

ADVANCED CONTROL ROOM DESIGN REVIEW GUIDELINES:

MERGING OLD AND NEW\*

CONF-921048--4

DE92 019212

Richard J. Carter

Engineering Physics and Mathematics Division

Oak Ridge National Laboratory

Jerry A. Wachtel

Office of Nuclear Regulatory Research

U. S. Nuclear Regulatory Commission

For Presentation at the:

The Human Factors Society

36<sup>th</sup> Annual Meeting

Atlanta, Georgia

October 12-16, 1992

**DISCLAIMER**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

"The submitted manuscript has been authored by a contractor of the U.S. Government under contract No. DE-AC05-84OR21400. Accordingly, the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or allow others to do so, for U.S. Government purposes."

APR 13 1992

\* Research sponsored by the U.S. Nuclear Regulatory Commission, Office of Nuclear Regulatory Research under U.S. Department of Energy interagency agreement number 40-775-50 with Martin Marietta Energy Systems, Inc. under contract number DE-AC05-84OR21400 with the U.S. Department of Energy.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

ADVANCED CONTROL ROOM DESIGN REVIEW GUIDELINES:  
MERGING OLD AND NEW

Richard J. Carter  
Oak Ridge National Laboratory  
Oak Ridge, Tennessee

Jerry A. Wachtel  
U.S. Nuclear Regulatory Commission  
Rockville, Maryland

ABSTRACT

The nuclear power industry is currently developing operator interface systems based on innovative applications of digital computers. To assure that this advanced technology is incorporated in a way that maximizes the potential safety benefits of the technology and minimizes the potential negative effects on human performance, human factors principles must be considered. NUREG-0700 contains guidelines for the review of operator interfaces. However, in light of the rapid technological advances in digital technology which have taken place in the eleven years since its publication, it is no longer adequate to assess the rapidly changing human-system interfaces. A research program, the purpose of which is to upgrade NUREG-0700, has been initiated. Thus far a set of draft advanced control room design review (ACRDR) guidelines has been compiled. Three tasks, which were oriented towards integrating the applicable guidelines in NUREG-0700 into the ACRDR document, are described in the paper.

INTRODUCTION

The nuclear power industry is currently developing advanced instrumentation and controls (I&C), and operator interface systems based on innovative applications of digital computers. Nuclear power plant (NPP) control rooms are gradually undergoing a conversion to advanced computer-driven display and control devices. Significant changes in the operation of NPPs can also be expected from the contemplated uses of computers for automation and operator aids. The control-room operator will be interfacing with more "intelligent" systems that will be capable of providing information processing support for his/her tasks. Furthermore, new technologies such as artificial intelligence and computer graphics already exist in human-machine interfaces within other industries and are moving into NPPs (Carter and Uhrig, 1990).

The advanced operator interface systems will take many forms. Computer-driven display devices include visual display terminals, audio and voice displays, projection devices, printers, and

plotters. Computer-driven control devices consist of keyboards, direct manipulation controls (i.e., x-y controllers and direct pointing controllers), and other controls (e.g., multi-degree of freedom hand controllers, glove controllers, eye controllers, and head movement controllers).

The introduction of advanced I&C and operator interface technology holds great promise to improve the safe operation of NPPs. The potential advantages of advanced technology over conventional control-room technologies are compelling. 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.

To help assure that advanced technology is incorporated in new and existing NPP control rooms in a way that maximizes the potential safety benefits of the technology and minimizes the potential negative effects on human performance and plant safety, engineers and developers must consider and review the design and implementation of significant changes to control rooms and the human factors engineering aspects of advanced control-room designs.

#### The Old Human Factors Guidelines

NUREG-0700 (Nuclear Regulatory Commission [NRC], 1981) contains guidelines for the review of analog hard-wired operator interfaces. These guidelines have been useful in performing detailed control room design reviews to identify and correct design deficiencies. The control room design reviews include an assessment of control room layout, the adequacy of the information provided, the arrangement and identification of important I&C displays, the usefulness of audio and visual alarm systems, the information recording and recall capability, lighting, and other considerations of human factors engineering that have an impact on the operator's effectiveness.

NUREG-0700 has six main sections and five appendices. They are as follows:

- o Sections
  - 1. Introduction
  - 2. Planning phase
  - 3. Review phase
  - 4. Assessment and implementation
  - 5. Reports
  - 6. Control-room human engineering guidelines
- o Appendices
  - A. Reference materials

- B. Systems/operations design analysis techniques
- C. Control-room operating personnel interview protocol
- D. Photography guidelines
- E. Guidelines for environmental measurements

Section 6 of NUREG-0700 contains detailed guidelines for reviewing the human factors suitability of control-room features. These guidelines provide the benchmarks for reviewing the human factors quality of specific control-room design features. The section is divided into nine primary areas:

- o Control-room workspace
- o Communications
- o Annunciator warning systems
- o Controls
- o Visual displays
- o Labels and location aids
- o Process computers
- o Panel layout
- o Control-display integration

The process computer area has a limited set of guidelines on keyboards, cathode-ray tubes, and printers.

In light of the rapid technological advances in digital technology which have taken place in the eleven years since the publication of NUREG-0700, the guidelines are no longer adequate to assess the rapidly changing human-system interfaces.

#### The New Human Factors Guidelines

The NRC Office of Nuclear Regulatory Research has initiated a research program with Oak Ridge National Laboratory (ORNL) and Brookhaven National Laboratory. The purpose of the research is to upgrade NUREG-0700.

A set of draft advanced control room design review (ACRDR) guidelines, based upon human factors principles and criteria, has been compiled in order to conduct human factors engineering reviews of advanced control room designs and advanced human-system interfaces which may be introduced in NPP control rooms. The general approach and rationale to the ACRDR guidelines was described at the Human Factors Society (HFS) annual meeting last year (O'Hara and Wachtel, 1991). The new guidelines are to serve as an aid to ensure that the human factors effectiveness established from a detailed control room design review is maintained in the conversion to digital technology.

The ACRDR guidelines are divided into seven main sections:

- o Information display

- o Operator input and control
- o Alarms
- o Operator aids
- o Inter-personnel communication
- o Information protection
- o Workstation design

Information display is separated into four primary components: screen organization and layout, types of displays, display elements, and coding. There are five subsections under operator input and control: entering information, operator dialogue, display control, information manipulation, and system response time. The operator aids section is broken down into three parts: routine system messages and guidance, decision aids, and supervised automation. Inter-personnel communication has six subsections: general, preparing messages, addressing messages, initiating transmission, controlling transmission, and receiving messages. Information protection is partitioned into: general, user identification, data access, and data transmission. Workstation design consists of: display devices, control and input devices, workstation configuration, and control-room configuration.

#### MERGING THE OLD AND NEW

ORNL conducted three tasks the purposes of which were: to integrate the applicable sections and guidelines of NUREG-0700 into the ACRDR document and to ensure that all applicable guidelines are merged together in one document and conveniently accessible to users.

#### Identification of Areas Not Addressed by the ACRDR Guidelines

The primary objective of the first task was to identify those areas in NUREG-0700 that are not addressed by the present draft ACRDR guidelines, but which are still applicable to advanced I&C and operator interface systems.

ORNL analyzed both sets of guidelines (i.e., NUREG-0700 and ACRDR) and determined that the control-room design review process is not currently discussed by the ACRDR guidelines. As a result, it is suggested that Sections 1 through 5 of NUREG-0700 be included in their entirety within the ACRDR guidelines.

Section 6 of NUREG-0700 was reviewed and evaluated against the draft ACRDR guidelines. Many areas that have not been adequately addressed by the new guidelines were identified. These deficiencies are briefly described below.

Control-Room Workspace. The guidelines dealing with general layout, workstation design, multiunit control rooms, emergency

equipment, and environment should be merged within the ACRDR document.

Communications. The voice communication systems and auditory signal systems guidance which is not duplicated in the audio and voice displays section of the ACRDR document should be subsumed under the new guidelines.

Annunciator Warning Systems. There is little similarity between the guidelines presented in this section of NUREG-0700 and guidance addressed in the alarms section of the ACRDR document. As a result, the annunciator warning systems guidelines should be added in their entirety to the ACRDR guidelines.

Controls. The selection of controls, design principles, and pushbutton, rotary, and other control specifications guidelines should be incorporated within the ACRDR document.

Visual Displays. The guidelines addressing principles of display, and meters, light indicators, graphic recorders, and miscellaneous display types should be integrated within the ACRDR guidelines.

Labels and Location Aids. The labeling principles, label location, label content, label lettering, use and control of temporary labels, and location aids guidelines in NUREG-0700 should be included within the ACRDR document.

Process Computers. This section of NUREG-0700 should be deleted in its entirety since it has been subsumed in the guidance provided in the ACRDR document.

Panel Layout. The guidelines dealing with general panel layout and layout arrangement factors, and specific panel layout design should be merged with the guidance provided in the ACRDR document.

Control-Display Integration. The basic control-display relationships, groups of controls and displays, and dynamic control-display relationships guidelines in NUREG-0700 should be incorporated within the ACRDR document.

ORNL conducted an assessment and comparison of the NUREG-0700 appendices with the draft ACRDR guidelines. The results of these efforts are discussed in the following paragraphs.

A number of references were used in preparing the ACRDR guidelines. There is, however, no reference section presently included as part of the new guidelines. Even if there was, there would still be no duplication between these documents and the references used in generating NUREG-0700. The entire NUREG-0700

bibliography, along the references utilized in preparing the ACRDR guidelines, should be integrated within the new guidelines.

Appendix A of NUREG-0700 exhibits a detailed reference matrix of the sources of the individual guidelines addressed in Section 6. The ACRDR guidelines also identify the source(s) from which a particular guideline was prepared; however, it does so in a different manner. Each ACRDR guideline includes a source field as part of the guideline. This field shows the source(s) from which the guideline was obtained. It is suggested that the NUREG-0700 guidelines reference material matrix be dropped and not added to the new guidelines. It is recommended that the way in which NUREG-0700 identifies its reference sources be changed to reflect the format used with the ACRDR guidelines.

The last four appendices of NUREG-0700 cover design analysis techniques, interview protocol, photography, and environmental measurements. Material in these appendices is not replicated within the ACRDR guidelines. As a result, they should be included in the new guidelines.

#### Update of Areas in NUREG-0700

The primary objectives of the second task were to: review the NUREG-0700 areas that are not addressed by the draft ACRDR guidelines against recent industry human factors engineering review guidelines, and to update the guidelines as necessary.

The NUREG-0700 guidance was reviewed against six industry human factors engineering review guidelines (i.e., HFS, 1988; Kinkade and Anderson, 1984; National Aeronautics and Space Administration, 1989; Sanders, and McCormick, 1987; U.S. Department of Defense, 1981, 1989).

ORNL analyzed the six industry human factors engineering review guidelines and determined that the control room design review process is not covered in any of the recent guidelines. As a result, it is suggested that no revisions should be made to Sections 1 through 5 of NUREG-0700.

Each of the guidelines and exhibits in Section 6 of NUREG-0700 was reviewed against one or more of the six industry human factors review guidelines. The guideline reference matrix which is subsection A.2 of Appendix A to NUREG-0700 provided the blueprint for the review.

NUREG-0700 guidelines and exhibits, designed using a source document which has been superseded by a new one, were reviewed against the new set of guidance. Control-room guidelines which were developed via the NRC, Office of Nuclear Reactor Regulation, Human Factors Engineering Branch (HFEB) Preferred Practices, were critiqued according to the following process. First, the NRC

Project Manager asked the HFEB whether there have been any changes to the NRC inspector preferred practices; the Branch responded that if there have been, they have not been documented. Second, the material was evaluated against Kinkade and Anderson (1984). Third, the guidelines were analyzed using the nuclear experience and technical expertise of the ORNL project team.

The Section 6 guidelines and exhibits which were generated using one or more of the other 19 source documents as a baseline were compared and contrasted with the industry human factors engineering guidelines as a whole. Individual guidelines were evaluated against each industry document one at a time.

Subsequent to the review of the Section 6 guidance, NUREG-0700 was revised where necessary in accordance with the industry human factors engineering review guidelines. Changes and modifications were made to a large number of the NUREG-0700 guidelines.

ORNL conducted an assessment and comparison of the six industry human factors engineering review guidelines with the NUREG-0700 appendices areas. It was determined that the information within the five appendices is not addressed in any of the recent guidelines. As a result, it is suggested that no modifications be made to Appendices A through E.

#### Guideline by Control Station System Matrices

The third task was oriented towards identifying those NPP control station systems to which the individual NUREG-0700 and ACRDR guidelines apply and developing matrices of such applicability.

Nine control station systems (main control room, safety parameter display system, remote reactor shutdown facility, remote reactor scram system, emergency diesel generator control, vital electrical system, emergency coolant injection system, containment hydrogen sampling system, and radiation waste monitoring and control) were identified. They were derived via a review of a number of technical documents, discussions with contractors who have conducted control room design reviews, and ORNL nuclear engineering staff expertise. The individual guidelines were evaluated against the control stations one at a time in order to determine applicability. During the review process, a conservative approach was taken in order to ensure that appropriate guidelines were not accidentally excluded. Also this approach will allow NRC inspectors and evaluators to modify each set of guidelines for a control station evaluation dependent upon what advanced technology is present at a specific nuclear site.

Subsequent to the guideline-control station evaluation, two matrices were constructed. The human factors engineering guidelines formed the rows; the control station systems constituted



the columns of the matrices. An X was placed in a cell of a matrix if the specific guideline may be applicable to the control station system.

#### NOTES

The research described in this paper was sponsored by the NRC under U.S. Department of Energy (DOE) interagency agreement 1886-8085-2B with Martin Marietta Energy Systems Incorporated under contract number DE-AC05-84OR21400 with the DOE. The views and opinions are those of the authors and should not be interpreted or construed as the official position of the NRC.

#### REFERENCES

- Carter, R. J. and Uhrig, R. E. (1990). Human factors issues associated with advanced instrumentation and controls technologies in nuclear plants (NUREG/CR-5439). Washington, DC: U.S. Nuclear Regulatory Commission.
- Kinkade, R. G. and Anderson, J. (1984). Human factors guide for nuclear power plant control room development (EPRI NP-3659). Palo Alto, CA: Electric Power Research Institute.
- Human Factors Society (1988). American national standard for human factors engineering of visual display terminal workstations (ANSI/HFS 100). Santa Monica, CA.
- National Aeronautics and Space Administration (1989). Man-systems integration standards (Standard 3000, Revision A). Houston, TX: Lyndon B. Johnson Space Center.
- O'Hara, J. M. and Wachtel, J. (1991). Advanced control room evaluation: General approach and rationale. Proceedings of the 35<sup>th</sup> annual meeting of the Human Factors Society, 1243-1247.
- Sanders, M. S. and McCormick, E. J. (1987). Human factors in engineering and design (6th Ed.). New York, NY: McGraw-Hill Publishing Company.
- U.S. Department of Defense (1981). Human factors engineering design for Army materiel (MIL-HDBK-759A). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.
- U.S. Department of Defense (1989). Human engineering design criteria for military systems, equipment, and facilities (MIL-STD-1472D). Aberdeen Proving Ground, MD: U.S. Army Human Engineering Laboratory.

U.S. Nuclear Regulatory Commission (1981). Guidelines for control room design reviews (NUREG-0700). Washington, DC.