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NUCLEAR POWER PLANT CONTROL ROOM OPERATORS' PERFORMANCE RESEARCH

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ABSTRACT

A research program is being conducted by the Oak Ridge National Laboratory for the U.S. Nuclear Regulatory Commission to provide information on the performance of nuclear power plant control room operators when responding to abnormal/emergency events in the plants and in full-scope training simulators. The initial impetus for this program was the need for data to assess proposed design criteria for the choice of manual versus automatic action for accomplishing safety-related functions during design basis accidents. The program also included studies of training simulator capabilities, of procedures and data for specifying and verifying simulator performance, and of methods and applications of task analysis.

INTRODUCTION

Oak Ridge National Laboratory (ORNL) has for the past several years been conducting control room operator performance research using commercial nuclear power plant (NPP) training simulators. The effort has been performed under two programs: the Safety-Related Operator Actions (SROA) Program, and the Training Simulator Experiments (TSE) Program.

The SROA Program, which was completed in 1983, provided information and data for use in assessing the performance of NPP control room operators in responding to abnormal/emergency events that have occurred in operating plants (field data). These data can be used to develop criteria for acceptability of the use of manual operator action for safety-related functions. The program also included studies of training simulator capabilities, of procedures and data for specifying and verifying simulator performance, and of methods and applications of task analysis.

The TSE Program, initiated in 1983, has examined effects on performance caused by variations of a basic crew consisting of a Reactor Operator (RO) and Senior Reactor Operator (SRO), sometimes augmented by a Shift Technical Advisor (STA).

This paper summarizes the major results of the SROA Program and the first year of the TSE Program.

METHODS

Methods used in this research were to: (1) collect plant records of empirical data on events that had occurred at an operating power plant; (2) document scenarios of the event as an "Operational Sequence" developed by a system/task analysis; (3) present the "Operational Sequence" to crews of control room operators in the subject plant's training simulator, and measure performance recorded by computerized records, trained observers, videotapes and self-reports; and (4) compare performance in the simulator to performance in the field.

SROA SIMULATOR AND FIELD DATA

The initial impetus for the SROA Program was the need for data to assess a proposed design criteria, ANSI-N660 (ANS 58.8) (American National Standard, 1981) for the choice of manual versus automatic action for completion of safety-related functions during design basis accidents. After a preliminary assessment of available data, a program of data collection during "quasi-controlled" training simulator exercises was initiated in March, 1980. A parallel program was initiated to collect whatever field data were available. These could be used to "calibrate" simulator results. In the proposed design criteria, if the designer chose to rely on manual operator action, he had to allow certain time margins, depending on the severity of the event, complexity of actions, etc. If those time margins were not available, the actions should be automated. Consequently, the emphasis in the SROA Program has been on collecting data on the time required for operators to take correct action, despite the recognition that a more comprehensive approach to allocation of functions is desired and that other measures of performance may be equally or more important in many cases. This simple approach was felt to be reasonable for interim use in a design standard until some basic changes are made in the approach to NPP control room design and a more comprehensive research and data base exists.

In the SROA program, a sizable base of data on operator performance has been accumulated, including primarily operator response times and some error data. Data on operator response times, i.e., the time from the activation of an

alarm or observable cue until the time of initial correct operator action, have been recorded for a series of preliminary simulator exercises on a pressurized water reactor (PWR) simulator and boiling water reactor (BWR) simulator, and a more extensive series of exercises on a PWR simulator was completed in early 1983. Response times are quite variable but tend to be correlated more to "operational" characteristics of the event, e.g., how rapidly it develops and how specifically it is annunciated rather than to the severity of the consequences of the event. Initial comparison of field data to simulator data suggested that for highly experienced operators, average response times in the simulator were less than the average response times in the field, but the 1983 experiments simulator data and field data comparison shows no significant differences in operators' response times. (These data will be published after the completion of the current PWR simulator experiments.)

During 1983, the field data collection methodology was modified to provide a much richer analysis of operator sequences. An extended form of the task analysis methods developed in this program and in the NRC Crew Task Analysis Program (Burgy, 1983) was used to document operating sequences which are then verified on a NPP training simulator, and calibrated to field data for the same sequences at that NPP. These operating sequences are then used in controlled simulator experiments to obtain performance data.

SROA Program Results

A simplified and preliminary model of operator performance during abnormal/emergency operation was developed and tested for demonstration purposes. The model - Operator Personnel Performance Simulation (OPPS) - is based on results of previous simulator and field data collection in this program and applications of task analysis methodology. It was computerized and programmed into SAINT simulation language to take advantage of an existing computer-based structure. The output of the OPPS model is a probability distribution of time required for the crew to successfully complete the operating sequence(s).

Details of the SROA program are covered in its final report (Kozinsky, 1984).

TRAINING SIMULATOR EXPERIMENTS (1983)

These experiments were controlled according to an experimental design which presented four operating sequences to each of 16 operating crews receiving requalification training in a BWR training simulator. The operating sequences were developed and verified by the system/task analysis procedures developed in the SROA Program. The operating crews were balanced according to experience and/or training levels of ROs and SROs and the presence or absence of an STA.

Individual operator performance and crew performance were recorded by a Performance Measurement System (PMS), by trained observers and by videotapes. Nine performance measures were compared with the individual's and system's performance shaping factors (PSFs). This project was the first attempt at comparing each individual's performance, at task element level, to his biographical data profile; previous experiments measured only crew performance (Beare, 1984).

The details of these experiments and the major findings will be discussed by Dr. Arthur Beare of General Physics Corporation, our subcontractor, in the next presentation.

CONCLUSION

The program of Control Room Operator Research has included a number of separate but related studies concerned with NPP Operator performance, task analysis techniques, and the use of training simulators. In 1983, the SROA Program was completed, with the development of an improved process for field data collection and of a proposed structure for design evaluation using a systems model. A simplified and preliminary systems model was developed and tested.

The methodologies and procedures developed under the SROA Program were used in 1983 in a series of controlled experiments conducted at an operating BWR plant's training simulator. Plant operating crews' performance during four standards operating sequences was recorded and analyzed. The 1984 experiments are currently being conducted on a PWR training simulator.

From this research program has come a methdology for developing criteria to be used in evaluating human/system allocations of functions and assignment of tasks for safety-related operator actions in existing or proposed designs, and procedures and techniques to measure in simulators, human performance which can then be used to predict performance in the field. A substantial base of performance data has also been accumulated.

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