory, Aberdeen Proving Ground.

Moseley, M.J., and Griffin, M.J. 1986. "Effects of display vibration and whole-body vibration on visual performance." *Ergonomics*, ISSN 0014-0139.

National Research Council (NRC). 1997. *Tactical display for soldiers: Human factors considerations*. Committee on Human Factors, Panel on Human Factors in the Design of Tactical Display Systems for the Individual Soldier. Washington, D.C.: National Academy Press.

Neurath, O. 1980. *International picture language/internationale bildersprache*. Reading, England, University of Reading.

Newman, R.L. 1987. *Improvement of head-up display standards, Volume 1: Head-up display design guide.* Flight Dynamic Laboratory, Air Force Wright Aeronautical Laboratories.

Newman, R.L. and Haworth, L.A. 1994. "Helmet-mounted display requirements: Just another HUD or a different animal altogether?" *Helmet- and Head-Mounted Displays and Symbology Design Requirements, Orlando, FL*, *Proceedings of the SPIE - The International Society for Optical Engineering* Vol. 2218, pp. 226-37. Apr. 5-7, 1994.

Nolan, P.R. 1989 "Designing screen icons: Ranking and matching studies." *Proceedings of the Human Factors Society 33rd Annual Meeting, Denver, CO*, Vol. 1, pp. 380-384. Oct. 16-20, 1989.

Nunn, S.W. 1989. *Keyword feedback for improving speech recognition in command and control information-acquisition tasks*. U.S. Navy. Naval Ocean Systems Center, San Diego, CA. DTIC Report Number: ADA208013.

Obermayer, R.W., and Campbell, N.L. 1994. *Human computer interface requirements specification for the Advanced Tomahawk Weapon Control System (ATWCS), Ver. 1.3, Rev B, Ch 1*. Naval Command, Control, and Ocean Surveillance Center, RDT&E Center. Sep. 30, 1994.

Okabayashi, S., Sakata, M., Furukawa, M., and Hatada, T. 1989. "How head-up display affects recognition of objects in foreground in automobile use." *Proceedings of the SPIE - The International Society for Optical Engineering, San Diego, CA,* Aug. 7-11, 1989.

Osga, G. 1992. *Color display improvement recommendations for aegis tactical displays*. Battelle Pacific Northwest Labs. Aegis Program Office. Combat Systems Engineering, Report no.: PMS-400B30C.

Osga, G. 1995. *Combat information center human-computer interface design studies, Technical Document 2822*. San Diego, CA: Naval Command, Control and Ocean Surveillance Center RDT&E Center.

Osga, G.A., Campbell, N.L., Keating, R.L., and Cherdak, S.J.B. 1995. *Human-computer interface standards for federal aviation administration traffic management applications, Version 2.0*. U.S. Navy, Naval Command, Control, and Ocean Surveillance Center.

Osga, G., and Keating, R. 1994. *Usability study of variable coding methods for tactical information display visual filtering*. Naval Command, Control, and Ocean Surveillance Center, RDT&E Center.

Oviatt, S. 1996. "User-centered modeling for spoken language and multimodal interfaces." *IEEE Multimedia,* 4(3):26-35.

Oviatt, S., Cohen, P., and Wang, M. 1994. "Toward interface design for human language technology: modality and structure as determinants of linguistic complexity." *Speech Communication,* 15(3-4):283-300.

Parasuraman, R. 1987. "Human-computer monitoring." Special Issue: Vigilance: Basic and applied research*.* *Human Factors*, ISSN 0018-7208.

Perry, C.E., Buhrman, J.R., and Knox, F.S., III. 1993. "Biodynamic testing of helmet mounted systems." *Proceedings of the Human Factors and Ergonomics Society 37th Annual Meeting, Seattle, WA,* Oct. 11-15, 1993.

Plaisant, C. 1991. *Touchscreen interfaces for flexible alphanumeric data entr*y. College Park, MD: University of Maryland, Center for Automation Research, Computer Vision Laboratory.

Rash, C.E. (Ed.) 1998. *Helmet-Mounted Displays: Design Issues for Rotary-Wing Aircraft.* Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. U.S. Government Printing Office.

Rauch, S. 1988. "Determination of a Gain-function Relating Control Force to Cursor Velocity." *Human Factors Society 32nd Meeting, Anaheim, CA.*

Reising, J.M., and Mazur, K.M. 1990. "3-D displays for cockpits: Where they pay off." *Proceedings of the SPIE - The International Society for Optical Engineering, Santa Clara, CA,* Feb. 12-14, 1990.

Reising, J.M., Solz, T.J., Jr., Barry, T., and Hartsock, D.C. 1994. "New cockpit technology: Unique opportunities for the pilot." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 7-8, 1994.

Ribot, E., Roll, J.P., and Gauthier, G.M. 1986. "Comparative effects of whole-body vibration on sensorimotor performance achieved with a mini-stick and a macro-stick in force and position Control modes." *Aviation, Space, & Environmental Medicine,* ISSN 0095-6562.

Rogers, Y. 1989. "Icons at the interface: Their usefulness." *Interacting With Computers - The Interdisciplinary Journal of Human-Computer Interaction*.

Rosenstein, M., and Weitzman, L. 1990. "The HITS icon editor - The specification of graphic behavior without coding." IEEE, 0073-1129/90/0523:523-529.

Rushton, S. Mon, Williams, M., and Wann, J.P. 1994. "Binocular vision in a bi-ocular world: New-generation head-mounted displays avoid causing visual deficit." *Displays*, ISSN 0141-9382.

Schafer Corporation. Oct 1998. *THAAD system status evaluation: An analysis of alerting techniques*. Technical report prepared by the Schafer Corporation for Department of the Army, THAAD Project Office, Huntsville, AL.

Sharkey, T.J., McCauley, M.E., Schwirzke, M.J.J., Casper, P., et al. 1995. *Effects of whole body motion, head mounted display, and hand control device on tracking performance*. U.S. Army. Tank-Automotive Research Development and Engineering Center, Warren, MI.

Shneiderman, B. 1982. "Human factors experiments in designing interactive systems," *Tutorial: End User Facilities in the 1980s,* ed, J.A. Larson, pp. 16-26. Proceedings of the IEEE Computer Society Sixth International Computer Software & Applications Conference, IEEE Computer Society Press, New York.

Site visit to General Dynamics Land Systems Division, Warren, MI. Feb. 26, 1996.

Site visit to Tank-Automotive Research, Development and Engineering Center (TARDEC), Warren, MI. Feb. 27, 1996.

Smith, M.C., and Magee, L.E. 1980. "Tracing the time course of picture-word processing." *Journal of Experimental Psychology*: General ISSN: 0096-3445, 373-392.

Smith, R. Dec. 1994. "Impact of variable initiative on a natural language dialog system." *Knowledge-Based Systems,* 7(4):279-280.

Smolders, J., Claes, T., Sablon, G., and Van-Compernolle, D. 1994. "On the importance of the microphone position for speech recognition in the car." *1994 IEEE International Conference on Acoustics, Speech and Signal Processing, Adelaide, SA, Australia,* Apr. 19-22, 1994.

Smyth, C.C. 1991. *Effects of user's training on the performance of an automatic speech recognizer for a self-paced task.* U.S. Army. Human Engineering Lab., Aberdeen Proving Ground, MD, Technical Memorandum 10-91. DTIC Report Number: ADA235844.

Spiegel, M. and Streeter, L. 1997. "Applying speech synthesis to user interfaces." In *Handbook of Human-Computer Interaction 2nd Edition*, edited by Helander, M.G., Landauer, T.K., and Prabhu, P.V. Elsevier Science, B. V. Amsterdam, The Netherlands, p 1067.

Stanton, N. and Baber, C. 1997. "Comparing Speech Versus Text Displays For Alarm Handling." *Ergonomics*, 40(11):1240-1254.

Steeneken, H.J.M. 1996. *Potentials of speech and language technology systems for military use: An application and technology oriented survey*. NATO Technical Report AC/243 (Panel 3) TR/21, TNO Human Factors Research Institute.

Steinberg, R.K., Goulet, R., and Pathak, K. 1994. "Perception of alert messages on computer displays." *Proceedings of the Human Factors Society 33rd Annual Meeting, Nashville, TN,* Oct. 24-28, 1994.

Storey, B.A., Osgood, R.K., and Schueren, J.C. 1994. "Aircraft/mission requirements approach for helmet-mounted display decisions." *Proceedings of the SPIE - The International Society for Optical Engineering, Orlando, FL,* Apr. 5-7, 1994.

Streeter, L.A. 1988. "Applying speech synthesis to user interfaces." in *Handbook of Human-Computer Interaction,* edited by M. Helander, pp. 321-343. Amsterdam, Elsevier Science Publishers B.V.

Stuart, R. 1995. "Audio display from the simple beep to sonification and virtual auditory environments." In *Understanding Images. Finding Meaning in Digital Imagery*, edited by Francis T. Marchese .(Ed.).TELOS, Santa Clara, CA, pp.283-307.

Takahashi, J., Sugamura, N., Hirokawa, T., Sagayama, S., et al. Nov. 1995. "Interactive voice technology development for telecommunications applications." *Speech Communication,* 17(3-4):287-301.

Todd, J., Summers, L., and Hammontre, P. 1995. "Image quality issues for an enhanced vision head up display." *IEEE Aerospace and Electronics Systems Magazine*, ISSN 0885-8985.

Tullis, T.S. 1981. "An evaluation of alphanumeric, graphic, and color information displays." *Human Factors,* 23(5):541-550.

U.S. Army. 1980. *Operational terms and graphics*. U.S. Department of the Army. Field Manual 101-5-1.

U.S. Army. 1992. *Human Factors Design Guidelines for the Army Tactical Command and Control System (ATCCS) Soldier-Machine Interface, Version 2.0.* Tactical Command and Control Systems Experimentation Site.

U.S. Army. 1993. *Bradley Modernization Program M2/M3A3 Operational Requirements Document (ORD), 3 December 1993.* Office of the Deputy Chief of Staff for Plans and Operations, Force Development.

U.S. Army. 1994. *Military Handbook Vetronics System Architecture*. Tank Automotive Research Development Center. Vetronics Technology Center.

U.S. Army. 1995a. *M1 abrams series tank program system technical support - system/segment document for the soldier interface, Part 1 of 4 Driver's Station*. U.S. Army.

U.S. Army. 1995b. *M1 abrams series tank program system technical support - system/segment document for the soldier interface, Part 2 of 4 Commander's Station*. U.S. Army.

U.S. Army. 1995c. *Operator systems interface (OSI) prototype manual (Version 2.2) for the theater high altitude area defense (THAAD) system*. U.S. Army.

U.S. Army. 1995d. *Operator system interface (OSI) prototype users manual (Version 2.2) for the theater high altitude area defense (THAAD) system*. U.S. Army.

U.S. Army. 1995e. *Project manager, soldier*. Land Warrior System Specification #A3246133G, U.S. Army. Project Manager - Soldier.

U.S. Army. 1995f. *System Specification for the Bradley M2A3/M3A3 Fighting Vehicle System (Draft) 19207-12386023, Rev A.*, Tank Automotive Command. Bradley Fighting Vehicle Program Office.

U.S. Army. 1995g. *Crewmen's Associate Advanced Technology Demonstration - Crewstation Design Document for the Notional 2010 Tank, U.S. Army.* Tank Automotive Research Development And Engineering Center, Warren, MI.

U.S. Army. 1996a. *AACS design document - crew station section (Extract), Version 0.1* (Note: Refer to CA ATD). U.S. Army.

U.S. Army. 1996b. *AACS design document - communicate section (Draft), Version 0.2* (Note: Refer to CA ATD). U.S. Army.

U.S. Army. 1996c. *Army technical architecture, Version 4.0*. U.S. Army.

U.S. Army. 1996d. *Commander's Tactical Display Supplement for the M2/M3A3 22.* Tank Automotive Command. Bradley Fighting Vehicle Program Office.

U.S. Army. 1996e. *Human Computer Interface Style Guide for the Ground Vehicle Domain, Draft Version 0.3*. Prepared by Monterey Technologies, Inc. (MTI) and Tank-Automotive Research, Development and Engineering Center for the Office for Command, Control, Communications and Computers (DISC4) and Program Manager, Armored Systems Integration.

U.S. Army. 1999. *Joint technical architecture - army (JTA-Army), Version 5.0*. U.S. Army.

U. S. Army Research Laboratory - HRED - USAIC Field Element. 1996. *Field of view (FOV) impact on soldier performance of infantry tasks using monocular night vision goggles (NVG)*. U.S. Army Research Laboratory.

U.S. Department of Defense (U.S. DoD). 1981. *Military handbook, human factors engineering design for army materiel,* MIL-HDBK-759A.

U.S. Department of Defense (U.S. DoD). 1987. *Human engineering procedures guide.* (S/S BY MIL-HDBK-46855) DOD-HDBK-763 NOT.

U.S. Department of Defense (U.S. DoD). 1988. *Lighting, aircraft, interior, AN/AVS-6 Aviator's Night Vision Imaging (ANVIS) Compatible,* MIL-L-85762A.

U.S. Department of Defense (U.S. DoD). 1991. *Aircrew station alerting systems,* MIL-STD-411E.

U.S. Department of Defense (U.S. DoD). 1994. *Dictionary of military and associated terms with JMTGM changes.* U.S. Department of Defense, Joint Publication 1-02.

U.S. Department of Defense (U.S. DoD). 1995. *Department of Defense Human Computer Interface Style Guide*,. Defense information systems agency. Center for standards, Washington, DC.

U.S. Department of Defense (U.S. DoD). 1996a. *Design criteria standard human engineering*. MIL-STD-1472E.

U.S. Department of Defense (U.S. DoD). 1996b. *Human engineering requirements for military systems, equipment and facilities*. MIL-HDBK-46855.

U.S. Department of Defense (U.S. DOD). 1996c. *System Safety Requirements*, MIL-STD-882C.

U.S. Department of Defense (U.S. DoD). 1999a. *User Interface Specifications for the Defense Information Infrastructure (DII), Version 4.0*. Defense Information Systems Agency. Joint Interoperability and Engineering Organization.

U.S. Department of Defense (U.S. DoD). 1999b. *Military Standard 2525B, Common Warfighting Symbology Version* 15. Defense INFORMATION SYSTEMS AGENCY.

U.S. Department of Defense (U.S. DoD). 1999c. *Joint technical architecture, Version 3.0*. U.S. Army Department of Defense.

Van Orden, K.F. and Benoit, S.L. 1994. *Color recommendations for prototype maritime tactical displays*. U.S. Navy. Naval Submarine Medical Research Laboratory, NSMRL Report 1192.

Venturino, M., and Kunze, R.J. 1989. "Spatial awareness with a helmet-mounted display." *Proceedings of the Human Factors Society 33rd Annual Meeting, Denver, CO,* Oct. 16-20, 1989.

Viveash, J.P., Cable, A.N., King, S.K., Stott, J.R.R., et al. 1994. "Aircraft vibration and the readability of an electronic flight instrument display." *Displays,* 15(2):76-82. ISSN 0141-9382.

Walrath, J.D. 1989. *Aiding the decision maker: Perceptual and cognitive issues at the human-machine interface.* U.S. Army. Human Engineering Lab., Aberdeen Proving Ground, MD.

Walrath, J.D. 1994. *Designing an information display for the parafovia: Implications for the U.S. Army's avenger optical sight.* U.S. Army. Army Research Lab., Aberdeen Proving Ground, MD.

Ward, N.J., Parkes, A.M., and Crone, P.R. 1994. "Effect of background scene complexity on the legibility of head-up-displays for automotive applications." *1994 Vehicle Navigation and Information Systems Conference Proceedings, Yokohama, Japan,* Aug. 31-Sep. 2, 1994.

Weapon System Style Guide (WSSG) Working Group. 1996. Comments and suggestions from the working group, convened to review the *Weapon System HCI Style Guide*.

Weapon Systems Style Guide (WSSG) Working Group. 1997. Comments and suggestions from the working group, convened to review the *Weapon Systems HCI Style Guide.*

Weapon Systems Style Guide (WSSG) Working Group. 1999. Comments and suggestions from the working group, convened to review the *Weapon Systems HCI Style Guide.*

Weinschenk, S., and Yeo, S.C. 1995. *Guidelines for Enterprise-Wide GUI Design*. New York, John Wiley & Sons.

Wickens, C.D. 1984a. *Engineering psychology and human performance.* Charles E. Merrill Publishing Company, Columbus, OH.

Wickens, C.D. 1984b. "Multiple resources model of human performance: Implications for display design." *North Atlantic Treaty Organization. Advisory Group for Aerospace Research and Development. Aerospace Medical Panel. Symposium, Williamsburg, VA*, pp. 17-1 through 17-6. Apr. 30-May 2, 1984.

Wickens, C.D., and Carswell, C.M. 1995. "Proximity compatibility principle: Its psychological foundation and relevance to display design." *Human Factors*, ISSN: 0018-7208.

Wickens, C.D., and Kessel, C. 1979. "Effects of participatory mode and task workload on the detection of dynamic system failures." *IEEE Transactions on Systems, Man and Cybernetics,* ISSN 0018-9472.

Wickens, C.D., and Long, J. 1994. "Conformal symbology, attention shifts, and the head-up display." *Proceedings of the Human Factors and Ergonomics Society 38th Annual Meeting, Nashville, TN,* Oct. 24-28, 1994.

Wickens, C.D., Sandry, D. and Vidulich, M. 1983. Compatibility and resource competition between modalities of input, central processing, and output: Testing a model of complex task performance. *Human Factors,* v. 25, pp. 227-248.

Williams, S.P., and Parrish, R.V. 1990. "In-simulator assessment of trade-offs arising from mixture of color cueing and monocular, binoptic, and stereopsis cueing information." *IEEE Southeastcon, New Orleans, LA*.

Wisely, P. L. 1994. "Design of wide angle head up displays for synthetic vision." *AIAA/IEEE Digital Avionics Systems Conference, Phoenix, AZ,* Oct. 30-Nov. 3, 1994.

Wood, W.T., and Wood, S.K. 1987. "Icons in everyday life." *2nd International Conference on Human-Computer Interaction, Honolulu, HI*, Vol. 2, pp. 97-105. Aug. 10-14, 1987.

Yankelovich, N., Levow, G., and Marx, M. 1995. "Designing speechacts: issues in speech user interfaces." *Human Factors in Computing Systems (CHI) - Conference Proceedings,* ACM, New York, NY, v. 1, pp. 369-376.

Ziegler, J.E., and Fahnrich, K.P. 1988. "Direct manipulation." *Handbook of human-computer interaction*, pp. 123-134. Amsterdam, Elsevier Science Publishers B.V.

APPENDIX C - GLOSSARY

Achromatic – possessing no perceived hue, i.e., perceived as being black, gray, or white.

Aerial Perspective (Cue) – a depth cue format combining the brightness and shading of a symbol, making it more gray and less bright to cue a perception of increased depth.

Auditory Icons – sounds drawn from the everyday user environment that are mapped to analogous computer events.

Auditory Preview – of an auditory signal that indicates to a operator the direction and approaching speed of a target that is not yet visible to the eye, either through a display or naked eye.

Autocompletion – the automatic completion of data fields by the computer system with data from a database cued by partial information supplied by the soldier.

Azimuth – horizontal direction expressed as the angular distance between a fixed point, such as a sensor or observer's head, and an object, such as a target.

Barge-in – a dialogue style in a voice output system that allows the user to respond before the end of the system verbal prompt/response.

Binocular – an approach to display design where monocular images are presented to both eyes at the same time with some overlap of the two monocular fields of vision.

Bi-Ocular – an approach to display design where an identical image is presented to both eyes at the same time.

Bump Switch – a type of input device used to minimize errors due to vibration and shock. The user can bump or tap on the control, while maintaining hands on the control devices of a vehicle or aircraft, to tab from input area to input area of a display.

Compound Earcons - earcons for multiple operations, such as weapon and arm, that are combined to provide a more complex message.

Conformal Symbology – symbology that conforms spatially with the far domain, for example, where the orientation of symbols will be consistent with the horizon orientation rather than with the vehicle body orientation.

Contrast – the ratio of the luminance of a foreground object to the luminance of the immediate background surrounding the object. The contrast ratio can be calculated in two ways, as provided below.

$$\text{Contrast Ratio} = \frac{L_b - L_t}{L_b}$$

Where L_b = the background
L_t = the foreground object

$$\text{Contrast Ratio} = B_s/B_b$$

Where B_s = average brightness of the foreground object
B_b = average brightness of the background

Specific types of contrast include the following:

- **Display/Surround Contrast** – the contrast between the illuminated indicator and its immediate panel surface.

- **Within-Display Contrast** – the contrast between light ON vs. OFF modes.

Control Object – an on-screen visual object that allows the user to execute a command or control input through the display screen. A control object is composed of the icon, symbol, and/or text that identifies the control as well as a zone surrounding the object that allows the user to select and activate the control.

Control Sensitivity – the amount of force that must be applied to, or distance of movement of, a control to achieve a set distance of movement of a pointer, cursor, or other displayed object. This is also referred to as "gain" or the control-display ratio.

Cursor – a visual indication on the screen of a display device that indicates the currently selected object, character, or space for input or output.

- **Analog Cursor** – a cursor that responds as an analog to the force applied to the controller/mouse. The cursor moves continuously across the screen at a rate that depends on the force or displacement applied to the cursor control.

- **Discrete Cursor** – a cursor that moves discretely from one active area of the screen to another, skipping over the inactive space between.

Data Auralization – a more complex form of sonification that is used to help in the perception of complex, frequently multidimensional data.

Decision Support System – a computer system designed to provide information deemed relevant to a decision being made by a human or group of humans. A decision support system supports humans in their decision-making, but does not replace them. When automated decision support systems are used, soldier tasks include monitoring, modifying, approving, and implementing the outcomes.

Declutter – the process of hiding certain types of information on a display such as classes of symbols and levels of detailed information associated with a symbol or track.

Diopter – a unit of measurement of the refractive power of lenses, equal to the reciprocal of the focal length measured in meters.

Direct Manipulation – an interaction technique that allows the user to control computer interaction by acting directly on objects such as windows, buttons, or icons on-screen. When using a graphical user interface, these objects are organized using metaphors and visual representations of real-life objects from the user's task environment.

Disfluency – pauses or self-corrections in speech**.**

Earcons – abstract, synthetic musical tones used to create auditory messages.

Enrollment – process of "training" a speaker-dependent recognizer to the voice of the user, accomplished by the user speaking repeatedly to the recognizer. The user speaks aloud with multiple examples of speech units, words, and/or phrases needed to elicit the desired recognition actions.

Flicker – where information on a display does not appear to be steady, usually due to a refresh rate that is too low.

footCandle (fC) – unit of measure of the intensity of light falling on a surface, equal to one lumen per spare foot, and originally defined with reference to a standardized candle burning at one foot from a given surface.

footLambert (fL) – unit of measure of the intensity of reflected or emitted light (luminance). The average luminescence of any reflecting surface in footLamberts is the product of the illumination in footCandles by the luminous reflectance of the surface.

Fovea – a small region at the center of the retina of the human eye, subtending about 2 degrees, that contains cones, but not rods, and forms the site of most distinct vision.

Function Keys – keys labeled with their function name that are used to input commands. Three basic types are:

- **Fixed** – dedicated to controlling single functions with their label on or adjacent to the control.

- **Multifunction** – also called programmable or variable function key, control a number of functions depending on system mode or state. The label for the current function is variable and is displayed on or adjacent to the control.

- **Soft** – a variation of a multifunction key where the function key functions are visually depicted on the display screen, mimicking keyboard keys or buttons.

Head-Up Display (HUD) – fixed displays mounted at the top of aircraft and ground vehicle instrument panels. Computer-generated information is projected onto a vehicle's windscreen or other reflective surface and, while looking through the glass, the soldier or pilot views both the scene in front of the vehicle and the HUD-projected information.

Helmet–Mounted Display (HMD) – small, high-resolution displays mounted on pilot/soldier helmets. HMD systems project images in front of the wearer's eyes and allow simultaneous viewing of vehicle/flight information, sensor information, and the real world.

Hot Symbols – allows the operator to select a symbol to quickly display additional information about that symbol.

Hot Zone – area around a control object, such as an icon, that enables an assigned control action to the object.

Human-Computer Interface (HCI) – common boundary between humans and a computer through which humans interact with computer hardware and software. This may include visual displays, input devices, dialogue, controls, environmental concerns (e.g., lighting and noise), workspace layout, procedures, and documentation taken together as a whole. In conceptual terms, the set of features that support communication between the user and the computer.

Human Factors Engineering (HFE) – application of human factors knowledge to the design of tools, machines, facilities, tasks, jobs, and environments for safe, comfortable, and effective human use.

Icon – pictographic symbol that represents objects, concepts, processes, applications, disk drives, folders, windows, or data. The icon is made up of a symbol or graphic that provides visual representation, together with the coded instructions to execute an associated action, (e.g., window icon is a visual representation of a window or window family that consists of a graphics image, image background, and a label). An icon can be directly manipulated.

Input Focus – the condition when a window is active, meaning ready to accept command or data input. Only one window on the screen has input focus at any time and, within that window, only one object at a time has focus. Two types of focus models for assigning input focus to a window are explicit and implicit.

- **Explicit** – input focus model when the user takes an overt action to move input focus, such as activating a trackball control when the cursor has been moved into the window. The focus can be moved among windows either with the pointing device or from the keyboard, and the keyboard can be used for navigation among the components in the window with focus.

- **Implicit** – input focus model that activates the window as soon as the cursor is moved into the window. The focus moves with the pointer and cannot be controlled from the keyboard.

Interactive Control – the two-way communication process between the computer and the user, where the user inputs commands and the computer responds to the input.

Jitter – Variations in the geometric location of a picture element.

Joystick – a cursor control device consisting of a lever that can be used to position the cursor on the screen. The two basic types of joysticks, isotonic and isometric, are defined as follows:

- **Isometric** – a joystick where there is no perceptible movement but output is controlled as a function of the amount of force applied.

- **Isotonic** – a joystick where output is controlled by displacement of the control from the center position. This is also referred to as a displacement control.

Keyword Spotting – a speech recognition dialogue technique in which the system is trained/designed to recognize certain keywords that are embedded in redundant utterances of conversational speech and in noisy speech. This improves performance for spontaneous speech.

Lift-off – removal of the finger or touching device from a touch-sensitive display surface.

Linguistic Convergence – in a speech recognition interface, ensuring that the system prompts use the same terms that the user is required to employ for correct recognition.

Luminance – the intensity of light, especially emitting self-generated light, per unit area of its source. Amount of light per unit area reflected from or emitted by a surface. Measured in footLamberts.

Masking – One auditory signal interfering with the perception of another because of frequency interactions.

Mnemonics – a pseudo code or abbreviation for information, usually instructions, that is represented by symbols or characters intended to be readily identified with the information, e.g., “div” for divide.

Monocular – where one eye is presented with an image.

Night – the period from End Evening Nautical Twilight (EENT) to Beginning Morning Nautical Twilight (BMNT).

Non-Conformal Symbology – symbology that does not conform to or overlap any spatial analog in its far domain, e.g., symbology that is consistent with the vehicle body orientation rather than the horizon orientation.

Pan – process to change the displayed region (often of a map) by moving a fixed frame or window over the scene in any direction.

- **Discrete Panning** – changing the displayed region by moving a fixed frame or window over the scene discretely, skipping over inactive apace between.

- **Continuous Panning** – changing the displayed region by moving a fixed frame or window over the scene continuously in a regular and smooth manner.

- **Parameterized –**Variations of a particular sound to create a family of auditory icons. For example, related sounds can be used to represent target detection, acquisition and lock-on.

Prosody – accenting different syllables and words in the context of speech recognition.

Proximity Compatibility Principle – proposes that information sources that require “mental proximity” will be enhanced by more integrated or proximal display sources. This principle attempts to relate the processing of information characteristics and asserts that tasks in which “close mental proximity” is required (i.e., information integration) will be best served by more proximate displays. Tasks that require the independent processing of two or more variables, or the focusing of attention on one while ignoring the others, will be best served by more separate displays.

QWERTY – standard alphanumeric keyboard layout, as found on the standard keyboard going from top left alphabet letters (QWERT) to the first right-hand letter (Y).

Real Time and Near-Real Time (RT/NRT) Systems – systems where little or no delay exists between the time an event occurs and the time it is presented to the user, and where there is an operational requirement for the user to quickly recognize this presentation, comprehend its significance, and determine and execute appropriate action(s). Though there are subtle technical differences between an RT and an NRT system, based on the above definition, there is no perceived difference to the user, (e.g., weapon systems, particularly Army RT/NRT systems from the domains of aviation, ground vehicle, missile, and soldier systems).

Reticle – a system of lines or symbols used as a weapon-aiming cue in weapon system targeting, e.g., standby reticle, bombfall line, breakaway symbol, continuously computed impact line, continuously computed impact point, pull-up cue, sensor search area, solution cue, target designator, target range, target range rate, target aspect, and weapon boresight axis.

Scroll – process to change the displayed region by moving the scene (or data) beneath a fixed frame or window using scroll bars or scroll arrows.

Sonification – the process of representing numerical data, or other types of data, by non-verbal sounds.

Spatial Seperation – the apparent distance between two or more sounds. Used to maintain distinctiveness of auditory signals.

Speech Recognition System – capability of a system to convert spoken language to recognized words. The system captures human speech through a transducer that translates syllables, words, phrases, sentences, or statistical speech patterns, which are compared with acceptable speech to recognize the input speech as the best similar acceptable speech sound.

- **Speaker-dependent** – speech recognition system that requires some degree of training for the system to recognize differences due to individual differences in speakers' voice characteristics.

- **Speaker-independent** – speech recognition system that is designed to maintain recognition accuracy independent of differences in individual speech patterns.

Stereopsis – stereoptic vision, or the viewing of objects as a three-dimensional phenomenon of simultaneous vision with two eyes in which there is a vivid perception of distance of objects from the viewer (three-dimensional or stereoscopic vision).

Stimulus/Central Processing/Response Compatibility – The principle of stimulus/central processing/response compatibility implies that the designer should ensure that the display format used is congruent with the response modality required of the task, either verbal or spatial.

3-D localization – providing auditory cues that assist the operator in orienting towards the physical location of a source

Touch Screen – (hardware) a touch-sensitive input device that allows user to interact with a computer system by touching the display screen. Touch screens offer a method to interact with a system through the intuitive mechanism of pointing with fingers and to combine both input and visual feedback devices into one unit. Types of touch screens include:

- **Piezoelectric Touch Screen** – when the touch screen glass is touched, the individual forces at four piezo transducers are converted into electric signals that are digitized and then processed by a microprocessor.

- **Resistance Touch Screen** – a contact touch screen with a resistive coating and a transparent foil with an electrical conducting surface on one side are applied to the glass panel. When a finger actually touches the panel surface, the conducting surface of the foil touches the resistive membrane, and the touch location is determined from the measured voltage across the resistive membrane.

Touch Zone – an area around a control object, such as an icon, that enables an assigned action. The same as a hot zone.

Transaction Selection – refers to the control actions and computer logic that initiate transactions (interchanges) between computers and users.

Transilluminated Display – display that is illuminated from behind.

User-Centered Design – a design approach that focuses on improving system usability through iterative design and significant user involvement.

Visual Angle – is the angle subtended at the eye by the viewed object, that is usually given in minutes of arc as computed by the following formula:

$$\text{Visual Angle (Min.)} = \frac{(57.3)\,(60)L}{D}$$

where L = size of the object, and D = distance from the eye to the object.

Weapon System – a combination of one or more weapons with all related equipment, materials, services, personnel, and means of delivery and deployment (if applicable) required for self-sufficiency.

Widget – (in graphical user interfaces) a combination of a graphic symbol and some program code, e.g., a scroll-bar or button, to perform a specific function. Windowing systems usually provide widget libraries containing commonly used widgets drawn in a certain style and with consistent behavior; basic graphical object that is a component of a user-interface component.

INDEX

I

O

P

Q

R

T

U

Z