

HUMAN-COMPUTER INTERFACE DESIGN

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Human-Computer Interface Design

1. Introduction

Modern military forces assume that computer-based information is reliable, timely, available, usable, and shared. The importance of computer-based information is based on the assumption that *"shared situation awareness, coupled with the ability to conduct continuous operations, will allow information age armies to observe, decide, and act faster, more correctly and more precisely than their enemies."* (Sullivan and Dubik 1994). Human-Computer Interface (HCI) design standardization is critical to the realization of the previously stated assumptions. Given that a key factor of a high-performance, high-reliability system is an easy-to-use, effective design of the interface between the hardware, software, and the user, it follows logically that the interface between the computer and the military user is critical to the success of the information-age military. The proliferation of computer technology has resulted in the development of an extensive variety of computer-based systems and the implementation of varying HCI styles on these systems. To accommodate the continued growth in computer-based systems, minimize HCI diversity, and improve system performance and reliability, the U.S. Department of Defense (DoD) is continuing to adopt interface standards for developing computer-based systems.

Given the direction of technology development, a long-term goal of DoD has been to develop a common operating environment (COE) and the subsequent standardized HCI. Federal Information Processing Standard (FIPS) 158-1 (NIST 1993) was originally implemented to provide guidance to DoD system designers/developers to encourage standardization of the "look and feel" (i.e., interface style) through the use of a common windowing architecture. FIPS 158-1 was also interpreted to mean that the developer should use Motif as an interface standard to ensure compliance with this standardization. This focus led to the development of the Defense Information Systems Agency (DISA)-sponsored *DoD HCI Style Guide* (versions 1 & 2), which encouraged using Motif. Due to changing technology, DoD is now more broadly interpreting the implications of FIPS 158-1 on interface style. Reasons for this broader interpretation include:

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- emerging capability of other interface styles, such as Apple® Macintosh™, Microsoft® Window™, and others—to operate on top of X Window
- commitment to provide guidance for both the operational (e.g., tactical) and business environments within DoD
- emergence of the uniform application program interface (UAPI) environment tools that allow portability from one computer platform to another and, as a result, one Graphical User Interface (GUI) style to another.

Whereas X Window provides the underlying technology through which HCI interfaces of different types will achieve standardization and portability, FIPS 158-1 is now being interpreted to allow use of any standard interface style. These interface styles consist of Open Look, Motif™, Macintosh™, Microsoft® Windows™, and OS/2® Presentation Manager. This broader interpretation, while providing greater flexibility to interface designers, also increases the potential for reduced consistency/commonality. Therefore, the need for standards and guidelines in general, and specifically the *DoD HCI Style Guide* and the *User Interface Specification for the Global Command and Control System (GCCS)*, becomes all the more important. Use of these style guides will ensure that HCIs are developed in accordance with sound principles of interface design and that consistency and commonality are encouraged.

Standardization contributes to an easy-to-use, effective HCI design. HCI standardization begins with selecting an accepted GUI, which in turn provides a standard Application Programming Interface (API) and style approach. Traditionally, the GUI has been determined by the software source selected, such as Commercial Off-The-Shelf (COTS) software, Government Off-The-Shelf (GOTS) software, or proprietary software applications. The emerging UAPI technology may free the designer from some of this dependence on the software and hardware platform for the interface "look and feel." Because users' needs are variable and GUI interpretations differ, this results in the lack of a common approach and the creation of dissimilar HCIs among systems and applications developed by independent organizations. Adding to the problems in standardization is the fact that commercial GUI styles do not address issues critical to some DoD organizations, such as geospatial systems, map interface controls, acronym standards, security, and symbol shape standardization.

The U. S. Department of the Army has begun addressing these issues by developing the Force XXI C4I Technical Architecture as a foundation for interoperability between tactical, strategic, and sustaining-base information systems. The Technical Architecture applies to all military personnel, weapons, and information systems programs in the Army. A key component in the Technical Architecture is the HCI.

2. Style Guides

Professional software design requires selecting and using standard practices for various aspects of an application or system design. This helps ensure consistency of appearance and behavior among applications within a system and develops good interfaces to enhance human performance. A number of documents are available that can help the system designer provide guidance to the HCI designer, including standards such as MIL-STD-1472D (DoD 1989b) and IEEE P1295 (IEEE 1993c), handbooks such as MIL-HDBK-761A (DoD 1989c), and style guides. Of these documents, the style guides may be the most helpful to HCI designers. Several categories of style guides are available to a system designer/developer once the specific GUI style has been selected. See Figure 1, "Style Guide Hierarchy." The style guide hierarchy begins with the commercial style guides and is refined by the *DoD HCI Style Guide*, with specific style decisions given in the domain-level style guide. The detail proceeds from the general "look" of the interface through to specific functionality. Each category of style guide is discussed in Paragraphs 2.1 through 2.4 below.

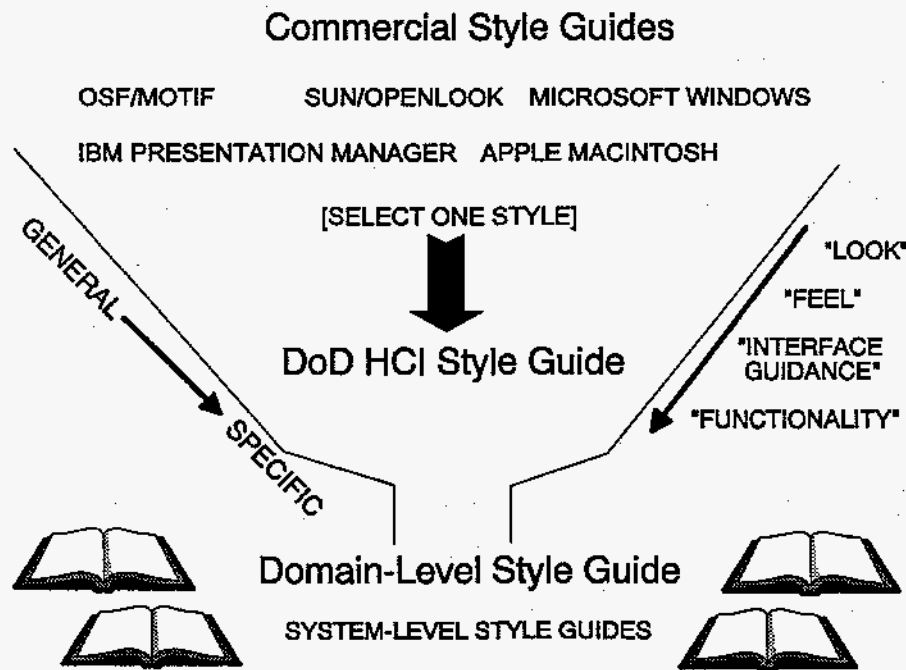


Figure 1. Style Guide Hierarchy

Description: graphical hierarchy of commercial, domain-level, and system-level style guides

2.1 Commercial Style Guides

Style guides provided by major software vendors and consortia cover horizontal aspects of effective design, or those aspects applicable to the widest breadth of systems, applications, and domains. Commercial style guides provide standard design practices for specific development environments, such as MotifTM or WindowsTM. Commercial style guides will provide a broad understanding of how the system will "look" and, to a certain degree, "feel" based on the software architecture underpinning the system.

Commercial style guides do not necessarily address human performance or military system considerations, but rather more general software behavior. Commercial style guides will provide general guidance that allows a system to deliver a consistent style if a single GUI, such as MotifTM or WindowsTM is used. However, the specific style defined by one GUI may differ from that for another GUI, so inconsistencies arise if different GUIs are available on a single platform or workstation.

The commercial style guides contain numerous stylistic differences because of different approaches taken by each vendor. These differences can be grouped into the following broad categories:

- **Terminology** - differences in names assigned to, and descriptions of, functions and features. Commercial style guides use substantially different terms to describe the functions and features associated with their respective GUIs. The main distinction is that different terms and descriptive phrases are used to define and describe equivalent or similar functions and features. However, in some instances, the same term is used to refer to different, unrelated functions or features. An example of using different terminology to describe similar functions is: MotifTM uses the term "radio button" and WindowsTM uses "option button." Both terms refer to lists of selections for which only one choice can be made.
- **Look** - differences in the appearance of displays based on different styles. The concept of look can be illustrated by comparing the graphic representations of each major style.
- **Feel** - differences in the actions a user takes to interact with an application. For example, the differences in the feel of MotifTM and WindowsTM interfaces are illustrated by applying keyboard special-purpose keys, mnemonics, and accelerators; and by using some special-purpose controls. Both MotifTM and WindowsTM support keyboard input, but there is very little consistency between the two GUIs in defining special-purpose keys.

2.2 The DoD HCI Style Guide

The *DoD HCI Style Guide (Style Guide)* provides an added source of interface design input to commercial style guides that can be used by a system developer/designer. The *Style Guide* addresses common user-interface design issues, contains guidance derived from research on human performance, and provides focus to elements applicable to DoD systems.

The *Style Guide* promotes consistency by providing generic guidelines that can be applied across multiple GUIs used within today's DoD environment. The *Style Guide* provides additional performance-based guidelines for designing GUI elements defined within the commercial style guides (e.g., menu/function names, accelerator keys, and mnemonics). The *Style Guide* addresses functional areas applying to DoD systems not addressed within commercial style guides (e.g., security classification markings, tactical color codes) and includes appendixes that identify domain-level style guides currently available for the services and other DoD organizations. The *Style Guide* has evolved into a format focusing on "How To" guidance for combining commercial style guide information with current standards and DoD HCI design considerations. The intent of the "How To" format is to complement information available in domain-level style guides, which are intended to provide more detailed "What To Do" specifications.

2.3 Domain-Level Style Guides

Domain-level style guides provide detailed guidance addressing requirements of a particular domain (e.g., C4I, space) as defined by a DoD organization (e.g., joint, individual service, or agency). Domain-level style guides reflect the consensus of the organization on the look and feel they want to provide in their systems. Over time, it is expected that DoD organizations will develop and publish domain-level style guides for directing the HCI design efforts for their systems. An example of a domain-level style guide is the *User Interface Specifications For The Global Command and Control System (GCCS), Version 1.0* (DoD 1994c), which defines a common look and feel for joint command and control systems.

2.4 System-Level Style Guides

A system-level style guide, when developed, is used to address system issues and to provide design rules for that specific system. When system-level style guides are used, the look and feel provided in the domain-level style guide is to be maintained. The system-level style guide will provide the "special" tailoring of the commercial, DoD, and domain-level style guides and will include explicit design guidance and rules for the system, as well as document design decisions made during the creation of the user interface. Other style guides may be available from commercial or government sources for a specific application being developed. The system developer should make these documents available to the HCI developer, identify them as reference documents, and call them out in the application-specific technical specification and design documentation.

3. System-Level User-Interface Design Decisions

3.1 Selecting A User Interface Style

The first design decision made for a new system should be the primary style under which the system will be fielded, usually driven by the selection of the hardware and software architecture. The commercial styles most frequently used within DoD include: OSF/Motif™, Sun/Open Look™, Microsoft® Windows™, IBM® Presentation Manager, and Apple® Macintosh™. However, the preferred style for all DoD tactical applications is OSF/Motif™. Because the DoD policy on software architecture allows systems to use various commercial styles, the *Style Guide* was developed to address design considerations germane to most style environments.

Selection of an interface style must consider hardware limitations. The Army tactical community has invested extensively in portable and single-use systems that have monochrome displays (plasma panel, etc.) and text-based and/or command line interfaces. The Army is concerned about interface design and system compatibility issues, as these systems begin communicating with the GCCS-compatible systems. In some cases, the portable and single-user systems are operating in the same spaces with the other command and control systems' computers, i.e., GCCS. The small screen portable systems may be more than one equipment procurement generation away from GUI and/or color interfaces. The design process for the text-based and/or command line interfaces will focus on effectively communicating with GUI-based systems and on making the text-based or command-line interfaces the most effective design possible for this type interface.

3.2 Deciding on a System-Level Style Guide

When required, system-level style guides—with “system” here defined as a family of applications—represent the tailoring of vendor, DoD, and domain-level guides to meet special needs of the system being developed. The goal of the system-level style guide is to ensure the development of a standardized, coherent, and usable HCI. A system developer should:

- Select a domain-level style guide, if one is available for the domain and GUI (Assume the domain style guide has evolved from the *Style Guide*).
- Define a system-specific appendix to the domain style guide, if there are system-unique requirements not addressed in that style guide.
- Develop a separate system-level style guide only if an appropriate domain-level document is not available. The system-level style guide should use the relevant commercial style guide and the *Style Guide* as starting points for its content, with tailoring as needed to meet system requirements.

3.3 HCI Design Process

The system designer/developer should make available all appropriate levels and types of style guides for use in designing the HCI. Figure 2 illustrates the process by which a design evolves from the different types of style guides, in essence moving from the general to the specific. The system concept is then derived from interpreting requirements within the guidelines of the standards, style guides, and functionality. While developing the system-level design guidelines and rules, the design should be prototyped as a way to explore and refine concepts with representatives of the user population. This concept exploration will usually help clarify the system requirements and identify aspects of the design or interface style that require special interpretation of the domain-level style guide and/or the creation of a system-level style guide.

3.4 Migration Strategy

The goal of the DoD migration strategy is to transition existing information-processing systems to a single HCI within an open system architecture. Current DoD policy calls for the HCI to be based on the X-Window system in order to provide interoperability among systems. The intent of a DoD migration strategy is to define a generic process that can be applied by all of its systems to achieving this goal.

DoD migration strategy is conceptualized as a process with short-term, intermediate, and long-term objectives. The short-term objective is to transition existing systems from their current user interface (e.g., one that is character-based) to one that is GUI-based. Because this transition allows systems to implement GUIs with different styles, the intermediate objective of the migration process is to maximize the common user interface features available within these different styles. Creating domain-level style guides as compliance documents is a step in the transition to a common interface style and a standard HCI. Although providing a single HCI based on an open system architecture represents a long-term goal, the transition process toward a common user interface style is one that can and should be undertaken by all DoD systems.

3.5 Portability Across Hardware Platforms

A critical concern for HCI developers within DoD is how to build an interface on one type of platform and then easily replicate that interface on diverse hardware platforms, either retaining the original interface style or taking on the style native to the new platform while maintaining standardization. A new, emerging technology that may have an impact on this concern and the HCI design process is uniform application program interface (UAPI). This technology enables the porting of HCI applications from one platform to another and is described in detail in the *Style Guide* Section 2.4.

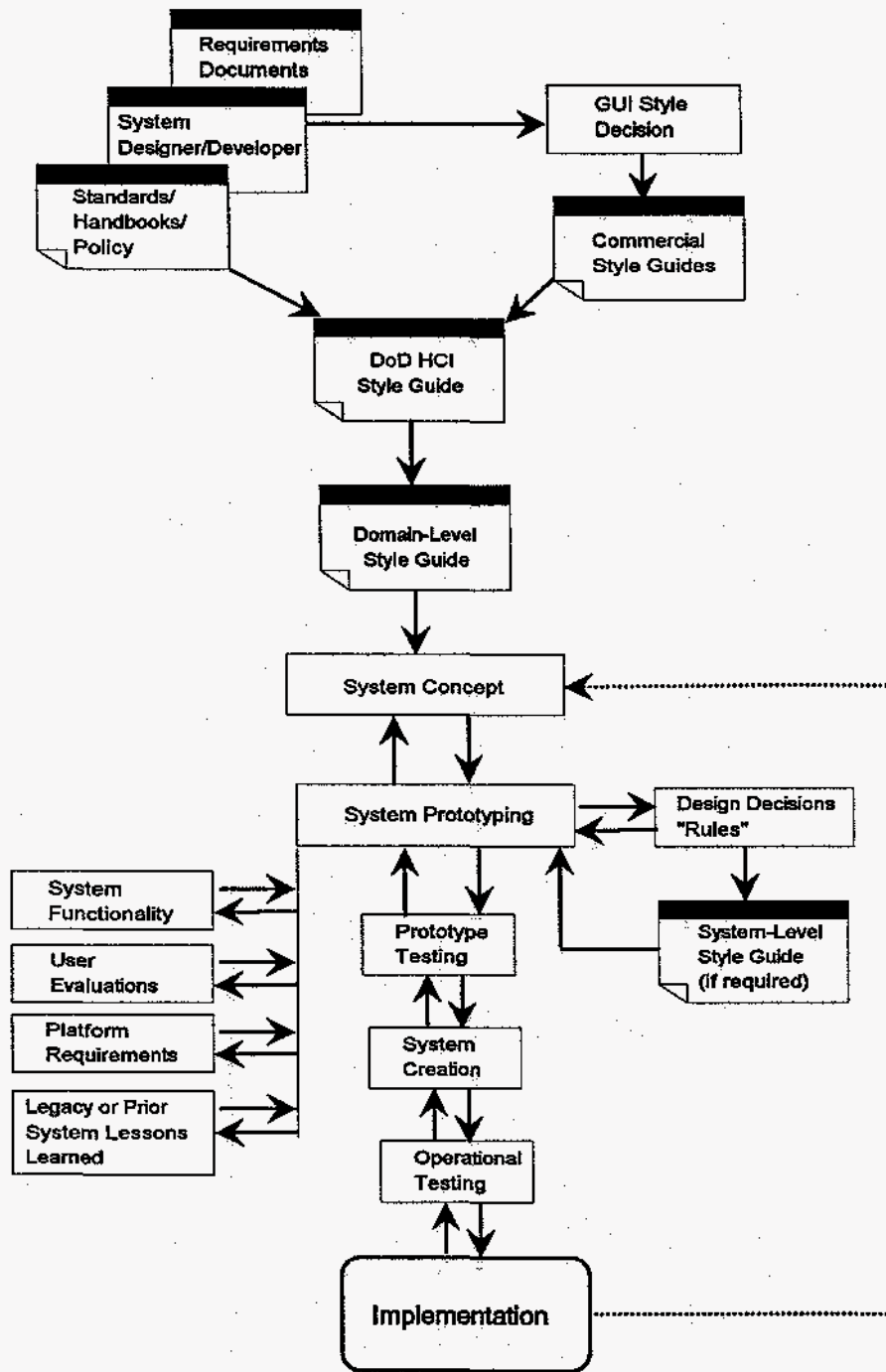


Figure 2. HCI Design Process

Description: Flow Diagram of the Human-Computer Interface (HCI) process

3.6 Integration of HCI Environments

Integrating business, tactical, finance, personnel, and all other DoD computer interface environments to common HCI principles is a long-term goal of DISA. Each of these environments shares common interface issues while, at the same time, each represents unique interface approaches. The principles of good interface design should be applied to all HCIs used within DoD. The goal of good interface design is to provide the user with the tools needed to complete the required tasks with the greatest ease and effectiveness.

The general difference between the various environments can be described in terms of the usual software within the environment. The business environment is characterized by the use of COTS software as the prime source of application software. The extensive use of COTS software reduces the ability of the system developer to affect the HCI design for the application. The tactical environment has the highest degree of custom-developed software applications, and the result has been the greatest diversity of interface styles and designs. The financial environment carries the legacy of mainframe applications oriented to command-line and text-based interfaces. The personnel and logistics applications have the largest databases (other than geographic data) of any DoD environment. Maintenance of the database input/output is the focus of these interfaces. The specialized interfaces, such as those used in real-time weapon system application, have interface requirements that have not been addressed by the current DoD policy documents. Creating domain-level style guides is especially important to those systems not completely covered in the *Style Guide*. The general principles given in this document apply to all interfaces, but some specialized areas require separate consideration.

4. Using the *Style Guide* to Solve User-Interface Design Problems

Integrating all DoD HCI environments (i.e., business, tactical, finance, personnel) to common HCI principles is a long-term goal of DoD. Each of these environments shares common interface problems while, at the same time, each has unique interface requirements. The following paragraphs address the *Style Guide* approach to the common problems and provide guidance for applying the principles so that users are provided with the tools needed to complete the required tasks with the greatest ease and effectiveness.

4.1 Selecting a User Interface Style

- a. **PROBLEM:** Many commercial applications in office environments use MicroSoft® Windows™. In addition, an increasing number of commercial applications are available with either the Motif™ GUI or with the Apple® Macintosh™ GUI.

RECOMMENDATION: A single GUI should be selected for use within a work group. Choices include MicroSoft® Windows™, Apple® Macintosh™, OS/2® Presentation Manager, or Motif™. This will improve productivity, reduce training requirements, and provide for better work flow.

4.2 Redesigning the HCI to Improve Usability

- a. **PROBLEM:** The software was not designed to do the task(s) to which it is currently applied. It follows that the labels, headings, and indicators are not consistent with the user requirements.

RECOMMENDATION: A cost-benefit analysis of the tradeoffs between redesign and retrofit of the software should be done as soon as possible, because continued use of an inappropriate interface will reduce productivity, increase training requirements, increase human error rate, and most likely lower morale. The losses due to poor design will continue to cost the workgroup.

- b. **PROBLEM:** The software has been designed to mirror a non-automated (i.e., paper) system without eliminating duplicate inputs, and it uses input formats that are not optimized for the computer.

RECOMMENDATION: The interface should be evaluated for redesigned as soon as possible, because continued use of an inappropriate interface will reduce productivity, raise the data error rates, and frustrate the users.

- c. **PROBLEM:** Terminology, jargon, acronyms, capitalization, and abbreviations are not consistent with the users' expectations and common understanding.

RECOMMENDATION: These aspects of the interface can cause critical errors in operation and reduce productivity. In these circumstances, the software should be revised or upgraded as soon as possible.

- d. **PROBLEM:** The task sequence within the software is not consistent with the operational tasks the operator/user is required to accomplish using the software. In some cases, the use of a software application may take more time and effort than the corresponding manual system.

RECOMMENDATION: The requirements/specifications for the software should be reviewed and redesign undertaken, if appropriate. A risk analysis is recommended to assess the trade-off of error versus cost of new software.

- e. **PROBLEM:** The application extensively uses data available in other applications, but no interoperability or connectivity is supplied. The operator/user spends large time sequences in duplicate data entry.

RECOMMENDATION: The data entry process is error-prone and should be minimized where possible. The use of interconnectivity to reduce duplicate data entry is encouraged.

- f. **PROBLEM:** The application software employs codes and/or procedures from prior software applications that are difficult to remember but no longer required due to changes in technology.

RECOMMENDATION: The interface should be designed to simplify the users' tasks and take advantage of improved technology. The requirement to use cryptic input codes should be eliminated wherever possible.

- g. **PROBLEM:** The software is very complex and requires extensive operator/ user training to make effective use of its capabilities. The result is that the software is rarely or never used, with subsequent loss of the capability offered by the application.

RECOMMENDATION: Adding software navigation aids, improved HELP, and, if possible, on-line tutorials should be considered in cases where complete redesigns are not cost-effective.

4.3 HCI Considerations in Selecting Commercial Software

- a. **PROBLEM:** The primary source of application software in a particular domain may be COTS software packages. This may be a problem because the COTS software has a great deal of variability in quality of interface design.

RECOMMENDATION: Evaluation copies of proposed software purchases should be subjected to compliance evaluation based upon the domain-level style guide or, if one is not available, the *Style Guide*. This should occur prior to procurement of multiple copies. The procurement of COTS software should provide for comparing applications with parallel functionality (i.e., Word Processor with Word Processor; Spreadsheet with Spreadsheet). Comparison should include user evaluation, HCI evaluation, functionality, and compliance with the appropriate domain-level style guide and/or the *Style Guide*.

4.4 HCI Considerations in Developing Custom Software

- a. **PROBLEM:** The acquisition of custom software often introduces nonstandard GUIs into the environment. There tends to be an increase in the diversity of the HCI look and feel due to stovepipe development, if more than one custom system is developed.

RECOMMENDATION: The procurement of custom software applications should require compliance with the applicable domain-level style guide or, if one is not available, the *Style Guide*. The standard commercial interface style used by the domain (environment) that will use the software should be specified for the application unless it is not a GUI. If the interface style normally used is not a GUI and the platform used is X Window-capable, the specification should be directed to an accepted GUI.

4.5 HCI Design in Tactical Environments

- a. **PROBLEM:** The tactical environment frequently involves operator/users using the same application on the same hardware in shifts. Consistent look and feel increases in importance under these conditions.

RECOMMENDATION: Compliance with the *Style Guide* and appropriate domain style guide should be combined with compliance to system-level specification and style guide (if needed) to establish as much consistency as possible within and between sets of applications available on the system.

- b. **PROBLEM:** Tactical applications frequently use maps as the basic screen background. Map usage is encouraged but presents difficulties in background—foreground contrast, clutter, resolution, and system response time.

RECOMMENDATION: These issues must be addressed in HCI design.

- c. **PROBLEM:** The tactical environment frequently has difficulty maintaining the availability of trained operators and circumstantially may require partially trained individuals to operate a given application.

RECOMMENDATION: This problem increases the importance of the HELP system, embedded training, ease of operation, and consistency of the interface.

- d. **PROBLEM:** The tactical environment frequently creates a high stress level on the operator/user during use of the application. The high stress environment makes operators more error-prone in their interaction with the application.

RECOMMENDATION: The software design teams should give special attention to error management methods and software within tactical applications.

- e. **PROBLEM:** The use of multiple operators on the same hardware and application creates interface management and time delay problems when the operators can reconfigure the application interface for personal preferences.

RECOMMENDATION: Although commercial software offers configuration and color choices to the operator, offering the choices is not recommended in cases where multiple operators share the use of the same equipment.

- f. **PROBLEM:** The use of color in the tactical environment has preassigned specific meaning.

RECOMMENDATION: The use of color and color combination must be carefully planned and controlled in tactical applications.

4.6 Migration Considerations

- a. **PROBLEM:** The interface is either "command line" or "text based," with the experienced users resisting change and new users requiring extensive training.

RECOMMENDATION: The DoD goal is to convert to GUI as soon as possible. However, in these cases, consideration should be given to allowing access to the original interface as a subset of the HCI to provide a transition for experienced users.

- b. **PROBLEM:** The software is different (not consistent) in look and feel from other applications in the same environment.

RECOMMENDATION: The goal of consistent look and feel within DoD applications should be a factor in determining application upgrades and replacements.

4.7 Portability Considerations

- a. **PROBLEM:** The software was not designed for the hardware system on which it is being used and contains inappropriate operator actions or is excessively slow in executing commands.

RECOMMENDATION: Using one of the methods for transporting software from platform to platform should be reviewed along with an investigation into the cost benefit of upgrading the software and hardware.

- b. **PROBLEM:** Individual users employ more than one workstation or share a workstation with other users.

RECOMMENDATION: A personal layer system should be created. In other words, the system sets the environment on initialization and changes environment defaults for each user log-on, creating a custom system for each user.

5. Conclusions

The *Style Guide* and the appropriate domain-specific style guide should be used within DoD to perform HCI design. These style guides provide the appropriate guidance and framework to guide the developer. The developer can thus tailor generic commercial style guides into an application- or system-specific style guide that addresses human rather than software behavior issues, is directed towards DoD design considerations, and presents a more standardized interface style to the user. Standardization of the interface is imperative to the success of the information-age military.

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