# BEST PRACTICES FOR INFORMATION PRESENTATION TO OPERATORS

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## ABSTRACT

This paper will present an approach for developing best practices for information presentation to control room operators. Proposed studies to evaluate new information presentation concepts will be presented. These approaches to information presentation were gleaned from a research survey as well as member company research and experience. The need for these approaches was motivated by the early findings of the consortium regarding abnormal situation contributing factors and evaluation of existing guidelines. Existing guidelines seem to lack specifics and lag behind in incorporating current display and multimedia technology. Since the information needs of the control room operator can be critical, the presentation of this information requires a best practices approach.

## INTRODUCTION

The Abnormal Situation Management Consortium (ASM) was formed to reduce the incidence of events that result in loss or injury. Extensive site surveys were conducted to gather information related to this effort. One of the identified areas of concern was the quality and effectiveness of information presented to the operator.

Over the years, process operator responsibilities have fundamentally changed. Today's process control environment has moved from an active field environment that was relatively unsophisticated to a passive, sophisticated centralized control room (1). Traditional "*ownership*" of a process has given way to the "*inside/outside operator*" function, with the inside or console operator spending most of his/her time in a passive role monitoring the control display and only intervening directly when required (1). Although there have been technological advances to help the operator control the plant, potential problems, such as information overload and detachment from the process, have evolved.

The process industry has slowly shifted its focus from the operator to advanced control systems. The responsibility of monitoring the whole process has been assumed by advanced control systems with less meaningful intervention from the operators, while the "information", based on old paradigms, presented to the operators continues to grow. For example, today we can easily add alarms, such as Hi, Hi-Hi, Hi-Hi-Hi level and now we can add expert system information that additionally notifies the operator of the existence of a high level alarm; but in doing so, have we helped the operator respond to abnormal situations or have we deadened his ability to respond? To answer such questions, we have to examine issues such as *information flow control*, *problem solving and troubleshooting*, *event criticality analysis and notification,* and *information*

*display.* Furthermore, we must investigate the influence of human factors such as vigilance, operator involvement and buy in, impact of presentation, reading level, experience, and preferencing of presentation, on our abilities to respond to abnormal situations.

This paper will discuss related areas of concern and an approach to developing best practices. This approach includes a review and analysis of guidelines and literature, selection and development of concepts, and the development of a test platform to perform usability and validation studies on the concepts developed.

## DISCUSSION

### Areas of Concern:

Based on member experience and site survey data the ASM Consortium selected the information needs of the operator and how best to meet those needs as one of it's key areas of focus.

Currently, operators have control displays that provide them with plant status conditions through monitoring of trends, graphs and on line analytical instruments. However, support information such as procedures, checklists, short term operating limits and expert advice, etc., are usually paper based and often difficult to access. The control room operator facing a critical process scenario will often be under stress and in a situation in which minutes, even seconds count. Alarm flooding and other information problems leading to the inability to rapidly access and understand support information can cause the operator to take inappropriate actions.

### Developing Best Practice:

There are new technologies and systems that provide for easy and cost effective integration today of critical support information into the control room setting. These systems are cost effective when compared to the costs incurred during upset conditions such as injuries, damaged equipment, and lost production. For example, PR*i*SM (Performance Support and Information System), developed by Applied Training Resources (ATR), provides immediate access to existing and enhanced electronic information bases (Procedures, PSI data for PSM, emergency checklists, etc.).

While current technologies provide an information support and compliance bridge, the ASM goal is development of future best practices. The key issues involved in the design of best practice operator support systems are:

- Careful analysis of the information inventory to be stored in the system. Analysis is necessary to provide all needed information, to categorize the information, and to manage the currency, and updating, of the future information base.
- Research on the presentation and filtering of information. Unapplied research findings and information technologies need to be reviewed, and analyzed for applicability.
- Evaluation and development of those concepts identified that will provide significant enhancements to the information support deficit while incorporating human factors. Lab and on-site usability studies are a crucial part of this development.

### The Operator Interface:

Other study areas in the Consortium effort are addressing information inventory, operator vigilance and alarm information presentation issues. This paper focuses on the operator interface, specifically the organization and delivery of information to that interface. These two factors, organization and delivery, affect the operator's access, and comprehension of support information, and bear directly on the Consortium's critical findings.

## GUIDELINES

Some existing guidelines address the issue of information presentation in the computer environment.  The literature includes guidelines developed by research organizations such as *Nureg* (Nuclear Regulatory Commission)(2,3); Aviation Industry, Control Companies, Process Industry,(4,5); *EPRI* (Energy producers research Institute)(6,7); *NASA* (National Aeronautics and Space Administration)(8); *ANSI* (American National Standards Institute)(9); Hardware and Software firms (Microsoft, Sun Microsystems, Macintosh, IBM).

The following is a list of  interface elements for which guidelines have been developed:
- Characteristics of Cursors (Source: EPRI TR-101814)
- Display Density (Source: EPRI TR-101814)
- Keyboard Design (Sun, IBM, Microsoft)
- Recommended Values for Selected Display System Parameters (Nureg)
- Navigation Guidance (Microsoft, Sun, IBM, Ergonomic Society)
- Color Coding and Shapes (Microsoft)
- Messaging (ANSI, IBM, Microsoft)

The existing guidelines for a few of the interface elements are relevant and applied in the process industry today. However, many of the existing guidelines either lack usable specifics or are outdated for today's multimedia world. For example, a guideline in the area of  "*Navigation Guidance*" tells us to "*Design one button access to time-critical display/stations*". This guideline helps realize the design problem of time-critical access, but lacks detail to implement. Is one button access possible for all critical information? In some cases, guidelines created by software companies have not been evaluated or incorporated in the process industry.

## RESEARCH FINDINGS

Existing guidelines alone are insufficient to move towards a new paradigm of operator support information. A review of existing literature in this area and member company research supplied some concepts for evaluation. Topics including menuing, text presentation and notification of events yielded interesting concepts worth pursuing. Following are some concepts and findings from those topics that represent some initial threads for future development:

### Menuing Research:
A menu structure has been characterized as the "backbone of a well-designed operator interface" (1). It represents a domain of information and helps the user access any part

of that information in a logical and organized fashion. Once a design team has determined the objects\or actions that will be available in a menu system, the critical step in the design of the interface is to decide how the options (objects\actions) will be distributed across the individual menu panels. The distribution of options to panels will determine the navigation pathways, that is, the sequence of selections that will be required to get from one menu panel to another.

Typically menus are arranged in a hierarchy with the top level menu providing access to one or more lower-level menus until an option is reached which provides access to a desired computer function. There are two dimensions associated with a menu structure, namely the "depth" and "breadth". Depth in a menu structure is generally defined as the number of levels in the hierarchy. Breadth is defined as the number of options per menu panel.

In a system where the user accesses information via a menu structure, the access time to the piece of information becomes the single most critical issue. If the "access time " is not optimal, the user may fail to realize the full potential of the system. Extensive research has focused on identifying factors that affect "*access time*".

As the number of levels of a hierarchical menu structure grows, users find it difficult to navigate from their current to the desired location. Despite the navigation problem designers of menu interfaces tend to trade more depth for less breadth (10).

MacGregor, Lee and Lam (11) presented an analysis of search time that suggests that the optimal number of options per menu panel range from four to eight. However, their analysis applies only to cases where the user cannot restrict the scope of the search based on either experience with the menu or the organization of the options on the panel.

Paap and Roske-Hofstrand (10) presented an analysis which involved cases of restricted search. In their view, "Assuming optimal grouping, the optimal number of alternatives on a single page ranges from 16 to 78" for a restricted search.

Fisher, Yungkurth and Moss (12) indicated in their studies that a logical schema in a menuing structure, that is close to the users' mental model of the information architecture, enhances the usability and reduces stress in a menu search.

Despite the navigation problem, three reasons were suggested for constructing a system with greater depth. *Crowding, Insulation* and *Funneling* (10).
- *Crowding* was defined as the "straight forward constraint imposed by the amount of available space on a panel".
- *Insulation* was defined as "forcing selections that are likely to be needed and hiding those that are unlikely or illegal."
- *Funneling* was referred to as "reduction in the total number of options processed that is achieved by designing a system with more depth and less breadth."

Further studies in the area of breadth/depth issues by Card, Moran, Newell (13) agreed with the implications presented by Paap and Hofstrand that, if values for *human*

*response times, computer response times*, and *processing time per option* can be predicted with some precision, then a designer could engage in a sort of "psychological engineering" that trades computed parameters of human performance against cost and other engineering variables.

Rips, Shoben & Smith (14); Collins & Quillian (15, 16); Studies by Rosch (17); on categorization of related objects in a menu selection task implied that the menu item selected will depend on the *semantic similarity* between the target and the set of alternatives presented on the menu page. (By 'semantic similarity' we mean similarity in context between two items or objects.) The importance of this factor was also evaluated and validated by Pierce, Parkinson and Sisson (18).

While using a multifunction display, one approach to organizing information is to place related screens of information closer to each other (19). Seidler and Wickens (19) identified three metrics that could be used to operationalize the concept of "distance" (closeness between related screens) in a multifunction display; *navigational* (the number of choice points lying between two screens), *organizational* (the hierarchical structure of the database), and *cognitive* (the users' perception of relationships among screens). Empirical evaluation established their importance in the context of configuring a multifunction display.

MacGregor et al. (11) and Fisher et al. (12) studied the issue of visual search across a menu - with relation to expertise (*item familiarity*) and item organization (e.g. *alphabetical, frequency of use*). Their conclusions indicated varying effects on access time according to the level of familiarity and expertise. They also suggested the need for empirical methods to better quantify their results.

Nagy and Sanchez (20) studied the effects of Chromaticity and Luminance as coding dimensions in visual search. They attempted to determine how different two colors had to be in order to produce fast parallel searches. They concluded that in order for the subjects to achieve fast, effortless searches, the target and distractor stimuli needed to differ by at least 20 CIELUV units.

Mitta (21) studied in her paper the applicability of the analytic hierarchy process (AHP) as a methodology to empirically rank or weight human judgement factors such as criticality and familiarity. She concluded that the methodology was effective and suggested fine tuning of it for specific related applications.

Besides qualitative analysis, attempts were made to quantify the evaluation process. Of particular interest was the empirical representation to measure search time (11).
 (ST) = ((bt +k+c) / (ln b)) (ln n) where,   b = breadth;t = processing time per option; k = human response time; c = computer response time; n = size of the database

**Menuing research summary.** It appears that there are compelling and competing factors affecting the "access time" of a menu structure. They are as follows:
- a) Dimensions of a menu structure
- b) Categorization (semantic similarity)
- c) Criticality and familiarity
- d) Chromaticity and Luminance for visual search
- e) Single versus multifunction displays

The above mentioned factors need to be studied for their effect on "access time" in a menu structured display. Individual as well as combined effects of these factors need to be evaluated before developing best practice.

**Menuing ASM perspective.** An operator in a plant, faced with a situation where he needs the safety information for a chemical using a process support information system is required to choose the correct alternative to branch until he/she reaches his/her target. The factors mentioned above may all effect his "access time".

The *Honeywell TDC* panel provides the operator with live plant data, trends and alarm points, etc. During an abnormal situation, the operator, after he/she takes an immediate safety measure, would normally be faced with follow-up actions for which he/she might need to access the Process Support Information structure. During regular operations, he/she might access the information system as a multifunction display (for training or analysis) to get access to different types of information simultaneously. However, the display structure during the abnormal situation might need to be a single function display.

**Textual Information Research:**
Visual display terminals are used as the primary person-machine interface for interactive computing, data entry, word processing, database access, and the like. In earlier applications, the user could read only a limited amount of text from the display screen at any one time. However, developments in information-system design have enabled the presentation of large amounts of text, as in videotex, electronic journals, dynamic books and similar applications.

The Process Industry has a wealth of information to manage including procedures, guidelines, checklists, plans and goals, descriptions, etc. The documents are lengthy and quite often run several pages. This information is increasingly being stored and accessed in electronic format.

Thus, important display issues include reading lengthy texts from VDT and the flow of information from display to user. As the display capacity of most standard VDT screens is about 2000 characters, the reader needs some means of controlling the flow of text from the display which contain more than 2000 characters (22).

Present obvious choices of paging and scrolling were initially suggested by Cakir, Hart and Stewart (23). Duchnicky and Kolers (24) compared their efficiencies and concluded that neither of these methods significantly outweighed the other.

Duchnicky and Kolers (24) additionally studied the effects of three variables, namely, line length, character density, and number of lines influencing the readability of lengthy text. Their conclusions showed a marked effect of these variables on readability.

Pastoor (25) examined in his studies the legibility performance and subjective preference for text/background color combinations displayed on a video monitor. His conclusions stated that, no significant evidence suggested differential effects of

luminance, polarity or hue, with the only exception that cool background colors *(blue and bluish cyan)* tended to be preferred for the light-on-dark polarity.

Mohageg (26) investigated several usability issues relating to linking configurations in an information retrieval application. He studied linear, hierarchical, network, and combination hierarchical/network linking. His results indicated that users of the hierarchical linking structure performed significantly better than those using network linking.

Member companies currently in transition from paper procedures to electronic format and display have shared their concerns on the lack of usability studies and guidelines to help in the process. They strongly advocate the need for verifying paper based rules and format against electronic representation and addressing the storage and access issues of textual information.

Applied Training Resources, in conjunction with member companies, has addressed the retrieval and presentation of procedures. While a useful stop gap, simply accessing word processor documents as on-line procedures does not incorporate current best practice for on-line information. Procedure Maker, a new application from ATR is designed to close this gap providing user definable template presentation of Procedure information.

**Textual research summary.** The process industry is at a cross roads, moving from paper based to electronic access of procedures. Usability of guidelines developed for paper based procedure presentation and format seem unlikely to be valid for electronic display. This display evolution poses additional issues regarding access of multipage procedures, emergency procedures, etc. The industry needs display guidelines in this area. Line length, character density, number of lines per display and hypertext linking are concepts that need to be evaluated to help develop better, and eventually, best practices.

**Textual ASM perspective.** An operator is faced with a situation of carrying out an "*accumulator draining procedure*". He/she is not well versed with the actual steps that go into the procedure. He/she does have a support system that contains these kinds of information electronically. The information he/she is dealing with is now in a lengthy text document. His/her understanding of the contents in a given time frame will certainly depend upon how this information, or the key subset, is displayed to him/her on-line.

**Notification Research:**
Messages are necessary components of displays which facilitate user/system interaction. Messages can be conjugated into four types: "you might want to know this" *(status)*, "you need to know this" *(alert)*, "you better do something about this" (*error*), and "hey, STOP!" (*hazard)*. The types of messages important in operator interfaces are status and alert messages.

Following are some interesting views from different software organizations and researchers on how the above messages need to be constructed and presented. Each category is discussed separately.

**Status messages.** Fowler and Stanwick (27) described this type of message to be used for both progress towards a goal and the accomplishments of the goals.

Schneiderman (28) proposed in his paper that although people can adapt to working with slower response times while interacting with an interface, they are generally dissatisfied with rates longer than *two seconds*. Galitz (29), however, stated in his paper that expected response times differ by the type of task, and a response that is suddenly too fast causes as much anxiety as one that is slow. Therefore, as well as providing feedback, status messages help mitigate the effects of too long or too short response times (27).

**Alert messages.** An alert message coveys information and asks for a response. It is only displayed to report on the current state of the system and let the user back out of an irreversible action (27). IBM (30), Windows (31) and Motif (32) have developed their standard icon representation for alert messages. For example, the suggested icon for a prompt or question is the character '?'. The suggested icon for an information only message is the lowercase character 'i'. Macintosh (33) and Motif (32) systems use 'talking head' icons.

Munter (34) suggested messages be no longer than two or three lines of 40 to 60 characters each (five to eight words).

Edworthy, Loxley and Dennis (35) discussed the importance of four components of acoustics that are needed to construct a warning sound.
- Loudness level, rising or falling
- Starting block: A small pulse of sound, 100 to 300 milliseconds long, that starts the warning
- Burst of Sound: A repetition of the pulse of sound
- Complete Warning: A burst repeated once or twice, followed by a period of silence

They further discussed the manipulation of the above factors to control the level of urgency in an acoustic warning sound.

Schneiderman (28) suggests that it is good practice to put all messages in resource files and not embed text in the dialog box.

Benbasat and Wand (36) reflected similar findings in their paper, but in a different context. Their article presented a conceptual model and software tool for designing and implementing flexible human-computer dialogues. The rationale for building such a tool was to give the user flexibility in designing his/her own dialogues rather than complex designer specified dialogues.

**Notification research summary.** In the design of notifications for the operator interface, a number of interesting new ideas and concepts need to be evaluated and formalized. All types of messages/notifications are important from the operator's perspective to the extent they provide real help in controlling the process.

**Notification ASM perspective.** Early ASM findings reflect ineffective tools for event notification to the operator. An event *(system or process)* notification serves the purpose of informing the operator about his/her environment. This functionality is a part of the

information support system that will help the operator perform diagnostics prior to the problem and will also notify him/her of the specific problem. Attributes associated with the notification presentation are important as they indicate urgency of the situation.

## PROPOSED STUDIES

The information presentation research review, briefly summarized here, identifies a number of areas for research, validation and possible incorporation into a new information technology. One of the problems with raw research is the limited access to, and input from, the intended user - the operator. Thanks to the Consortium effort, a test platform and member company sites are available to evaluate the most promising of these research findings interactively with control room operators in simulated and live plant control room settings. The operator input and feedback is considered crucial to this development effort. Currently studies are planned in the areas of menuing, text presentation and situation notification.

The platform to be used is ATR's PR*i*SM supported by other solution products including Dexter, Procedure Maker and Quiz Development System (QDS). PR*i*SM has the capability to flexibly develop different configurations in the area of menuing and notification. It has the additional capability of delivering information in a multimedia context. Dexter is a real time dynamic simulator/trainer that can be used to mimic stress situations experienced by operators in real time process operations. Procedure Maker enables development and presentation of procedures in different formats. It is to be used to test concepts related to presentation of textual information. QDS, a multimedia testing tool, is to be used for gathering empirical results of the studies especially in the area of notification.

## FUTURE DIRECTIONS

In addition to the areas slated for early studies, the following topics are of interest for future work:

Multimedia:  Alternate information tools including graphics, audio, video, etc., that could enhance, or distract from, the effectiveness of support information. Virtual reality approaches and other future technologies will also be considered.
Multi-function displays and Multiple CRTs:  Issues related to organizing information in multi-function displays, optimum number of windows in a display, optimum number of CRTs, and the related presentation issues in these configurations.
Field Systems:  Information systems dedicated to operators in the field and integration of this information with the control room system.

Support information is critical and must be presented with best practices to improve operator performance and minimize losses. Additionally, best practices need to be constantly reevaluated to meet changing technology, standards and needs.

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