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Review of Advanced Control Rooms: Methodological Considerations for the Use of HFE Guidelines*

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Control rooms for advanced nuclear power plants use advanced human-system interface (HSI) technologies that may have significant implications for plant safety in that they will affect the operator's overall role in the system and the ways in which operators interact with the system. The U.S. Nuclear Regulatory Commission (NRC) reviews HSIs to ensure that they are designed to accepted human factors engineering (HFE) principles. The principal review guidance, however, is more than ten-years old (U.S. NRC, 1981). Accordingly, an Advanced HSI Design Review Guideline (DRG) was developed to provide criteria for these reviews. The DRG contains seven major sections: Information Display, User-System Interaction, Process Control and Input Devices, Alarms, Analysis and Decision Aids, Inter-Personnel Communication, and Workplace Design (see O'Hara & Brown, 1993). The purpose of this paper is to describe the methodology for DRG use.

HFE reviews help assure that an HSI design accommodates general human physiological and cognitive capabilities. In addition, since HFE guidelines are derived from years of lessons learned from actual systems, they can pinpoint design characteristics than can detract from human performance. However, the use of HFE guidelines has several significant limitations. First, since guidelines are not sensitive to time dependency, their use can not fully determine if the crew can meet system performance requirements. Second, guidelines are insensitive to interactive effects between multiple guidelines, e.g., consistency and flexibility tradeoffs. Third, since the establishment of a validated set of guidelines requires a consensus that is based on professional experience, HFE guidelines will always be incomplete in scope and coverage when applied to advanced technology.

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Therefore, it is essential that an HSI review strategy acknowledge and accommodate both the strengths and weaknesses of HFE guidelines. These limitations can be minimized by using a review methodology, as described below, that addresses the characteristics of tasks operators must perform. This methodology is intended to improve the reviewer's ability to make the guidelines more sensitive to the task context and to overcome some of the unique issues associated with the review of advanced systems, such as the potentially large number of displays in a virtual workspace. However, since the limitations cannot be completely eliminated, a complete review must use multiple evaluation methods (e.g., a dynamic simulation evaluation to complement the use of HFE guidelines).

The DRG review methodology is based on a multi-step procedure as summarized below.

Step 1. Assemble Review Team and Supporting Information

A Review Team should be composed primarily of individuals with expertise in human factors and operations, with access to additional skills that may be required for specific reviews. The generic information requirements are identified below:

- A description of the plant system(s) which the HSI supports
- The human role in the system
- The concept of operations
- A description of the HSI.

Step 2. Identify Human Functions and Tasks

Using documented system requirements, function allocation, and task analyses, the human functions and tasks in the overall system should be identified in terms of information, decision-making, and control performance requirements.

Step 3. Sample Human Tasks and HSIs

A detailed review of all displays and controls is impractical due to the large number of interfaces that can be provided in a computer-based workspace. Therefore, a sampling strategy should be employed to guide the selection of HSIs for review. The sampling strategy should be function/task driven and include human interactions with a wide range of plant systems to incorporate an evaluation of the HSIs that support the crew's roles. A multidimensional sampling space can be defined by the following primary dimensions:

1. Major operator functions in the system (e.g., status monitoring, surveillance testing, fault detection/analysis/diagnosis/mitigation, monitoring of automated safety functions, and override/control of automated systems).

2. Range of operational and abnormal conditions in which operators are involved (e.g., normal plant evolutions, instrument failures, equipment and processing failures, transient/emergency response, and accident management).

3. Extent of task structure (e.g., from procedure supported to knowledge-based tasks).

4. Range of operator interactions (e.g., among control room operators, between control room operators and auxiliary operators).

5. Risk-significant operator interactions (e.g., human actions, systems, and sequences contributing highly to risk, as defined by risk assessments).

Step 4. Detailed Characterization of Selected Tasks and Supporting HSIs

For the selected operator tasks in Step 3, detailed requirements should be identified. The HSIs supporting these tasks should be characterized in terms of implementation and functionality. While task analyses define required HSI functionality, the following should also be identified:

- Unwanted/unnecessary/unintended functionality
- Potential safety issues (e.g., operator set-point adjustment)
- Potential security concerns (e.g., potential software modification).

Step 5. Conduct Evaluation

The subset of individual DRG guidelines appropriate to the specific design being reviewed should be identified. The review should address aspects of the HSI:

1. A Global Features Review that addresses general HSI features that relate to the configurational and environmental aspects of the HSI, such as control room layout and lighting.

2. A Standardized Features Review that addresses the HSI features governed by the designer's standards and conventions.

3. A Detailed Features Review that addresses the task- relatedness of HSI features and aspects of the HSI not governed by the designer's standards and conventions.

Step 6. Interpretation of Findings

The interpretation of guideline-based evaluations should acknowledge the potential limitations of such an approach. Therefore, a mechanism has been established to evaluate the technical basis of guideline discrepancies. Where justified, such discrepancies may be found acceptable.

The DRG methodology described above is intended to improve the use of HFE guidelines for the review of HSIs.

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