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September 23, 1980

Division of Human Factors Safety
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D. C. 20555

Attention: R. W. Froelic

Subject: Human Engineering Guide to Control/Room Evaluation
NUREG/CR-1580, Draft Report

Gentlemen:

Whitston Associates has reviewed the subject document and has prepared the following comments in order to assist in obtaining relevant useable documentation for control room evaluations.

The "Human Engineering Guide to Control Room Evaluation," published by The Nuclear Regulatory Commission and composed by the Essex Corporation, was directed toward the development of an approach to performing Human Factors evaluations of Nuclear Power Plant control rooms. It was anticipated that, as a result of implementation of this methodology, the control room operators' contribution to the effectiveness and successful performance of the overall nuclear generating system would be improved, and the impact of this complex system upon the control room operator would be reduced. In addition, as a corollary, it was expected that control room operator error frequency and severity rates would be decreased and be accompanied by reduced demands upon manpower, resources, skills, training efforts, and costs.

However, it is the opinion of Whitston Associates that these goals cannot be realized on the basis of NUREG 1580. Our reasoning is as follows:

In order of progressively increasing complexity and costs, Whitston Associates sees the levels of Human Factors changes to a nuclear power plant control room to be ranked as follows:

Level 1: Cosmetic Change to Hardware
Level 2: Physical Change to Existing Hardware
Level 3: Rearrangements of Existing Hardware
Level 4: Replacement or Addition of Hardware
Level 5: Change to the Human/Machine Interaction Design Philosophy

In attempting to "...help in identifying potential Human Factors problem areas in control room design..."...to provide a means to locate and remove

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causes of operator error...", NUREG 1580 has provided a reasonably sound and coherent methodology for the Human Factors evaluation of general as-is hardware. There can only be minor exceptions taken with the NUREG 1580 depiction of the Section I approach to general hardware evaluation and modification (Levels 4, 3, 2 and 1). However, nowhere in Section II (Human Factors Guidelines) is the control room and its components specifically addressed. Most information and designs have obviously been directly extracted from MIL-STD-1472C and/or Woodson and Conover (1964), and little has been added to justify this effort. As a demonstration of the lack of attention to the Nuclear Power Plant, several pieces of hardware are described (e.g., Joysticks) in Section II that are not present in the control room.

It is the opinion of Whitston Associates that the aforementioned nuclear power plant system goals of maximum Human/Machine performance cannot realistically be attained on the basis of an after-the-fact general evaluation of existing hardware. Whitston Associates contends that the design of the control room has clearly been one based more on historical evolution than on a conscious attention to Human Factors principles and data. Therefore, at this point the achievement of maximal operator performance can only be obtained from a thorough Human Factors analysis which attends to the specific functions of the nuclear power plant subsystems and the control room components, and from other basic relevant Level 5 analysis.

Simply stated, Whitston Associates believes that the apparent lack of Human Factors design efforts in traditional nuclear power plant control room designs cannot be adequately corrected by merely noting superficial hardware discrepancies, and then by performing the recommended detail design changes and modifications per Human Factors design guides MIL-STD-1472C, Woodson and Conover (1964), Von Cott and Kincade (1972), McCormick (1976). Whitston Associates contends that a system-based Human Factors analysis is required that will treat more than the individual equipment detail inadequacies that are treated in NUREG-1580.

Moreover, Human Factors analyses are required by Human Factors Specialists with an understanding of power plant functions to evaluate the adequacy in which the control room was planned and developed.

Whitston Associates believes that for this particular application, the Level 4, 3, 2 and 1 approaches to Human Factors analysis (based on MIL-STD-1472C, etc.) will not yield the desired results (i.e., a successful Human/Machine interface in the nuclear power plant control room. Instead, Human Factors evaluative approaches proposed in more systems-oriented design specifications such as MIL-H-46855A appear to be more appropriate. Thus, it is believed that the evaluative methodology proposed by the Nuclear Regulatory Commission should, indeed, be an integral part of this procedure, but that an effective evaluation cannot be based entirely on the basis of it alone.

Whitston Associates suggests that before the details of control room hardware are evaluated, several evaluative Human Factors analyses should be conducted by Human Factors specialists, knowledgeable in power plant functioning, to determine the adequacy and appropriateness of the very existence of the hardware under consideration. These analyses should define the specific subsystems functions being controlled; determine the appropriate allocation of these functions to humans, equipment, or humans and equipment; analyze the tasks derived from these functions; and develop, as a result, Human Factors based control room operation and maintenance equipment specifications, human roles, and procedures for effective system performance.

To perform this evaluative analysis, Whitston Associates suggests the following tasks (several of which are denoted in detail on MIL-H46855A, MIL-H-81444, and Meister's Human Factor Theory and Practice (1971), and are listed here for reference):

Task 1 - Definition of System Functions

The functions that must be performed by each nuclear power plant subsystem are diagrammed by Human Factors Specialists (who have a knowledge of the power plant) schematically using Functional Flow Diagrams (FFD's).

Task 2 - Definition of Information Flow Requirements/Communication Analysis

An analysis is performed to determine the basic information flows necessary for effective control of subsystems by control room operators and plant personnel.

Task 3 - Allocations of Functions to Humans vs. Machines

Defined nuclear power plant process control requirements, necessary information flows, required processing capabilities (in terms of lead, accuracy, rate and time-delay expectancies), and known constraints are analyzed in tradeoff studies to determine the subsystem functions that should be machine-implemented, and those which should be reserved for the human operations and maintenance personnel.

Task 4 - Evaluation of Selection of Control Equipment

On the basis of the nuclear power plant subsystem functions and the results of Task 3, the adequacy of the selection of types of control room hardware can be specified.

Task 5 - Human Task Analysis

Human Factors data and principles are employed in order to develop performance criteria for the resulting tasks decided to be performed by Human operators. Operator jobs, operations, tasks, and elements are hierarchically defined and a time-oriented description of human/control equipment instructions involved for subsystem process control is included. This analysis demonstrates the sequential and simultaneous physical and cognitive activities or human operation, maintenance, and control. This evaluation aids in determining whether subsystem performance requirements can be met by combinations of control equipment and personnel, and will assure that human performance requirements do not exceed human capabilities. These analyses are also used as the basis for evaluating manpower levels, equipment procedures, skill training levels required, and communication requirements, (see MIL-H-46855). Tasks identified herein that include control room components to be operated or maintained by human personnel and will require critical performance or will involve safety considerations are analyzed and evaluated on a critical task analysis.

Task 6 - Critical Task Analysis/Contingency Analysis

A critical task analysis is conducted involving tasks that, if not accomplished in accordance with system requirements, will most likely have adverse effects on subsystem reliability, efficiency, or safety. Human performance will be considered "Critical" whenever equipment design characteristics demand performance which exceeds human capabilities or approaches their limits, and thereby contributes to the occurrence of the following conditions: jeopardized performance of a subsystem function, or increased error probability to an unacceptable level.

An analysis of "Critical Tasks" identifies: 1) information required by the operator, including cues for task initiation; 2) information available to the operator; 3) evaluation processes; 4) decisions reached after evaluation; 5) action taken; 6) body movements required by action taken; 7) workspace envelope for operators required by actions taken; 8) workspace available to operator; 9) location and condition of work environment; 10) frequency and tolerances of actions; 11) time base; 12) feedback informing the operator of the adequacy of actions; 13) tools and equipment required; 14) number of operators required and their experience and background; 15) job aids or references required; 16; operator interaction with other operators; 17) limits of operator performance, and 18) limits of control equipment performance.

Task 7 - Maintenance Requirements Analysis

A maintenance requirement analysis is conducted to evaluate the adequacy of preventive and malfunction correction procedural effectiveness. This analysis involves MTTF and MTBF enumerations to control equipment components.

Task 8 - Operational Sequence Analysis and Flow Process Analysis

These analyses graphically depict and evaluate the flow of decisions, operations, physical transmissions, receipts of information, delays, monitoring activity, and storage of information as sequence of occurrence. This analysis is performed either in a column, format, or on a scale layout of the control room.

Task 9 - Environmental Analysis

Environmental conditions are evaluated according to the degree to which particular environmental stressors are within defined comfort tolerance limits.

Task 10 - Control/Display Link Analysis

This analysis devises optional control/display proximity arrangements for appropriate control room hardwares based on respective functions, sequences, and relative importance levels of controls and displays.

Task 11 - Control Room Manpower Analysis

Individual and control room crew work level analyses are performed and compared to expected Human Factors performance criteria in order to develop required manpower levels.

Task 12 - Control Room Layout Analysis

This analysis devises optional proximity arrangements of major control room subsystem components based on mutual interrelationships of these subsystems and components.

Task 13 - Procedure and Aids Analysis

This analysis derives the degree of effectiveness of established job procedures with regard to the required operator performance levels. Analysis involves evaluation of task approaches and job simplification measures.

Task 14 - Man Machine Interface Analysis

At this point of the Human Factors analysis wherein human and machine roles have been thoroughly defined the appropriate hardware components have been selected, the Human/Machine interface can be evaluated according to MIL-STD-1472C or to Volume II "Human Engineering Guide to Control Room Evaluation."

The use of these hardware checklists without the initial verification of the selection of the hardware may erroneously yield what appears to be adherence to Human Factors data and principles. Completion of the aforementioned antecedent system oriented tasks are therefore fundamental to maximizing the probability of successful operator performance.

We trust you will find the above comments to be constructive. If you need additional clarification, please contact the writer.

Sincerely,

James A. Oliver, P.E.
Director of Development

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