Human-Computer Interaction for Alert Warning and Attention Allocation Systems of the Multi-Modal Watchstation

R. W. Obermayer*, Pacific Science and Engineering Group
W. A. Nugent, Space and Naval Warfare Systems Center, San Diego

---

Table of Contents

ABSTRACT

The SPAWAR Systems Center San Diego is currently developing an advanced Multi-Modal Watchstation (MMWS), design concepts and software which are intended for transition to future United States Navy surface combatants. The MMWS features multiple flat panel displays and several modes of user interaction, including voice input and output, natural language recognition, 3D audio, stylus and gestural inputs. In 1999, an extensive literature review was conducted on basic and applied research concerned with alerting and warning systems. After summarizing that literature, a human computer interaction (HCI) designer's guide was prepared to support the design of an attention allocation subsystem (AAS) for the MMWS. The resultant HCI guidelines are being applied in the design of a fully interactive AAS prototype. An overview of key findings from the literature review, a proposed design methodology with illustrative examples, and an assessment of progress made in implementing the HCI designers guide are presented.

Keywords: Alert, Warning, Alarm, Attention Management, Attention Allocation, Interruption, Human-Computer Interaction, Multi-Modal Watchstation

1. INTRODUCTION

This paper presents a method and guidelines for the design of alerting and attention management systems. In 1999, two documents-a literature review[1], and a human-computer interface (HCI) designer's guide[2]-were prepared to assist software engineers in designing an attention allocation subsystem (AAS) for the Multi-Modal Watchstation (MMWS). This paper summarizes key portions of those documents.

The terms "alert", "warning", and "alarm" are often used interchangeably for systems that involve attention-getting and presentation of information about significant, abnormal or threatening situations. While sharp distinctions can be drawn between these terms, we have chosen to operationally define all three as: Any system- or human-generated message that needs to be brought to the attention of the operator in conjunction with ongoing, pending, or future tasks.

Back to Table of Contents

2. WHAT'S WRONG WITH CURRENT ALERTING SYSTEMS?

Given the ubiquity of computers in everyday life, the failings of computer-mediated alerting systems has gained the attention of the print media, as evidenced in newspaper articles titled: "That bleeping beep, beep, beep has got to go, but it won't go quietly" (San Diego Union-Tribune, 24 August 1999) and "The beep goes on ...but many want to silence technology's terrible tune". (San Diego Union-Tribune, 22 February 2000).

Similarly, even a cursory review of the scientific and technical literature reveals the following list of ills with computer-mediated alerting systems:

- There are simply too many alerts;
- Alerts are too strident, often startling the operator;
- False alarms create a "cry-wolf" effect;
- Alerts can be distracting & annoying, particularly when the operator knows why the alert is being triggered;
- Routines for handling multiple, simultaneous alerts are inadequate;
- There are more alerting sounds than can be learned, retained or discriminated;
- Spoken alerts are often indistinguishable from other voice communications; and
- Interruptions from alerts often cause errors.

In short, many contemporary alerting and warning systems fall short of their goal of providing needed information to the operator in a manner that can be integrated into ongoing tasks; rather, they are often annoying, don't inform, and create havoc with tasks in process.

Back to Table of Contents

3. CHANGES INDICATED FOR FUTURE SYSTEMS

"Do more with less" has become a de facto requirement facing acquisition programs throughout all branches of the US Armed Forces. To meet this requirement, the US Navy has established a goal of a 95-person crew for its future land attack destroyer (DD 21) program. This ambitious goal represents a nearly 80 percent reduction in crew size compared to existing Spruance Class destroyers. A likely outcome from the trend toward smaller crew sizes and increased dependence on automation is that the nature of work performed by operations, maintenance and support personnel on future Navy ships will change from one of direct observation, manipulation and control, to initiating and supervising multiple, automated, functions concurrently. As a consequence, the design of systems for future Navy ships must include provisions for effectively managing the operator's attention to ensure balanced workload, efficient and effective task performance.

Back to Table of Contents

4. MULTI-MODAL WATCHSTATION (MMWS)

The MMWS depicted in Figure 1 is being developed to deliver lessons-learned, software and test results to support industry in the US Navy's DD-21 shipbuilding effort. The following provides a partial list of HCI features being incorporated into the MMWS:

- Visual-multiple flat panel & head-worn displays to support both mobile & seated operators
- Voice-supports voice input, output and keyword spotting
- Audio-supports 3D audio & user-defined replay of digitized audio
- Manual entry-keyboard, mouse, trackball, stylus, bare hand touch
- Models, agents, collaboration tools-optimized for specific operator tasks

Figure 1. The Multi-Modal Watchstation (MMWS); for additional details, consult: http://www.manningaffordability.com

Back to Table of Contents

Traditional approaches to HCI design do not account for rapid and dynamic changes in the operator's visual, auditory, cognitive or psychomotor workload "states" as tasks and functions are being performed. For that reason, the HCI designer is forced to make fixed decisions regarding methods and sensory modalities to use in signaling or communicating information to the operator. The MMWS, in contrast, includes provisions for continually monitoring operator state and task progress factors. Specifically, the AAS component of the MMWS will include algorithms for determining the most appropriate method and sensory modalities with which to convey information to the operator-depending on the circumstances at the time.

5. A BRIDGE IS NEEDED

To initiate this effort, a detailed review of the literature on visual, auditory, and haptic (tactile/touch) modes of alerting and attention-getting was conducted. Particular emphasis was given to a review of the following topics: (1) criteria for selecting an appropriate sensory modality (e.g., visual, auditory, haptic) for signaling and/or communicating , (2) methods for capturing attention, and (3) presenting time- and event-critical event information. To ensure that information obtained from the literature was maximally useful, , it was recognized that a companion document was needed to provide a "bridge" between the available literature and guidelines to support the design of an effective AAS.

Back to Table of Contents

6. ALERT TAXONOMY

Key considerations in the design of an effective AAS are (1) the type of information to be presented, and (2) the urgency of the information to be conveyed, and (3) the need to intrude on the current activities of the operator. A conceptual model for the design of the AAS, which accounts for the above considerations, is presented in Figure 2. As shown in that figure, the HCI designer must consider each alerting message in the context of the task being performed to determine the level of attention-getting desired for the message. Further, the designer must progressively decide if the message should completely capture the operator's attention and how quickly (if at all) the operator should respond. Because the number of levels of attention-getting will depend on the specific application, the designer may decide to use more or fewer levels than are shown in Figure 2.

Inspection of Figure 2 shows that different types of information require different HCI design considerations. For example, rather that repeatedly interrupting the operator with a message indicating that a particular system or equipment is vacillating between an "up" or "down" state, a Level V (unobtrusive alert) is suggested wherein current operational status data would be presented in a fixed location that the operator could consult if, and when, needed. Conversely, an emergency situation may require immediate attention capture and immediate response on behalf of the operator. In these situations, a Level I alert is suggested wherein a modal dialog is presented which interrupts all ongoing tasks until the message is acknowledged and/or acted upon by the operator. For Level II in the hierarchy, only partial interruption of ongoing tasks is desired, and only a near-term response is necessary, while Level III and IV alerts allow the operator to decide if, and when, a response is necessary.

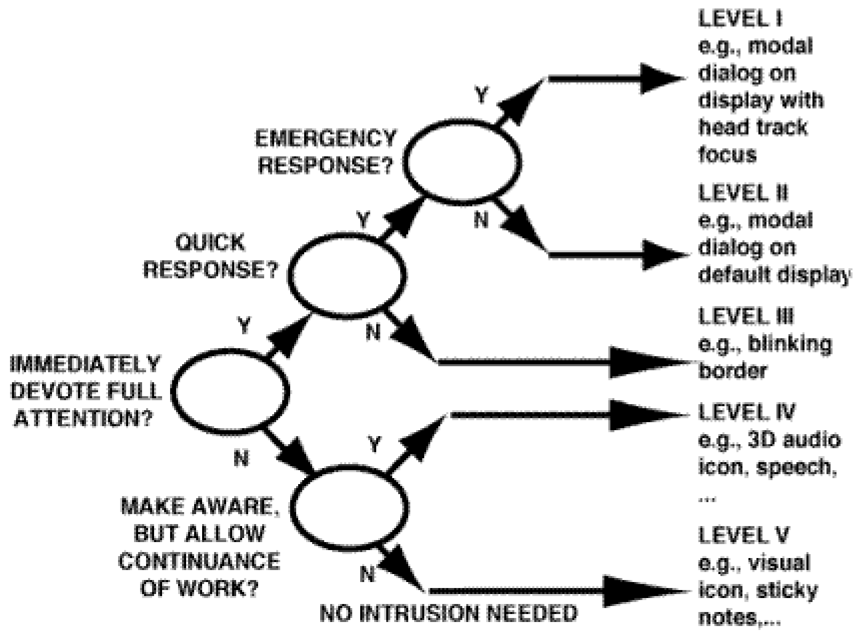

Figure 2. A decision tree to be used by the HCI designer in determining the appropriate level of attention getting

Back to Table of Contents

7. TASK ANALYSIS FOR MULTI-LEVEL ATTENTION-GETTING

Task analysis is a prerequisite for HCI design, and also plays a central role in the AAS design. Task analysis must consider each alerting message in the context of the task being performed to determine the level of attention-getting that is desired for the message. For example, a lengthy text message may have to be displayed in a manner that permits the operator to re-check specific portions of the message, whereas shorter and simpler messages may be presented both visually and auditorially. Other task or window specific information can be presented as part of the task displays (or perhaps in a sticky-note format) such that information is found in the appropriate time and context. Tactical situation updates, or other graphic information, may best be displayed graphically or symbolically in a geographic context.

Back to Table of Contents

8. THE DESIGN PROBLEM

Given a specific message which has been classified in accordance with the forgoing taxonomy, the designer must next determine how to present the information with the appropriate degree of intrusion into ongoing tasks. As shown in Figure 3, the designer must determine, for each type of information, how to present messages at each level of urgency (e.g., using visual and/or auditory modes, or if the system permits, haptic (tactile) stimulation, as in the MMWS). Additionally, rules must be developed to select between alternative sensory modes (e.g., a message may be presented aurally, in cases where the operator's visual channel is heavily loaded, or signaled by haptic stimulation if both audio and visual channels are loaded).

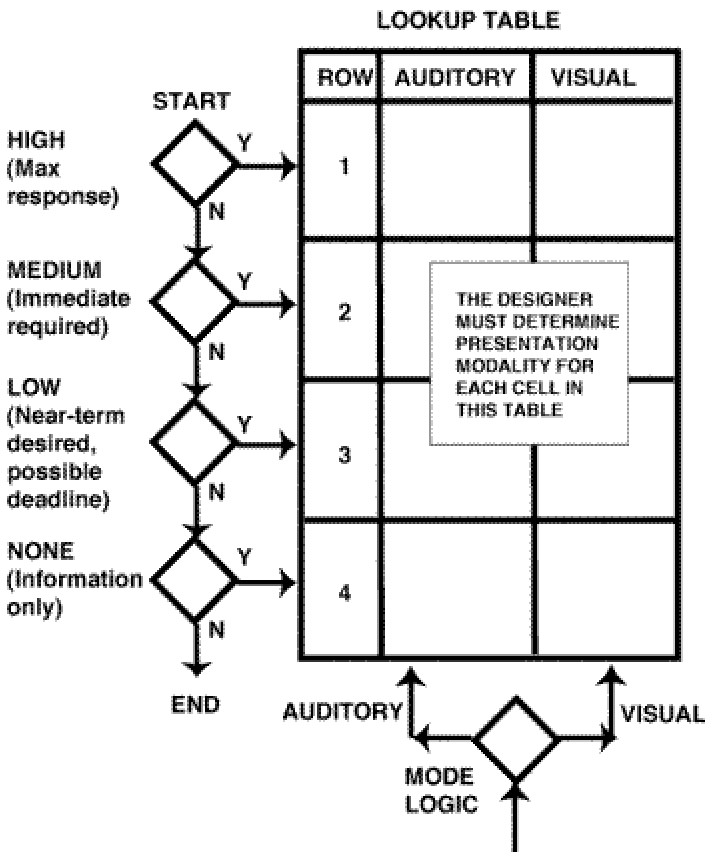

Figure 3. A matrix of levels of alerting and presentation mode the HCI designer must complete for each message type

Back to Table of Contents

9. HOW GOOD IS THE BRIDGE?

Given a design structure as described above, it is then possible to examine the literature review to determine the extent to which information is available to support the design process. The research literature provided strong coverage for part of the design process, but was relatively weak in other parts.

For example, the literature provides useful information for determining the minimum detection level for auditory and haptic stimuli, as well as parameters for maximum attention capture of alerting signals in the visual, auditory and haptic modes. There is much information about the construction of alerts to convey a desired level of perceived urgency. Furthermore, there are relatively good rules for deciding when to use visual and auditory modes.

The research literature provided only limited information on methods for ameliorating the disruptive effects of alerts on task performance, facilitating selective or divided attention, and the use of haptics (tactile stimulation) as an adjunct to, or a replacement for, visual and auditory alert presentation.

Consequently, as with all guideline documents, much of the information presented in the Designer's Guide is firmly based on an abundant research literature, and other portions are based on incomplete literature, and were supplemented with the author's judgment.

Back to Table of Contents

10. SOME EXAMPLES

Examples are provided in the following paragraphs to illustrate display techniques which present alerting messages with varying degrees of interruption on the operator's tasks. These examples, shown in order of increasing intrusion into operators tasks and increasing demand for quick response, are derived from AAS prototype designs. To date, none of these designs has been subjected to extensive use or testing.

Figure 4 shows an example of a Level V alert message, which, at least initially, does not justify any intrusion or interruption of the operator's activities. However, the information must be posted where the operators can readily locate it, if and when needed. For the multi-page window shown, alerting icons are placed on tabs, which, when selected, displays the associated alerting message. For this level, use of audio icons or speech messages is not recommended.

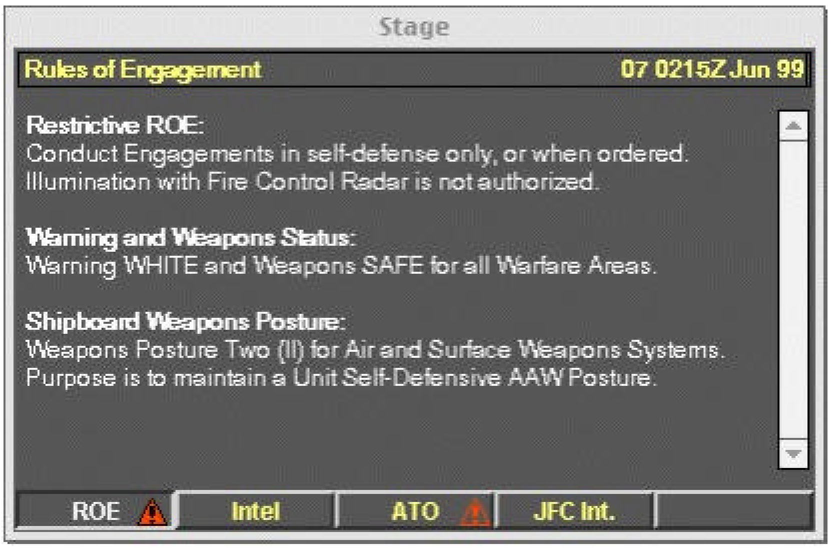

Figure 4. Alert message presented with no intrusion into operator's tasks (a filled icon indicates operator attention is requested, an unfilled icon indicates that the associated message has been viewed)

Back to Table of Contents

Figure 5 presents an example of a Level IV alert message which is intended to present information with minimal disruption of on-going activities, thereby permitting the operator to decide if and when to respond. The key display is a low-urgency audio icon, possibly accompanied by a short speech message. Visual icons are also provided to lead the operator to specific detailed information.

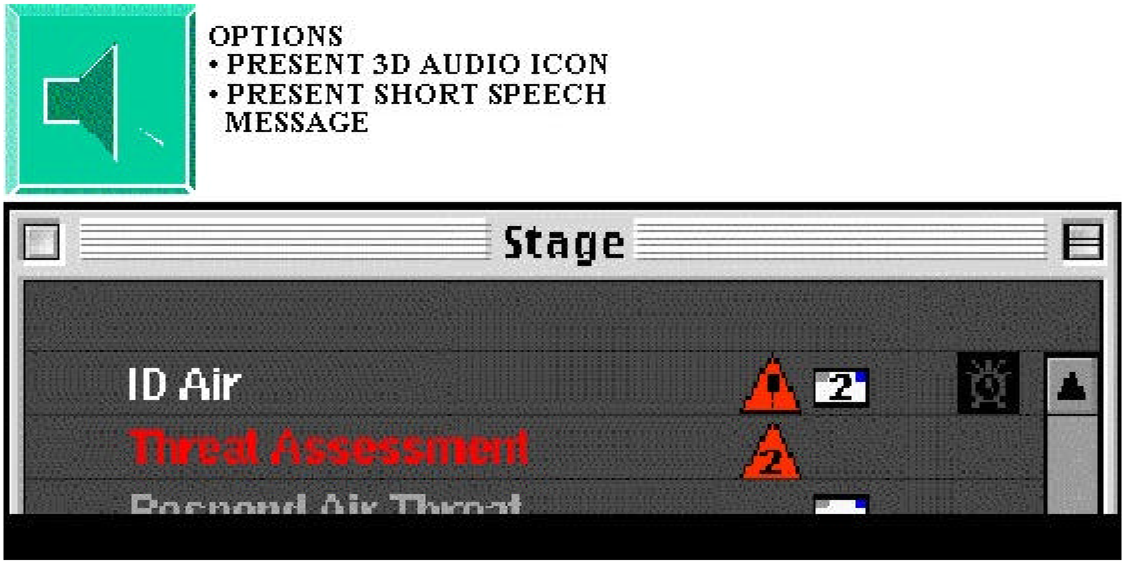

Figure 5. Alert message presented without requiring immediate attention

Figure 6 shows an example of a Level III alert message which is designed to capture the full attention of the operator, but for which there is ample time available to respond. In this example, the border of a screen, or the menu bar across the top of a window, may flash to capture the operator's attention.

Figure 6. Alert message presented to capture the operator's attention (menu bar may flash)

Back to Table of Contents

Figure 7 presents a Level I/II alerting message which requires maximum attention-getting and is of such importance that it will interrupt on-going work and require immediate operator response. The key display is a high-urgency audio icon that has been repeatedly presented and practiced during operator training. A modal window (either on a default screen or the screen at which the operator is currently looking) occupies a central location and presents detailed message information and options for operator response; no other task activity is permitted until the operator has attended to the alert.

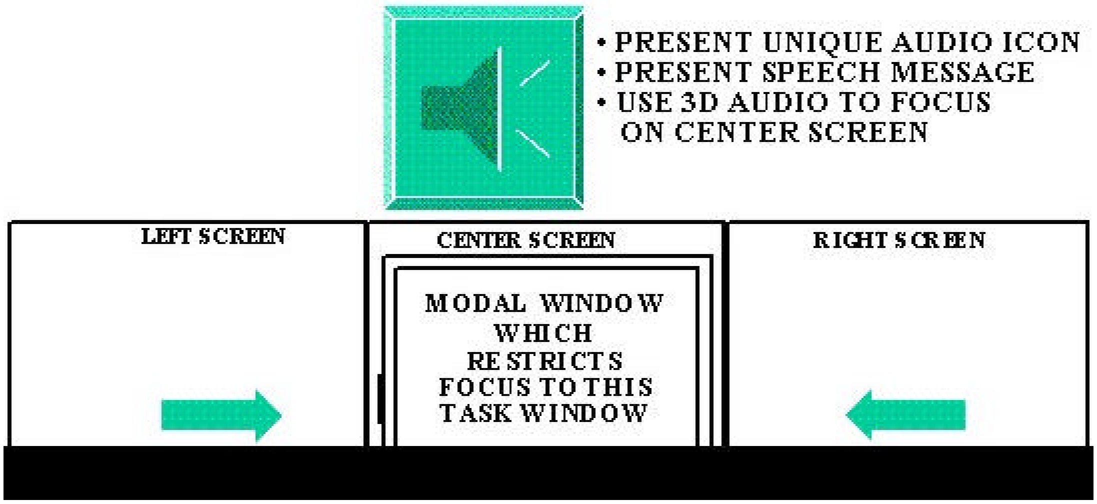

Figure 7. Alert message presented to demand immediate attention and response

Back to Table of Contents

11. A BROADER VIEW: ATTENTION MANAGEMENT

The designer is urged to take a broader view than just focusing on capturing the operator's attention for the purpose of presenting a given alert message. The designer must also guide the operator (i.e., redirect attention through the appropriate task steps of acknowledging and/or acting-on the message, then facilitate the operator's return to the original task(s). In particular, when the alert message requires action, the designer should open the appropriate window for taking action as shown in Figure 8.

The designer should be aware that presentation of an alert or alarm is an interruption, and that the operator may be prone to error upon returning to the original task. For example, operators may think that they have completed part of a procedure (e.g., a checklist item) but in fact have not done so, or alternatively, may repeat something they have already done. Interruption should be considered a design challenge and provide for information needed upon resuming a task.

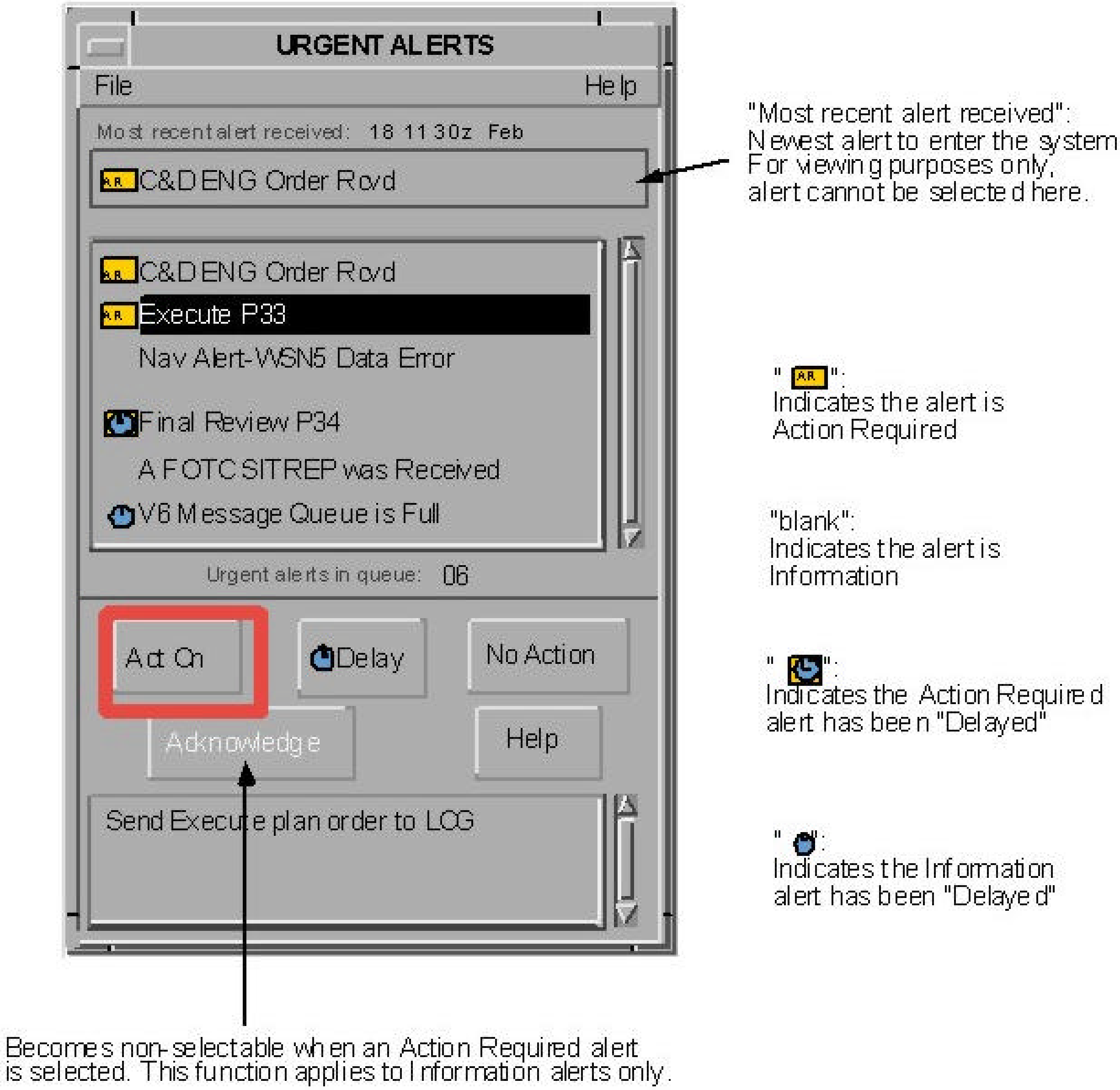

Figure 8. An example alerting window providing for the operator to take action

Back to Table of Contents

12. IMPORTANT ALERT SYSTEM CHARACTERISTICS

Although numerous guidelines are presented in the Design Guide document, the following list provides global recommendations considered most important to the AAS design:

- Ensure all messages are relevant. Filter, do not broadcast all alert messages to all watchstanders as is often done in currently fielded systems. Present operators only with alerting information necessary for the effective performance of their tasks.

- Use multiple levels of attention getting. Interrupt the operator only to the extent necessary. Be aware that unobtrusive methods are appropriate for many situations, such as indicating changes in system/operational status.
- Manage attention (capture & redirect). To the extent possible, the design should lead the operator to the next most appropriate activity, and not merely interrupt.
- Manage simultaneous, competing messages. Be aware that in a system in which there may be many hundreds of alerting messages there will be occasions where there are multiple, competing messages. The system must have a strategy for ordering and suppressing messages.
- Permit the operator a degree of control in delaying, deferring, and canceling messages. The AAS should provide, where the urgency of the message permits, a means for the operator to control the message stream. The system should also provide for intelligent upgrading of message urgency when the operator delays for an excessive time period.
- Archive messages and provide rapid search. The log of alert messages can be a valuable resource requiring means for rapid and efficient searching.
- Provide interrupt-resistant HCI. Recognize that interruptions may cause errors, and design measures for countering these errors.

Back to Table of Contents

REFERENCES

1. Nugent, W. A. and Obermayer, R. W., *Human Computer Interaction Design Guidelines for an Alert Warning and Attention Allocation System. I. Literature Review.* San Diego, CA: Space and Naval Warfare Systems Center, Code D44209, 17 February 2000.

2. Nugent, W. A. and Obermayer, R. W., *Human Computer Interaction Design Guidelines for an Alert Warning and Attention Allocation System. II. Design Guide.* San Diego, CA: Space and Naval Warfare Systems Center, Code D44209, 7 January 2000.

Back to Table of Contents

* Correspondence: Email: Obermayer@pacific-science.com; wnugent@spawar.navy.mil