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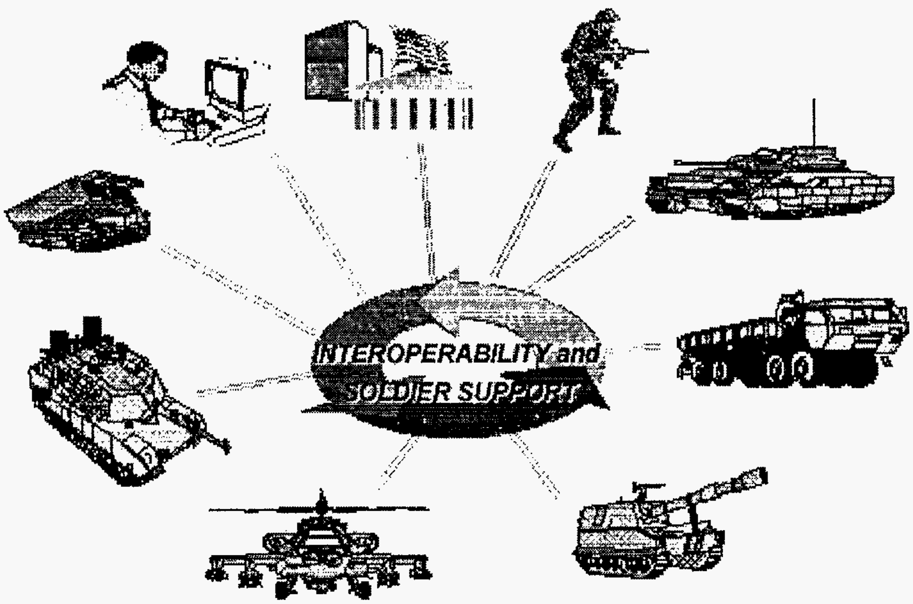
U. S. Army Weapon Systems Human-Computer Interface Style Guide



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U.S. Army Weapon Systems Human-Computer Interface (WSHCI) Style Guide, Version 1

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FOREWORD

A stated goal of the U. S. Army has been the standardization of the human computer interfaces (HCIs) of its system. 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 style guides. These include Volume 8 of the *Technical Architecture Framework for Information Management (TAFIM)*, 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). To address this need, DISC4 tasked the Pacific Northwest National Laboratory (PNNL)[1] to develop an Army weapon systems unique HCI style guide. This document, the U.S. Army *Weapon Systems Human-Computer Interface (WSHCI) Style Guide*, represents the first version of that style guide.

The purpose of this document is to provide HCI design guidance for RT/NRT Army systems across the weapon systems domains of ground, aviation, missile, and soldier systems. Each domain 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 domains.

This document was developed through a comprehensive review of the open literature and domain system documentation, as well as iterative review and input from a specially organized working group composed of representatives from each of the Army weapon system domains. 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 domain 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:

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Copies can also be downloaded from the following Website:

http://www.hqda.army.mil/webs/enterprise/hci/hci.htm

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.

The Working Group was particularly critical to the success of this effort through their valuable insights into the requirements of each of the domains 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.

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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 soldier and the machine. This has led to an increased potential for work overload of the soldier, 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 the following:

- Volume 8 of the *Technical Architecture Framework for Information Management (TAFIM)*, the *DoD HCI Style Guide* (257)
- *User Interface Specification for the Defense Information Infrastructure (DII)* (258)
- *Human Factors Design Guidelines for the U.S. Army Tactical Command and Control System (ATCCS) Soldier-Machine Interface* (261).

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 most appropriate to command, control, communications, computers, and intelligence (C4I) systems that use extensive windowing and that are deployed in shelters and tents. What these documents do not address very well are the unique requirements of real time and near-real time (RT/NRT) systems, such as weapon systems and particularly Army RT/NRT systems from the domains of aviation, ground vehicle, missile, and soldier systems. The following style guide is the first step in providing that missing guidance.

1.2 OBJECTIVE

The objective of this style guide, the *U.S. Army 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 Army 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* (257).
- address guidelines that are applicable across most or all of the Army RT/NRT domains.
- provide a starting point for developing domain-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 the domain 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. These will not be repeated in this document. Section 8.2 of the *Aviation System of Systems Architecture (ASOSA) Soldier/Aircrew Machine Interface Style Guide* (260) provides an excellent discussion of these methodologies, as does MIL-HDBK-46855, *Human Engineering Requirements For Military Systems, Equipment, and Facilities* (297). 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.

The four key principles of user-centered design are (adapted from 259):

- **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 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.

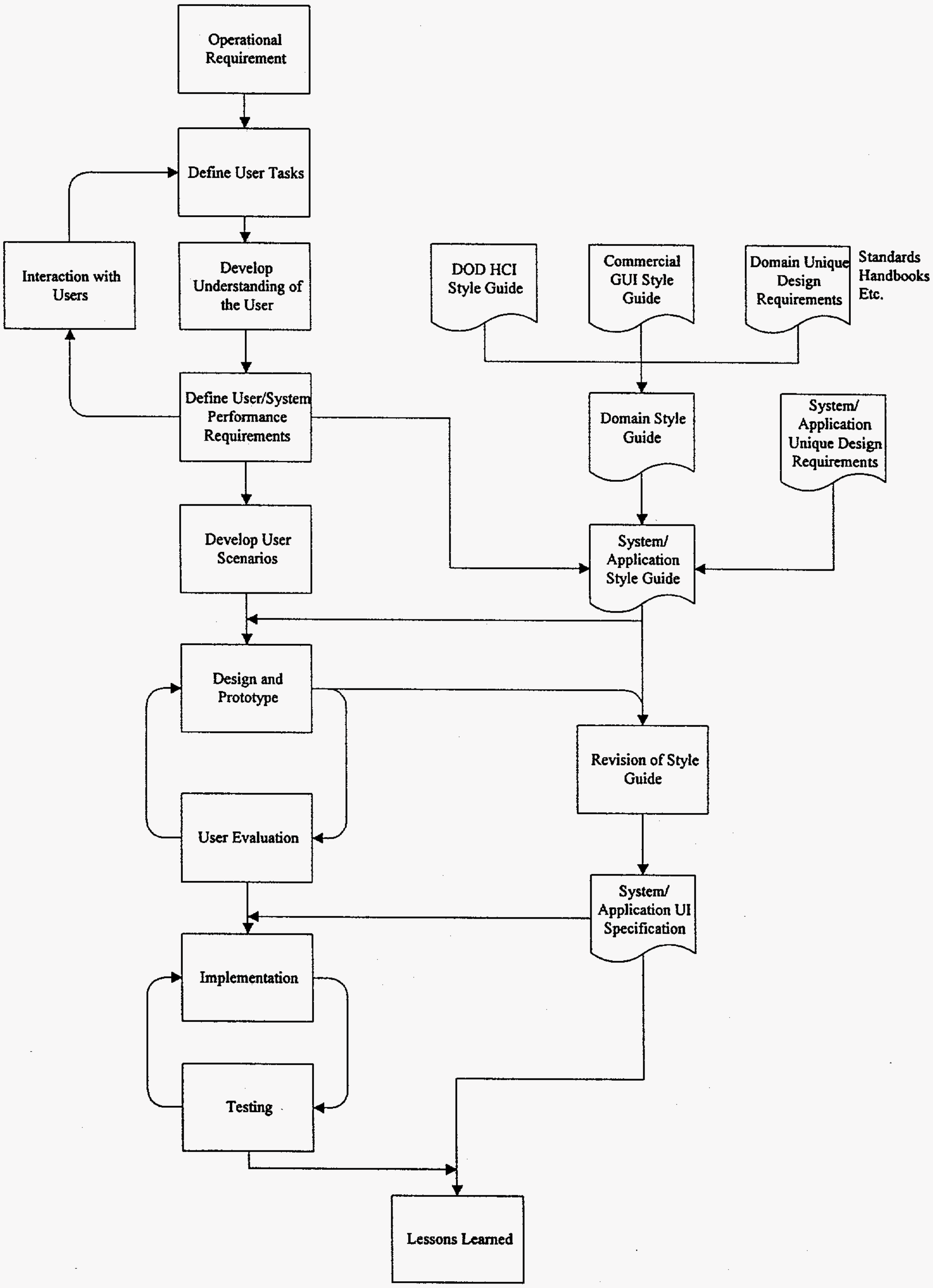

Figure 1.1 User-Centered Design and Style Guide Development Process

1.3.3 Use of the *WSHCI Style Guide*

The *WSHCI Style Guide* should be used as a starting point for developing domain-specific style guides. The relevant guidance from the *WSHCI Style Guide* should be expanded with domain-specific requirements and tailored to meet the requirements of the domain. Figure 1.2 illustrates this process.

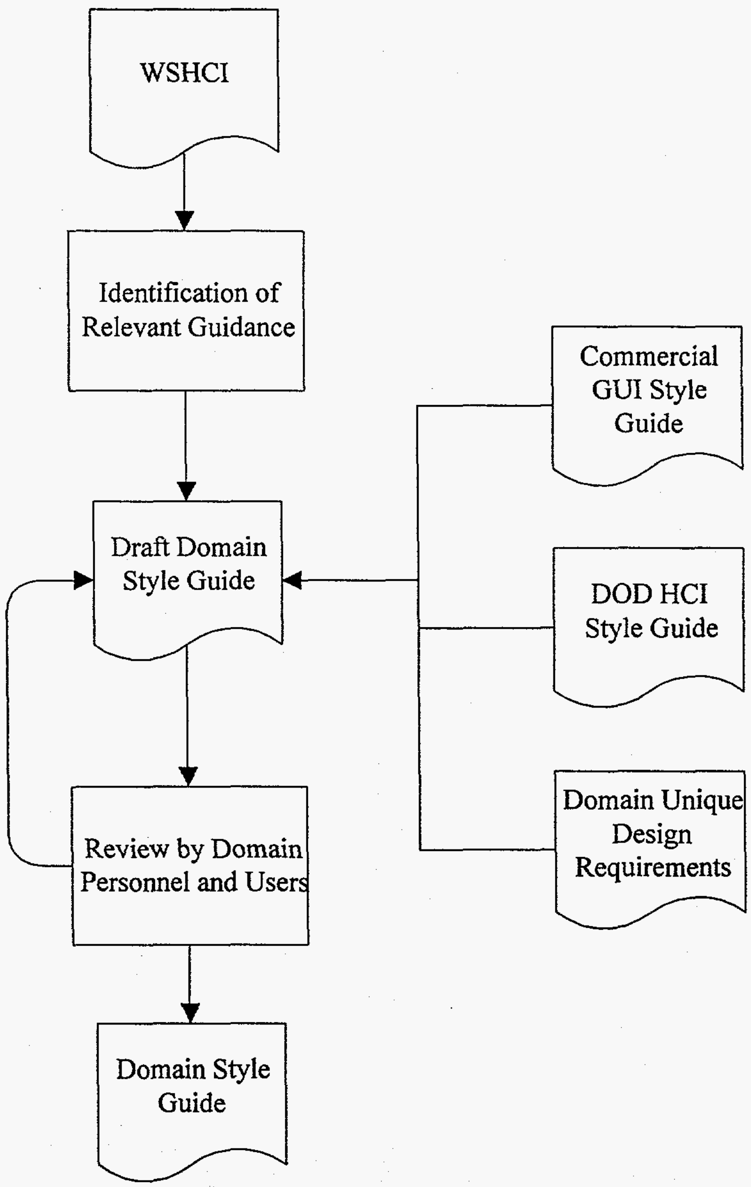

Figure 1.2 Process for Developing a Domain-Specific Style Guide from the *WSHCI Style Guide*

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 - Bibliography by Reference Number
- Appendix C - Alphabetical Bibliography.

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 DEFINITION

At the current time, 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 (261) 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. There is general concurrence, though, 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 army systems constitute the true RT/NRT system baseline.

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

> "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)."

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 generally are designed to provide users with immediate situational awareness of rapidly changing events and often include position location information (PLI) or related information, i.e., 2-D/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 mission awareness and focus in a rapidly changing environment.

2.3 REAL TIME AND NEAR-REAL TIME 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 soldier-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 soldier, such as those associated with moving vehicles (ground and aircraft) and impulse shock due to firing weapons, can make it difficult for soldiers 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* (256) for a discussion on the impact of vibration on human performance. Also, soldiers 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 soldiers to notice audible cues, alerts, and alarms.

- **Variable Ambient Lighting.** Variable ambient lighting conditions can make it difficult for soldiers to quickly focus–and therefore comprehend–visually presented data. This is particularly pronounced in environments where the soldier 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 soldiers 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 soldier performance.

- **Temperature Extremes**. Operation in extreme heat or extreme cold can impact both soldier and system performance. Soldiers, 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 soldier 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 work space and may also yield requirements for remoted controls and displays.

3.0 GENERAL GUIDELINES

The following section provides general guidelines for the design of HCIs for Army 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.

Soldiers 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 humans:

- flexible time-critical decision-making, for example, to engage or not to engage a target
- complex pattern recognition, for example, determining whether the target is a T-80 or a T-72 tank
- 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 soldier 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 soldier will always make the final input. For non-mission-critical tasks, permit the soldier to determine whether to let the computer make the decision. (57, 78, 88, 263)

3.2 RT/NRT DESIGN GOALS

The developer of an RT/NRT system should consider a number of high-level design goals, including the following:

- Minimize requirements for the soldier to focus on the internal environment, and maximize the focus on the external environment.
- Minimize cursor travel requirements across and between displays.

- Minimize switching visual focus between different displays during a procedure.
- Minimize the use of color, except where it enhances performance.
- Minimize the number of steps within a procedure.
- Minimize the amount of window sizing, placement, and manipulations.
- Minimize the rate and significance of soldier error.
- Minimize the requirement for soldier memory recall.
- Maximize the distribution of both physical and cognitive workload for individual soldiers and between crew members.
- Maximize the availability and speed of feedback, and keep the soldier informed about system processing.
- Maximize the use of error recovery.
- Maximize the use of similar procedures.
- Maximize the relevance of human-computer dialogue to the soldier's job.
- Maximize the use of standard and consistent human-computer dialogue.
- Maximize the use of preset, templated, and automated setup procedures.
- Minimize the display of information not directly relevant to the immediate decision the soldier must make.
- Maximize, for crew-served systems, the ability of the crew to directly share information and control functions between crewstations.
- Minimize the number of times the operator's hands need to leave vehicle controls. (105, 263)

3.3 DESIGN FOR CREW TASKS

3.3.1 Design for Simultaneous Complex Task Performance

Design the human-to-system interaction for crew performance rather than for individual performance, when complex tasks must be performed simultaneously. This limits situations where soldier performance is degraded because soldiers must perform simultaneous complex tasks, such as piloting a vehicle while concurrently recognizing and acting on target acquisition data. (87)

3.3.2 Design for Shared and Redundant Functionality

When crew can share functionality with control being exclusive to one crew member, provide a visual indication of who has control. When one crew member may have to take over control for another injured crew member, provide the capability for an override of any lock-out of control functionality. (263)

3.4 DESIGN TO HUMAN LIMITATIONS

Design the user interface for RT/NRT systems to ease demands on user perception, decision-making, and manipulation. This helps avoid over-stressing the soldier because limitations in human sensory, perceptual, and cognitive abilities have been considered. Designing to human limitations is particularly important for decision support systems. (57, 61, 67)

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 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. (57)

3.5.2 Mission-Critical Function Execution

Design the HCI so that mission-critical functions require a minimum number of actions to execute. (57, 73)

3.5.3 Redundant Methods for Execution of Mission-Critical Functions

Provide the soldier 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 soldier which method is secondary. (57, 73)

3.6 RETAINING CONTROL

Ensure that the soldier retains control of the system so that system status, e.g., target engaged or location is always known and the soldier has final determination of system actions. (57)

3.7 CONTROLS AND DISPLAYS

3.7.1 Control Input Data Feedback

Design the system so that the soldier receives clear, unambiguous, and rapid feedback for control data being entered and that any data displayed does not mislead the soldier with regard to nomenclature, units of measure, sequence of task steps, or time phasing. (165)

3.7.2 Control and Display Compatibility with Soldier Skill Levels

Ensure that the design of controls and displays is compatible with the appropriate soldier skill levels as well as tailorable for differing skill levels, e.g., novices versus experienced users. Provide "Help" functions to augment skill levels. (165, 263)

3.7.3 Control and Display Relationships

Ensure that control and display relationships are straightforward and obvious to the soldier and that control actions are simple and direct. (165)

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. (264)

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. (264)

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. (264)

3.7.3.4 Simultaneous Use

Ensure that, when the soldier 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. (264)

3.7.3.5 Minimization of Eye Focus Shifts

Design the soldier-system interface to minimize visual shifts between displays and controls—as well as displays and displays—that require the eye to refocus. (263)

3.7.4 Multifunction Displays

Provide multifunction displays, where appropriate, that allow access to any of the system functionality, rather than dedicated displays—with redundancy to ensure that system safety is not compromised. This reduces the number of physical controls and displays required where control panel surface is limited (57). Multifunction displays should be designed 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."

3.7.5 Design for Left and Right Dominance

Consider, when designing the controls and displays for some types of weapon systems, that soldiers may be either left- or right-handed or eye dominant. (263)

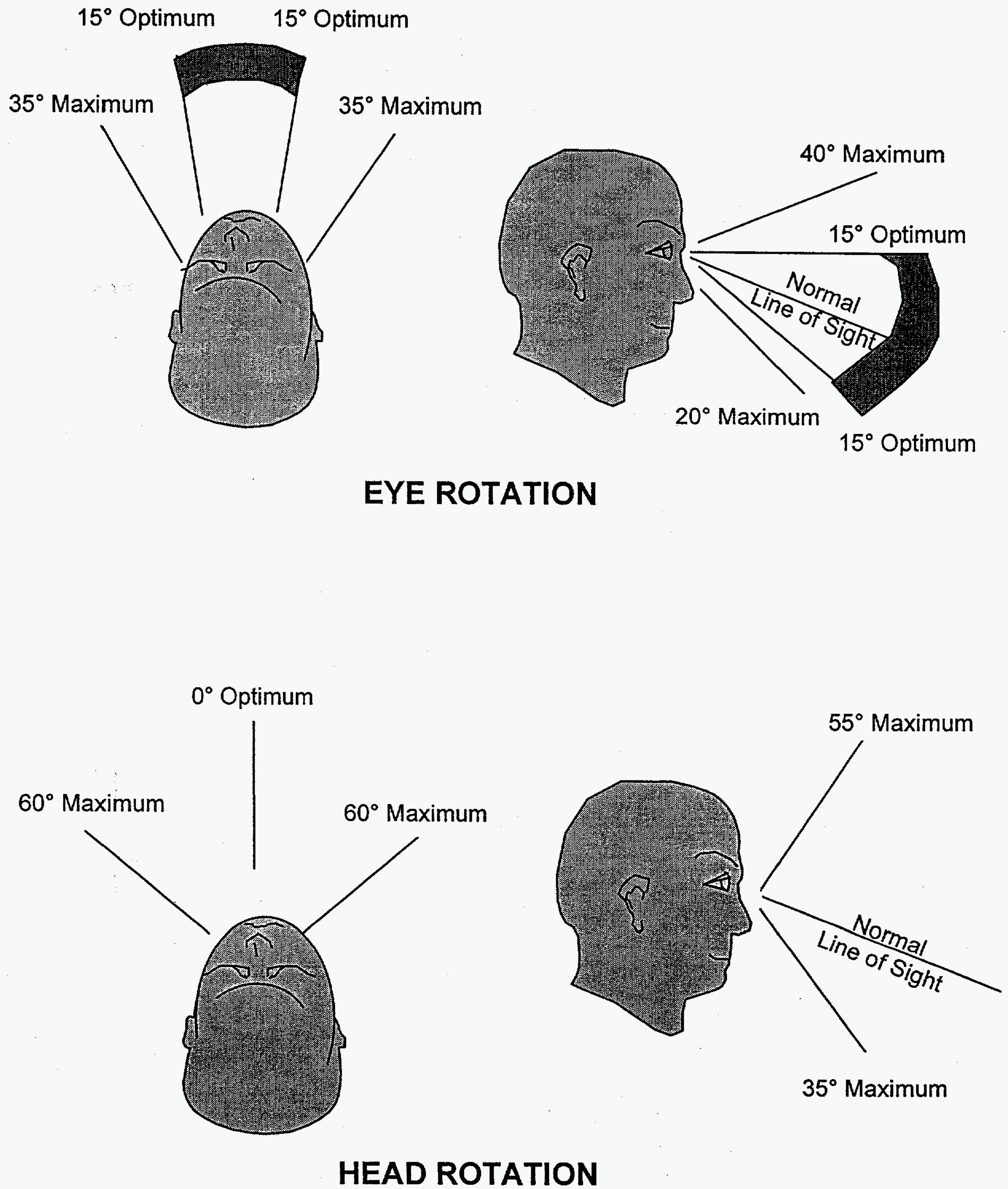

FIGURE 3.1 Illustration of the Primary Visual Zone

Adapted from MIL-STD-1472 (264)

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. (165)

3.9 SYSTEM SET UP 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, not during real-time operations, through methods such as autofilling databases or data entry templates. Ensure that the design allows modification of the data to reflect changes as the mission progresses. (78, 263)

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. (165)

3.11 DISPLAY RESPONSE TIMES

Ensure that display response times, e.g., latency, update rates, jitter, etc., are consistent with operational requirements. (165)

3.12 MESSAGING

3.12.1 Message Queue

Queue incoming messages by priority and time of receipt, and provide the capability for the soldier to quickly view summary information on the messages. Also provide the capability for the soldier to sort messages by time, type, author, or other way that better meets an operational need for message display. (213, 263)

3.12.2 Automatic Verification of Message Format and Content

Provide automated processes to verify message formats and content, and allow the soldier to verify that messages have been sent and received. (213)

3.12.3 Message Received Alert

Provide a means for alerting soldiers 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 soldier must use that zone to place or align a weapon reticle on a target. (213, 263)

3.12.4 Message Management

Provide the soldier 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 soldier interaction with the messaging system. (263)

3.13 DECISION SUPPORT SYSTEM DESIGN

Design decision support systems for RT/NRT systems to:

- Allow the user to monitor the on-going decision-making process, to facilitate intervention when necessary. (3)
- Be consistent with the user's expectations and mental model of the battle management process and the tactical problem at hand.

Soldier tasks when automated decision support systems are used include monitoring, modifying, approving, and implementing the outcomes. (3)

3.14 DESIGN FOR EMERGENCY SHUTDOWN AND RECOVERY

Design RT/NRT systems to provide for system emergency shutdown, initiated by either the soldier or the system. System-initiated emergency shutdown should provide a warning indicating the source or event initiating the shutdown and allow confirmation of shutdown actions. Emergency shutdown should preserve system configuration information and data to facilitate recovery. (263)

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 that are deployed in shelters such as air defense systems, which have more workspace and are not operated "on the move," tend to employ full QWERTY keyboards and track balls, as well as other technology. Soldier systems tend to employ unique keypads and cursor control devices attached to the soldier'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* (257)
- *User Interface Specification for the Defense Information Infrastructure (DII)* (258)
- Section 11.4 of the *Handbook of Human Factors* (269).

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 soldier while on the move, either in a vehicle or dismounted. (263)

4.1.1.1 Design for Operation on the Move

Consider that the soldier'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. (73, 248)

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. (248)

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 soldier 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. (73)

4.1.1.4

Controller Use

Consider using a two-handed controller when the soldier must perform a compensatory tracking task in a moving vehicle. This controller may allow the soldier to attenuate the effects of vibration on tracking accuracy. See Figure 4.1 for an illustration of a two-handed controller. (70)

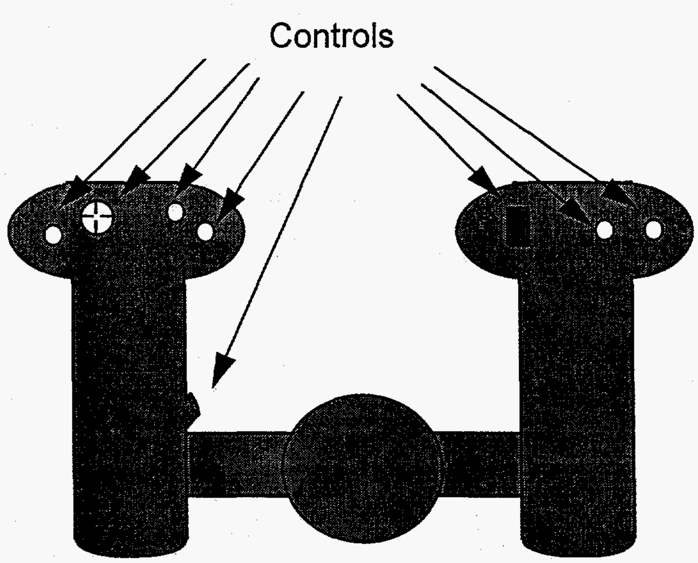

Figure 4.1 Illustration of a Two-Handed Controller*

** Figure 4.1 was rendered from a Cadillac Hand Control Unit schematic.* (70)

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 (105). 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 soldiers to take their hands off the control stick and/or move forward, possibly causing poor vehicle handling performance and potential accidents. (248)

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. Data suggests 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. (84, 256)

4.1.4 Control Sensitivity

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

- Use lower control sensitivity for RT/NRT systems where soldiers must operate in environments containing vibration. The lower control sensitivity should not negatively impact use while the soldiers are wearing gloves (cold weather, mission-oriented protective posture [MOPP], or fire retardant). (256, 263)

- Provide the soldier with the ability to set the velocity sensitive gain for pointing devices to control cursor response to pointing device movement. This enables better control depending on the task needs. Ensure that the soldier can not set the sensitivity to the off position. (105, 263)

4.1.5 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. (295, 296)

4.1.6 Direct Manipulation Keypads and Keyboards

Design keypads and keyboards that are visually represented on a display screen with input performed by a pointing device in accordance with the guidance contained in Paragraph 6.3, "Touch Screen Keyboards." (263)

4.1.7 Appropriate Hand Access to Controls

Locate controls where one hand will be used consistently for input, such that the controls are located to ensure that the soldier does not have to cross hands or arms to use them. (263)

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. 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 touchscreens, 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. (257)

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. (257)

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 there is no function currently available to the key, it should be grayed out or blank. (257)

4.2.1.4 Feedback for Inappropriate Key Activation

Provide visual, audible, and/or tactual feedback to a soldier who tries to use an inappropriate or unavailable function key. (54)

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. (165)

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. (57)

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. (57)

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. (54)

4.2.1.9 Function Key Labeling

Ensure that function keys have appropriate contextual labels that represent the soldier's missions and tasks. (263)

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. (165)

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*. (257)

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. (165)

4.2.3 Multifunction (Programmable) Keys

Multifunction keys allow users access to variable system functions, depending on system mode or level within an interactive dialog. The available function of a multifunction key is communicated to the user through variable labeling located on or adjacent to the key. Multifunction keys are also referred to as programmable or variable function 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. (165)

4.2.3.2 Multifunction Key Feedback

Provide the soldier 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. (57)

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 soldier. (165)

4.2.3.4 Labeling of Multifunction Keys without Functions

When a multifunction key has no function associated with it, make sure that it is blank. (57)

4.2.4 Function Keys on Screen Displays (Soft Keys)

Soft keys are objects displayed on a display screen that correspond to multifunction keys. As the function associated with the multifunction key changes, the labeling of the soft key also changes.

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. (257)

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. (257)

4.2.4.3 Redundant Activation of Soft Key Function

Ensure that the soldier is able to activate the function represented by the soft key, by using the key or by means of a pointing device, such as a track ball. (257)

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. (257)

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. (257, 263)

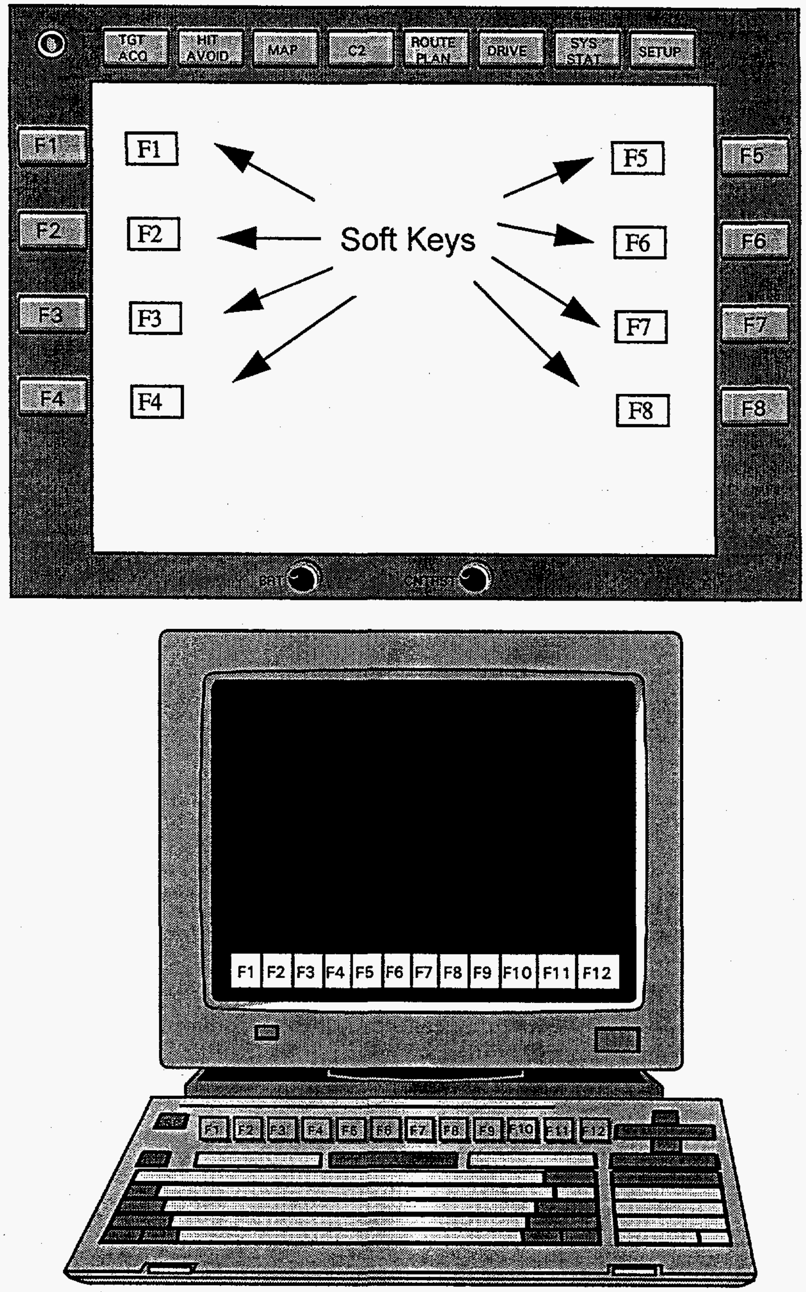

Figure 4.2 Illustration of Soft Keys

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5.0 GENERAL GUIDELINES FOR DISPLAYS

5.1 GENERAL

5.1.1 General Display Design for RT/NRT Systems

Design displays to conform to these general guidelines:

- Present information in such a way that any failure or malfunction in the display or its circuitry will be immediately obvious.
- Group displays functionally or sequentially, so the soldier can use them more easily.
- Ensure that all displays are properly illuminated, coded, and functionally labeled—including symbols.
- Ensure that controls and displays are located in the same visual area.
- Ensure that failure in the display does not cause failure in the associated equipment.
- Display graphics to the resolution required for the mission. Excess graphics may blur in vibrating environments.
- Ensure that the soldier can easily view displays with minimum head or eye movement.
- Display information in the appropriate sequence for the mission or task currently being performed.

(165, 263)

5.1.2 Cues for Detecting Changes in Vehicle Attitude

Provide visual cues, such as color shading or patterns, when soldiers must detect changes in attitude from a display. Provide pitch lines and numbers where exact information is required. (65)

5.1.3 Alerting Display

Ensure that alerting displays clearly indicate the urgency of the message and whether that message requires a response from the soldier. Also ensure that symbology used for alerting conforms to the general criteria contained in Paragraph 12.6, "Symbology." (213)

5.1.4 Selection of Alerting Methods

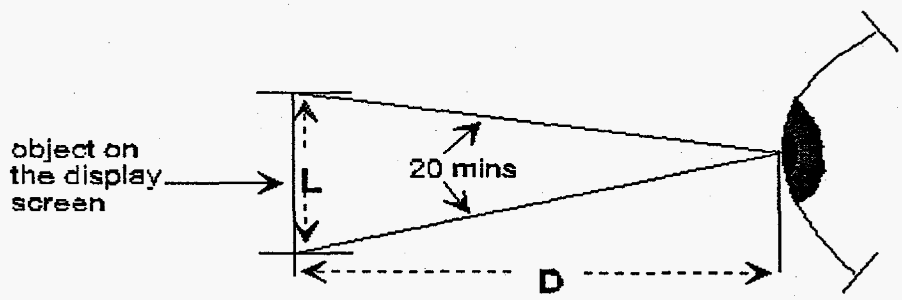
Ensure that the method(s) used to alert the soldier, potentially disrupting the soldier's current task to process the alert, are contingent on the urgency of the alert and the need to disrupt the ongoing soldier task. The methods used should not conflict with existing signals in the system environment and should not compromise survivability requirements. (195, 263)

5.1.5 Character Size

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

- Ensure that alphanumeric characters subtend a minimum of 15 minutes of visual arc, and complex shapes such as symbology subtend a minimum of 20 minutes of arc. Figure 5.1 illustrates how this is calculated. Symbology should be appropriately sized upward for vibrating environments. (263, 264, 268)

- Ensure that alphanumeric character size for displays mounted in shelters are 1/200 of the viewing distance. (105, 257)



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

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

Figure 5.1 Visual Angle Subtended

5.1.6 Font Style for Legibility

Design fonts to facilitate legibility of alphanumeric characters. In general, legibility is a function of the height-to-width ratio, strokewidth, basic vertical orientation of the characters, and the lack of extraneous detail such as serifs. Keep in mind that legibility refers to individual characters and does not necessarily improve comprehension of words and phrases. (256)

5.1.7 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." (153)

5.2 DISPLAY LIGHTING

Requirements for display lighting may vary among domains. 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. Displays to be used in direct sunlight should be readable in a combined environment consisting of up to 10,000 footCandle (fC) diffuse illumination and the specular reflection up to 2000 footLamberts (fL) glare source. During night operations, display lighting should provide the soldier with a capability to rapidly and accurately obtain required display information with unaided vision. Display lighting should not have an adverse effect on external unaided night vision or, when required, on the soldier's capability to obtain required information external to the vehicle while employing night vision goggles (NVGs). (58, 266)

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 5.1 for the recommended contrast levels.

Table 5.1 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	≥4.66, to make at least six √2 gray scale ratio shades visible ("off" counts as one)
Otherwise	≥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

(58, 266)

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. (58)

5.2.2 Display Brightness Adjustability

Design displays so that the display brightness is soldier-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. (58, 78)

5.2.3 Brightness of Illuminated Indicators

Ensure that the brightness of illuminated indicators, e.g., simple indicators or transilluminated displays, is at least 10% greater than the immediate surface on which they are mounted. When a two-level indicator is used, the difference between the two levels of brightness should be approximately 2:1. Where glare must be reduced, the luminance of transilluminated displays should not exceed 300% of the surrounding luminance. (165)

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:

- **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.

- **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.

- **Soldier Visual-Adaptation**. Ensure that display luminance is compatible with the soldier's requirement to detect low-level signals or targets in the external visual environment, to perceive faint signals on a 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.

- **Conspicuity and Attention-Demand Requirements**. Ensure that the luminance of alerting signals provides the required alerting to ensure that the soldier 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.

- **Distraction**. Ensure that luminance levels do not dazzle or otherwise distract the soldier in a manner that could be detrimental to safe, efficient system operation. (165, 263)

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. Vibration has the following impact on display readability: Under 10 hertz (Hz) vibration, readability is least affected when the soldier and display device are vibrating at the same or similar frequencies. (81, 83, 256)

6.0 TOUCH SCREEN DESIGN

Touch screens offer soldiers 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.

6.1 GENERAL GUIDELINES

6.1.1 Touch Screen Use

Consider using touch screen input devices where data entry is limited, flexibility of layout or language is required, display and input device will be in a confined area, or hardware durability is a concern. Be aware of the potential fatigue factor associated with frequent use of a touch screen. (217, 263)

6.1.2 Operational Environment and Touch Screens

Be aware when designing touch screen applications for Army RT/NRT systems that the operational environment may have dust, oil, and hydraulic fluid present, which may be picked up on the soldiers' hands and conveyed to the touch surface. (72)

6.1.3 Touch Screen Application Development

Build application screens keeping 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. (170, 263)

6.1.4 Inadvertent Activation Protection

Provide a method that will preclude inadvertent activation due to casual touching. (170)

6.1.5 Touch Screen Control Object Interaction

6.1.5.1 Cursor Movement for Finger Removal Activation

Note that where activation of a control object using touch is performed by removing the finger from the control surface, the initial touch of the control should cause the cursor to relocate onto the control. This causes the control to be selected, unless safety or critical mission requirements are associated with the control. (102)

6.1.5.2 Finger Removal and Control Object Selection

Note that when activation is performed by removing the finger from the display surface, and if the soldier's finger slides off the control before removing it from the screen surface, no selection should take place. 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 the default position. (102)

6.1.5.3 Visual Feedback for Control Object Selection and Activation

Provide visual feedback to the soldier 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. (72)

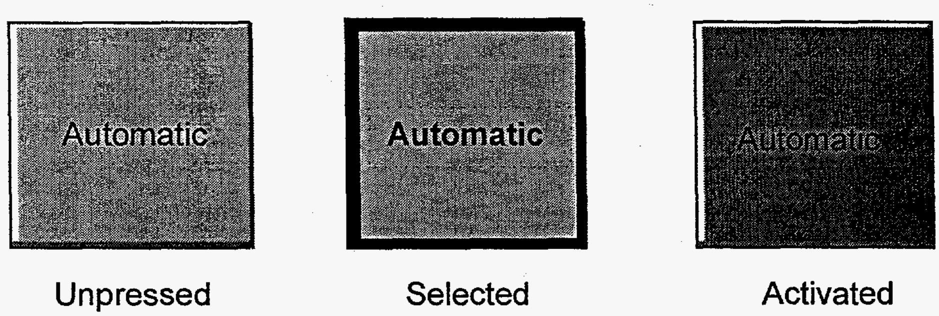


Figure 6.1 Illustration of Visual Feedback for Touch Screen Control Objects

6.1.6 Hardwiring of Critical Safety Controls

Consider using hardwired controls for critical safety input rather than touch screens. (170)

6.1.7 Touch Screens and Autocompletion Capability

Design touch screens through which the soldier must perform data entry with an autocompletion capability to reduce keystrokes, fatigue, and errors. The soldier 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 soldier. (249)

6.1.8 Touch Force Required for Piezo Electric and Resistance Touch Screens

Ensure that touch force is low for touch screens using technologies such as resistance and piezo electric to reduce fatigue. In general, resistance for these types of touch screens should be similar to that for alphanumeric keyboards. See Table 6.1. (176, 264)

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

6.1.9 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. (102)

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.

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 soldier 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 soldier can adjust finger location and lift to activate. (102, 170, 217, 219)

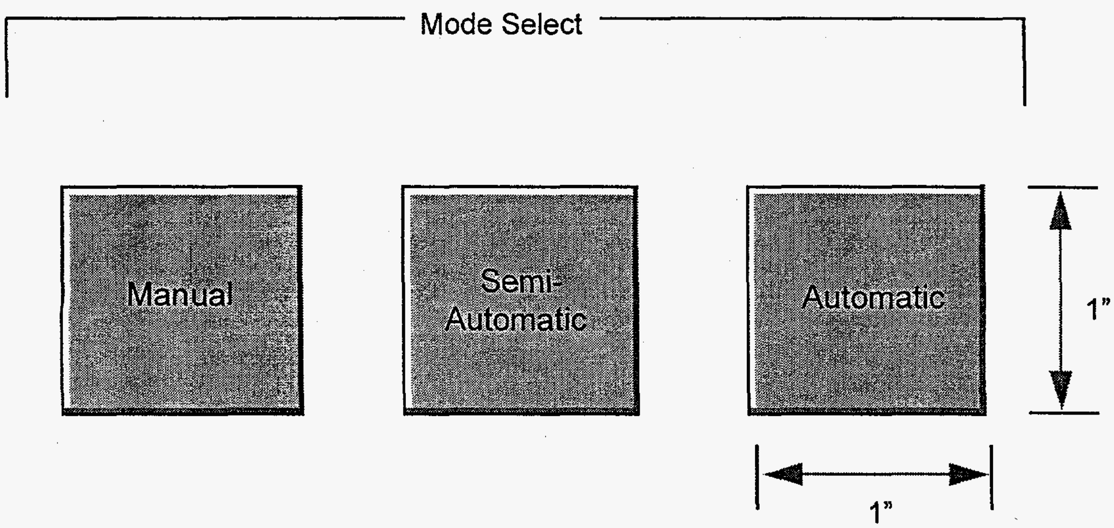


Figure 6.2 Touch Screen Control Object Size

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 soldiers tend to touch below an object, for possible misregistration between the video and touch screens, for wearing of gloves, and for sloppy touching. (170, 249)

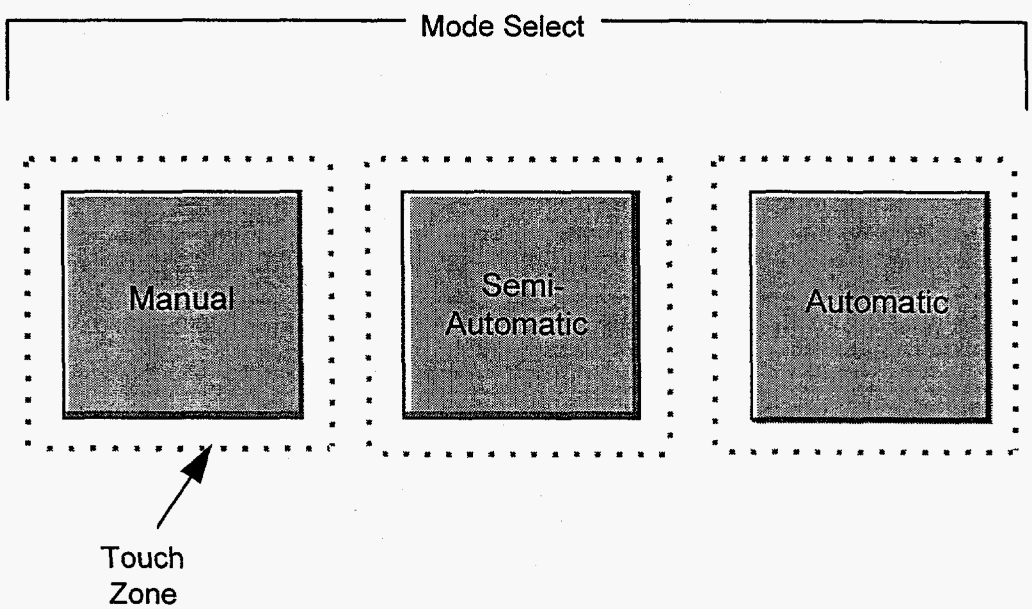


Figure 6.3 Illustration of Touch Zone Size

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. (102)

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. (221)

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. (221)

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7.0 HELMET MOUNTED DISPLAYS

Helmet Mounted Displays (HMDs) are small, high-resolution displays that can replace cathode ray tubes 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. Section 8.6 of the *ASOSA Soldier/Aircrew Machine Interface Style Guide* (260) provides a good general discussion on HMDs that is germane to other domains. 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

Consider, for situational assessment, using an HMD for:

- tracking the soldier's head position and slaving sensors and weapons to the helmet line of sight
- displaying combat and critical vehicle/system status information. (13)

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. This will reduce distracting clutter. (57)

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 this 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. (118, 263)

7.1.4 Multi-Image HMD Design

Note that 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 for minimum impact on the user:

- FOV a minimum of 40 degrees
- center of gravity and weight that minimizes risk of injury and fatigue
- real-world transmission greater than 70%
- one design for both day and night use
- symbology contrast greater than 1.2 in daylight without using a visor
- night vision goggles (NVG) gain greater than 2000
- compatible with required NBC equipment
- 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 soldier and system through the loss of night vision. (181, 263)

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:

- rotor chop/sun modulation
- reflections/ir energy sources
- limited motion box/helmet surface integrity
- presence of cockpit/vehicle metal/changing metal location/magnetic fields. (198)

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:

- Defined obstacle edges are the most important requirement for navigation.
- High contrast enhancement, absence of blur, and good picture stability have to be achieved for visual recognition or identification of targets.
- Good uniformity of the picture background is important in the case of small target visual detection.
- Uniform measurement systems are important when using different image sources. (158, 263)

7.1.7 Use of Head-Up Display (HUD) Lessons Learned for HMD Design and Development

When designing or developing HMDs, consider the lessons learned during HUD technology development. Many parallels between the two technologies can help the designers of HMDs. Examples include the following:

- Add symbology only if it measurably contributes to the primary objectives of the HMD, improves human performance, reduces human workload, and increases hazard detection.

- Avoid using an HMD as the primary vehicle control reference, as this will likely create visual clutter and user confusion.

- Retain a centrally located primary vehicle control reference using a virtual HUD, HUD, or head-down display (HDD).

- Do not use symbology in the off-axis of the HMD that looks like primary vehicle control reference information. This will avoid misinterpretation.

- Display symbology that represents secondarily important information in an alerting role, rather than having it constantly visible.

- Note that world reference displays, such as conformal symbology, provide good off-axis external reference cueing. Control-display confusion should not occur because the symbology response is correct for the control input. (155)

7.1.8 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. (153)

7.2 BINOCULAR HMD DESIGN

7.2.1 Use of Binocular HMD Design

Consider using binocular stereo displays where soldiers 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. (238)

7.2.2 Partial Binocular-Overlap Imagery

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

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

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

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

- **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. (109, 201)

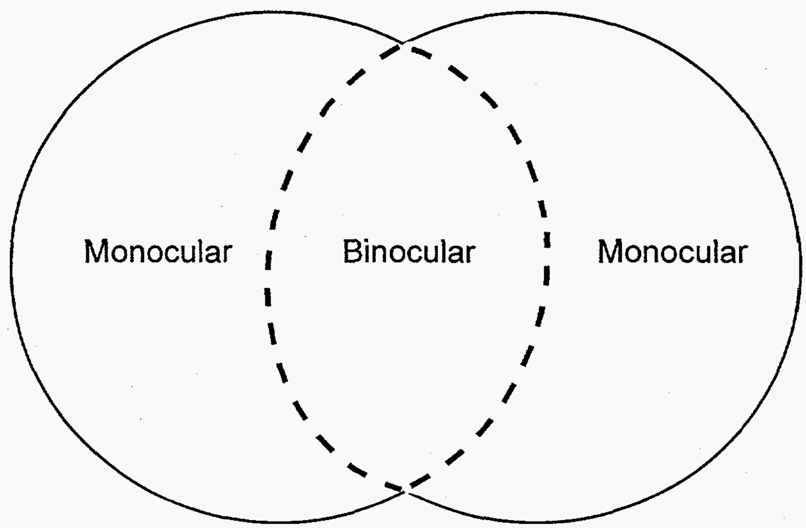

Figure 7.1 Illustration of Partial Binocular-Overlap

7.2.3 Adjustability

Consider providing soldiers 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. (263)

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. (187)

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. Where possible, control sensor orientation by eye movements. Use two integrated sensors to provide an extra margin of safety when using binocular HMDs. (187)

7.2.6 Display of Symbology to Both Eyes

Ensure that HMDs are capable of displaying symbology to both eyes for binocular applications. (187)

7.2.7 Bi-Ocular HMD Use

Consider the use of bi-ocular versus binocular displays in HMDs where stereoscopic depth judgments are not critical. Bi-ocular displays present each eye with an identical image. (190)

7.3 MONOCULAR HMD DESIGN

7.3.1 Use of Monocular HMDs

Use monocular HMDs when the soldier 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 (243), they may cause binocular rivalry for night video displays and are therefore undesirable at night. (138, 254, 255)

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 soldier performance is not compromised. (138, 263)

7.4.2 Adjustment of HMD Optics

Provide control over optics adjustment during operations, specifically interpupillary distance (IPD), eye relief, and vertical positioning. A 28-34mm eye relief has been found to be acceptable, depending on overall system design. (138)

7.4.3 HMD Optics Transmissivity

For night use, design HMDs to 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). For day use, provide 70% to 80% transmissivity to avoid reducing target detection performance. (138, 254)

7.5 FIELD OF VIEW

There are arguments against the use of NVG HMDs because of their narrow FOV, which can block the soldier's use of peripheral vision cues (153). 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. (150)

7.5.1 Field of View Size

Design the HMD with the following FOV:

- Minimum FOV - 30 degrees. This is most appropriate for day-optimized and video sensor HMDs. (138)
- Desired minimum FOV - 40 degrees. (138, 187, 254, 255)

7.5.2 Slaving Sensor Devices to HMDs

Consider, when widening the soldier's FOV by slaving a sensor device such as a FLIR to the line of sight (LOS) of the HMD, that time lags between the soldier'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 soldier may tend to minimize head rotations, which diminishes the wide-angle coverage provided by the slaving system, thereby impairing search performance and spatial orientation. (202)

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. Ensure that the designer is careful not to over-clutter the central part of the display, which can degrade viewing of the outside world. (138, 263)

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. (254, 255)

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 soldier performance. (70)

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. (254, 263)

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. (255, 265)

7.6 PHYSICAL DESIGN OF HMDs

7.6.1 General

Ensure that HMD designs:

- are comfortable and do not restrict head movements.
- display capability that does not otherwise compromise safety, e.g., impact and penetration protection, eye and hearing protection. (138, 186, 263, 265)

7.6.2 Weight

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

- Ideal weight is between 3.5 lb. and 3.99 lb. or less to reduce soldier fatigue. (147, 244)
- Night-equipped HMDs, which will weigh more than day HMDs due to additional optics, should weigh less than 4.5 lb. (186)
- Total head-supported weight (e.g., helmet, HMD, etc.) should be less than 5.3 lb., because soldier performance is degraded in vibrating environments after 1 hour with greater weights. (138)

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. (186)

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. (153, 187, 265)

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:

- reflect the light projected from the optical assembly to the soldier's eye.
- keep the size of the solution envelope as small as possible, in order to keep to a minimum the limitations on soldier's head movements in restricted space. (200)

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. (200)

7.6.4.3 Handedness and HMD Visors

Where visors are used on HMDs, ensure that visors are operable with either hand. (186)

7.6.5 HMD Design for Safety

Consider the following safety concerns when designing an HMD:

- Design the HMD used for daytime operations so that it does not obstruct the soldier's view of the outside scene. Otherwise, the HMD can have an impact on the soldier's ability to safely perform tasks. Ensure that, if one eye is obstructed, the other has a clear view. (254)

- 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.
- Ensure that cables running to the helmet have a quick disconnect.
- 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. (265)
- Eliminate cables, snaps, etc. from snagging or interfering with other equipment or crew operations. (263)

7.7 VIBRATION AND HMDs

7.7.1 Design for Vibrating Environments

Design HMDs with the understanding that vibration may be present in the soldier's environment. In particular, human task performance on tracking tasks is the worst at 4Hz. (70)

7.7.2 Attenuation of Head Motion

If HMDs are used in vehicles, include engineering features that attenuate head motion in the 4Hz range, particularly if the seating position requires head support. This will improve tracking performance and reduce the chances of motion sickness. (70)

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. (185)

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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 soldier looks through the glass, both the scene in front of the vehicle and the HUD projected information are viewed. This arrangement allows the soldier 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 soldiers 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 (179). Additional information may be found in the following documents:

- *Improvement of Head-Up Display Standards, Volume 1: Head-Up Display Design Guide* (270)
- *Human Factors Aspects of Using Head-Up Displays in Automobiles: A Review of the Literature* (271)
- *Head-Up Displays for Automotive Applications* (272).

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 a HDD are the reduction of eye movement and the reduction of eye refocusing. (119, 134)

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. (153)

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. (63)

8.1.4 Perceptual Segregation of Near and Far Domain Cues

If a task requires that the soldier 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. (126)

8.1.5 Depth Cues

Use depth cues such as stereo 3-D, aerial perspective (symbol becomes more gray or less bright with depth), and familiar object size to improve soldier performance, e.g., the speed and accuracy in determining locations of friendly, enemy, and unknown aircraft. (64)

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. (63)

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. (270)

8.1.8 Nonreflectivity of HUDs

Ensure that HUDs are designed to be nonreflective to the outside world, to reduce any external visual signature. (263)

8.1.9 Placement of HUDs

Place HUDs as close as possible to the horizontal center position and eye level relative to the soldier. This enhances user performance. (123, 263)

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. (179)

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. (153)

8.2.2 Information Origin Certainty

Design symbols and information presented on a HUD to ensure that soldiers have no uncertainty about the origin of the information being displayed. (153)

8.2.3 Overuse of Non-Conformal Symbology

Avoid the overuse of 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 soldier scanning can be neutralized or defeated by too much clutter from non-conformal symbology. (128)

8.2.4 Declutter Capability

Provide the soldier with the capability to declutter the symbology and/or information displayed on a HUD. (270)

8.3 USE OF COLOR IN HUDs

8.3.1 Use Color Sparingly

Use color sparingly in HUDs. Although soldiers like color subjectively, color appears to have little positive impact on performance when using HUDs. Trade-offs must be made by the designer in terms of costs versus a potential minimal performance enhancement. (151)

8.3.2 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. (263)

8.3.3 Color Control and HUD Background

Provide the soldier with the capability to change the color codes and contrast to adjust for varying backgrounds. (263)

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. 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. Data is 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. (178, 270, 271, 272)

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. (231)

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. (130)

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. (270)

8.6.2 Jitter

Ensure that symbols have no discernible jitter. Jitter is considered motion at frequencies above 0.25 Hz. (270)

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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 and voice synthesis that are intended 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 may not understand system interfaces and input devices or when users may lack certain written language skills.

In recent years, the performance of speech recognition systems has improved dramatically; and performance on tasks such as command and control, simple data input, and text dictation for known subject areas has achieved commercial success (290). For tasks such as the recognition of simple isolated English commands or digits, speaker-independent error rates may be as low as 0.3%. Speaker-independent, continuous speech applications that use restricted vocabularies of 1,000-20,000 words have been associated with error rates in the range of about 3% to 7% (290). However, error rates may be 50% or higher for spontaneous conversations over communications lines such as telephones.

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 systems are likely to be used. Some of the guidelines based upon these factors are discussed in this section.

9.1 GENERAL

9.1.1 Soldier Request for Repeat of Signal

Provide the soldier with the capability to request a repeat of the nonverbal or verbal auditory signal. (105)

9.1.2 Redundant Cues for Auditory Signals

Ensure that auditory display signals are always accompanied by a redundant, visual indication. (57, 105)

9.1.3 Redundant Cues for Visual Signals

Use auditory cues to augment visual cues for out-of-tolerance conditions, when soldiers are monitoring rather than actively controlling automated actions. (90)

9.1.4 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. (57)

9.1.5 Auditory Localization of Signal

Consider using 3-D localization of the auditory signal to cue the soldier on the direction from which a target or signal is coming, or to help localize where the soldier needs to focus attention. (57)

9.1.6 Lack of Data Transmission Interference

Ensure digital data transmission does not interfere with voice communication or auditory signals and is not masked by background noise. (75)

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 soldier under mission conditions. (105, 263)

9.2.2 Control of Auditory Signal

Provide the soldier with the capability to control or disable the audio signal volume. However, do not allow the disabling of mission and safety critical signals. Design the volume control to ensure that the soldier can not inadvertently decrease the volume level to where it is inaudible. 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-1472* (264). (57, 105, 263)

9.2.3 Limits to Auditory Signal Categories

Limit the number of auditory signal categories to no more than six, where absolute identification is required. (165, 263)

9.2.4 Selection of Tonal Frequencies and 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 hertz. (165)

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. (165)

9.2.6 Speech Synthesis

Ensure that synthetic speech warnings used in conjunction with visual warnings are synchronized. (92)

9.3 SPEECH RECOGNITION

There are two basic types of speech recognition systems: speaker-dependent and speaker-independent. Most speech recognition systems with large recognition vocabularies are speaker-dependent, requiring some degree of training for the system to recognize differences due to individual differences in speakers' voice characteristics. Examples include commercial dictation products. 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 voice 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.

Consider the following when designing a speech recognition system:

- 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.

- 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. (290)

- 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), degraded modes such as wearing MOPP equipment, etc.

- Design speech systems to degrade gracefully when operating under unusual conditions, and consider methods for automatically adapting system characteristics to changing conditions and new speakers.

- 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.

- 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.

- 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.

- Ensure that the speech system is able to recognize the keywords out of the signal. 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. (177)

- Note that microphones used in tactical environments may have a limited frequency range and peak clip inflections and other aspects of speech. (263)

9.3.1 Speech Intelligibility

Design systems that use voice presentations to provide a degree of speech intelligibility (precise measures of the accuracy of word recognition) consistent with listening conditions, user characteristics, and mission requirements.

9.3.1.1 Testing Requirements

When very high degrees of intelligibility are required, systems should be tested using the target word sets (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 (outlined in ANSI S3.2-1960); and, the articulation index (described in ANSI S3.5-1969). For less stringent requirements, modified rhyme testing or similar methods can be used. (268)

9.3.1.2 Use of Prerecorded Speech

Consider using prerecorded speech rather than synthesized speech when high degrees of intelligibility are required. (292)

9.3.2 Speech Recognition Interaction with Other Primary Tasks

Consider the possible ramifications on other tasks when selecting speech recognition systems. Data suggests that concurrent use of voice recognition with a primary visual task, i.e., piloting or driving, may degrade performance on the primary task. However, these possible limitations should be balanced against the potential benefits when soldiers must use their vision and hands for other tasks. (151)

9.3.3 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 and induce stress in the soldier, thus changing voice characteristics. (57, 72)

9.3.4 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. (213)

9.3.5 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. (57)

9.3.6 Push-to-Talk Control

Provide the soldier with a push-to-talk button or other suitable type of control when using a speech recognition system. (57)

9.3.7 Location of Microphones

Design the microphone location to fit the combat mission. In general, use headset-mounted microphones for voice recognition input devices in RT/NRT systems. Ensure that the microphone design for speech recognition does not interfere with the standard communications microphone. (234, 263)

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." There are nine basic principles for designing a good human-computer dialog:

- Strive for consistency of design across terminology, menus, command structure, and other aspects of design for all applications.
- Enable the use of shortcuts for experienced users, improving soldier acceptance and overall system performance.
- Offer rapid and informative feedback for all soldier actions.
- Design dialogs to yield closure. The soldier 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, such as an UNDO capability.
- Enable the soldier 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.
- Provide easily accessible and easy-to-understand Help.

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. (78, 213)

10.1.2 Use of Default Values

Ensure that when message fields or forms need to be completed, as much data as possible is provided by the system as default values and/or autofilled from the database. (77)

10.1.3 Early Indication for Visual Detection

Provide advance or early approximate location information, when visual detection is an important task. Information should be consistently displayed in the same location. (66, 263)

10.1.4 Soldier Control of Processes

Provide the soldier with the capability to control, interrupt, or terminate processes. When this is not possible, ensure that the application/system informs the soldier of a change in status. (58, 213, 263)

10.1.5 Soldier Selection of Displayed Information

Consider providing the soldier 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 soldier should be domain-defined. (37, 263)

10.1.6 Design for Information Security

Standards governing the design of information security for Army systems are provided in Section 6 of the *Army Technical Architecture* (273). Guidelines for designing log-on screens for RT/NRT systems are described in the *DoD HCI Style Guide* (257). 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 Soldier Initiated Log-Off

Ensure that log-off for real-time systems is initiated by a soldier, not by the system. (263)

10.1.6.2 Prompting to Save Data

Prompt soldiers when logging off to save or not to save any new or changed data. (105)

10.1.6.3 Confirmation of Log-Off

Require the soldier, if log-off is required from an RT/NRT system, to confirm the log-off action to ensure that it does not occur inadvertently. (263)

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. (105)

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 soldier is prompted to save any changes, if appropriate. (97, 263)

10.1.8 Access to Help

Provide immediate access to "Help" through a dedicated capability, such as a function key or other object that is always available. (102)

10.1.9 Multiple Page Displays

Provide dedicated display keys for “Page Up” and “Page Down,” when designing multiple page displays that require using function keys. When a soldier is at the top or bottom page, the corresponding “Page Up” or “Page Down” key should be disabled. 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. (102)

10.1.10 Prompt to Save Changes

Ensure that the system prompts the soldier to save changes prior to closing a file or terminating a process. In a system that does not support multiple windows, prompt the soldier to save any changes to the current option before closing it and opening a new option. (126)

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 (3) when used in an operational sequence or task. (165)

10.2.2 Display and Control Formats Within Levels

Ensure display and control formats are consistent within levels. (165)

10.2.3 Control of Information Update Rates

Allow the soldier to control the rate at which display information is updated, when appropriate in an RT/NRT system. (105, 213)

10.2.4 Tailoring Information Flow and Control Actions

Tailor the information flow and control actions to those specific to the soldier's operational needs at that moment. For example, when in combat mode, the displays, controls, and available information should support only that mode. (165)

10.2.5 Display of Control Options

When a soldier 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 soldier to try to remember the alternatives. Control options could be selected from a pop-up list box or a pull-down menu. (165)

10.2.6 Availability of Necessary Information

Make all necessary information available to the soldier at the time an action is to be performed. (165)

10.3 ERROR MANAGEMENT AND FEEDBACK

10.3.1 Error Management

10.3.1.1 Confirmation of Destructive Entries

Ensure that soldiers can confirm control entries that may be hazardous, destructive, cause extensive changes in databases or system operations, or cannot otherwise be undone. (58, 100, 105, 165, 213)

10.3.1.2 Indication of Error Conditions

Ensure that the system provides a clear indication and explanation of error conditions. Error descriptions should indicate the cause of the error and suggest corrective actions. For RT/NRT systems, error messages must be carefully presented. Noncritical errors should not be overtly displayed, because they may distract the soldier from the primary operational task. (213, 263)

10.3.1.3 Undo Function

Provide the soldier with the capability to reverse or undo the effects of the last edit action, as well as previous actions. (105, 263)

10.3.1.4 Consistent Error Message Location

Display error messages in a consistent location. (263)

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. (105)

10.3.2 Feedback

10.3.2.1 General Guidelines for Feedback

Provide feedback to the soldier, as necessary, to provide 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* (258).

- Provide periodic feedback to indicate normal system operation when system functioning requires the soldier to stand by.
- Present positive indication to the soldier concerning outcome of the process and requirements for subsequent soldier action when a control process or sequence is completed or aborted by the system.
- Provide a means to cue the soldier to the mode in which the system is currently operating when the system has multiple modes of operation.
- Highlight the displayed item when it is selected to indicate acknowledgment by the system. (165)

10.3.2.2 Warning of Time to Complete Action

Ensure that the application warns the soldier when a selected action will require more time to complete than would be normally expected, and provide the soldier with the capability to cancel the requested action. (213)

10.3.2.3 System-Busy Indication

Ensure that a visual indication of "system-busy" is displayed when results of the soldier-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, the application should provide an indication that processing is taking place. (105, 213)

10.3.2.4 Feedback of Input Acceptance

Provide soldiers 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 and no more than 0.2 seconds. When input is rejected, the feedback should indicate why and what corrective action is required. (58, 257)

10.3.2.5 Error Feedback Timing

Provide error feedback, such as feedback for an invalid action, to the soldier within 2 seconds from the time the system detected the error. (105)

10.3.2.6 Critical Information Availability

Alert the soldier 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, the system should provide an immediate indication to soldiers allowing them to return to automatic updating. Once the display is unfrozen, the system should indicate the information that has changed. (105)

10.3.2.7 Loss of Target Track

Provide a visual indication when a tracking system loses the target track. This is particularly important for systems that rely on sensor input and predictive algorithms. (57)

10.3.2.8 Auto-Tracking

Provide a visual indication that auto-tracking is engaged. For systems where the soldier 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 soldier with visual feedback, depending on the functionality being accessed or system mode. See Figure 10.1 for an illustration. (57, 58, 105)

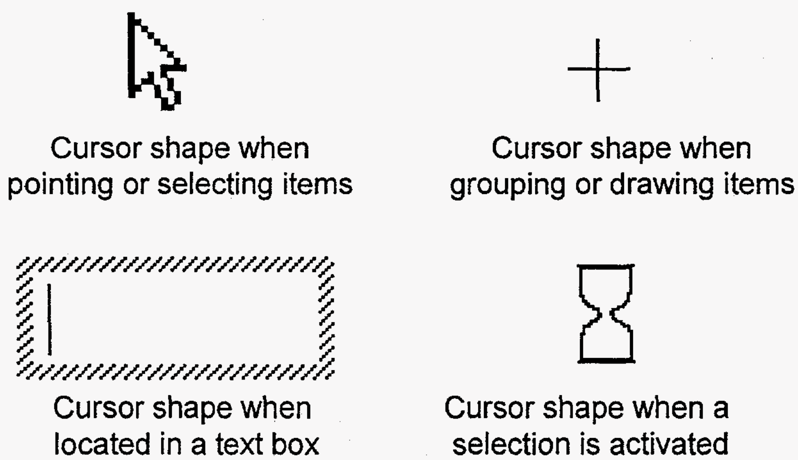


Figure 10.1 Illustration of Pointer Shape Used for Feedback

10.4.1.2 Cursor Visibility

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

- 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. (58)
- Provide the soldier 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. (105)
- Ensure that the cursor is constrained from moving off the screen. (58, 105)

10.4.1.3 Cursor Movement

Provide the following, where appropriate, for cursor movement:

- smooth movement in any X and Y direction.
- ability for auto-increment or step function movements for some modes, such as movement between grids on a map. (263)

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 arrows keys can be a backup method of cursor control. (102)

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. (57)

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. (57, 263)

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. (105)

10.4.4.2 Discrete and Analog Cursors

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. (101, 102)

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 none, ensure that the cursor is automatically placed at the top of the option list. (73, 263)

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 graphical user interface, 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* (257) and the *UI Specification for the DII* (258).

10.5.1 Object Design

Objects consist of icons, control widgets, and menu options. When designing 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* (257).

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. (213)

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. (58)

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 10.2 for examples. (105)

Figure 10.2 Examples of Pushbutton Labels

10.5.1.4 Destructive Options

Do not default to an option that represents a potential destructive action. (213)

10.5.1.5 Dialog Box Design

Follow the guidance found in the *DoD HCI Style Guide* (257) when designing dialog boxes.

10.5.1.6 Dialog Box Default

Include a default pushbutton in dialog boxes that represents the most frequently selected option or one that is most appropriate for the current situation. (213)

10.5.1.7 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. (103)

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. (293)

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. (213)

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. (58)

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. (105)

10.5.2.5 Indication of Action Taken

Provide a positive visual indication to the soldier once an action is taken with a symbol or object, such as having the object remain highlighted. (105)

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 better than scrolling a window. (257, 294, 295)

10.6 MENU DESIGN

More detailed guidelines for designing menus are included in the *DoD HCI Style Guide* (257).

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. (102)

10.6.1.2 Multipage Menu Design

Design multipage menus so a soldier 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. (72, 263)

10.6.1.3 Number of Menu Options

Design menus so there are no more than 10 options per menu, and preferably no more than 3 to 5. (57, 105)

10.6.1.4 Indication of Option Selection

Highlight the option when the cursor rests on a menu option in an RT system. See Figure 10.3. (58)

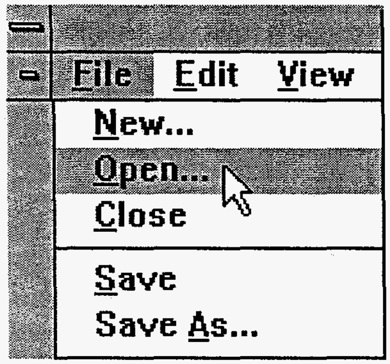


Figure 10.3 Illustration of How a Menu Option Should be Highlighted

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. (58, 96, 97, 263)

10.6.1.6 Organization of Options

Organize menu options as follows:

- 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. (58, 105)
- Organize options alphabetically or numerically, if there is no apparent organization based on logical groups or frequency of use. (105)
- Organize similar options on different menus consistently. (105)

10.6.1.7 Location of Infrequently Used or Destruction Options

Locate less frequently used or potentially destructive options at the end of a menu structure. (58, 105)

10.6.2 Return to the Top Level

Provide the capability for the soldier to cancel out of any menu and return to the top level, or to the previous level, with one action. (102, 263)

10.6.3 Visual Distinction Between Selected and Non-Selected Options

Provide a visual distinction between selected and non-selected menu options. Highlight or underline selected options. (165)

10.6.4 Menu Navigation

10.6.4.1 Indication of Submenus

Provide a visual indication when a menu option will take the soldier to a submenu. For example, use an arrowhead to indicate a cascading menu or three ellipses to indicate a pop-up menu. See Figure 10.4 for an illustration. (103)

10.6.4.2 Hierarchical Location Indicators

Ensure that the system provides a constant indication of the soldier's current place within a hierarchical task or operational sequence, as well as provides navigational aids to help soldiers identify where they are in a hierarchical menu structure. See Figure 10.5 for an illustration. (72, 165)

10.6.4.3 Menu Control Using Keyboards

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

- If only the menu bar is active, the right keyboard arrow should move the option selection cursor to the next option at the right, and the left arrow should move 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.
- The down arrow should cause the menu option list to drop down and the first option to be highlighted.
- If the menu option list is already dropped, the down arrow should move 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. (263)

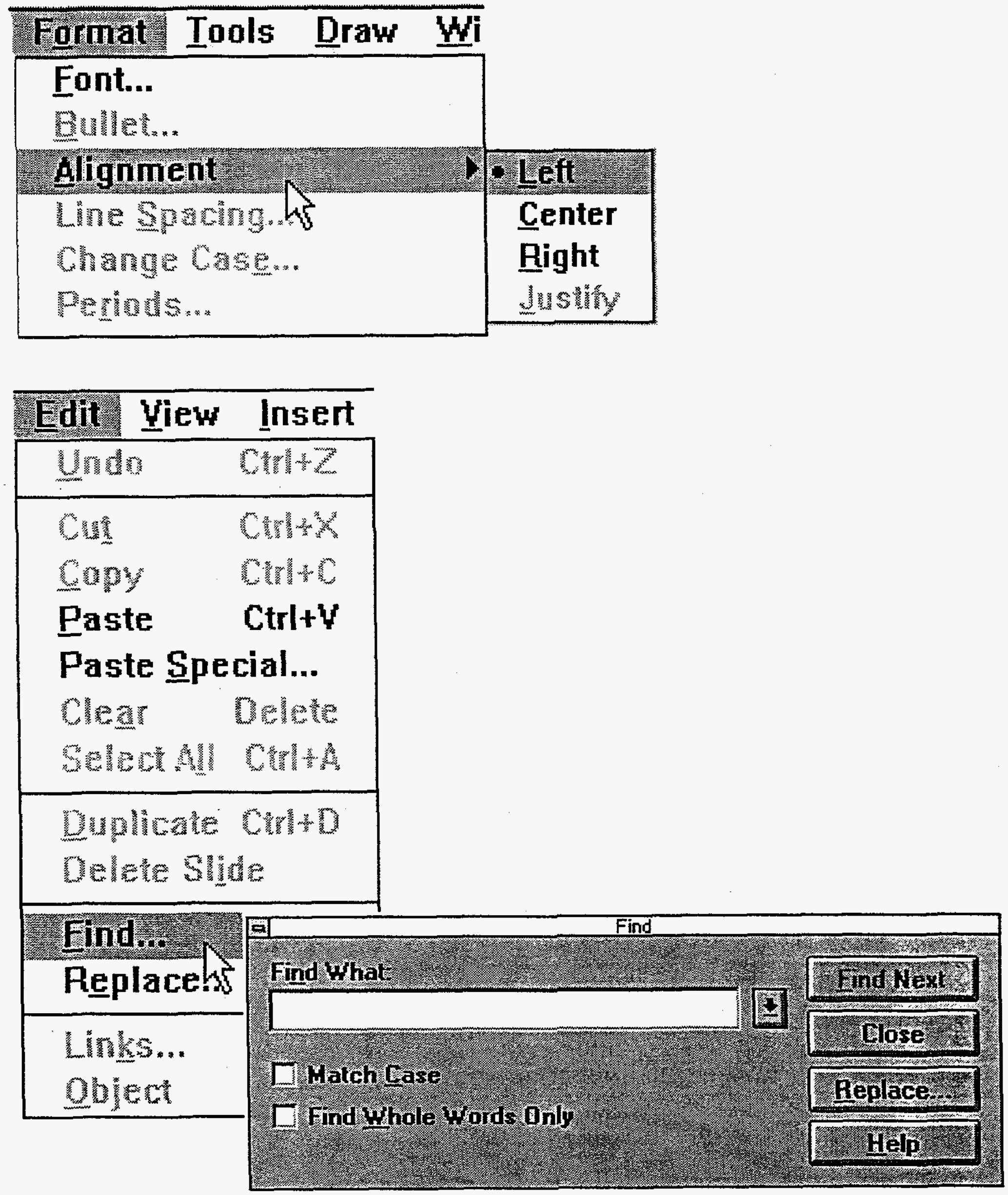
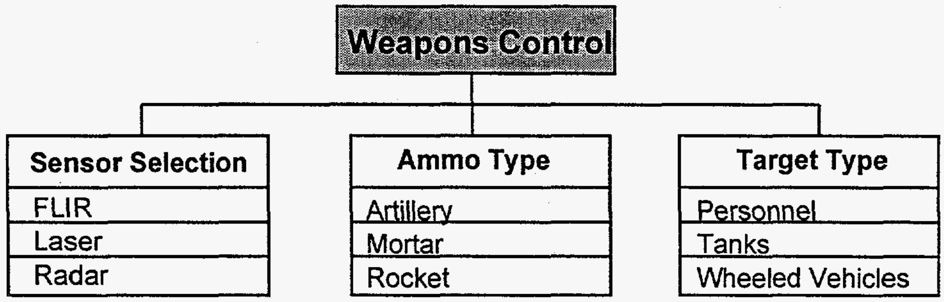
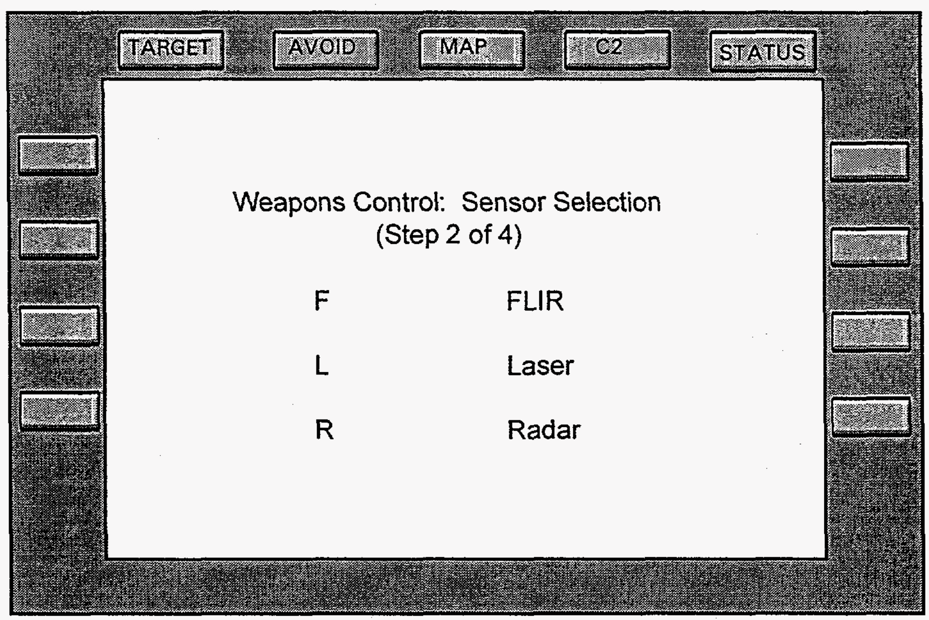


Figure 10.4 Illustration of Visual Indication of Submenu



Menu Map



Screen Navigation Indication

Figure 10.5 Illustration of Two Types of Menu Navigation Aids

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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 domain of systems—ground, aviation, missile, soldier—depending on the system's primary function. The designer needs to understand the primary function of the system being developed in order to provide an effective screen design. For RT/NRT systems, the designer needs to keep in mind that screen design must support the soldier'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.
- Present information simply and in a well-organized manner.
- Improve user performance by implementing the following screen features:
  - 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. (257)
- Display only the information that is essential to mission performance.
- Display information only as accurately as the soldier's decisions and control actions require. For example, do not provide numerical information to decimal places beyond which the soldier needs to make a decision.
- Present data in the most direct, simple, understandable, and usable form possible.
- Arrange information on displays so the soldier 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. (69, 263)

11.1.2 Presentation of Alerting Information

Present alerting information in the soldier'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. (71, 263, 268)

11.1.3 Key Features Protection

Ensure 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. (213)

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. (213)

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. (57, 263)

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. (57, 263)

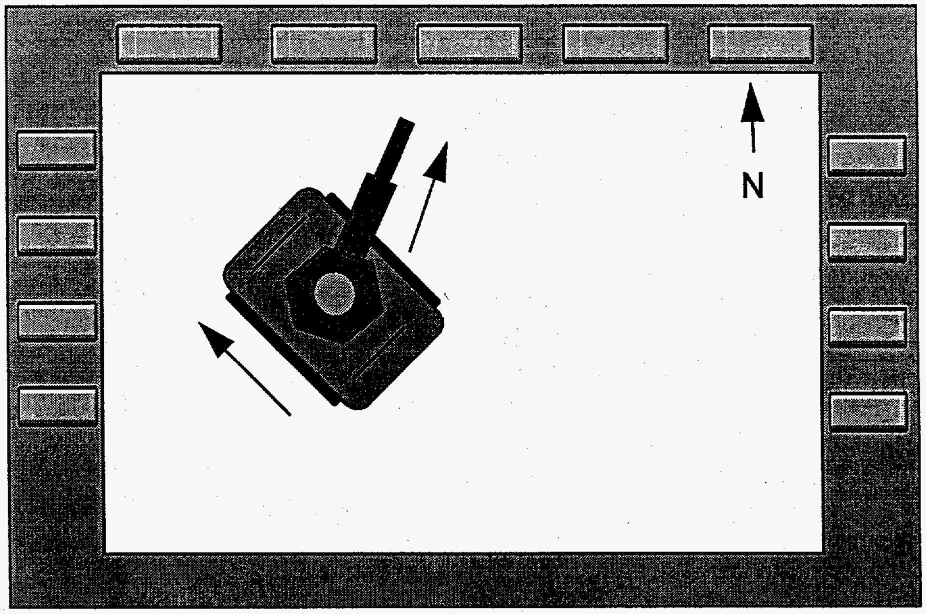

Figure 11.1 Illustration of Weapon/Sensor Orientation

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. (96)

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. (213)

11.1.9 Screen Elements Identification by Appearance

Clearly identify controls and other screen elements by their appearance. See Figure 11.2 for examples. (213)

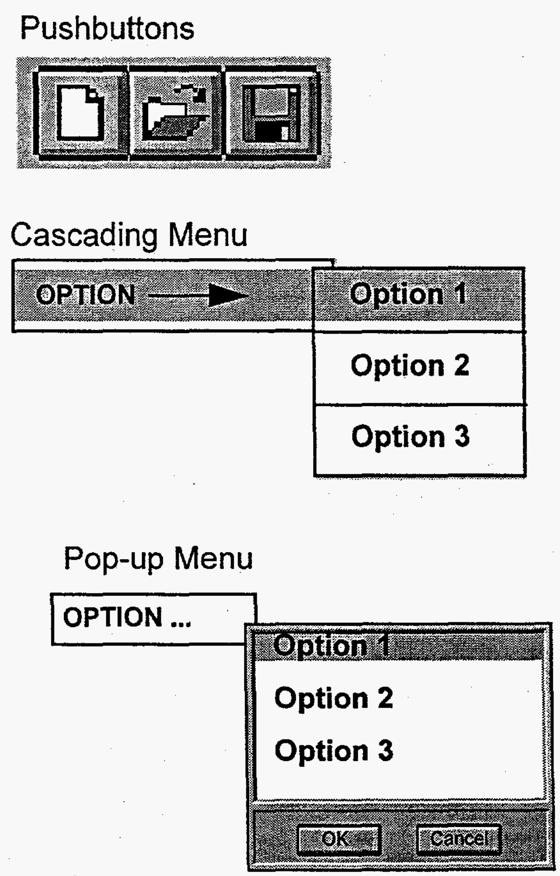

Figure 11.2 Examples of Visually Identifiable Controls and Screen Elements

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. (57)

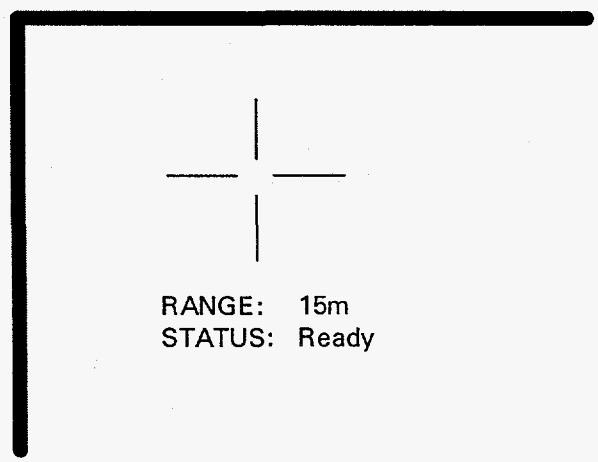

Figure 11.3 Example of Fire Control Information Placement Relative to the Reticle

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. (57)

11.1.12 Use of 3D Presentations

Consider the use of 3D presentations, rather than 2D, only when it will improve soldier performance of the mission. (263)

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* (257) and the *User Interface Specification for the Defense Information Infrastructure* (258).

11.2.1 Window Appearance

11.2.1.1 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. (105)

11.2.1.2 Window Titles

Ensure that windows have descriptive titles centered at the top. (101)

11.2.1.3 Design of Windows Performing the Same Tasks

Design windows performing the same basic task to look and behave the same. (105)

11.2.2 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 soldier. (101)

11.2.3 Window Control

11.2.3.1 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. (51)

11.2.3.2 Closing a Window and Associated Subwindows

Ensure that closing a primary window (parent) causes all subwindows (children) associated with that window to close. (51)

11.2.3.3 Location of Window Opened with Multifunction Key

Design such that, when opening a window using a multifunction key, the window appears close to the multifunction key that opened it. See Figure 11.4. (101)

11.2.3.4 Menu Overlap of Critical Screen Information

Pull-down or pop-up menus should not overlap critical screen information, such as message alert areas. (263)

11.2.3.5 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. (263)

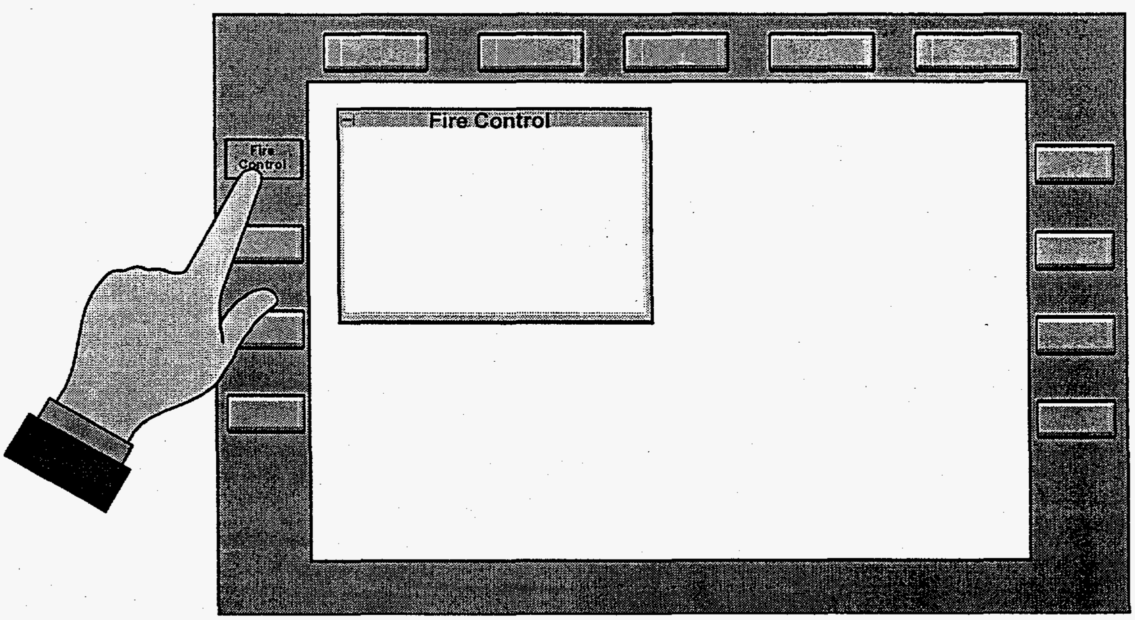

Figure 11.4 Illustration of Window Location When Opened by a Multifunction Key

11.2.4 Window Dialog

11.2.4.1 Single Selection Pop-up Windows

Consider using single selection pop-up windows when the soldier 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. See Figure 11.5 for an example. (101)

11.2.4.3 Current and Default Selection Highlighting

Ensure that, for single selection pop-up windows, the current or default selection is highlighted when the window opens. See Figure 11.6 for an example. (101)

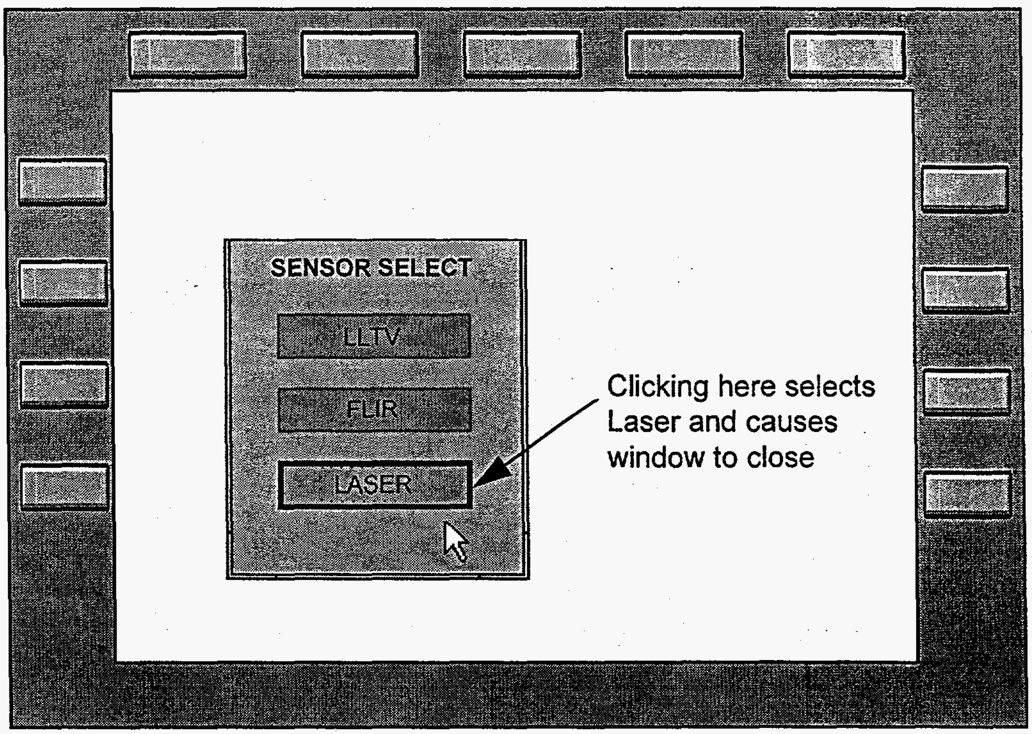

Figure 11.5 Example of a Single Selection Pop-Up Window

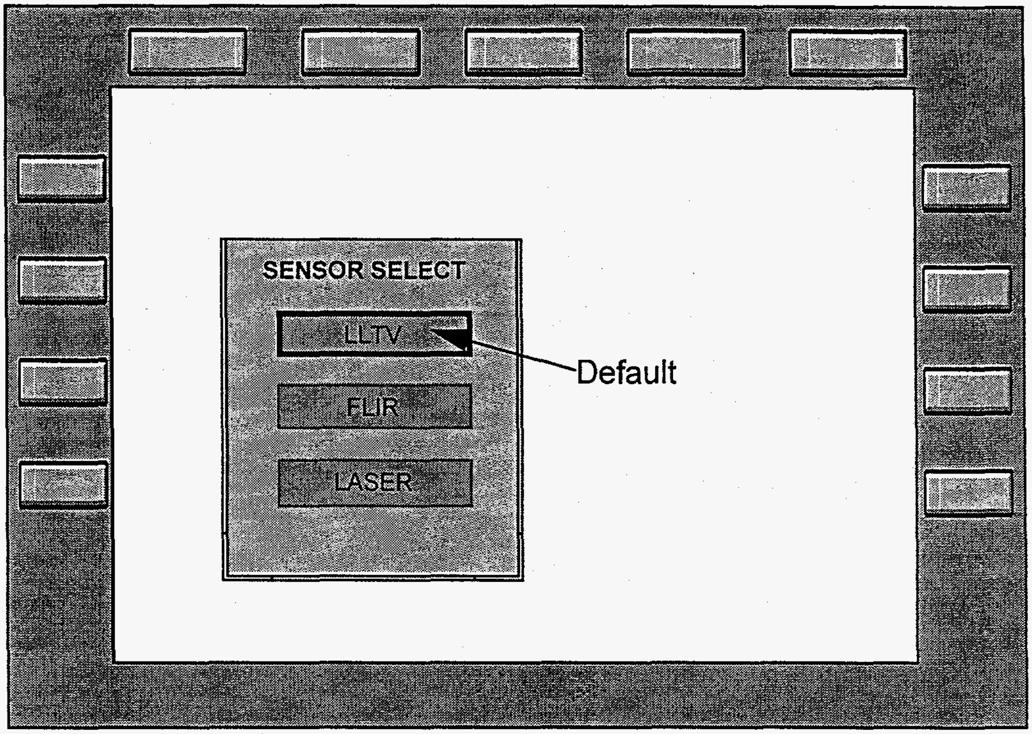

Figure 11.6 Example of Current or Default Selection on Single Selection Pop-Up Windows

11.2.4.4 Multiple Selection Pop-Up Window

Provide a multiple-selection pop-up window, when the soldier needs to select more than one option from a list. See Figure 11.7 for an example. (101)

11.2.4.5 Option Highlighting for Multiple Selection Pop-up Windows

Highlight at least the default or the previously selected option when a multiple-selection pop-up window opens. The soldier can then highlight, thereby select, additional options. Activation can be performed through an "OK" or "DONE" button. (101)

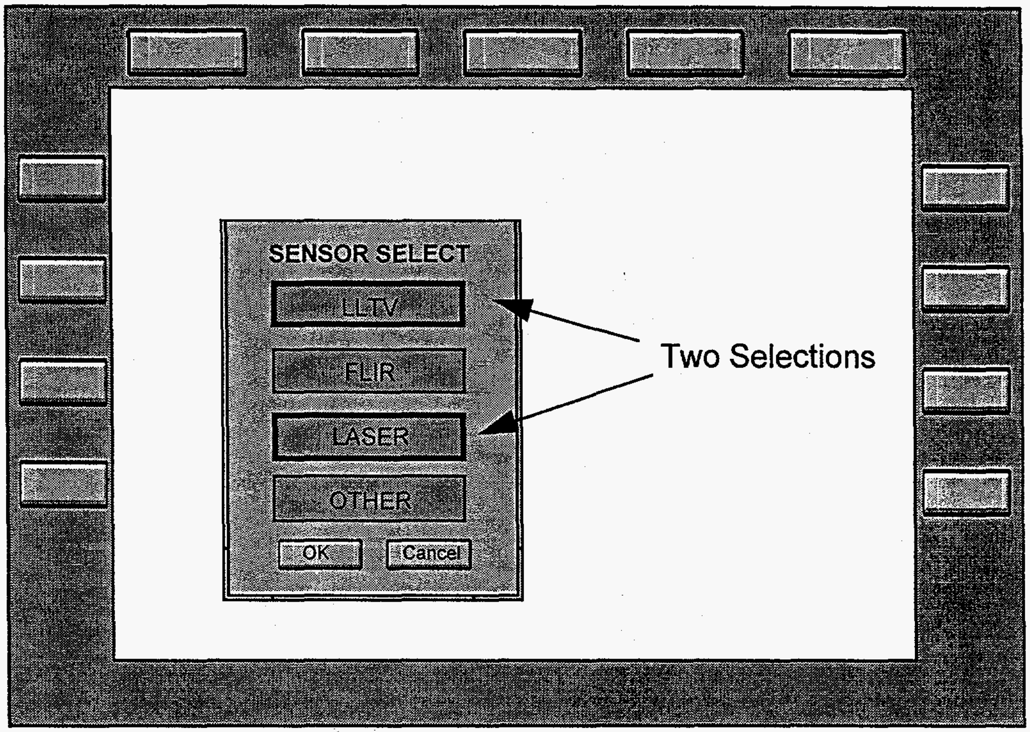

Figure 11.7 Example of a Multiple-Selection Pop-Up Window

11.2.4.6 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. (258)

11.2.4.7 Indicating Window Input Focus

Visually indicate input focus by a change in either the window frame, if it has one, or the window title. See Figure 11.8 for an example. (103)

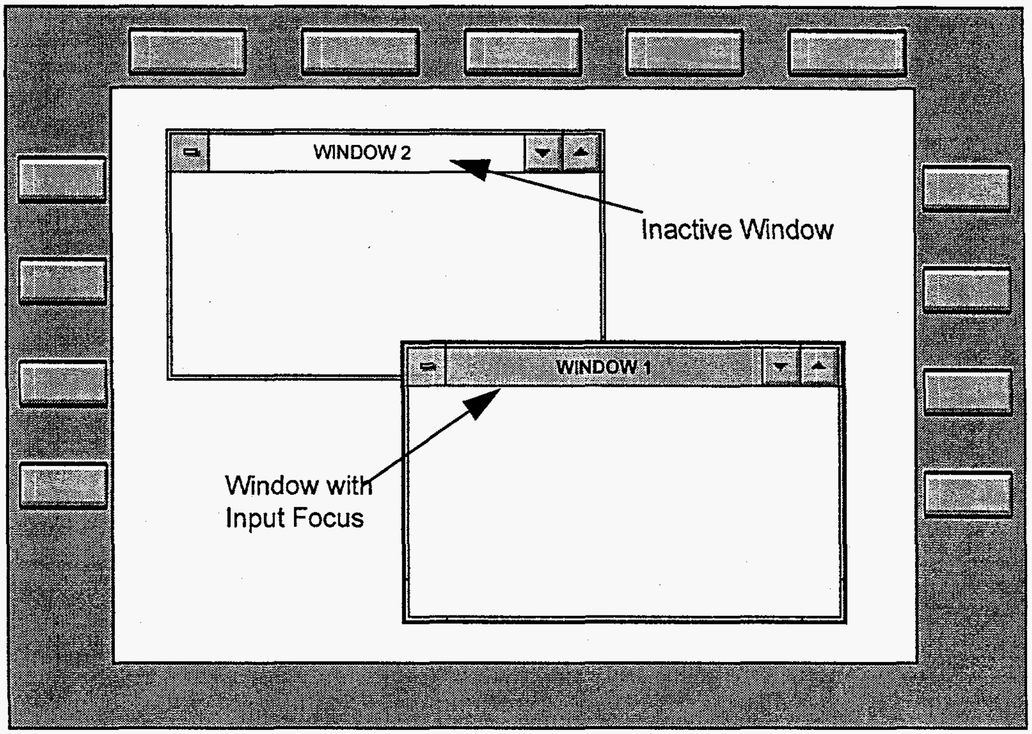

Figure 11.8 Illustration of How To Visually Indicate Input Focus

11.2.4.8 Include All Required Information Within a Window

Include, where possible to maintain an efficient and effective user interface, all the information necessary to complete the task within a window. (213)

11.2.5 Multiple Layers of Windows

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

- non-critical windows cannot be moved such that they obscure critical screen areas, e.g., message alert areas.
- windows containing critical information cannot be closed without confirmation by the user.
- critical windows cannot be moved off the screen.

- critical windows move to the top (or front) when critical events occur with the information being displayed or controlled from that window. This should not disrupt on-going user tasks.

- 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.

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

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

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 soldier operating an RT/NRT system to that which is necessary for performing specific actions, monitoring a situation, or making decisions or assessments. (165)

11.3.1.2 Precision

Display information only to the level of precision that is operationally meaningful and useful to the soldier. For example, if the soldier uses distance data to the nearest kilometer, do not provide data down to the meter. (165)

11.3.1.3 Format

Present information to the soldier in a directly usable form to minimize the requirements for actions such as transposing, computing, interpolating, and converting units. (165)

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. (165)

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. (105)

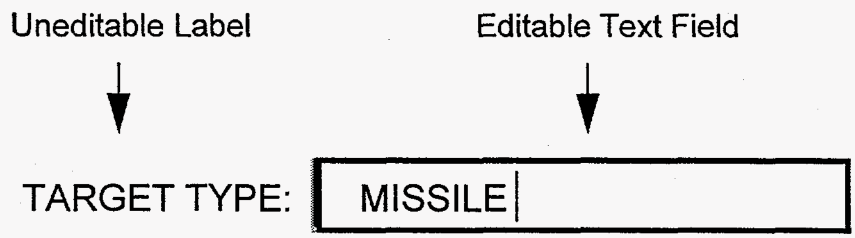

Figure 11.9 Illustration of Editable and Uneditable Text Fields

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. (105, 263)

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. (105)

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. (105)

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 soldiers. (105)

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

11.3.2.6 Grouping Columnar Data

Indicate grouping of data within a column by blank space between the columns or by a separator line. (105)

11.3.2.7 Separation of Columns

Clearly separate each column of data from other columns by a minimum of 3 spaces. (105)

11.3.2.8 Headings for Columns and Rows

Ensure that data presented in columnar or tabular format has a heading describing the type of data. (105)

11.3.2.9 Presentation of Probability of Outcome Information

Display items, when presenting information in terms of probability of an outcome, either in rank-order or present only the highest probable item. Do not include the absolute probability ratings. See Figure 11.11 for an example. (5)

This	
Likelihood of Kill	90%
Order of Possible Target Types	SCUD SAM

Not This	
Likelihood of Kill	90.105%
Possible Target Types	SAM (40.6%) SCUD (59.4%)

Figure 11.11 Example of How to Present Probability of Outcome Data

11.3.3 Text/Data Entry

11.3.3.1 Autofilling of Critical Messages

Design all critical messages 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 soldier. Provide the soldier with the ability to accept and edit autofilled information. (73, 263)

11.3.3.2 Cues for Autocompletion of Data

Provide the soldier a cue to indicate when a field has been filled, if the system uses autocompletion to automatically complete data entry based on partial soldier input. (220)

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 soldier has the capability to change from insert to overwrite mode, ensure that the current mode is indicated. (105, 263)

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* (257). 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 soldier progress. (78, 263)

11.4.1.2 Indication of Critical Information for Scrolled Map Displays

Provide an indication to the soldier of critical information being displayed in an area of a scrolled map window that is not currently being displayed on the screen. (263)

11.4.1.3 Variable Scrolling Speed

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 1 viewing area per second to 3 viewing areas per second. (263)

11.4.1.4 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. (105)

11.4.1.5 Modification of Map Overlays

Ensure that soldiers can modify the contents of a map overlay by adding, deleting, editing, or relocating labels and symbols. (105)

11.4.1.6 Adjustment of Background Intensity

Ensure that the soldier can adjust the background intensity of a map to fade out selected portions without losing all map features. (105)

11.4.1.7 Calculations of Range, Bearing, and Position

Ensure that range, bearing, and position calculations reflect the degree of accuracy appropriate to the scale of the displayed map. (105)

11.4.1.8 Querying Symbols

Provide the capability to query symbols for more information. The soldier 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. (78)

11.4.1.9 Map Graphic and Overlay Control Functionality

Provide the following control functionality for map graphics and overlays:

- **Scale** - Allow either zooming or stepped scaling of maps and overlays.
- **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.
- **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.
- **Declutter** - Allow declutter of the map or overlay graphic. (78, 101)

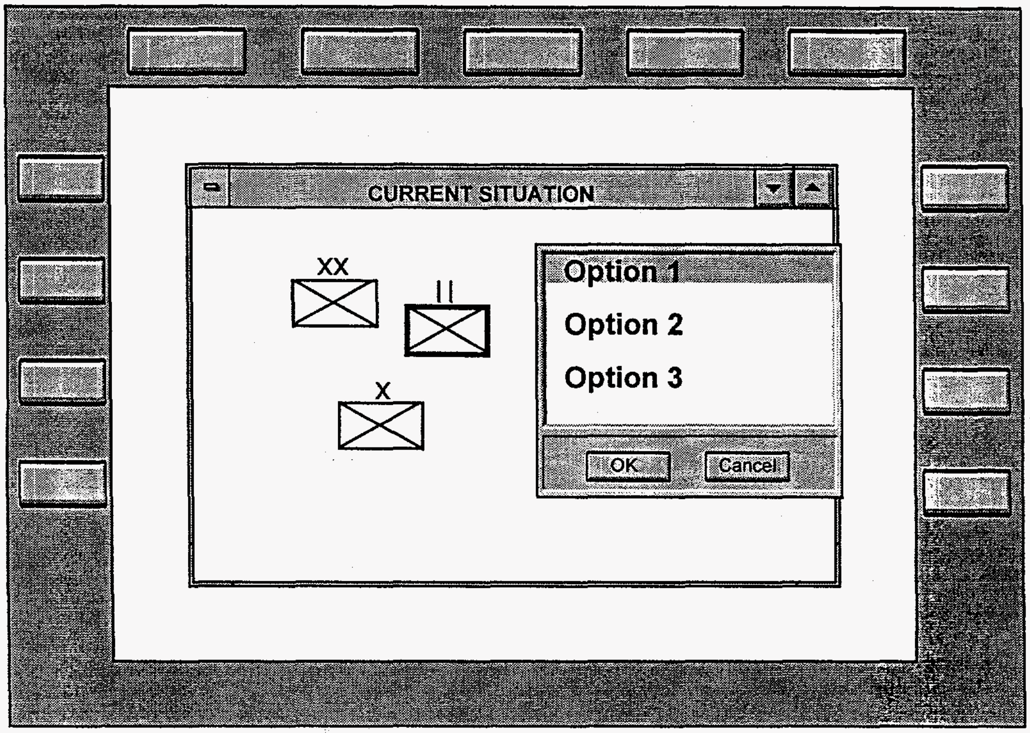

Figure 11.12 Illustration of Querying Symbols on a Map Display

11.4.1.10 Map Symbology

Design map symbology in accordance with the standards cited in the *Army Technical Architecture* (273), as well as *Operational Terms and Graphics,* U.S. Army Field Manual 101-5-1 (298). See Section 12.6, "Symbology," for more information on symbology. (78)

11.4.2 Presentation Graphics

Design presentation graphics in accordance with the appropriate section of the *DoD HCI Style Guide* (257).

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 soldier's attention on time-critical information and changes in the state of the system. (105, 165, 213)

12.1.2 Code Consistency and Meaningfulness

Use consistent, meaningful codes that do not reduce legibility or increase transmission time. (165)

12.2 BRIGHTNESS CODING

12.2.1 Use of Brightness Coding

Use brightness coding for no more than two adjacent items of information. (165)

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. (165)

12.3 FLASH CODING

12.3.1 Use of Flash Coding

Use flash coding to display only information urgently requiring the soldier's attention, such as mission-critical events or emergency conditions. Do not flash text. Instead, flash an icon or border, or display a focus area associated with the text. (105, 165, 213)

12.3.2 Flash Rates

Use no more than two flash rates. When using flash coding, each displayed item has a different flash rate. Therefore, no more than two items should be flash coded. (105, 165)

12.3.3 Rate of Flashing

Ensure that flash rates are between 3 and 5 seconds when one flash rate is used. When two are used, ensure that the second flash rate is less than 2 per second. (165, 268)

12.3.4 Acknowledgment of Flash Coding

Ensure that soldiers can acknowledge the causal event and suppress the flashing. (105)

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. (165)

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* (257).

12.5.1 Use of Color Coding

Use color coding to differentiate between classes of information in complex, dense, or critical displays—in particular, for complex computer-generated symbology. (36, 163, 165)

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.

(103, 268)

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)

(267)

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. (163)

12.5.4 Minimal Use of Color for Quick Response

Minimize the use of color when quick and accurate responses by the soldier are important. (213)

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. (73, 165, 213)

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 soldier. Color increases detections and decreases extraneous detections of information change. Color cueing information that must be monitored can also aid in tracking performance. (238)

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:

- Each piece of symbology must add value to the display, providing essential information for a specific task in such a manner that it reduces operator workload.
- Operators must be cued in a clear, unambiguous manner to system limitations and be automatically provided with the information necessary to execute appropriate procedures.
- Habit transfer should not limit innovation in symbology design. Rather, symbology design should be 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 a symbol is provided in more than one location, it should be of the same design in all locations so as to preclude the operator from having to memorize multiple symbols for the same information.
- Developmental testing must be conducted in the design mission environment.
- Operators should have the capability to declutter a display when required.
- Designers should consider using hot symbols to provide quick access while reducing display clutter.

(156, 263)

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. (165, 213)

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 soldier-system, or reduces operator workload. (155)

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. (165, 213)

12.6.4 Army RT/NRT Symbology Standards

Ensure that the general design of symbology for Army RT/NRT systems is consistent with the symbology standards identified in the *Army Technical Architecture.* (273)

12.6.5 Use of Graphics and Colors with Symbols

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

- asset location
- track/target awareness
- filtering out low-priority background information
- highlighting threats or potential threats
- classifying tracks for database management
- highlighting weapons deployment and employment. (104)

12.6.6 Size Coding

Ensure that, if size coding is used with symbology, the larger symbol is at least 1 and 1/2 times the size of the smaller symbol. There should be no more than three size levels. (165, 268)

12.6.7 Multiple Coding Variables

Consider the use of multiple coding variables in symbology to facilitate information coding. If used, ensure that they are consistent with *MIL-STD-2525* (52). (104)

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:

- Use occlusion zones to "black out" video where symbology is displayed.
- Use different colors for video and symbology.
- Use separate brightness controls for video and symbology. (263)

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.

The following paragraphs provide very high-level guidance on the design of icons for RT/NRT systems. Refer to the *DoD HCI Style Guide* (257) 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 (274, 275). 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. (50, 283, 288)

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 icons are familiar and have intrinsic meaning for the user, and that the function associated with an icon is obvious. (50, 276)

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. (277)

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. (50, 257, 288)

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 12.1. (50, 276, 279, 281, 282, 288, 289)

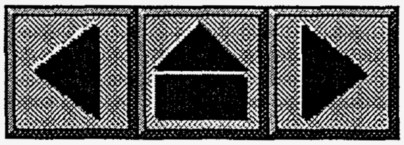

Figure 12.1 Example of a Single Icon Set

12.7.2.5 Standardization

Always use standardized icons to inform the user of risk or danger factors. (281)

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. (50, 274, 276, 278, 280)

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. (50, 276, 281)

12.7.3.3 Function

Ensure that the icon shape indicates its function. Use mirrored shapes to represent opposite functions/modes. See Figure 12.2. (50, 275, 276, 279, 283)

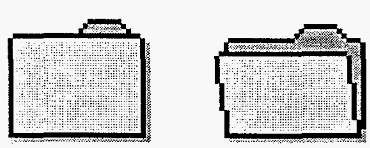

Figure 12.2 Example of Mirrored Icons

12.7.4 Icon Size

Ensure 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. (50, 275, 276, 283)

12.7.4.1 Size for Operational Systems

Ensure that icons are no smaller than 45 minutes of visual angle, as calculated in Section 5.0, "General Guidelines for Displays." Use no more that three sizes of icons for an operational system. (50, 275)

12.7.4.2 Size for Commercial Systems

Note that commercial graphic user interface environments allow only two sizes of icons: small (16 x 16 pixels) and large (32 x 32 pixels). See Figure 12.3. (50, 275)

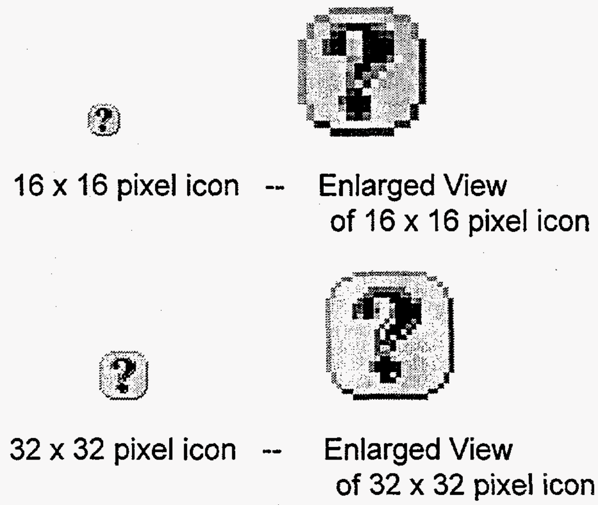

Figure 12.3 Small Versus Large Icon

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. Using color can reduce a cluttered look. (50, 274, 275, 280)

12.7.5.1 Amount 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. (274, 276, 283)

12.7.5.2 Background Color

Use background colors that are dissimilar from the icon color. (274, 276)

12.7.6 Icon Boundary Lines

Ensure that icon boundary lines or borders are solid, closed, and of consistent line weight. See Figure 12.4. Icon borders should have high contrast with the screen background and smooth corners. Do *not* put a box around an icon because this can impair visual discrimination. (50, 280, 284)

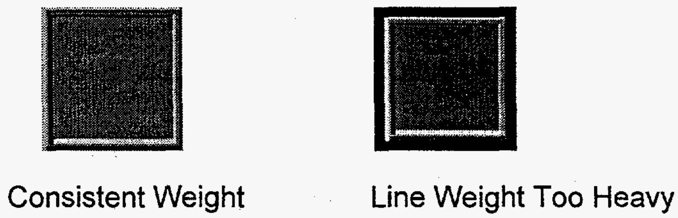

Figure 12.4 Examples of Icon Boundaries

12.7.7 Icon Labeling

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.

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. (50, 276, 285, 286, 287)

12.7.8 Hotzone

The hotzone is the part of the icon that enables an assigned action. Ensure that the hotzone is as large as possible. The hotzone usually encompasses the entire area of the icon, including the label. See Figure 12.5. (275)

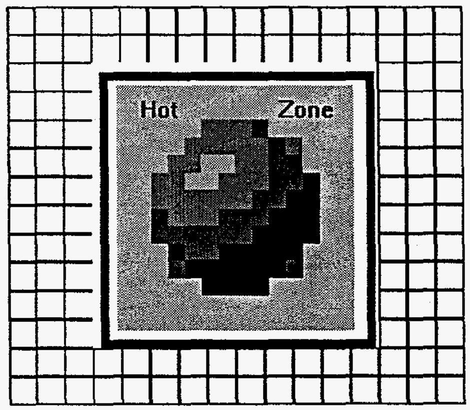

Figure 12.5 Example of Hotzone

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APPENDIX A

ACRONYMS

ASOSA	Aviation System of Systems Architecture
ATCCS	(U.S.) Army Tactical Command and Control System
ATA	Army Technical Architecture
BMNT	Beginning Morning Nautical Twilight
C4I	command, control, communications, computers, and intelligence
CRT	cathode ray tube
DII	Defense Information Infrastructure
DISC4	Director of Information for Command, Control, Communications, and Computers
DoD	(U.S.) Department of Defense
EENT	End Evening Nautical Twilight
EMI	electromagnetic interference
EMP	electromagnetic pulse
fC	footCandle
fL	footLambert
FLIR	forward looking infrared
FOV	field of view
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
LAN	local area network
LCD	liquid crystal display
LED	light emitting diode
LLTV	low light television
LOS	line of sight
MOPP	mission-oriented protective posture
NBC	nuclear, biological, and chemical
NRT	near-real time
NVG	night vision goggles
NVIS	night vision imaging system
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
UI	user interface
WSHCI	(U.S. Army) Weapon Systems HCI (Style Guide)
WSTAWG	Weapon Systems Technical Architecture Working Group

APPENDIX B

U.S. ARMY WEAPON SYSTEMS HCI STYLE GUIDE

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APPENDIX C

U.S. ARMY WEAPON SYSTEMS HCI STYLE GUIDE

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