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The Development and Evaluation of Guidelines for the Review of Advanced Human-System Interfaces

John M. O'Hara
Department of Nuclear Energy
Brookhaven National Laboratory
Upton, NY 11973

Jerry Wachtel
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ABSTRACT

Advanced control rooms for future nuclear power plants are being designed utilizing computer-based technologies. The U.S. Nuclear Regulatory Commission reviews the human engineering aspects of such control rooms to ensure that they are designed to good human factors engineering principles and that operator performance and reliability are appropriately supported in order to protect public health and safety. This paper describes a general approach to advanced human-system interface review, development of human factors guidelines to support NRC safety reviews of advanced systems, and the results of a guideline test and evaluation program.

INTRODUCTION

Advanced control room (ACR) concepts are being developed in the commercial nuclear industry as part of future reactor designs. The ACRs will utilize advanced human-system interface (HSI) technologies that may have significant implications for plant safety in that they will affect the operator's overall role (function) in the system, the method of information presentation, the ways in which the operator interacts with the system, and the requirements on the operator to understand and supervise an increasingly complex system. The U.S. Nuclear Regulatory Commission (NRC) reviews the HSI aspects of control rooms to ensure that they are designed to good human factors engineering principles and that operator performance and reliability are appropriately supported in order to protect public health and safety. The principal guidance available to the NRC (NUREG-0700)[1], however, was developed more than ten years ago, well prior to these technological changes. Accordingly, the human factors guidance needs to be updated to serve as the basis for NRC review of these advanced designs. The purpose of this paper is to discuss the development of an NRC Advanced HSI Design Review Guideline, hereafter referred to as the "Guideline." The term "Guideline" (with a capitol "G") refers to the entire document, while the term "guideline" refers to the individual guidelines within the document. The discussion addresses the issues impacting the review and evaluation of advanced HSI, the development of a general review model to address the issues, the development of the Guideline, the test and evaluation of the Guideline, and the Guideline's current status.

ISSUES AFFECTING HSI EVALUATION

In order to develop an approach to the evaluation of HSIs, it is necessary to consider: (1) standardization of design, (2) the trends in advanced nuclear power plants (NPPs), (3) the human factors issues that are associated with advanced technology, and (4) the state-of-the-art of human factors guidelines for advanced HSIs.

Standardized Designs

Over the past several decades commercial NPP design and construction in the US has resulted in considerably different plant, system, and control room (CR) designs across the industry. During this period, NRC reviews of control rooms have been directed toward the existing, as built, plant-specific equipment. Recently both the NRC and the utility industry have embarked upon an effort to standardize future NPP designs. Toward this end, the NRC has issued Part 52 of Title 10 of the Code of Federal Regulations (Part 52) in order to encourage standardization and to streamline the licensing process. Nuclear plant designers and vendors have begun the design of advanced standard plants, which are now being submitted to the NRC for review and certification under Part 52. If all were to proceed according to plan, then these standard plants, including the control rooms, would be approved and a utility could apply to build such a plant and merely reference the already approved standard design. This would result in control rooms which were essentially identical in all future plants.

An early issue to arise from the review of the first standardized NPP control room submittal was the lack of a control room design sufficiently complete to allow a safety and human factors engineering design review by the NRC. Thus, in order to proceed with the review and certification, the NRC had to devise a process by which to review the preliminary control room design material, and also a design implementation process whereby the detailed control room design would be completed by the utility building the standard NPP, in accordance with the approved design implementation process. The review of such a design implementation process is unprecedented, and evaluation criteria for such a review are not addressed by current regulations or guidance. Human factors engineering (HFE) reviews of advanced reactor control rooms must be capable of supporting both fully designed control rooms and through a specified design process plan, control rooms that are only in the conceptual design stage.

Trends in Advanced NPPs

Diversity in Advanced Reactor Technology: The current generation of commercial nuclear power plants (NPPs) operating in the U.S. numbers more than 100; all of those are based upon light water reactor technology. Although the next generation of plants will reflect advances on this technology base, the industry has also developed designs based on different technologies, including heavy water reactors, liquid metal reactors, and gas-cooled reactors. Some of these are proposed to be multiple units of smaller, modular reactors at a single site. One important design initiative to improve safety and reliability has been the move from active safety features (based upon active components such as pumps) toward more "passive" safety features (based upon natural physical processes such as convection flow, radiation cooling, and gravity). This plant diversity and the new passive features introduce new and different systems for operators to control, test, and monitor. There are questions as to how the reliable functioning of these passive systems can be verified (by the operators) during operation. Also, the role of the operator during transients and accidents changes considerably with these new passive systems. Important questions include: (1) How operators verify that these systems are ready during normal operation; (2) How proper operation can be confirmed when the systems are called upon; (3) What parameters should be monitored; and (4) What the proper operator response is when the passive systems do not function properly. Clearly, advanced NPPs will result in different operator roles and tasks, different CRs, and different operator-control interfaces. One implication of this diversity is that a narrow view and therefore a prescriptive approach to interface design based upon known operator tasks is not possible in an NRC guideline which must be capable of enabling reviews of all possible designs and a great diversity of operator functional roles in the system.

Control Room Evolution: There are several important trends emerging in advanced HSI design concepts in the nuclear industry, including: (1) greater use of automation and a corresponding shift of the operator's role in the system as monitor, supervisor, and back-up to automated systems; (2) greater centralization of controls and displays into "compact" digital work stations; (3) use of large display panels that can be seen from anywhere in the control room to present high-level information and critical parameters; (4) a primary operator interface with a data management system (DMS) with little interaction directly with components; (5) use of data integration and graphic displays; and (6) information processing and decision-support aids. As these trends are implemented, they will result in a further diversification of CR types from conventional to hybrid to advanced to "intelligent" CRs. Related to CR evolution is the wide range of technological approaches to HSIs in computer-based CRs. In part, this is due to the tremendous flexibility offered by software-driven interfaces to provide for alternative data processing, display and control. The NRC will need guidance to review new CRs and modifications to existing CRs which represent these industry trends.

<u>Advanced Technology and Human Performance</u>: While the use of advanced technology is generally considered to enhance system performance, computer-based operator interfaces also have the potential to negatively impact human performance, spawn new types of human errors, and reduce human reliability.[2,3,4,5] However, since the contributors to unreliability in an advanced control room are likely to be different from those which are present in conventional CRs, they are less obvious and generally less well understood.[6] Some of the factors contributing to the problems of integrating human operators and advanced systems are reviewed below.

<u>General State of Knowledge</u>: Despite the rapidly increasing utilization of advanced HSI technology in complex, high-reliability systems such as NPPs and civilian aircraft there is broad consensus that the knowledge-base for understanding the effects of this technology on human performance and system safety is in need of further research.[7,8] The operating environment associated with advanced systems is very different from that of a conventional control room. Cognitive and human information processing issues are emerging as more significant than the physical and ergonomic considerations which dominated the design of conventional HSIs. While these issues have been recognized for a long time, their full implications for human performance and system safety have only recently begun to be addressed in research, and there is not a long history of operational experience upon which to draw. The National Academy of Sciences, for example, has identified areas such as automation, supervisory control, and human-computer interface as high priority research areas for the human factors community in general and for the commercial nuclear industry in particular.[7,8]

<u>Allocation of Function and Automation</u>: Many human factors problems originate early in the design process. Historically, functions were allocated to automated systems based largely on the capability of available technology to reliably and safely execute the function, rather than on the human operator's ability to perform as part of the overall system. This was true even though the human factors problems associated with automation had been known for some time[9] and the emergence of new types of human and system errors had been identified.[10] Increases in automation have been associated with a shift from physical to cognitive workload, with a loss of operator vigilance and a concomitant increase in vigilance-associated human errors,[11] with difficulty maintaining adequate "situation awareness,"[12] and with loss of skills to perform the task in the event of automated system failure. In part, many of these issues may be the result of a shift in the operator's role from that of an active, in-the-loop controller to an out-of-the-loop supervisor and monitor, together with a failure on the part of the HSI and system designers to adequately account for this shift.[13,14,15]

<u>Advanced HSI Design</u>: Computer-based HSI design requires, to a far greater extent than traditional control room designs, the specification of cognitive requirements and processing resources that the operator must utilize in task performance; i.e., cognitive task analysis. That information is needed for proper evaluation of the interface. Four aspects of HSI are primarily responsible for this requirement. First, information is typically presented in "predigested" form; i.e., raw data parameters are processed and integrated into a higher level of information, thus potentially obscuring their meaning. Second, the operator typically has much more information available which, if not properly organized and presented, can be overwhelming. Third, information is typically resident in a "virtual" work station, rather than in dedicated spatial locations spread out across control stations. Information is

located somewhere in a computer system which provides only a glimpse of its contents (through a display device) at any one time. A poorly designed interface can make location of information and navigation through data difficult. Fourth, the flexibility of software-driven interfaces can increase the workload associated with managing the interface itself.

System Complexity and Operator Skills: NPP operations have always demanded a high level of skill and readiness on the part of the operating staff. These demands may increase, however, because of the need for operators to understand and evaluate the performance of advanced systems, to know their limitations, and to be ready to assume manual control when appropriate. There is a somewhat paradoxical relationship between these requirements and the day-to-day tasks that operators must perform, which in a highly-automated plant are predominantly monitoring functions. Thus, there is a risk that these carefully selected and highly trained operators may be required to perform a routinely boring and monotonous job.

Advanced HSI Guidelines Issues

Hardware vs. Software Guidelines: In an ACR, the physical layout of the display devices and computer input devices may be less important than the design of the human-software interface; i.e., the information management system and the methods with which information is displayed to the operator. This information can be displayed in a complex network of thousands of computer displays and flexible, operator-defined display formats. The difficulty of developing guidelines for human-software interfaces when compared with human-hardware interfaces has been elaborated by Smith.[16] Perhaps most significant to the evaluation of human-software interfaces is that the most important design features are often hidden to the reviewer and transparent to the operator, while important hardware design features are usually readily observable. For example, the observable display may be an end product of data integration providing higher-level, more abstract displays in contrast to the "single sensor/single display" characteristic of conventional CRs. As a result, while hardware guidelines tend to be relatively clear and specific, software guidelines tend to be stated in more general language.

Status of Guidelines for Advanced Technology: ACRs are based upon relatively new technology which is rapidly changing. Relative to the guidelines available for traditional hardware interfaces, the guidelines available for computer based, software interfaces have a considerably weaker research base, and have not been as well tested and validated through many years of design application. Thus, the human factors guidelines available for the review of advanced CR technology are less firm and, as indicated above, are typically stated in more general terms. Further, the cognitive task requirements, critical to human software interface design, are typically less familiar to designers and reviewers.[17,5] These characteristics of advanced technology guidelines can make the reviewers' job more difficult.[18]

Suitability of Guidelines for Evaluation: Another issue related to the maturity of advanced technology guidelines is whether evaluations based only on conformance to HFE guidelines provide a sufficient basis for review. Gould has indicated that, due to the nature of advanced human-system interfaces (as discussed above), a good system cannot be designed by guidelines alone.[19] A similar conclusion resulted from an effort to evaluate a computer-based system using only guidelines.[20] Evaluations need to be broader and, in terms of final design must include dynamic, real-time testing under simulated or actual operating conditions.

PROPOSED HFE PROGRAM REVIEW MODEL

The issues discussed above have implications for the development of an approach to the safety review of the HFE aspects of advanced reactor designs. These implications are summarized below.

1. The review model should provide guidance for reviews to be performed throughout the design life cycle, i.e., from proposed/conceptual design to final designs and for periodic modifications during the life of such designs.

2. Reviews of the HSIs should extend beyond checklist-based evaluations and should include a variety of assessment techniques, such as validations of the fully integrated system under realistic, dynamic conditions using experienced operators performing the types of tasks the HSI has been designed for (including various types of failures and transient conditions).

3. The Guideline will have to provide for the review of a broad range of CR "types" and a diversity of approaches to advanced HSI technology. The Guideline should focus heavily on human-software interface since this is where some of the most significant human performance issues reside.

4. Violations of human-software guidelines have been found to be more difficult to detect than violations of hardware guidelines. This places a greater burden on the judgement of the reviewer and the reviewer's ability to adapt and interpret the guidelines in the context of a particular review.

These factors have led to the development of a top-down approach to the review of HSIs. A generic HFE Review Model was developed based largely on applied general systems theory. The model is composed of eight elements and is divided into four review phases: HFE program planning, design analysis, interface design, and verification & validation (see Figure 1). The review process should permit the tracking of the design from initial conception through final design implementation. Details of the model are described elsewhere[21]. The purpose of Guideline development to be described in this paper is to evaluate HSIs for their conformance to accepted human factors engineering principles, standards, and guidelines. It has two specific applications within the context of the HFE Review Model:

- NRC review of design-specific guidelines and specifications (as may be submitted to the NRC as part of Element 6 Human System Interface Design)

- NRC HFE Verification review of detailed HSI designs (as required be Element 8 - Human Factors Verification and Validation).

GUIDELINE DEVELOPMENT METHODOLOGY

Based upon an evaluation of research and industry experience related to the integration of personnel into advanced systems, a set of High-Level Design Review Principles was developed (see Table 1). These principles provide the generic HSI characteristics necessary to support operator performance and make systems more tolerant to human errors when they occur. Since these principles are stated at a fairly general level, they were developed to a level of detail sufficient to support HSI review and evaluations. The principles were translated into terms that can be applied to specific applications by developing guidelines for the review of the specific types of technology (e.g., graphic displays, touch screens, and expert systems).

The effort to develop detailed guidelines began with an identification of human factors guidance documents for advanced HSIs. Through a review of the human factors literature and contact with organizations which sponsor such research, approximately 50 guideline efforts were identified. The next step was to select those documents that would serve as the "primary sources" for the initial set of guidelines to be incorporated in the NRC Guideline. A high priority was given to establishing the validity of the guidelines; i.e., assuring that they were based upon empirical research and/or accepted human engineering practice. Validity was defined in terms of two aspects of document development. "Internal" validity was evaluated by the degree to which the individual guidelines within a document were based upon empirical research and an audit trail to the research maintained. "External" validity was evaluated as a function of the degree to which the guidelines were subjected to independent peer review. The peer review process was considered a good method of screening guidelines for conformance to accepted human engineering practices. In general, documents which had strong validity were considered primary source documents to serve as a basis for the Guideline.

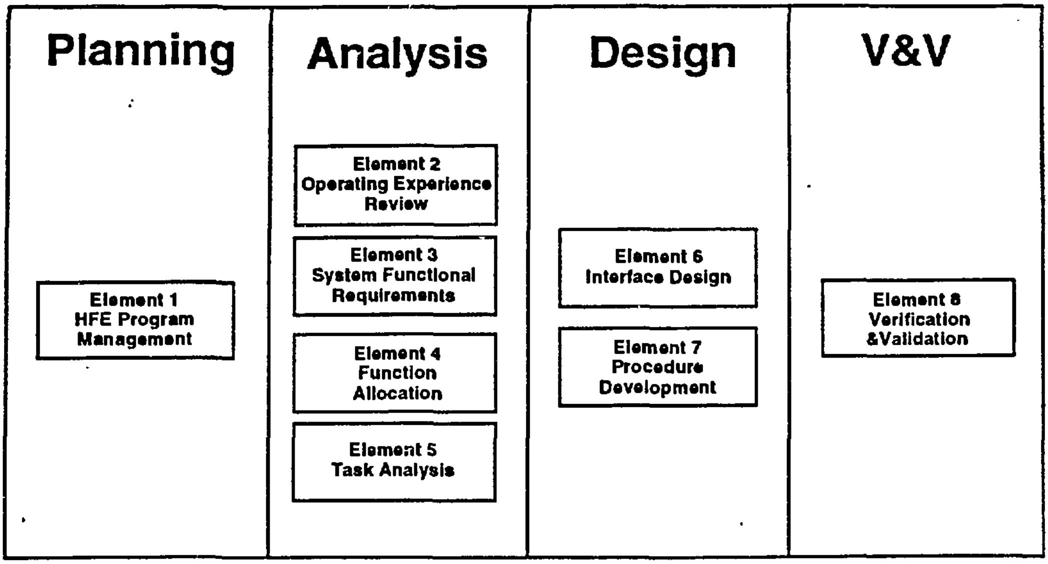

Figure 1. General HFE review model

Table 1. High-Level Design Review Principles

Category	Principle
General	Safety, Cognitive Compatibility, Physiological Compatibility, Simplicity of Design, Consistency
Primary Task Design	Situation Awareness, Task Compatibility, User-Model Compatibility, Organization of HSI Elements, Logical/Explicit Structure, Timeliness, Controls/Displays Compatibility, Feedback
Secondary Task Control	Cognitive Workload, Response Workload
Task Support	Flexibility, User Guidance and Support, Error Tolerance and Control

The guidelines from the primary sources were edited to combine similar guidelines and to transform the material into a standardized format. Where compound guidelines were encountered (several guidelines in a single statement) an effort was made to break them into logical units and represent the units as separate guidelines. Conflict resolution between guidelines was handled on a case-by-case basis.

The guidelines were sorted into seven major sections which are described below. Some of the sections/subsections are currently empty pending the completion of other NRC projects which are developing guidelines in those areas. Each of these sections contains a set of general guidelines and more detailed guidelines addressing specific HSI implementations, techniques, and formats.

The seven sections were:

- **Information Display** - This section deals primarily with the formatting of visual displays, both text-based and graphics-based. Following a section of general guidelines, guidance are provided in top-down fashion beginning with display formats (such as P&IDs and trend graphs), display format elements (such as labels, icons, symbols, color, text, coding, etc.), data quality and update rate, and display devices (such as video display terminals and large board displays).

- **User-System Interaction** - This section addresses the modes of interaction between the operator and the HSI. Topics include dialog format, navigation, display controls, entering information, system messages, prompts, and system response time. This section also contains guidelines pertaining to methods for ensuring the integrity of data accessed through the user interface. Guidance covers prevention of inadvertent change or deletion of data, minimization of data loss due to computer failure, and protection of data such as setpoints from unauthorized access.

- **Process Control and Input Devices** - This section addresses information entry, operator dialogue, display control, information manipulation, and system response time. Considerations of display-control integration are also included here.

- **Alarms** - This section is a place holder for the results of another NRC research project to develop review guidance in the area of advanced alarm systems.

- **Analysis and Decision Aids** - This section addresses the use of knowledge-based systems.

- **Inter-Personnel Communication** - This section contains guidelines for activities related to speech and computer-mediated communication between plant personnel, e.g., preparing, addressing, transmitting and receiving messages.

- **Workplace Design** - This section addresses the organization of displays and controls within individual workstations, control room configuration, and environment.

In addition to a hard-copy document, the Guideline has been developed as an interactive, computer-based review aid. The interactive document will facilitate guideline access and review, editing, compilation of individual guidelines for a specific review, and incorporation of new guidelines as they become available. Availability of the Guideline on a portable computer will also facilitate in-the-field reviews. An Apple Macintosh™ computer and Hypercard™ software were selected for prototyping and testing.

Each guideline in the database is represented by several primary fields: guideline number, title, guideline statement, additional information, and source (link to primary source document). Other user assistance fields are also available, e.g., to provide location (in the document) information and a note pad for users to append comments related to specific guidelines. The prototype user interface provides for many document functions such as instant table of contents (ToC) access, context index, glossary, and placemarkers. Users can automatically go to desired sections by clicking on the ToC or index entry. Guideline evaluation, evaluation summary and reporting functions are also available.

GUIDELINE TEST & EVALUATION

The Guideline is being evaluated with respect to its scope and technical content (i.e., its adequacy for the review of advanced control room technology), and usability (i.e., Guideline presentation, interactive document functionality, and user interfaces). Not all these evaluation objectives can be accomplished in one test. The test and evaluation (T&E) program consisted of three phases, each using a different methodology: Development Test, User Test, and Peer-Review Workshop.

Development Test

The Development Test provided a preliminary evaluation of the prototype Guideline and an opportunity to correct interface problems prior to subsequent testing. The purpose of the test was to assess the Guideline's technical content, user interface design, document functionality, and usability as a review aid evaluation. The Development Test consisted of three types of evaluations: a function implementation evaluation, an HFE review, and a limited field test. The function implementation evaluation was designed to test the ease with which novice users understand the interface and could use the document's many functions. For the HFE review, the project staff evaluated the user interface design of the interactive document using the guidelines contained in the Guideline itself. The field test was designed so that the project team could evaluate the Guideline's technical content and interface for conducting an evaluation in a control room environment. A variety of data were collected during and following the evaluations, including rating scales, questionnaires, and both user and test conductor comments. (It should be noted that the Development Test was not a formal experiment and that the results are based on a relatively small number of participants who were mainly project personnel. All results should be considered with this limitation in mind.)

User Test

The User Test was a field test of the Guideline in environments of greater fidelity to an advanced control room and encompassing a greater diversity of advanced control room technologies than the Development Test. The User Test utilized representative advanced control room reviewers to conduct the evaluation, rather than the project staff. Therefore, the User Test was a simulation of the actual Guideline utilization. Both technical content and Guideline implementation objectives were assessed. With respect to technical content, the objectives of Guideline scope and Guideline content were evaluated. Since the test participants were novices with respect to use of the interactive, computer-based document, the User Test was well suited for evaluation of the Guideline implementation objectives.

Peer-Review Workshop

The third evaluation was a Peer-Review Workshop. Thirteen individuals were selected based upon their expertise in at least one of the following: (1) human factors evaluations for advanced systems, (2) inspections of NPP CRs, (3) NRC regulatory reviews and issues, and (4) advanced nuclear power plant control room technology. The workshop provided a different type of evaluation than the two testing tasks and addressed the broader aspects of the Guideline, such as the general model for advanced HSI review and the Guideline value in meeting the NRC's need to evaluate advanced HSI. The workshop also assessed objectives which could not be adequately addressed in the other T&E tasks, i.e., the validity and technical basis for the Guideline.

RESULTS

The results provided below represent an overview of the results of all three T&E methods. The results are organized by topic area: the general HFE Review Model, the HFE Review Guideline, and the interactive document.

HFE Review Model

The overall review model was considered comprehensive and appropriate to the review of advanced HSIs. T&E participants indicated that certain aspects of the model (e.g., function allocation and task analysis) required further development in order to provide specific acceptance criteria.

HFE Review Guideline

This section is organized by the main objectives of the T&E program; i.e., assessment of the Guideline with respect to technical basis/validity, scope, and content. In addition, the issue of review procedures is addressed.

Guideline Technical Basis/Validity: One principal objective of the T&E program was to determine if the technical basis of the guideline was valid, i.e., accurately reflects current human engineering standards, guidelines, and practice. T&E participants' comments supported overall Guideline validity and the technical basis upon which the guidelines were developed. The primary source documents were considered appropriate. It was suggested that the list of primary source documents could be expanded. This will be done when the NRC moves into the phase of developing additional guidance in areas needing further support. However, this recommendation does not detract from the primary finding of guideline validity.

Guideline Scope: The main issue in this area of evaluation was to determine if the review areas for which available guidance is deficient or missing have been identified. Several new topics (such as large screen displays, ambient lighting systems, soft controls and integrated controls) were identified and confirmatory comments were provided for those topics already defined as weak.

Guideline Content: The guidelines were evaluated to be technically valid and appropriate for application in safety reviews, however, several further developments were recommended before the Guideline is put to use in NRC reviews. The recommended developments can be divided into two main categories: prioritization and level of resolution. Each is discussed below.

The issue was raised that the number of guidelines was large enough to make the Guideline's use as a practical review tool somewhat cumbersome. It was recommended that the development of further prioritization be accomplished to identify a smaller set of key guidelines that would principally guide the NRC review. T&E participants indicated that the remaining guidelines should not be eliminated since they will provide further detail to reviewers and designers concerning HSI design.

T&E participants expressed concern about the differential level of resolution of individual guidelines. Some are relatively general and may be subject to different interpretations by reviewers. Other guidelines were thought to be "below regulatory threshold"; that is, to address details of HSI design that need not be of concern to reviewers. Few specific recommendations were made concerning how to address these two issues.

The appropriate level of resolution of HFE guidelines is a difficult issue which depends, in part, on guidelines' documents intended use. The NRC Guideline must be capable of supporting reviews of diverse HSI designs. Judging the level of resolution that is appropriate for a review document involves finding a balance between the generality required to support breadth of coverage and the specificity to support ease of use and reliability of reviewer judgements. This represents a tradeoff in that with increasing generality comes increasing breadth of coverage but decreasing ease of use. As specificity increases the guideline becomes easier to use with greater inter-rater reliability, but its breadth of coverage decreases and the guidelines become more prescriptive and increasingly tend to preclude design options.

Efforts to make guidelines that are worded in general terms more specific can be inappropriate for review guidance that must be utilized for many different control room designs and where the goal is not to be prescriptive. Typically guidelines are worded in general terms when they represent a general principle which is not amenable to more specific definition in the absence of a specific application. For example, Guideline 1.1.1-12 - Necessary Data Displayed (see below) is fairly general. However, such a guideline cannot be made more specific in a Guideline that is to be used by NRC reviewers to evaluate a wide range of control room designs. Instead, the guideline must be interpreted within the context of a specific control room review and the specific operator tasks that the display under review is intended to support. Therefore, such a guideline needs to be tailored by the reviewer to each specific HSI under evaluation. Tailoring must be based upon additional task-related information that is specific to tasks that operators perform in the reactor design and the specific implementation of the control room designed to support these tasks. One modification to the Guideline that may facilitate a reviewer interpretation of more general guidelines is a greater use of examples, illustrations, etc. in the Guideline.

1.1.1-12 Necessary Data Displayed
All data required for any transaction should be available for display.
COMMENT: Displayed data should be tailored to user needs, providing only necessary and immediately usable data for any transaction; displays should not be overloaded with extraneous data.

The presence of guidelines that are "below regulatory threshold" poses a different problem. One implication of this concept is that some guidelines are not important enough to impact operator performance and safety. While this may be true, it is difficult, given the state-of-the-art concerning our understanding of the effects of individual design factors on human performance, to confidently judge that a given guideline is unimportant in every review context. Guideline 1.3.3-7 - Conventional Use of Mixed Case, was identified by one T&E participant as an example of such a guideline. The guideline is presented below. In control room designs where little text-based information is presented, this guideline would be inapplicable or of very low priority. However, if the control room design incorporated computer-based EOPs, computer-based alarm response procedures, or some other more "text-intensive" VDU displays, then the readability of text is quite important. This is especially true when one considers the research indicating that text readability is diminished when presented on VDUs when compared with conventional paper presentations. This guideline was considered to be important enough to appear in three of the primary sources and was considered by the project staff to be at a Tier-2 level.

> **1.3.3-7 Conventional Use of Mixed Case**
> Text should be presented using upper and lower case characters.
> **COMMENT**: Reading text is easier and faster when capitalization is used conventionally to start sentences and to indicate proper nouns and acronyms. There are several exceptions, however. An item intended to attract the user's attention, such as a label or title, might be displayed in upper case. Also, upper case should be used when lower case letters will have decreased legibility, e.g., on a display terminal that cannot show true descenders for lower case letters.

The importance of individual guidelines is a function of its context within a specific review. In general, therefore, it may be more appropriate to address guidelines judged to be of generally lesser importance within the context of prioritization (as discussed above) rather than by eliminating them. Thus, the determination that an individual guideline is "below regulatory threshold" should be made by the NRC reviewer based upon the requirements of each individual review.

Review Procedure: The T&E participants identified the need for a more clearly specified review process or procedure to facilitate Guideline usage by a review team.

Interactive Document

Most interface characteristics thought to be indicative of usability (such as visual clarity, consistency, explicitness, ease of use, ease of learning and remembering, response time, etc.) were rated highly. Some difficulties were encountered, mainly in the areas of input devices, reporting and help functions. While T&E participants indicated that improvements in screen design and organization could be achieved, the Guideline was judged to be easy to use and readable. Some inconsistencies in appearance and functioning across different display screens were noted. Most of the functions and controls were evaluated as highly useful and easy to use. The exception to the highly useful category was the glossary function. Since the glossary was not tailored to the Guideline, many terms for which definitions were needed were not present. In addition, several controls/functions were evaluated as not being easy to use. These included the evaluation function, information input functions, and the reporting function. The evaluation function was hindered by the lack of adequate guideline selection support. The exclusive reliance on the mouse/trackball for evaluation and navigation functions was considered time consuming and tedious. Most T&E participants indicated a desire for using command (keyboard) inputs for these functions. Finally, the reporting function was very time consuming.

GUIDELINE MODIFICATIONS

Based upon the results of the T&E program, modifications were made to the technical content of the guidelines. These included reducing the number of guidelines and "layering" the guidelines (as described earlier) into (1) general principles, (2) general guidelines in each of the major sections, and (3) more detailed guidelines addressing specific HSI implementations, techniques, and formats. The Guideline was also reviewed technically in order to eliminate redundancy and revise technical terminology to ensure consistency throughout the document.

Procedures have been developed for use of the Guideline in the evaluation of a designer's HSI guideline or design specification document and for use in performance of an HFE verification review.

Many modifications have been made to the interactive document. These include the development of a review planning aid to support the identification and selection of guidelines for a specific review and improvements in the review functions to mitigate the troublesome characteristics of the interface identified in the user evaluations. In addition, a maintenance function has been developed to enable easy export of the guidelines to a text file for editing and import of the revised guideline.

FUTURE DEVELOPMENT

The approaches established to review, develop, and integrate additional information into the Guideline will be an ongoing task in order to ensure that the document always has the most up-to-date and valid human factors review guidance. Since the technology is rapidly changing and the nuclear industry's experience (as well as that of other application areas) will be increasing, the Guideline will need to remain a living document in order to meet NRC needs.

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