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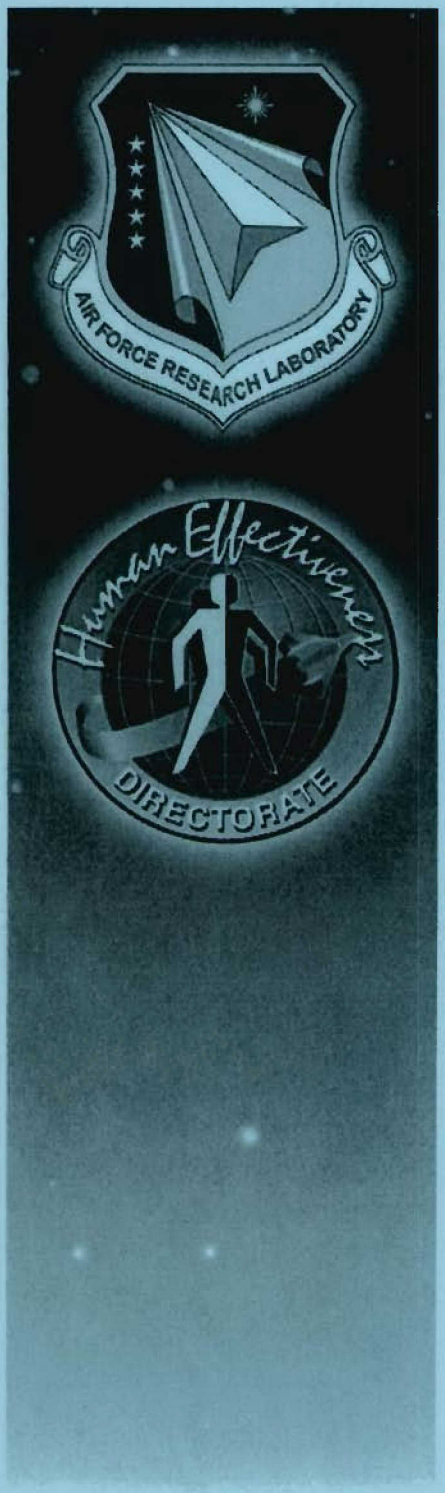

AIR FORCE RESEARCH LABORATORY

Battle Management Command and Control (BMC2) Human Machine Interface (HMI) Design Guide

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Warfighter Interface Division
Wright-Patterson AFB OH 45433-7022

June 2005

Interim Report for the period March 2004 to August 2005

Human Effectiveness Directorate
Warfighter Interface Division
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This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER

//Signed//

MARIS M. VIKMANIS
Chief, Warfighter Interface Division
Air Force Research Laboratory

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ABSTRACT Purpose
e Human-Machine Interface (HMI) Design Guide is the product of collaboration between the Air Force Research boratory Human Effectiveness Directorate (AFRL/HE) and the Air Combat Command's C2ISR Operations Division C/DOY) and Directorate of Requirements (ACC/DRR). This design guide attempts to merge best practices and dance from the HMI, human factors, and usability engineering disciplines with significant input from BMC2 erator interviews. The objective of this design guide is to provide HMI architects and designers with more nsistent and intuitive design guidance to ensure that future interfaces are useable and that training requirements minimized, while ensuring COTS compatibility and interoperability with comparable "look and feel" across future C2 workstations.

SUBJECT TERMS
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1. Introduction

1.1. Purpose / Objective of This Guide

This Human-Machine Interface (HMI) Design Guide is the product of collaboration between the Air Force Research Laboratory Human Effectiveness Directorate (AFRL/HE) and the Air Combat Command's C2ISR Operations Division (ACC/DOY) and Directorate of Requirements (ACC/DRR).

The HMI Working Group was formed in December 2003 to oversee usability and human factors issues in the design of future Battle Management Command and Control (BMC2) HMIs. This working group served as the infrastructure for the development of an HMI Design guide for future tactical-level BMC2 workstations.

This design guide attempts to merge best practices and guidance from the HMI, human factors, and usability engineering disciplines with significant input from BMC2 operator interviews. It is intended to be a living document, with subsequent editions and formatting changes expected. The objective of this design guide is to provide HMI architects and designers with more consistent and intuitive design guidance to ensure that future interfaces are useable and that training requirements are minimized, while ensuring COTS compatibility and interoperability with comparable "look and feel" across future BMC2 workstations.

ESC/AC formally recommended that ACC develop a BMC2 HMI Style Guide in Oct 03. This document fulfills that recommendation and implies compliance via Key System Attribute for future BMC2 systems acquisitions and for HMI upgrades to legacy systems per the Oct 03 memo.

1.2. Scope

The HMIWG will oversee and facilitate the development of a standards-based design guide focused by inputs from the following stakeholders: operations (HQ ACC/DOY, 552 ACW, 116 ACW, and operational unit/group BCS representation), requirements community (HQ ACC/DRR, AFC2ISRC/E-10 SMO), acquisition (Electronic Systems Center (ESC)), and science and technology (Air Force Research Laboratory (AFRL)).

As the design guide is expected to be a living document, the HMIWG will use the captured knowledge to review current, related HMI efforts under contract to support new, planned efforts. It was agreed to baseline the document on the AWACS Block 40/45 HMI, while exploring other current programs for attribute modification and/or retention. The AWACS Block 40/45 HMI Users Working Group (HUWG) process is an excellent HMI development venue for DoD contractor and US government personnel alike. The process is a model for continuity, discipline and sound development procedures. POC's are Don Gricol (Government), 405-734-2734 and Joe Lammers (DoD Contractor) 253-773-5025.

AFRL and ESC will lead the effort to include other DoD/AF agencies' HMI lessons learned/best practices. AFRL will also visit field units to get first-hand operator input, and consolidate that with documented information to incorporate into the guide with HMIWG approval.

The HMIWG will then consolidate all inputs and oversee publishing the first draft design guide within 12 months of this Charter's approval. NOTE: If there are opportunities to smartly insert HMI

modifications into existing contracts in order to capture additional benefit from the design guide recommendations that will remain the purview of the in-place structure between ACC and ESC.

1.3. Intended Audience for the HMI Design Guide

The HMI Design Guide is intended to serve as a resource for individuals involved in the design of future BMC2 workstation interfaces. It is intended to provide meaningful interface design guidance based on human factors and interface design best practices. The design guide is NOT meant to serve as an exhaustive list of interface specifications or design rules, nor is it intended to serve as a replacement for detailed overarching style guides such as the MS Windows style guide or even platform-specific HMI style guides such as the BMC2 HMI style guide. Instead, it is meant to complement such documentation.

1.4. Organization of the HMI Design Guide

Unlike many style guides, this document is designed to be used. Accordingly, it is organized around a dozen or so best practices adapted from the work of Nielsen and Mack (1994) involving interface design *heuristics* ("rules of thumb"). These best practices are then applied to major functional components of the BMC2 workstation interface, such as the Situation Display, Alarms and Alerts, Communications, etc. Each section includes simple and clear descriptions of the design rules, followed by illustrative examples of both *effective* and *ineffective* interface design, and a brief summary. In addition, several of the illustrative examples are labeled "HMI Core Components." This special class of interface concepts was identified by operators during the interviews and is considered to be fundamental to a common HMI.

2. Interface Design Best Practices

2.1. Visibility of system status

The system should always keep operators informed about what is going on, through appropriate feedback within reasonable time.

2.2. Match between system and the real world

The system should speak the operators' language, with words, phrases and concepts familiar to the operator, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

2.3. User control and freedom

Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo where practical.

2.4. Consistency and standards

Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

2.5. Error prevention

Even better than good error messages is a careful design which prevents a problem from occurring in the first place.

2.6. Recognition rather than recall

Make objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

2.7. Flexibility and efficiency of use

Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

2.8. Help users recognize, diagnose, and recover from errors

Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

2.9. Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

3. Situation Display: Overall Layout, Design, Navigation

3.1. Maximize continuous uncluttered viewing of the Situation Display

The Situation Display is one of the primary sources of situation awareness. The overall HMI should be designed such that the Situation Display is not occluded and that it is continuously viewable to the greatest extent possible. The inclusion of interface elements that diminish the availability of the Situation Display such as pop-up windows, dialog boxes, menu drop-downs, etc. should be minimized. Transparency effects should be considered as means for minimizing these effects.

Effective Information Design

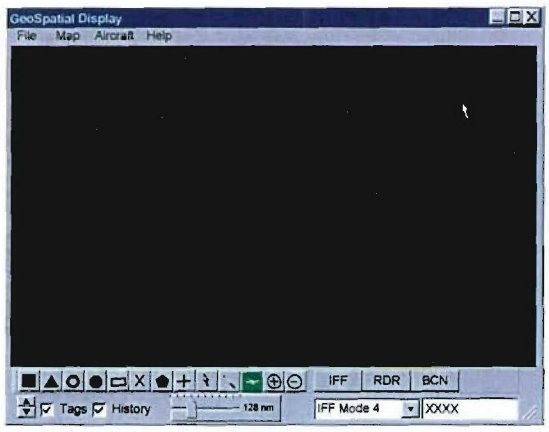


Figure 1. Uncluttered Situation Display

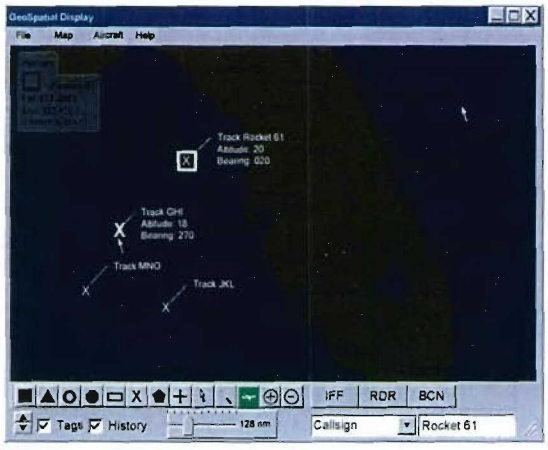


Figure 2. Tags and rollovers to minimize clutter and provide direct access to information

Summary

Design uncluttered interfaces using integrated portrayal of mission-critical information.

Ineffective Information Design

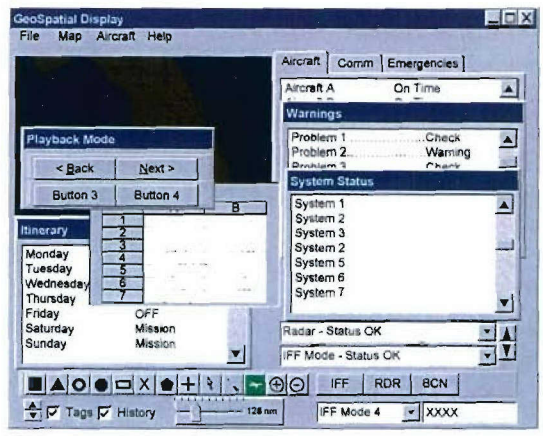


Figure 3. Cluttered Situation Display

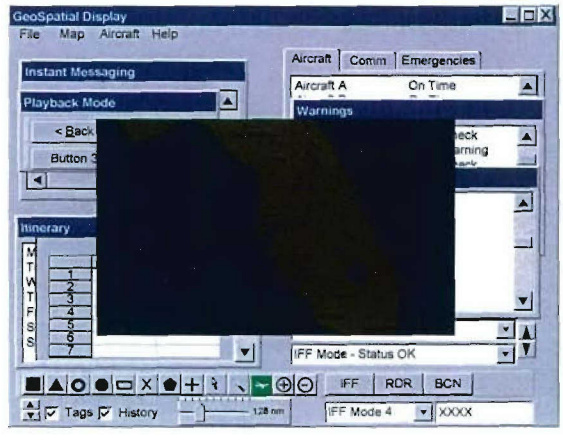


Figure 4. Indirect information access using multiple windows

Summary

Do not design / architect Situation Displays that prohibit direct, uncluttered access to mission-critical information.

3.2. Make the Situation Display as "flat" possible

Lead operators to information in as few mouse clicks as you can. Many BMC2 interfaces are organized in a very linear and hierarchical, requiring users to drill down multiple levels before reaching meaningful content. Utilize user-specified hot-buttons and rollover tags to provide meaningful information to operators in an efficient manner.

Effective Information Design

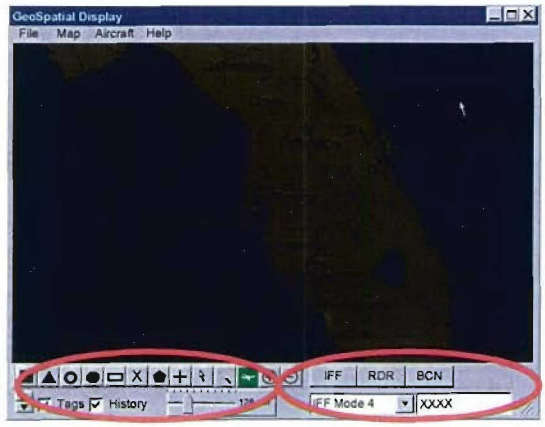


Figure 5. Customizable toolbars and hot buttons for direct manipulation of information

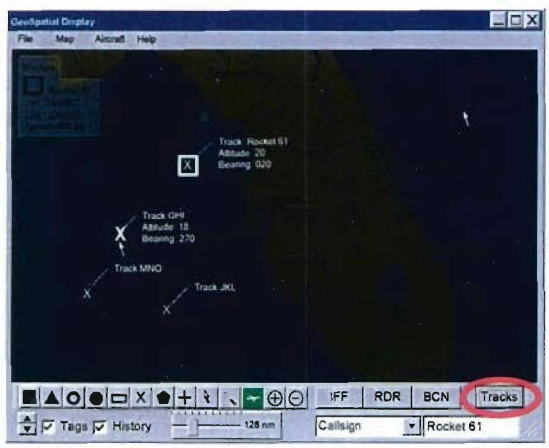


Figure 6. Customized hot buttons used to directly access track information with a single mouse click

HMI Core Component

Key bindings permit operators to map essential functions to a set of keys on the workstation keyboard (e.g., the Drop Track command can be mapped to one of the keys).

Summary

Optimize the efficiency with which operators interact with the Situation Display by permitting customizable hot buttons, toolbars, and key bindings.

Ineffective Information Design

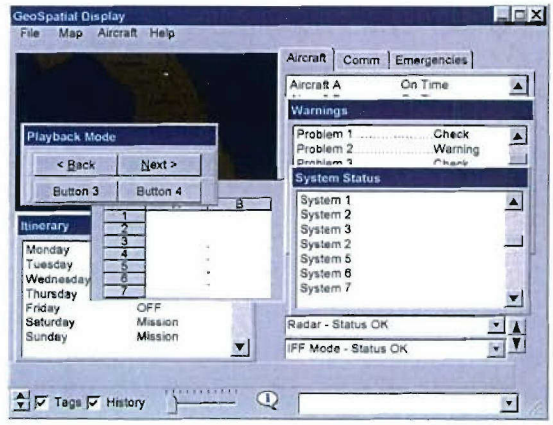


Figure 7. Situation Display without customizable hot buttons and/or toolbars

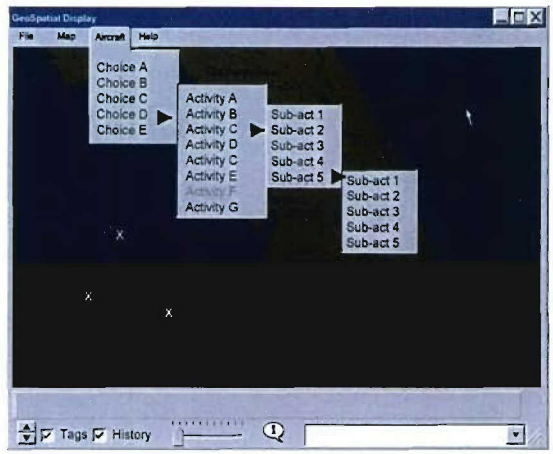


Figure 8. Situation Display employing inefficient hierarchical navigation structure

Summary

Do not design / architect interfaces that require excessive user input to acquire meaningful information.

3.3. Structure Situation Display by tasks users want to perform

One important aspect of user-centered design is developing an understanding of how users intend to use the interface. Often, complex BMC2 interfaces provide features and functionality that may receive little or no use. This generally wastes valuable screen real estate and likely degrades performance efficiency.

Effective Information Design

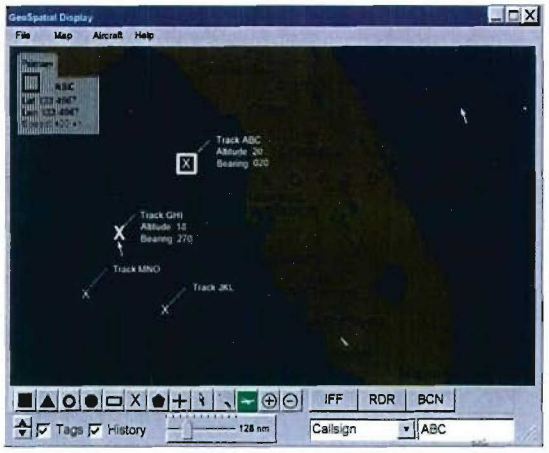


Figure 9. Primary track information retrieval via rollovers is efficient and intuitive

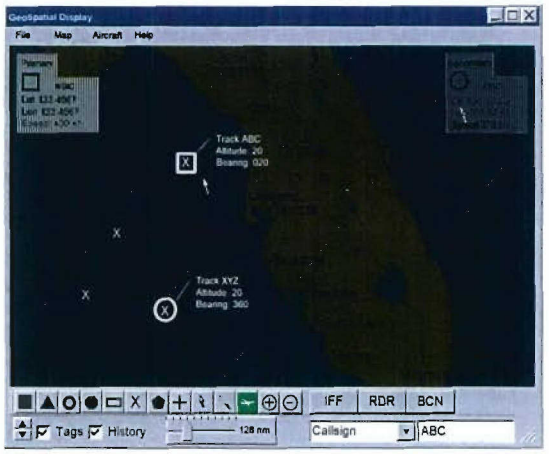


Figure 10. Hooking primary and secondary tracks using mouse clicks is intuitive and efficient

Summary

Design interfaces that enable operators to perform their primary tasks.

Ineffective Information Design

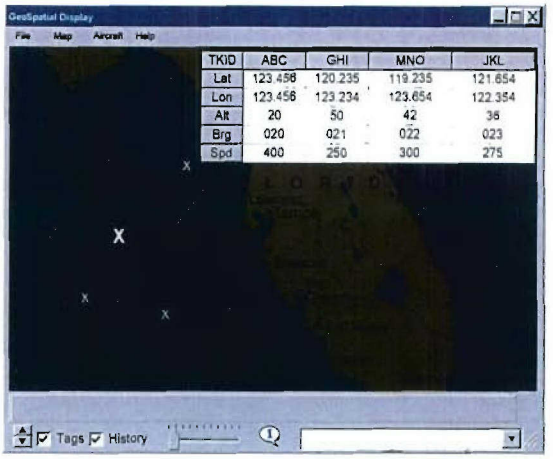


Figure 11. Inefficient portrayal of track information

Summary

Do not design interfaces that require operators to shift attention between track representations and track data.

3.4. Structure Situation Display by tasks users want to perform (cont.)

Situation awareness can be enhanced by providing multiple views of the battlespace on the Situation Display. In the example below, a Picture-In-Picture interface concept is used to enhance overall awareness by providing an independently configurable (e.g. maps, brightness/contrast, range in/range out, sensor and track history, overlays, etc.) miniature Situation Display.

HMI Core Component

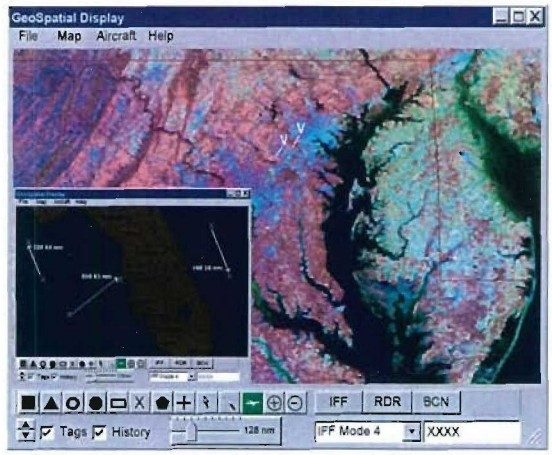


Figure 12. Picture-in-picture

Summary

Design interface concepts that aid the maintenance of situation awareness.

Structure Situation Display by tasks users want to perform (cont.)

Design interface features and functionality that enhance operator performance efficiency. Hot buttons that serve as filters are an example of this type of interface component. As depicted in the figure below, quick filter buttons are included on the main toolbar, and allow operators to quickly filter the display by identity, platform, activity, etc.

HMI Core Component

Figure 13. Quick filter HMI core component

Summary

Employ quick filter functionality to provide efficient decluttering of the Situation Display and access to important information.

Structure Situation Display by tasks users want to perform (cont.)

Operator efficiency may be enhanced by affording user-configurable toolbars and expandable toolbar icons. In the example shown below (top figure), the customized toolbar appears on the upper-right side of the Situation Display when the user rolls over the right portion of the Situation Display with the mouse (bottom figure) and disappears after a few seconds or a button activation. An alternate configuration would be to have the user-configurable toolbar "fly-out" from the left side of the Situation Display. Similarly, expandable toolbar icons can be used to provide access to additional toolbar options by placing the mouse cursor over the toolbar icon.

HMI Core Component

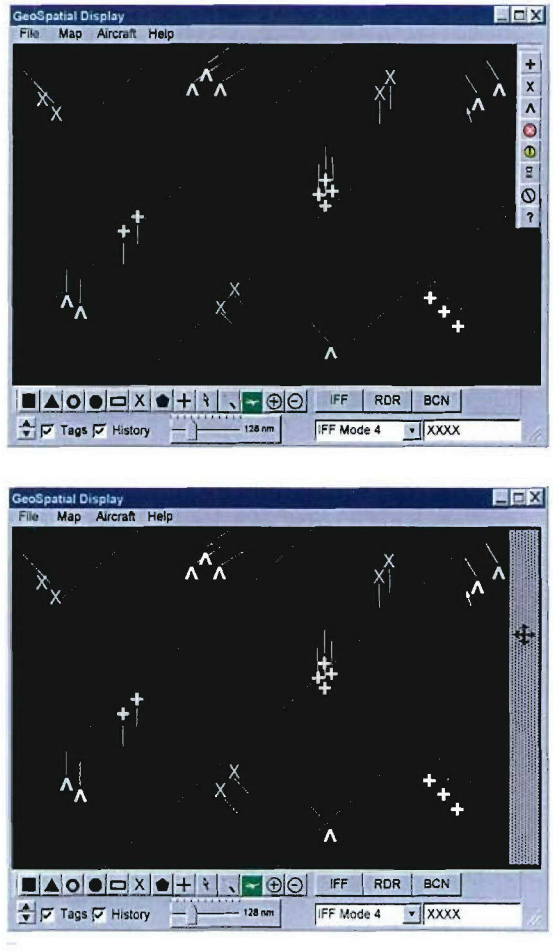


Figure 14. User configurable toolbar commands

Summary

User configurable toolbars are employed to provide additional performance efficiency enhancements.

3.5. Structure Situation Display by tasks users want to perform (cont.)

Situation awareness can be enhanced by providing user-selectable iconic symbol sets. The symbol sets should be Link 16 and joint service compliant (e.g. Naval Tactical Display Symbol (NTDS)).

HMI Core Component

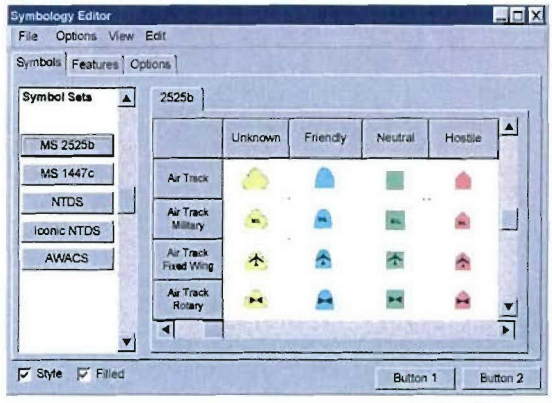


Figure 15. Selectable iconic symbology

Summary

Selectable symbol sets provide increases to situation awareness.

3.6. Provide consistent and intuitive navigation on the Situation Display

Global navigation refers to navigation elements that are always available to the operator. Effective global navigation occurs when portions of the interface are dedicated for this purpose (for example, menu bars, toolbars, hot buttons, backward and forward buttons, etc).

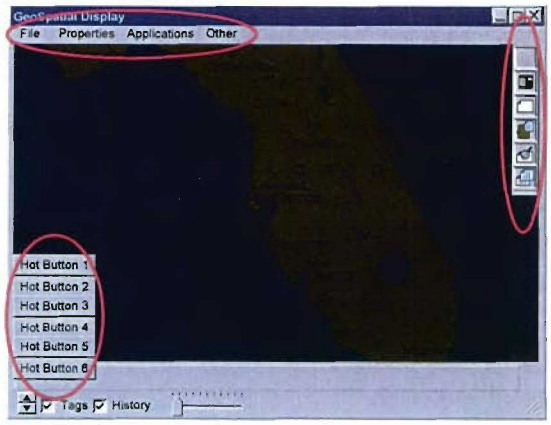
Effective Information Design

Figure 16. Situation Display with permanent primary menu bar (top) and toolbars and hot buttons allocated to a fixed location

Summary

Maintain consistent primary menu bar and dedicated locations for toolbars, control bars, and hot buttons.

Ineffective Information Design



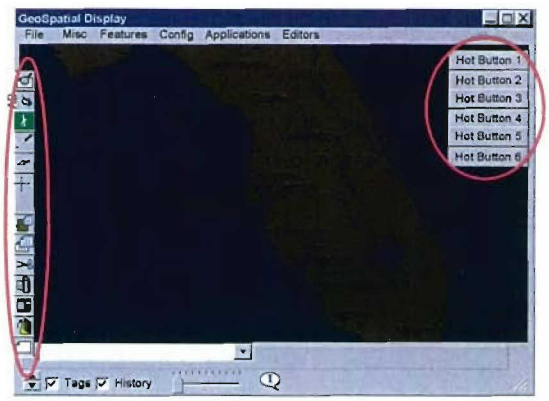


Figure 17. Inconsistent primary navigation caused by ambiguous menu labels and unpredictable location of hot buttons and toolbars

Summary

Avoid changing the primary and secondary navigation for the Situation Display.

3.7. Provide redundant and complimentary access to interface features

To best accommodate the needs of all operators at all times, develop multiple paths to access the same interface features. For example, users may opt to employ menu drill-down, hot buttons, toolbars, or keyboard shortcuts depending on their tasks at hand.

3.8. Design interfaces and functionality that do not compromise system update rates

Design interfaces and features that strike an appropriate balance between overall display capability and efficiency. Advanced graphical features and future data visualization capabilities need to be designed so that they do not introduce unacceptable system latency which may compromise operators' situation awareness.

3.9. Group navigational elements

Position navigational elements such as toolbars and hot buttons in close proximity to one another. By positioning navigation features close together, operators will spend less time navigating the Situation Display with the mouse, trackball, or keyboard, thus increasing the efficiency of operator performance.

Effective Information Design

Figure 18. Toolbar and hot button functionality grouped in meaningfully clusters

Summary

Place navigational elements strategically and consistently on the Situation Display. This reduces the effort required to navigate the interface.

Ineffective Information Design

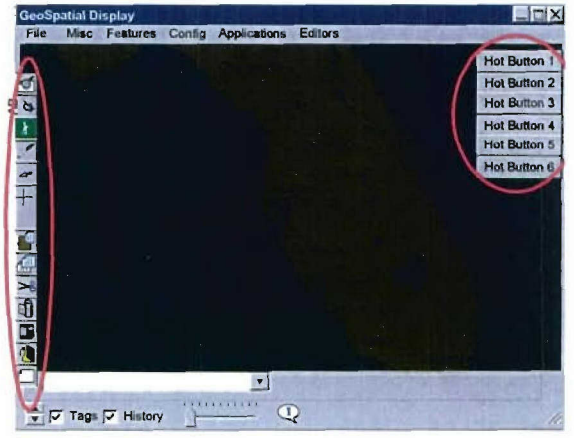


Figure 19. Toolbars and hot buttons located on opposite sides of the Situation Display

Summary

Do not overwhelm operators with navigation that is scattered across the page or clustered in non-meaningful arrangements.

3.10. Design legible and intuitive navigational elements

Create navigational elements that are highly legible, consistent, and intuitive. In addition, consideration must be given to the overall number of distinct icons employed throughout the Situation Display such as to balance recognizability and memory load.

3.11. Design robust map viewers

BMC2 operators frequently require map overlays that may be supplied by a variety of organizations. Map viewers must be designed to accommodate different formats of map content and must also ensure that scaled content is legible at all reasonable resolutions.

3.12. Avoid excessive white / gray space in editor windows

Avoid excessive use of white space on track editor screens. This will permit a smaller and more efficient editor window which is more easily scanned. In addition, minimizing white space allows more information to be shown on the Situation Display.

3.13. Employ browser-based navigation conventions such as "Back" and "Forward" buttons to maintain battlespace awareness

Maintaining an accurate "picture" of the battlespace is a primary activity of many operators. Conventions common to Web-browser navigation such as *back* and *forward* buttons permit operators to efficiently shift between alternate viewing configurations of the Situation Display.

In addition to enhancing the efficiency of returning to previously viewed configurations, this feature would also permit a one-click solution for correcting unanticipated consequences of operator input such as accidental deletions or modifications of the Situation Display.

3.14. Develop robust search capability as a supplement to navigation

Parsimony is key to effective search interfaces. Operators are not interested in elaborate search technologies. Users are more satisfied with receiving a few very refined search results rather than sorting through multiple pages of results that are often irrelevant. Even sophisticated users can easily become confused and frustrated by poorly designed search interfaces and search results pages.

When designing search functionality, follow these guidelines:

- Use terminology that matches users' terminology, and provide simple instructions and tools to help guide users through the search.
- Place the search box in a consistent location on the interface.
- Design a search box that is large enough to allow a minimum of 20 characters to be entered.
- Use Arial font for the search box because it is a narrow font and allows the reader to enter more characters.
- Allow users to start the search with either the touch of the Enter key or the click of the "Search" button.
- The basic search should allow for Boolean commands ("and," "or"); although, this does not need to be explained.

4. Guidelines for Efficient User Interaction

4.1. Enable intuitive and efficient bearing and range functionality

Determining the bearing and range of entities on the Situation Display is a fundamental responsibility of BMC2 operators. Accordingly, HMI features and functionality should serve to enhance the ease with which operators can extract this information from the Situation Display.

HMI Core Component

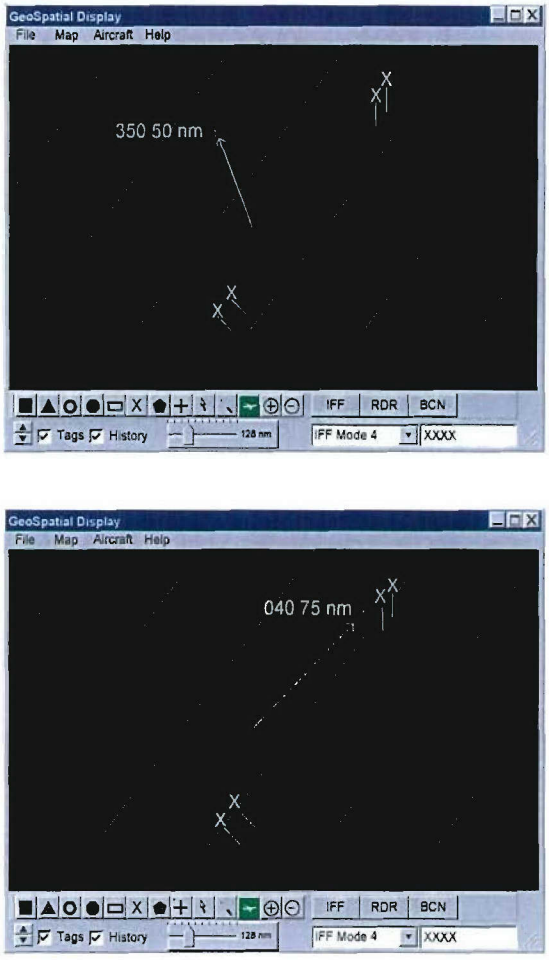


Figure 20. Quick line functionality displays continuous bearing and range information from a left-click point of origin to the placement of the mouse cursor.

HMI Core Component

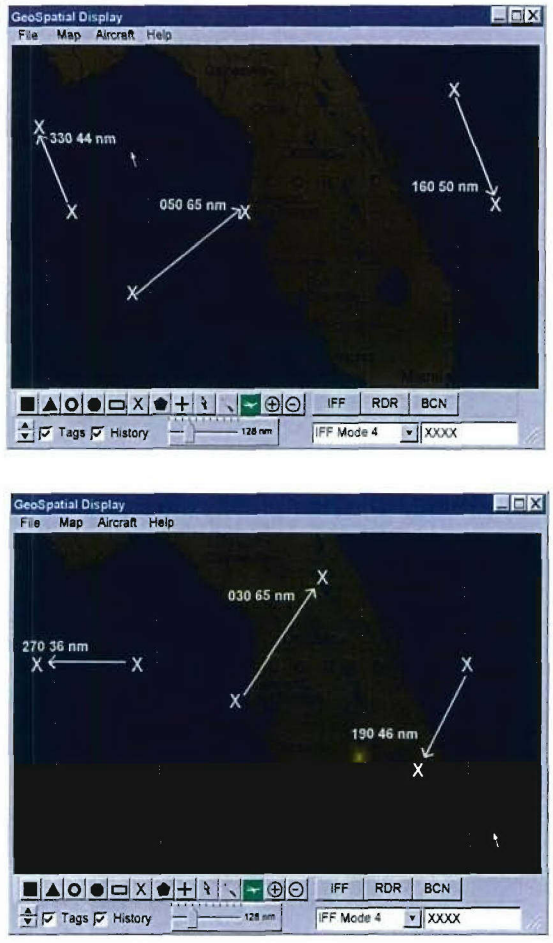


Figure 21. Dynamic line functionality involves "hooking" the point of origin and selecting a destination (object or location). This display results in a dynamically-updated bearing and range line and readout based on the movement of the origin and/or destination points.

HMI Core Component

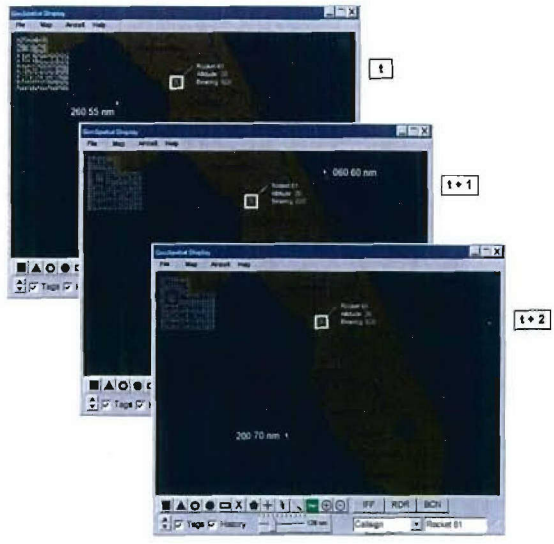


Figure 22. Dynamic cursor functionality involves hooking a track, object, or setting a bullseye. It depicts the bearing and range from the Primary hook, Secondary hook, or bullseye to the cursor.

Summary

Obtaining bearing and range information can be enhanced by HMI core components such as quick line, dynamic line, and dynamic cursor.

HMI Core Component

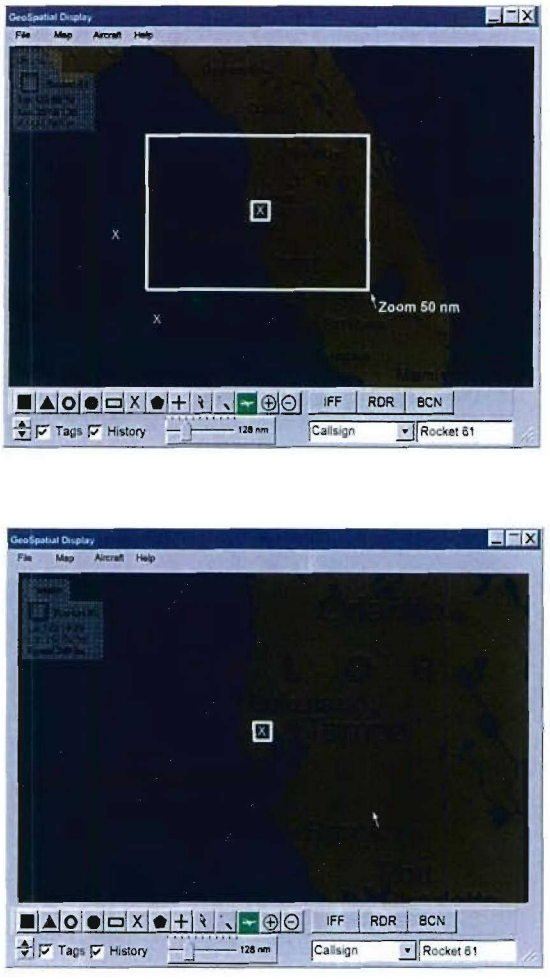


Figure 23. Rubber-band zoom feature allows the user to specify the zoom area of the Situation Display by drawing a rectangle with the mouse.

Summary

Efficient range in and out functionality includes core features such as rubber-band zoom and the range slider, which is located at the center of the main toolbar.

HMI Core Component

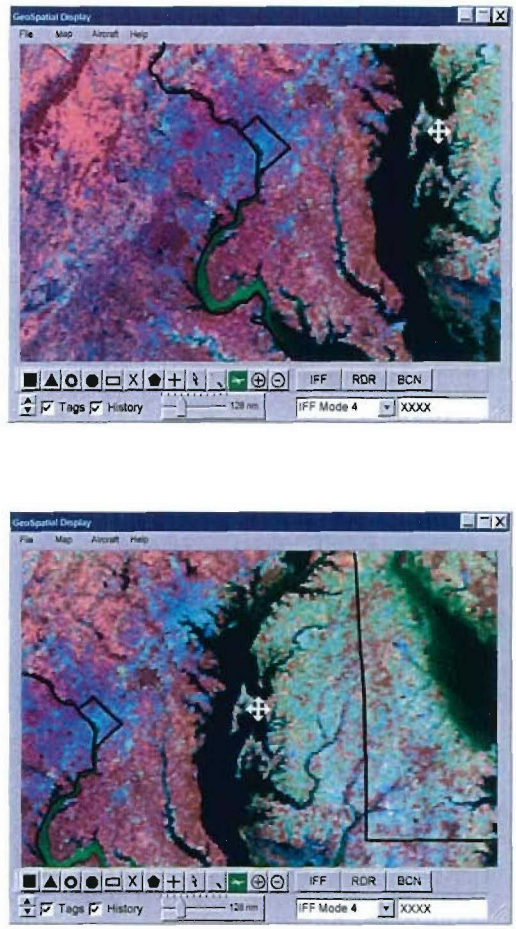


Figure 24. Offset screen functionality affords an efficienct means for re-centering the Situation Display based on cursor position

Summary

Efficient user interaction is afforded by HMI core components such as direct re-centering of the Situation Display.

HMI Core Component

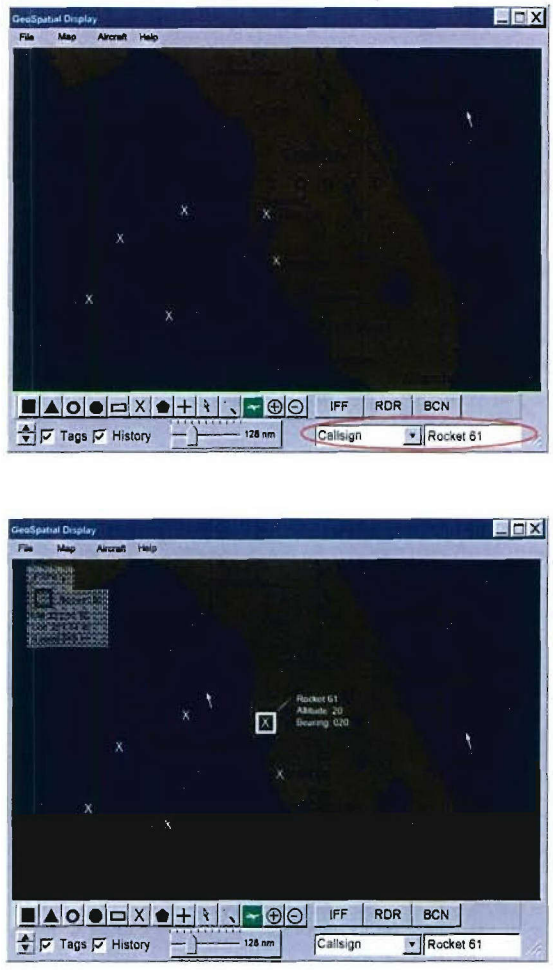


Figure 25. Track search functionality

Summary

Place navigational elements strategically and consistently on the Situation Display. This reduces the effort required to navigate the interface.

4.2. Enable commonplace windows GUI functionality wherever practical

Drag-and-drop and cut / copy / paste functionality not only increases the efficiency with which operators can edit and manipulate the Situation Display and other electronic documents; it also reduces the likelihood of errors due to manual data entry.

4.3. Provide search and sorting capabilities for tabular data

The utility of electronic documents that are organized in spreadsheet format is dependent upon an operator's ability to efficiently access and modify the data they contain. As such, search and

sorting capabilities should always accompany data presented in this format. For example, operators may need to search an electronic Air Tasking Order (ATO) for specific call signs, or sort the ATO based on time, platform, etc.

4.4. Provide efficient customization of displayed information

Operator effectiveness can be enhanced by providing efficient customization of information displayed on the Situation Display. For example, operators should be able to select which information they want to display about tracks (e.g., altitude, speed, heading, mode/codes, lat/long, local, etc.) on rollovers and tabular displays, and in what order this information is displayed.

4.5. Enable rollover and right-click interaction with graphical objects on the Situation Display

The inclusion of rollover and context-based right-click functionality to the Situation Display enables object-based drill down, providing a means for operators to obtain more detailed information about tracks and other battlespace entities. Rollovers should provide operators with immediate access to customized information that they require most frequently. Right-click functionality provides an efficient means for directly accessing the full compliment of information about a track or entity.

This is particularly applicable in the case of Combat ID. Positive identification requires that operators have access to the sources of information that contribute to automated track ID. Interfaces should be designed to allow operators to quickly and easily verify these fused data by drilling down to various levels of specification, using primary navigation (i.e., mouse click, speech command). Given the importance of this capability, it is highly recommended that usability engineering methods such as prototype and interface evaluations be conducted before interface deployment.

4.6. Provide text-to-text and text-to-object hyperlinking where appropriate

Efficient navigation within text-based documents (e.g., help, user guides) is enhanced by hyperlinking of related topics and content. This minimized the need for unnecessary scrolling and inefficient scanning of lengthy documents. It may also be useful to hyperlink elements of the ATO with their corresponding graphical representations (i.e., tracks, air and surface, etc.) on the Situation Display. This capability provides a more fluid transition by eliminating intermediate steps.

4.7. Provide intuitive and efficient drawing functionality

Operators require an intuitive and efficient means for creating graphical objects on the Situation Display. Drawing functionality should mimic best practices commonly used in commercial software packages. As an example, operators should be able to quickly draw basic shapes using the pointing devices as compared to only being able to create these shapes by typing coordinates into an editor.

Effective Information Design

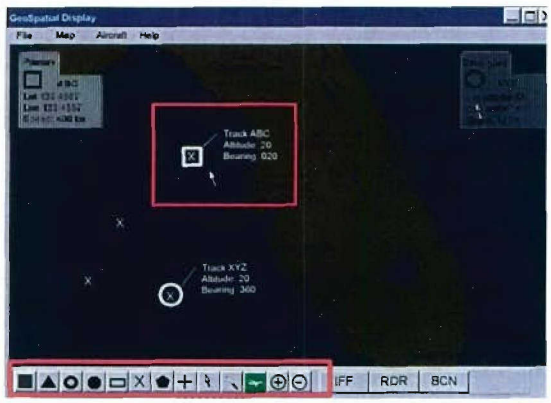


Figure 26: Toolbar drawing features permit efficient mark-up of the Situation Display.

Summary

Design drawing and editing tools to enhance operator efficiency.

Ineffective Information Design

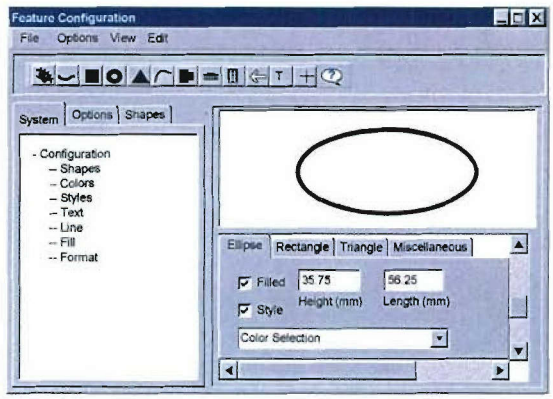


Figure 27: Inefficient drawing tool editor for creating shapes that are often used by operators.

Summary

Avoid tool editors that disengage the operator from the Situation Display.

5. Login and Setup

5.1. Permit operators to maintain multiple set-up configurations based on roles and responsibilities

If possible, only require operators to log-on once by creating a profile for each operator that specifies their unique set-up and interface configurations. Default profiles based on roles and responsibilities should also be made available.

5.2. Provide global workstation / operator assignment information

Workstation assignment and current operator status should be made available to promote team awareness of crew configuration, operator availability, seat position, and role. This interface should be available to all operators and may take the form of a schematic of the platform showing workstation locations.

5.3. Limit the operator's ability to customize critical display properties

If given the opportunity to customize important display elements and their properties, such as color or symbol set, operators run the risk of severely degrading situation awareness when building, sharing, and adapting the tactical picture. Accordingly, customization privileges should be restricted to authorized individuals.

5.4. Contrast font and symbology color against background color

Provide high contrast between font color and Web site background color.

Effective Information Design

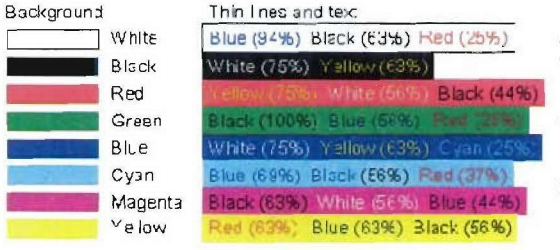


Figure 28: Good color combinations for thin lines and text by order of acceptance.

Summary

For thin lines and text displayed on a white background, blue is a good choice in more or less 94% of cases, black is in 63% of cases, and red is in 25% of cases. For thin lines and text displayed on a black background, white is a good choice in more or less 75% of cases, yellow is in 63% of cases. The other lines can be read similarly.

Ineffective Information Design

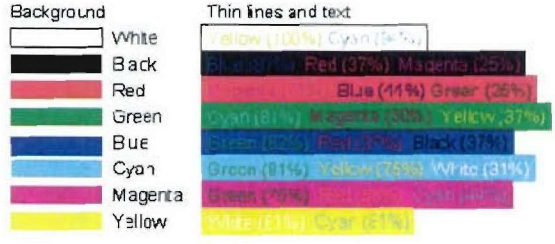


Figure 29: Bad color combinations for thin lines and text by reverse order of acceptance.

Summary

For thin lines and text displayed on a white background, yellow induces a legibility problem in almost all cases, while cyan does it in 94% of cases, and so forth.

6. Alarms and Alerts

6.1. Design alarms and alerts to be meaningful

The design of meaningful warnings, alerts, and alarms is crucial to maintaining operator and team situational awareness. Alarms and alerts can be made more meaningful and useful by avoiding the application of system-specific codes and acronyms.

Effective Information Design

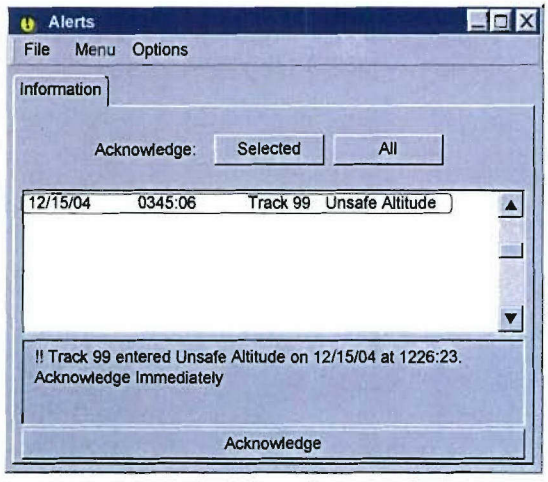


Figure 30: Meaningful alarm labels.

Summary

Provide meaningful descriptions of alert and warning conditions.

Ineffective Information Design

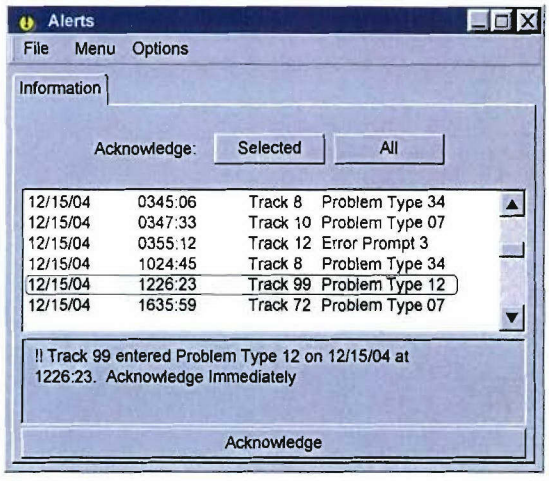


Figure 31: Arbitrary numerical codes used for specifying alarm conditions.

Summary

Do not require operators to decipher arbitrary error codes.

6.2. Design redundant multi-modal alarms and alerts

Multi-modal warnings and alarms that take advantage of voice, visual, and auditory cues may be effective during attentionally-demanding tasks. The idea is not to restrict alarms and alerts to one modality but rather to employ redundant multi-modal cueing to ensure that important warning and alarms are noticed by operators. In the case of auditory and voice alerts, care must be taken not to overwhelm the operators with a cacophony of alarms, especially in such a communication intense environment.

6.3. Avoid designing intrusive warnings, alarms, and alerts

Given the potential for an unwieldy number of alarms and alerts, only the most critical should be displayed atop the Situation Display. This recommendation is consistent with the general guidance of preserving an uncluttered Situation Display and promoting optimal situation awareness (see 3.1).

Effective Information Design

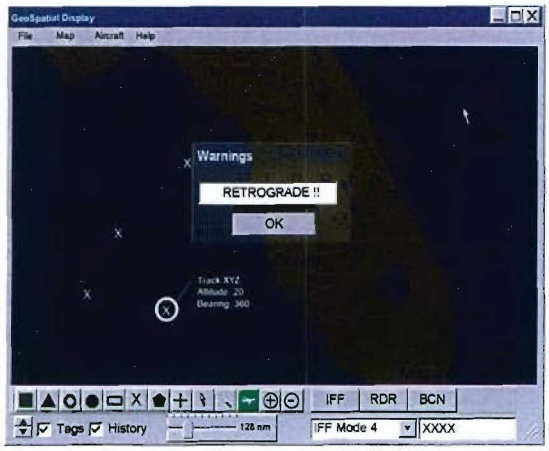


Figure 32: Intrusive warning used only when urgent action is required.

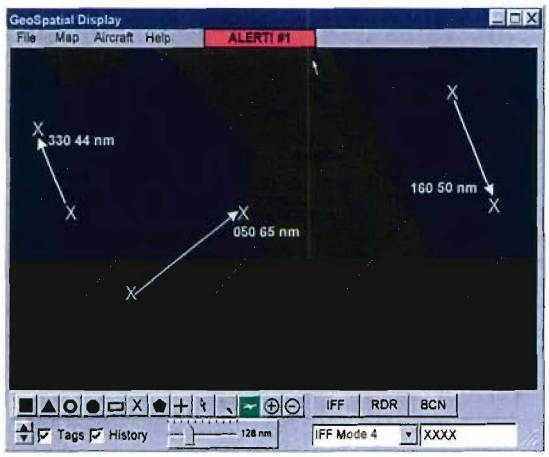


Figure 33. Alerts should be designed to minimize occlusion, while at the same time capturing the attention of the operator. This can be accomplished by a judicious application of color, blinking, etc.

Summary

Design alerts and alarms according to human factors best practices and guidelines.

Ineffective Information Design

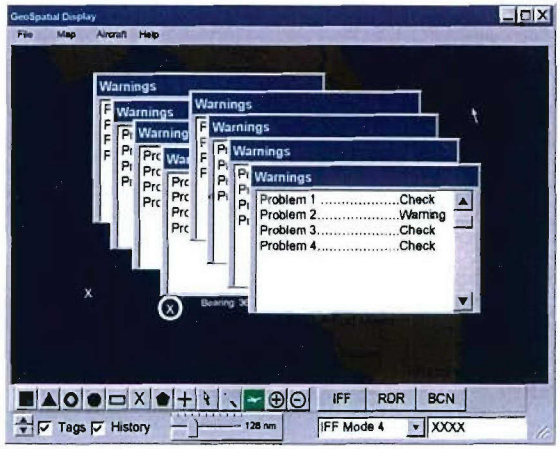


Figure 34: Non-judicious application of intrusive warnings.

Summary

Avoid frequent use of distracting alarms, warning, and alerts.

6.4. Design alarms to convey real urgency and importance and discourage complacency

The criteria for displaying an alarm should be carefully considered in terms of the urgency of the triggering event and the relevance to the operator. If an operator has to frequently acknowledge alarms that are irrelevant for his role, he will likely interpret the system as "crying wolf" and unintentionally dismiss alarms that may be critical.

Effective Information Design

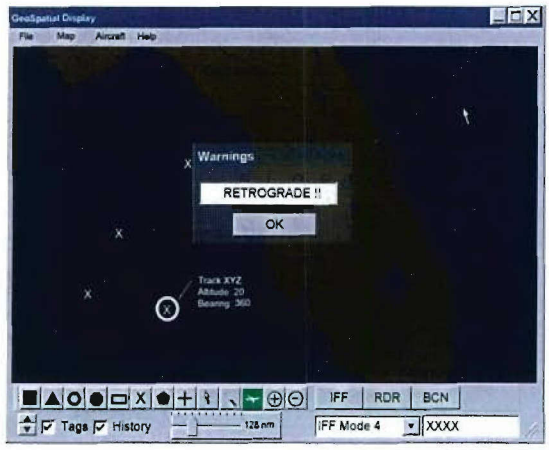


Figure 35: Warning display that conveys real urgency by location on the Situation Display.

HMI Core Component

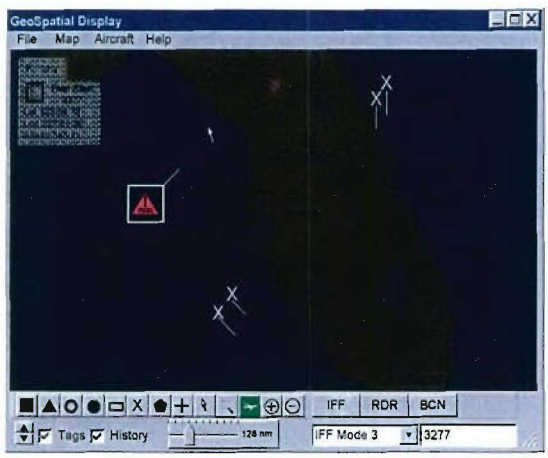


Figure 36. Special IFF/SIF alerts and symbols are used to alert operators when a track has been assigned a Mode 3 code of 7500, 7600, or 7700.

Summary

Alarms and alerts that are urgent should be designed such that they provide clear indication of the alerting conditions.

Ineffective Information Design

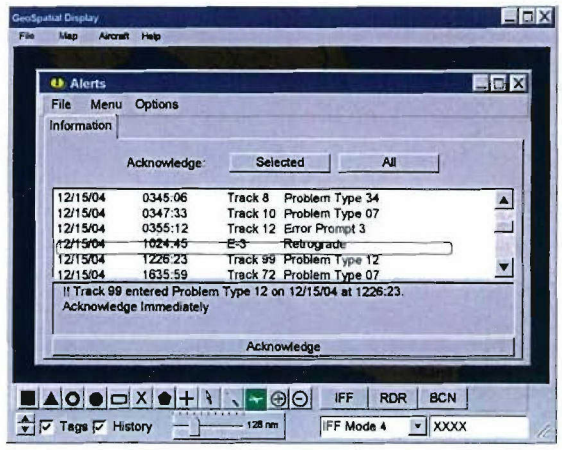


Figure 37: Urgent condition and warning camouflaged by routine warning conditions.

Summary

Undifferentiated warnings and alerts compromise the intended urgency of important messages.

7. Communication Interfaces

7.1. Design to minimize mode awareness errors

Operators in communication-intense domains require intuitive and efficient communication interfaces that provide explicit feedback regarding the settings on their communication devices. Specifically, they need to know precisely to whom they are talking and listening, and whether their transmissions are secure or not secure.

7.2. Efficient navigation of communication features

Consistent with section 3.2, navigation of communication interfaces must be designed to enable efficient manipulations of the most common and important communication features such as channel selection, volume control, and security settings. Requiring operators to navigate multiple menus and submenus to perform these tasks diminishes situation awareness and increases workload and frustration.

7.3. Design spatial intercoms to maximize operator performance

For communication systems that employ spatial audio technology to separate intercom and/or radio channels, configurations of the spatial separation of channels should be bounded by spatial locations that have been determined to provide optimal performance. Although not intuitive, maximal angular separation does not imply optimal spatialization (see figure below).

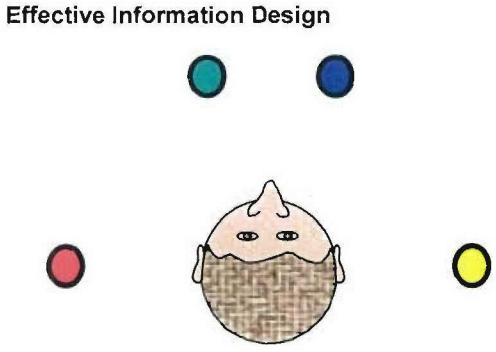


Figure 38: Optimal arrangement for four spatial audio channels

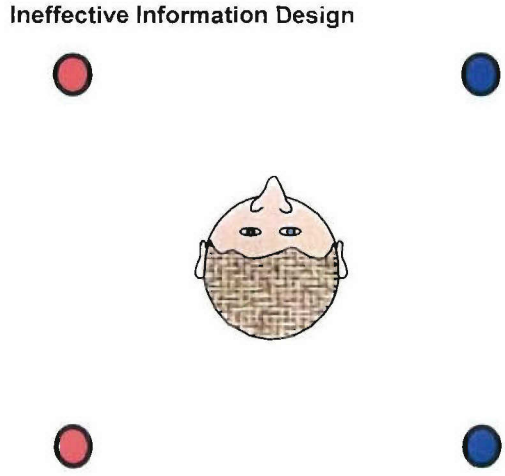


Figure 39: Non-optimal spatial separation of communication channels due to confusion of the location of channels sharing the same color

7.4. Collaboration interfaces and Chat / Instant Messaging (IM)

Commercial-off-the-shelf instant messaging and collaboration applications are sufficiently easy to use and efficient and therefore should be adopted wherever possible. Special consideration should be given to the ability of the interface to provide feedback regarding:

- Chat room participants and their operational roles
- Participants' status (busy, online, away, etc.)
- Participation in multiple, simultaneous collaborations
- Participants' engagement status (typing, drawing, speaking, etc.)
- Channel security level
- Context indicator (e.g., time stamp, topic)
- Location of shared content

HMI Core Component

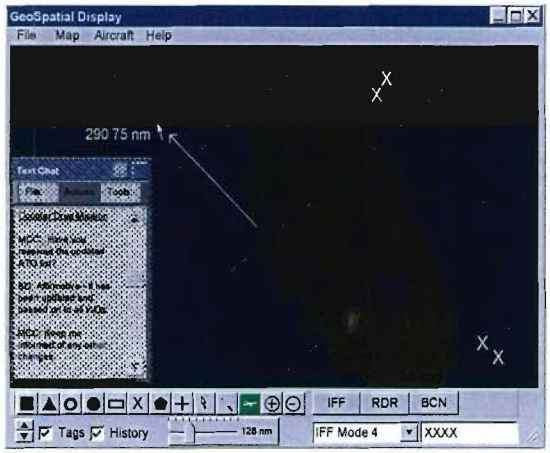


Figure 40. Text chat (Instant Messaging) among workstations

Summary

Real-time collaboration is enhanced by integrated text chat / instant messaging.

8. Brower-based Interface Design

Future BMC2 system will most likely employ browser-based content, such as manuals, data bases, and help screens. Accordingly, the following guidelines are provided as a quick reference to the design of browser-based interfaces. While not exhaustive, these simple to follow rules will help to ensure the consistency and usability of such systems. A comprehensive set of research-based web design and usability guidelines can be found at: http://usability.gov/guidelines/index.html.

8.1. Place global navigation, logo links, and persistent page elements consistently

Position navigational elements in the same place on each page. Effective global navigation occurs when a portion of each page is dedicated for this purpose. This reduces the time users need to learn to navigate through the site. This also increases the efficiency of the users' interaction.

8.2. Position critical information "above the fold"

As with navigation, users may miss or ignore critical information located below the fold. Help users locate this information by positioning it within the top half of each page.

8.3. Design page layout to facilitate scanning

Design pages that facilitate scanning. Designs should accommodate small modules or chunks of information. Enhance scanning by creating clear link titles and headings and by utilizing short phrases, sentences, and paragraphs.

8.4. Align page elements into columns and rows

Align page elements into columns and rows. Users are better able to scan text in short narrow columns (like a newspaper) rather than long, wide columns.

8.5. Exploit white-space between columns and rows to guide visual attention

White space between columns helps direct users as they read, particularly those who scan. Use white space judiciously to balance text density with page length.

8.6. Left-align text

In most cases, it is preferable to left-align text, particularly large blocks of content, because English speakers are accustomed to reading top-down, left-to-right. Centering is fine for buttons, headlines, and captions.

8.7. Provide high contrast between the text and the background

Create sufficient foreground/background contrast to improve legibility of text and graphics. Black text on a white or light background is best.

8.8. Minimize the number of colors you use for image maps

Image maps are graphics that contain one or more regions that are hyperlinked. When using image maps, be sure to provide "alternative text" for each region of the graphic so that text-only browsers can recognize the content, and search engines can include the content of the graphic in its index of the site. In general, image maps require more time to download and may take users longer to comprehend than comparable forms of text navigation.

8.9. Horizontal scrolling

Create pages that are limited to one page horizontally. Requiring users to scroll left and right while reading frustrates users over time and greatly reduces the speed of their interaction.

8.10. Include a title at the top of each page

Begin each page with a descriptive title that matches the links that bring users to the page.

8.11. Compose descriptive and unique titles for each page

Construct titles that are descriptive and unique to each page. This helps users to identify the content on the page quickly and provides greater search capability.

8.12. Compose meaningful and descriptive headings and subheadings

As with page titles, compose meaningful and descriptive headings. Headings should inform users about the purpose of the section and content, and they should be written to stand alone. Use subheadings to further divide lengthier portions of text.

8.13. Use serif or sans serif fonts

Current research on font selection shows that user performance is equivalent for serif fonts and sans serif fonts alike; however, users show a preference for sans serif fonts (that is neither bold nor italic) when reading online.

8.14. Use relative font sizes

Relative font sizes enable the text to conform to the user's screen resolution being used to display the page content.

8.15. Limit the number of unique fonts/typefaces

Readability and scannability are adversely affected when a page contains multiple unique typefaces; users require more time to process the information contained on the page, and they cannot quickly establish relationships between the text and its relative importance.

9. References

Nielsen, J., & Mack, R. (1994). *Usability inspection methods*. New York: John Wiley & Sons, Inc.