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Regulatory Review of Advanced and Innovative Human-System Interface Technologies

John M. O'Hara and James Higgins
Brookhaven National Laboratory

Paul Lewis, J. Persensky, and James Bongarra, Jr.
U. S. Nuclear Regulatory Commission

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Brookhaven National Laboratory
P.O. Box 5000
Upton, NY 11973-5000
www.bnl.gov

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REGULATORY REVIEW OF ADVANCED AND INNOVATIVE HUMAN-SYSTEM INTERFACE TECHNOLOGIES

John M. O'Hara and James Higgins
Brookhaven National Laboratory
Upton, New York 11973
ohara@bnl.gov; higgins@bnl.gov

Paul Lewis, J. Persensky, and James Bongarra, Jr.
U.S. Nuclear Regulatory Commission
Washington, DC 20555
pml1@nrc.gov; jjp2@nrc.gov; jxb@nrc.gov

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ABSTRACT

Given the rapid evolution of digital technology and its inherent flexibility, there may be concern that the regulatory review process could stifle new and innovative approaches to human-system interface (HSI) design even though such innovations may improve operational performance and safety. The U.S. Nuclear Regulatory Commission (NRC) has addressed this concern in recent revisions to its human factors engineering (HFE) review guidance that focuses on the design process as well as the HSI itself. That process has a number of built-in mechanisms to provide a basis to review and accept new approaches to HSI design. These include the use of applicant-specific HSI style guides, the identification of specific criteria for deviating from NRC design review guidelines, and the use of applicant tests and evaluations in lieu of HFE guidelines.

1. INTRODUCTION

A potential criticism of the regulatory review process is that it can stifle new and innovative approaches to human-system interface (HSI) design even though such innovations may improve operational performance and safety. The historical roots for such criticism comes from the post Three-Mile Island control room design reviews. To support these reviews the U.S. Nuclear Regulatory Commission (NRC) developed human factors engineering (HFE) review guidelines for the HSI technology that existed at the time (NRC, 1981). The HSI technology was primarily analog such as meters, gauges, rotary dials, and J-handle controls. The guidelines were very detailed and defined a rather narrow window of acceptance.

Today's control rooms are rapidly changing with the introduction of digital instrumentation and control (I&C) technology and computer-based HSIs. These technologies were first used in "advanced" plants such as the Advanced Boiling Water Reactor, but are increasingly being applied in large-scale modernization programs at existing plants.

There are two very significant differences between analog and digital technology. The first is how rapidly it changes. While analog technology changed very little over decades of use, digital technology evolves so rapidly that when new computers are installed in plants they are already somewhat out-of-date or at least new operating systems are available. The second difference is flexibility. With analogy technology, once HSIs were installed, they were fixed devices in terms of both characteristics and functionality. Such is not at all the case with computer-based HSIs. They are extremely flexible. They can be changed in terms of look and feel almost limitlessly, and with modifications to software, can provide changes in functionality very easily.

Unless a regulatory review process can accommodate these two characteristics of digital I&C and computer-based HSIs, the regulatory process could be a potential obstacle to achieving the benefits of new technology. Applicants and licensees may be reluctant to make digital improvements over fears of regulatory uncertainty.

This paper addresses these concerns and will describe recent revisions to the HFE review guidance used by the U.S. Nuclear Regulatory Commission (NRC) to evaluate plant HSIs (a description of these revisions can be found in O'Hara, 2002). These revisions were undertaken, in part, to keep pace with related changes in the nuclear industry. An important aspect of this guidance is the ability to review new and innovative technology.

The NRC's general approach to HFE review reflected in the guidance is discussed first, followed by it's application to new and innovative technology.

2. GENERAL APPROACH TO HFE REVIEW

Careful attention to the human factors aspects of design is essential in order to realize the full operational and safety benefits of modernization programs. This guidance reflects a systems engineering approach to the design of complex systems, such as nuclear power plants. IEEE Standard 1220-1998 is an example and provides guidance for a systems engineering approach to design (IEEE, 1999).

Three key principles to addressing the human factors aspects of design are: a "top-down" approach; a "life-cycle" process; and grading the HFE to focus on those areas of greatest significance.

"Top-down" refers to an approach starting at the "top" with the plant’s high-level mission and goals. These are divided into the functions necessary to achieve the goals. Functions are then allocated to human and system resources. Each function can be broken down into tasks. The tasks are analyzed to identify the alarms, displays, procedures, and controls that will be required for task performance. Tasks are arranged into work activities to be performed by individual crewmembers or teams. The HSIs, procedures, and training are designed to best support personnel to perform their tasks. The detailed design (of the HSI, procedures, and training) is the "bottom" of the top-down process.

As a "life-cycle" process, HFE considerations should be evaluated from concept planning through operations. Grading the HFE activities means that a process is in place to evaluate proposed changes and adjust the amount of HFE design and evaluation effort to the importance of the change. Such an approach enables the application of HFE and HFE review to be directed to where it has the most impact.

The NRC reviews the HFE aspects of plants to ensure that personnel performance and reliability are appropriately supported. The NRC approach to safety review is modeled to track the design process along the three key principles identified above. The Standard Review Plan (NUREG-0800), specifically Chapter 18, Human Factors Engineering, provides a high-level review framework for the conduct of HFE reviews (NRC, 2004a). It has three review applications: (1) review of the HFE aspects of a new plant, (2) review of the HFE aspects of HSI modifications, and (3) review of the HFE aspects of modifications involving credited human action. Within the context of the current discussion, NUREG-0800 references two other main documents for detailed review criteria: Human Factors Engineering Program Review Model, NUREG-0711, Rev. 2, (NRC, 2004b) and Human-System Interface Design Review Guidelines, NUREG-0700, Rev. 2, (NRC, 2002).

NUREG-0711 was originally developed to support NRC review of advanced reactor design certification applications. Its focus was on the design process in addition to the design product. The general "process-based" approach is now used for all HFE review activities. The underlying technical basis and development methodology for NUREG-0711 are described elsewhere (NRC, 1994; O'Hara, J., 1994; O'Hara, J. et al. 1996). Figure 1 shows the detailed elements of the regulatory review process. While the process defines 12 areas of review, not all may be applicable to a particular design review.

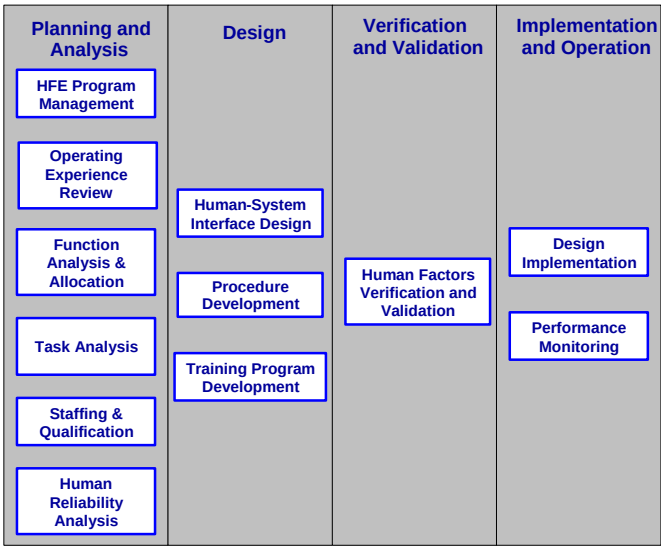

Fig. 1 Human factors program review elements.

NUREG-0711 provides review criteria of the design process, and points to NUREG-0700 (NRC, 2002) for detailed review criteria for HSI characteristics and functions. The HSI topics are identified in Figure 2.

Part I Basic HSI Elements
1 Information Display
2 User-Interface Interaction and Management
3 Controls

Part II HSI Systems
4 Alarm System
5 Safety Function and Parameter Monitoring System
6 Group-View Display System
7 Soft Control System
8 Computer-Based Procedure System
9 Computerized Operator Support System
10 Communication System

Part III Workstations and Workplaces
11 Workstation Design
12 Workplace Design

Part IV HSI Support - Maintaining Digital Systems

Fig. 2 Organizational Structure of NUREG-0700.

3. APPROACHES TO REVIEWING INNOVATIVE TECHNOLOGY

Within this regulatory approach to HFE review, evaluations of new and innovative technology can be performed. Of course, the first step in accommodating new technology within existing regulatory guidance is to keep that guidance up-to-date and consistent with the state-of-the-art. The NRC has endeavored to accomplish this with a proactive HFE research program that has evaluated and anticipated industry trends so that guidance is available when it is needed - not after the fact. Review guidance on such HSI technologies as computer-based procedures and computerized operator support systems is an example. This also encourages applicants to make such changes since they can see the review guidance and acceptance criteria thus reducing regulatory uncertainty.

Even with such a program, the nature of digital technology is such that innovations are always possible. Thus, the NRC review approach accommodates the review of new and innovate technology in four ways:

- the review of the design process, as well as, the HSIs themselves

- the use of applicant-specific HSI style guides
- the identification of specific criteria for deviating from NUREG-0700 design review guidelines
- the use of applicant tests and evaluations in lieu of HFE guidelines

Each is discussed below.

3.1 Review of the Design Process

The NRC HFE review does not rely solely of an evaluation of an existing design using predefined HFE guidelines. While that was the approach following the TMI accident, HSIs are now evaluated by focusing on the design process as well as the final product. This allows the NRC staff to review the manner in which HSI requirements are developed and evaluated. Thus there is not strict reliance on NUREG-0700 guidelines as the sole review criteria. Instead, new and novel technologies can be evaluated within the full context of an HFE design and evaluation program that considers operating experience, function allocation, task requirements, HSI validation, etc. as an integral part of the design.

3.2 Use of Applicant-Specific HSI Style Guides

While the NRC has updated, state-of-the-art review, guidance for computer-based HSI technologies, such as soft controls and computer-based procedures, in NUREG-0700, Rev. 2, the NRC also recognizes that applicants may develop style guides for their HSI designs. The style guides can be reviewed and used in place of NUREG-0700. A style guide is a design-specific HSI guideline that is more detailed than the more general guidelines in NUREG-0700. Table 1 provides some examples of the differences between NUREG-0700 level guidelines and plant specific guidelines.

Table 1 Examples of general and plant-specific HSI guidelines.

Guideline Level	Screen Organization	Font Size
NRUEG-0700 Guideline	1.5-1: Display Screen Partitioning for HSI Functions - A standard display screen organization should be evident for the location of various HSI functions (such as a data display zone, control zone, or message zone) from one display to another.	1.3.1-4: Character Size for Text Readability - The height of characters in displayed text or labels should be at least 16 minutes of arc (4.7 mrad) and the maximum character height should be 24 minutes of arc (7 mrad).
Style Guide Plant-Specific Guideline	Each screen will be divided into four zones: an upper zone providing label and identifying information; a left zone providing navigation controls; a lower zone providing alarm, status, and message information; and a large center zone displaying user selected information.	The size of text in displays appearing at workstations (eye to monitor distance of 25 inches or 635 mm) will be as follows: • Display Titles 5 mm • Equipment Labels 4 mm • Parameter values 3 mm • General Messages 3 mm • Warnings 4 mm

This allows different vendors and utilities to develop their own design solutions, which can then be reviewed using the guidance in NUREG-0711.

3.3 NUREG-0700 Deviation Criteria

A new and innovative HSI design may generate human engineering discrepancies (HEDs) when reviewed with NUREG-0700 guidelines. An HED is an HSI design feature or function that is not consistent with the NRC review guidance documented in NUREG-0700. However, within the context of the overall design process, these discrepancies may be completely justified. Thus, NUREG-0711 makes specific provisions for evaluating HEDs to determine whether they have a technical basis that make them acceptable. The technical basis for such a determination could include an analysis of recent literature or current practices, tradeoff studies, or design engineering evaluations and data.

3.4 Use of HSI Tests and Evaluations

The NRC recognizes that as technology evolves, there may not be a sufficient time or basis to develop NRC HFE review guidelines. Thus in lieu of the availability of HFE design review guidelines such as those in NUREG-0700, applicant tests and evaluations can be used as part of the HSI design, evaluation, and validation process.

4. CONCLUSIONS

Given the rapid evolution of digital technology and its inherent flexibility, there may be concern that the regulatory review process could stifle new and innovative approaches to human-system interface (HSI) design even though such innovations may improve operational performance and safety. The NRC has addressed this concern in recent revisions to its HFE review guidance that focuses on the design process as well as

the HSI itself. That process has a number of built-in mechanisms to encourage such designs and to provide a basis to review and accept new approaches to HSI design.

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