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Critical Human Factors Issues in Nuclear Power Regulation and a Recommended Comprehensive Human Factors Long-Range Plan

Programs Evaluation and Recommended Long-Range Plan

Prepared by C. O. Hopkins, H. L. Snyder, H. E. Price, R. J. Hornick, R. R. Mackie, R. J. Smillie, R. C. Sugarman

Human Factors Society, Inc.

Prepared for
U.S. Nuclear Regulatory Commission

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ABSTRACT

This comprehensive long-range human factors plan for nuclear reactor regulation was developed by a Study Group of the Human Factors Society, Inc. This Study Group was selected by the Executive Council of the Society to provide a balanced, experienced human factors perspective to the applications of human factors scientific and engineering knowledge to nuclear power generation.

The report is presented in three volumes. Volume 1 contains an Executive Summary of the 18-month effort and its conclusions. Volume 2 summarizes all known nuclear-related human factors activities, evaluates these activities wherever adequate information is available, and describes the recommended long-range (10-year) plan for human factors in regulation. Volume 3 elaborates upon each of the human factors issues and areas of recommended human factors involvement contained in the plan, and discusses the logic that led to the recommendations.

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PREFACE

Project History

The nuclear reactor accident at the Three Mile Island-2 (TMI-2) unit in Pennsylvania on March 28, 1979 set in motion a series of events that resulted in the preparation of this comprehensive long-range human factors plan for the Nuclear Regulatory Commission (NRC).

The reports of the President's Commission (Kemeny Commission), the NRC Special Inquiry Group (Rogovin Committee), and four other major investigation and review groups all concluded that a major factor in the TMI-2 accident was the failure to consider adequately the human element. Indeed, prior to the TMI-2 accident the human factors discipline was either unknown to or ignored by almost all of the nuclear power community. Human factors practices that had been commonplace for several decades in other high technology industries in the design, development, and operation of complex man-machine systems were almost completely absent in the nuclear industry. Before the accident at TMI-2 and for several months afterward, there were no experienced human factors personnel in the NRC organization.

A series of meetings between the NRC and Human Factors Society (HFS) personnel began late in the year 1979. After several months of meetings the NRC issued to the HFS a request for a proposal for the development of a comprehensive human factors plan for nuclear reactor regulation.

The HFS Executive Council deliberated the request and the nature of the Society's response. There was no precedent for this kind of activity by the Society. After considering such matters as the importance of the proposed work and the technical, business, legal, and financial aspects, the Executive Council of the Human Factors Society on October 12, 1980 passed the following resolution:

> As a public service to the human factors profession, and consistent with the stated purposes of the Human Factors Society "to promote and advance . . . understanding of the human factors involved in the design, manufacturing, and use of machines, systems, and devices of all kinds," the Executive Council authorizes the preparation of a proposal for "Development of a Comprehensive Human Factors Plan for Nuclear Reactor Regulation" in response to the 17 September 1980 request of the U. S. Nuclear Regulatory Commission (RFP No. RS-RES-80-227).

A proposal was prepared and a contract was awarded to the HFS. Work on the one-year project began on December 15, 1980.

Overview of the Report

This report contains a relatively large amount of background information not ordinarily found in most human factors plans for the regulation of design, development, operation, and maintenance of large-scale, complex man-machine systems. This background material is a necessary part of this plan because of the conditions that have existed until very recently, and, in some cases, still exist, in the nuclear power industry and the in Nuclear Regulatory Commission.

The comprehensive Human Factors Plan and supporting material are presented in three volumes. Volume 1 is an Executive Summary. The introductory section of Volume 2 presents the overall human factors problem in the field of nuclear power generation. It provides the historical background within which recently occurred the widespread, albeit belated, recognition of human factors by the nuclear power community. The recognition of a broad spectrum of human factors problems came about as a result of the publications of the findings and recommendations of several groups which investigated the accident at Three Mile Island.

The second part of the introduction describes the development of the comprehensive long range human factors plan in terms of the objective and scope, choice of the Human Factors Society to develop the plan, the project organization, and the project plan and method.

The introductory section also includes a selective summary account of the human factors discipline. It is intended to be useful both to persons who are familiar with human factors and to those who are relatively unfamiliar with the field. It is not a comprehensive text on human factors. Most of the topics have been selected because of their relevance to the past and current status of human factors peculiar to the nuclear power industry, and to the perception of the human factors discipline by some individuals in the nuclear power industry. Topics are in this account include origins and objectives, growth and development, and some fundamental concepts and misconceptions regarding the human factors discipline.

In Section 2 the systems approach to human factors in nuclear power plant regulation is described. This material is presented in full recognition of the fact that this approach was not followed in nuclear power plants that currently are operational in the United States. It is difficult and, in most cases, impossible to apply, retroactively, the fundamental concepts of human factors design to nuclear power plants whose original design and development were not the result of a strong, formal system engineering and integration activity. Nevertheless, in this section of our report we present the human factors system model. This model serves as a point of departure for identification and evaluation of human factors problems in operating already designed plants. It serves a unifying function in that relationships and dependencies among the various elements of a comprehensive, integrated human factors program are delineated.

The status of human factors in the field of nuclear power generation is reviewed in Section 3. The known current and planned human factors activities are described. These include organizational changes, administrative actions, and research and applications programs. Individual programs and projects are summarized and evaluated in terms of the appropriateness of objectives, timeliness, cost/benefit, and quality of work to meet objectives. Organizations included in the review are the NRC, DOE national laboratories, and industry elements including utilities, industry sponsored organizations, reactor manufacturers, architect-engineers, human factors companies and consultants, and professional societies.

The recommended comprehensive long-range human factors plan is presented in Section 4. Most of the individual areas of concern are treated under one of four major headings: human engineering, operational procedures and performance aids, personnel and staffing, and training and training equipment. Another general category includes human factors concerns that may not fit neatly into one of the four named classifications and some concerns that bridge two or more of the formal areas. A sixth category of concern was added at the request of the NRC. When we were asked to include in our work, which originally was directed at human factors problems associated with nuclear power generation, a review of the NRC incident reponse plan and facilities.

For each human factors area of concern one or more technical requirements is identified. Each technical requirement is rated in terms of urgency and relative importance. Estimates are provided for the manpower resources, special facilities, and program duration to meet each technical requirement.

Volume 3 consists of detailed reviews and analyses of the human factors areas of concern that are the basis for the recommended comprehensive long range plan. Each problem area is treated in terms of the following categories: the requirement and its significance in the nuclear power generation context; constraints including technical, organizational, regulatory, and personnel; present status, along with any current activities which may partially or fully meet the requirement; planned activities; missing elements; technical feasibility; interaction with other system requirements; and recommendations.

In some places we have provided definitions, explanations, and descriptions that are unnecessary for some of the potential readers and users of this report. We consider this to be desirable because we expect that the report will be used by persons whose formal educational backgrounds and fields of experience differ widely. Behavioral concepts that are a part of the everyday work of the engineering psychologist or human factors engineer may be foreign to an instrumentation and control engineer. Processes and terminology that are a part of everyday work and communication of the nuclear engineer may not be familiar to the human factors specialist in instructional system development or procedures development. Therefore, wherever it seemed that the usefulness of the report to a wide variety of readers would be enhanced by providing definitions, explanations, and descriptions, we have done so. The sophisticated reader will recognize this kind of material and may wish to skip over it.

Finally, this report was prepared by a Study Group assigned to the project and approved by the Executive Council of the Human Factors Society. The draft report was reviewed by Dr. William B. Knowles on behalf of the Executive Council of the Society. While the specific contents of this report may not agree with the opinions of individual members of the Executive Council of the Society, the report has been approved on behalf of the Society and therefore represents the Society's contractual response to the request from the Nuclear Regulatory Commission.

1.0 INTRODUCTION

1.1 Problem

On March 28, 1979 a major accident occurred at the nuclear power generating facilities located at Three Mile Island near Harrisburg, Pennsylvania. A combination of events, no one of which would have had serious consequences had it occurred in isolation, resulted in a loss of coolant accident (LOCA) in the nuclear reactor of Unit 2. After the first alarm that signalled turbine trip, two hours and twenty-two minutes elapsed before action was taken (closing a block valve) that stopped the loss of coolant. It has been calculated that if the block valve had remained open another 30 to 60 minutes a substantial amount of fuel would have begun to melt down. As it was, the reactor core was uncovered and sustained significant damage. All three of the plant's safety barriers were breached, resulting in uncontrolled release of radiation; however, there was no consequential release to the general public. Clean-up operations are expected to require at least six years and may cost several billion dollars.

The events that were involved in the accident sequence included both equipment malfunctions and human errors. Prior to, and during, the course of the accident humans not only failed to make appropriate responses to situations, but also took some actions that exacerbated rather than relieved problems.

Subsequent to the accident at Three Mile Island-2 (TMI-2) several groups conducted major investigations, reviews, and evaluations of the antecedents and the circumstances surrounding the accident. One of these was a commission appointed by the President of the United States (The President's Commission on the Accident at Three Mile Island, frequently referred to as the Kemeny Commission). A second group was the NRC Special Inquiry Group (widely known as the Rogovin Committee). The Special Inquiry Group was established and sponsored by the NRC, but was an independent investigatory body directed by the law firm of Rogovin, Stern & Huge. A third group was the TMI-2 Lessons Learned Task Force, an internal NRC group made up of representatives from various NRC Offices and Divisions. A fourth investigation was carried out by the Subcommittee on Nuclear Regulation for the U. S. Senate Committee on Environment and Public Works. The fifth major investigation was performed by the NRC Office of Inspection and Enforcement. Still another review and evaluation was conducted by a Special Review Group within the NRC Office of Inspection and Enforcement. Several hearings were held by the Subcommittee on Energy Research and Production of the U. S. House of Representatives Committee on Science and Technology. Additional limited scope reviews and evaluations of various facets of the TMI accident have been performed. However, the findings and conclusions of these six formalized groups were responsible for widespread, albeit belated, concern about human factors in the design, construction, operation, and maintenance of nuclear power plants.

On April 11, 1979 President Carter signed Executive Order 12130 establishing the President's Commission on the Accident at Three Mile Island. Eleven persons were appointed to the Commission under the chairmanship of Dr. John G. Kemeny, President of Dartmouth College. The Commission was charged with technical assessment of TMI-2 events and their causes; analysis of the role of the managing utility; analysis of the emergency preparedness of the NRC and other Federal, state, and local authorities; evaluation of NRC licensing, inspection, operation, and enforcement procedures applied to TMI-2; assessment of how public right to information concerning the events at TMI was served; and formulation of appropriate recommendations based upon the findings. The Commission published a report of its findings and recommendations on 30 October 1979 (58).

A major conclusion of the Commission was that the basic problems were people-related:

> When we say that the basic problems are people-related, we do not mean to limit this term to shortcomings of individual human beings - although those do exist. We mean more generally that our investigation has revealed problems with the "system" that manufactures, operates, and regulates nuclear power plants. There are structural problems in the various organizations, there are deficiencies in various processes, and there is a lack of communication among key individuals and groups. (58, page 8)

The Commission further concluded that these shortcomings, deficiencies, lacks, and problems contributed to the inappropriate operator actions at TMI-2. More specifically, some of the factors that were identified as adversely influencing the operators' actions were deficiencies in training, lack of clarity in operational procedures, failure to transmit and utilize information concerning operational experience from previous incidents, and deficiencies in the design of displays and controls (58).

On June 13, 1979 the NRC contracted with the law firm of Rogovin, Stern & Huge to direct a special inquiry into the TMI-2 accident. Mitchell Rogovin of the law firm was director and George T. Frampton, Jr. of the University of Illinois College of Law was deputy director of the inquiry. The scope of work of this Special Inquiry Group (SIG) was to include the sequence of events during the accident; the history of the NRC review of the utility's license application and related NRC inspection activities; the susceptibility of Babcock and Wilcox plants to accidents; TMI operations, including training and qualifications of personnel; and emergency planning and response to the TMI-2 accident by various organizations and the NRC. The SRG was composed of some 70 lawyers, scientists, and nuclear engineers and a large number of consultants. It published its conclusions and recommendations in January 1980.

The summary of the conclusions and recommendations of the SIG includes the following statements:

> The one theme that runs through the conclusions we have reached is that the principal deficiencies in commercial reactor safety today are not hardware problems, they are management problems. . . .
>
> We have found, based upon our study of TMI and our interviews with knowledgeable people in the industry, that many nuclear plants are probably operated by management that has failed to make certain that enough properly trained operators and qualified engineers are available on site in responsible positions to diagnose and cope with a potentially serious accident. The NRC, for its part, has virtually ignored the critical areas of operator training, human factors engineering, utility management, and technical qualifications. (123, Vol. 1, page 89)

Several detailed conclusions and recommendations by the SIG were directly concerned with human factors.

> While there is no question that operators erred . . . we believe there were a number of important factors not within the operators' control that contributed to this human failure. These include inadequate training, poor operator procedures, a lack of diagnostic skill on the part of the entire site management group, misleading instrumentation, and poor control room design. For these failings, the industry and the NRC must share responsibility with Met Ed. (123, Vol. 1, page 102)

One of the major sections of the SIG Conclusions and Recommendations was entitled "Greater Application of Human Factors Engineering, Including Better Instrumentation Display and Improved Control Room Design." In this section of the report the following paragraph indicts the nuclear industry for failure to consider human factors:

> During the period in which most large nuclear plants have been designed, the nuclear industry has paid remarkably little attention to one of the best tools available for integrating the reactor operator into the system: the relatively new discipline of "human factors." Human factors engineering was born of military needs during World War II and has since blossomed in the aerospace, defense and aircraft industries. But nuclear utilities, vendors, and

> architect-engineer firms have done very little to incorporate such learning into their designs, and the NRC has done virtually nothing to require them to do so. (123, Vol. 1, page 122)

In May, 1979 the NRC formed the TMI-2 Lessons Learned Task Force (LLTF). The purpose of the LLTF was to identify and evaluate safety concerns originating with the accident at Three Mile Island-2 that require licensing actions for presently operating reactors as well as for pending operating license (OL) and construction permit (CP) applications. On the basis of these evaluations, the LLTF was to recommend changes to licensing requirements and the licensing process for nuclear power plants. The task force, formed by the Office of Nuclear Reactor Regulation (NRR), was composed of 22 scientists and engineers from various branches, divisions, and offices in the NRC.

The scope of LLTF covered reactor operations, including operator training and licensing; licensee technical qualifications; reactor transient and accident analysis; licensing requirements for safety and process equipment, instrumentation, and controls; on site emergency preparations and procedures; NRR accident response role, capability, and management; and feedback, evaluation, and utilization of reactor operating experience.

In July 1979 LLTF issued a document (72) recommending that short-term actions be taken on 23 specific requirements in 12 areas. Human factors items were among those listed. In the description of the requirement for information to aid operators in accident diagnosis and control, the report stated, "A widely accepted lesson learned from the TMI-2 accident is that the man-machine interface in some reactor control rooms needs significant improvement." (72)

In October 1979 the LLTF issued its final report (73), which was concerned with safety questions of a more fundamental policy nature. The principal conclusion was that:

> . . .although the accident at Three Mile Island stemmed from many sources, the most important lessons learned fall in a general area we have chosen to call operational safety. This general area includes the topics of human factors engineering, qualifications and training of operations personnel; integration of the human element in the design, operation, and regulation of system safety; and quality assurance of operations. Specifically, the primary deficiency in reactor safety technology identified by the accident was the inadequate attention that had been paid by all levels and all segments of the technology to the human element and its fundamental role in both the prevention of

accidents and the response to accidents. (73, page 102)

Most of the 13 final recommendations of the TMI-2 Lessons Learned Task Force involved classical human factor issues. The recommendations were concerned with the following areas: personnel qualifications and training; staffing of control room; working hours; emergency procedures; verification of correct performance of operating activities; evaluation of operating experience; man-machine interface; reliability assessments of final designs; review of safety classifications and qualifications; design features for core-damage and core-melt accidents; safety goal for reactor regulation; staff review objectives; and the NRR Emergency Response Team.

On June 29, 1979 the U. S. Senate approved a resolution to provide funds for the Committee on Environment and Public Works to conduct a Special Investigation of the nuclear accident at Three Mile Island and a series of related studies on civilian use of nuclear power. The investigation was carried out for the Committee by its Subcommittee on Nuclear Regulation. Subcommittee Members were Senators Gary Hart (Chairman), Jennings Randolph, John C. Culver, Daniel Patrick Moynihan, Alan K. Simpson, Howard H. Baker, Jr., and Pete V. Domenici. Additional studies were conducted primarily by the Special Investigation staff, with substantial contributions by the General Accounting Office and by the Congressional Research Service.

The Senate Special Investigation was selective in scope to avoid duplication of other inquiries. It focused primarily on the first 24 hours of the accident, the cleanup operation at the site of the accident, and the evolution of the TMI-2 plant from its originally proposed site at Oyster Creek, New Jersey, to Three Mile Island in the Susquehanna River in Pennsylvania.

Among the findings and conclusions regarding the causes of the accident the Senate Special Investigation reported:

> Plant operators and managers inappropriately overrode the automatic safety equipment - actions that were the immediate cause of the uncovering of, and severe damage to, the reactor core. However, it is inappropriate and unfair simply to blame these personnel for the Three Mile Island accident. It should be emphasized that the utility, the reactor-vendor, the architect-engineer, and the NRC were responsible for deficiencies in training, in control room design, in instrumentation and equipment, in plant design, and in emergency procedures. These deficiencies were the underlying cause of the accident. Many of these deficiencies resulted from insufficient attention by the utility, the reactor-vendor, the architect-engineer, and the NRC to human factors in nuclear plant design and operation. These

> human factor problems were beyond the control of the operators on duty during the accident and were so serious that they had consequences equivalent to those that could be caused solely by major mechanical failures and design defects. (128, page 9)

The NRC Office of Inspection and Enforcement (IE) began, immediately following the TMI-2 accident, an investigation to establish the facts of the accident and to evaluate the performance of the licensee (Metropolitan Edison Company) in association with the accident as a basis for corrective action or enforcement action as appropriate. The investigation determined the sequence of events and the immediate cause of the accident including equipment, procedures, staff performance, licensee management of the accident, and emergency plan activation.

The IE investigators confirmed inadequacies in six major areas that included operator training and performance, and equipment and system design (74).

On July 21,1979 the NRC Office of Inspection and Enforcement established the Special Review Group "to consider changes which should be made in IE and in the way IE does business based on lessons learned from TMI."(75) The Special Review Group (SRG) directed its work at both the preventive aspects and responsive aspects of the accident. In its summary of findings the SRG stated:

> Human factors played a key role in the precursor events, in the accident scenario, in the response to the accident, and in many other related aspects. Human factors are involved in the perception of the precursor events in the man-machine interface, and in the operators' response to the event. Human factors appear to be a fertile area for consideration. . . .This area, which is not well understood, should be better developed. (75, page 3)

The Subcommittee on Energy Research and Production of the U. S. House of Representatives Committee on Science and Technology held several hearings on Nuclear Power Safety in 1979 following the TMI accident. The main objective of the hearings was to examine the issues associated with nuclear power plant safety and to help the committee understand the level of safety in nuclear power plants. The hearings also served to determine what additional efforts, particularly in the area of research and development, are needed to further improve safety.

In the report on the findings of the hearings, the Subcommittee stated:

> Possibly the most important lesson learned from TMI for making reactors safer is the realization of the important role that operators and operating

> procedures have in insuring safety. Operator errors were responsible for making TMI a serious accident. The root causes of these errors were determined to be the deficiencies in the education and training of operators and inadequate instrumentation available for the operators to determine the state of the reactor system. (127, page 36)

and

> In addition to possible improvement in personnel selection and training, and management to improve power plant operations, TMI showed the need to improve the man-machine interface to enhance the capabilities of the operator to perform at maximum potential. Considerations of this sort are called human factors engineering. Lessons were learned regarding the need to identify the proper parameters to be measured or monitored to assure that actual reactor conditions are displayed, the need to display these conditions to operators in a fashion which is simple to understand, and the need to assist operators in diagnosing unusual conditions and suggest appropriate corrective measures. More attention to control room design and the use of computers will be required to address these needs, as will further research in human engineering as it applies to nuclear reactor operation. (127, page 38)

The findings and conclusions of these groups regarding the failure to take human factors into account in the design, construction, operation, and maintenance of the nuclear power plant at Three Mile Island were generally applicable to the entire nuclear industry. During the 1960s and 1970s when nuclear power plants were being designed, built, and put into operation, the human factors discipline was ignored by various sectors of the nuclear industry.

There were occasional warnings and recommendations from groups and individuals that insufficient attention was being given to human factors, but almost no action was taken. In 1972 a study group appointed by the Atomic Energy Commission reviewed incidents of inadvertant releases of coolant from the primary coolant system of operating reactors. Among the findings and recommendations were several concerned with control room design, operator training, procedures, control room manning, and feedback of operational experience (132). Action was initiated on less than a half dozen of the recommendations and as of 1979 only one of them had been implemented (123, Vol. 2, page 607). This one was the award of a contract by the NRC to the Sandia Laboratories to conduct a study of human factors problems at the Zion Nuclear Power Plant.

The Sandia study of the engineered safety features panels at Zion identified a number of human factors deficiencies (129). The report pointed out that the problems that had been identified had also been observed during visits to other power plants. Recommendations were made for improving the panels, procedures, and training. Additional recommendations were made for NRC consideration. In its investigation following TMI-2 in 1979, the SIG (Rogovin Committee) reported:

> To date, virtually none of the report's recommendations have been implemented. It should be noted that even though the 1975 Sandia report on the Zion plant found that minor inexpensive improvements would enhance plant safety and operations, to our knowledge not one has been implemented, and as of March 28, 1979, none had been planned for implementation. (123, Vol 2, page 610)

The Technical Advisor to the Executive Director for Operations of NRC, Stephen H. Hanauer, sent a memorandum regarding reactor safety issues to Commissioner Gilinsky on March 13, 1975 which included the following statements:

> Present designs do not make adequate provisions for the limitations of people. . . .The relative roles of human operation and automation (both with and without on-line computers) should be clarified. (123, Vol. 2, page 608)

The results of a large-scale study of reactor safety, under the independent direction of Professor Norman C. Rasmussen of the Massachusetts Institute of Technology, were published by NRC in 1975. In the section of this report concerned with human reliability analysis the following statement was made:

> In general, the design of controls and displays and their arrangements on operator panels in the nuclear plants studied in this analysis deviate from human engineering standards specified for the design of man-machine systems and accepted as standard practice for military systems (69, III-63).

The Electric Power Research Institute awarded a contract to Lockheed Missiles and Space Company to review the human factors aspects of the control rooms of nuclear power plants that had recently become operational. The Lockheed investigators were highly qualified, competent human factors professionals with many years experience in the aerospace industry. They performed a comprehensive 16-month human factors review of five representative nuclear power plant control rooms. In the summary of the study results, published in 1976, they stated:

> This study revealed a variety of areas in which application of human factors engineering would

improve the operability of present generation control rooms . . . In general, the study findings paint a rather negative picture.

Human factors engineering attention to problem areas will promote more effective and reliable operator performance, will reduce the training burden on utilities and trainees, and will ease the selection criteria in recruiting operators. (31, page 1-3)

In their conclusions the Lockheed group stated:

As a first priority, a detailed set of applicable human factors standards must be developed and industry-wide acceptance should be promoted.

In addition to a comprehensive set of standards, a need is perceived for human factors engineering design guides specific to the needs of the nuclear power industry. (31, page 1-28)

The Aerospace Corporation performed a study for the NRC to evaluate the effects of human engineering on operator performance in the control room. The study encompassed 18 control rooms. The report, published in 1977, made three recommendations to NRC:

1. Development of a regulatory guide to provide directions to the utilities in human engineering of control rooms; the guide should be designed to encourage an increased rate of incorporation of advanced control and display designs.

2. A thorough analysis of LER (Licensee Event Report) data on personnel errors.

3. A detailed study of the programmed malfunctions provided in the software routines of current simulators to determine whether they have the capability . . . to provide student operators with the level of training needed to minimize operator errors under conditions of severe stress. (40, pp. 7-13, 7-14, 7-15)

The SRG in its 1980 report on Three Mile Island (123), stated that virtually no action had been taken by the NRC to implement these recommendations.

Following the publication of the reports of the major investigations of Three Mile Island, the NRC initiated a variety of actions to rectify some of the more significant human factors deficiencies that have been identified in the nuclear power community. In addition to these actions, which are described and evaluated in Section 4, a comprehensive long-range human factors plan is necessary to insure the most efficient and cost-effective incorporation of human factors considerations in all the necessary aspects of nuclear reactor regulation.

1.2 Development of a Human Factors Plan

A series of meetings between Nuclear Regulatory Commission and Human Factors Society personnel began in late 1979. The HFS representatives were Richard W. Pew, Past President; H. E. "Smoke" Price, Chairman of the HFS Public Interest Committee; and Harry L. Snyder, President-Elect. The purpose of the meetings was to explore ways that the NRC might be able to draw upon the experience and expertise of members of the HFS in the establishment and development of human factors programs and utilization of human factors methods and knowledge in the nuclear power industry. Several alternatives were considered. The meetings resulted in tentative plans for the NRC to negotiate a contract with the HFS to support an intensive study of human factors issues and needs in the nuclear industry. A solicitation of interest for individual participation in this activity was published in the December 1979 issue of the Human Factors Society Bulletin.

Meetings between NRC personnel and the HFS liaison committee continued for several months. In September 1980, the NRC requested the HFS to submit a proposal for development of a comprehensive human factors plan for nuclear reactor regulation.

The HFS Executive Council deliberated the request and the nature of the Society's response. There was no precedent for this kind of activity by the HFS. After considering such matters as the importance of the work and technical, business, legal, and financial aspects, the Council on October 12, 1980 passed the following resolution:

> As a public service to the human factors profession, and consistent with the stated purposes of the Human Factors Society "to promote and advance . . . understanding of the human factors involved in the design, manufacturing, and use of machines, systems, and devices of all kinds," the Executive Council authorizes the preparation of a proposal for "Development of a Comprehensive Human Factors Plan for Nuclear Reactor Regulation" in response to the 17 September 1980 request of the U. S. Nuclear Regulatory Commission (RFP No. RS-RES-80-227).

The proposal was prepared by Charles O. Hopkins, Harry L. Snyder, and H. E. "Smoke" Price. It was approved in the name of the Human Factors Society by President Earl A. Alluisi with the concurrence of an Advisory Committee composed of Dr. Alphonse

Chapanis, Professor, The Johns Hopkins University; Dr. John J. O'Hare, Assistant Director, Enginering Psychology Programs, Office of Naval Research; and Dr. Richard W. Pew, Principal Scientist, Bolt Beranek and Newman, Inc., Dr. Chapanis and Dr. O'Hare were serving as Members of the Executive Council of the HFS. Dr. Pew and Dr. Chapanis are Past Presidents of the HFS.

A contract was awarded and work on the project began December 15, 1980.

1.2.1 Objective and Scope

The objective was to develop for the NRC a comprehensive long-range human factors plan to cover the next 10 years. The plan is intended to meet the diverse requirements for human factors imposed by the different regulatory functions and responsibilities of the various NRC Program Offices and to identify needed programs throughout the NRC. It focuses on those areas concerned with nuclear power plant safety. Nuclear fuel cycle activities, such as mining, transportation, and waste disposal, are not included.

The plan provides estimates of priorities and schedules for accomplishment and includes estimates of resources required. It identifies all NRC activities associated with nuclear reactor regulation that involve human factors considerations such as design, standards development, licensee qualifications, research, construction, operation, maintenance, inspection, safety review, and training. It includes recommendations for the collection of specific types of human factors operational data and for their analyses and dissemination to the appropriate activities within the NRC. The plan does not address human factors considerations in the areas of plant security or health physics.

1.2.2 Choice of the Human Factors Society to Develop Plan

The NRC decision to seek help through the aegis of the Human Factors Society was based upon several important considerations. The most significant factor was that an area of science and technology, human factors, was being introduced into the context of the organizations, programs, and operations of a regulatory agency and the industry it regulates. At the time of the TMI accident and for several months afterward, there were no human factors policies, programs, organizations, or personnel in the NRC.

During the summer and fall of 1980, the NRC was organizing and beginning to staff human factors groups in the Office of Nuclear Reactor Regulation (NRR) and the Office of Nuclear Regulatory Research (RES). A few human factors professionals were being recruited to join the NRC. Some NRC personnel who were qualified in other technical areas were transferred into newly created human factors positions and groups.

The development of a comprehensive long-range human factors plan for nuclear reactor regulation requires an intensive study, by qualified human factors personnel, of all the different kinds of human activities that are integral to the design, operation, and maintenance of a nuclear power plant. This kind of intensive review of the wide range of human factors elements involved could not be accomplished by the limited NRC human factors resources simultaneously with their other responsibilites for carrying out on-going programs that had been transferred to the newly formed human factors groups and for planning, initiating, and conducting new short-term programs that had resulted from the TMI Action Plan.

Identification of requirements and preparation of a comprehensive plan by qualified human factors personnel outside the NRC organization provides an important independent assessment and evaluation of problems and programs. During the 15 months that the HFS Study Group was working on the long-range plan to cover the next 10 years, the NRC human factors groups were continuing to recruit personnel, identify and assign priorities to human factors problems, initiate programs, and engage in both near-term and long-range planning.

The arrangement with the HFS provided the NRC with the potential for drawing upon a wider range of expertise than was likely to be available in a single company or other institution. By requiring only part-time availability of individuals over the period of a 15 months it was possible to obtain the services of qualified, highly experienced, and successful human factors experts who would have been inaccessible otherwise.

The contract with the HFS minimized the potential problem of conflict of interest. The Society, as a non-profit professional organization, has no desire or interest for follow-on contracts that might in some way be based upon the recommendations of the Study Group.

A less direct, but important, advantage of the contract with the HFS is communication between the NRC and the human factors profession. Each of the Study Group members is from a different organization. They represent different kinds of institutions (universities, industry, government laboratories, and human factors consulting firms) and are from different parts of the country (Northeast, Southeast, Midwest, and West Coast). This should contribute to a more widespread diffusion of knowledge about human factors problems and programs in the field of nuclear power. Increased exposure of the requirements and of the opportunities for applications of human factors methods in the nuclear power field is likely to help create interest among human factors professionals who are working in other areas.

There is another aspect of the communication between the NRC and the human factors profession represented by this contract that is more subtle than the diffusion of information. The request for the HFS to sponsor the development of a comprehensive long-range human factors plan is a demonstration of the NRC commitment to the integration of human factors into its regulatory programs.

1.2.3 Project Organization

The organization of the Study Group consists of a project manager, a technical director, an agency liaison technical officer, and four technical area specialists. The four technical areas are human engineering, operational procedures and performance aids, training and training equipment, and personnel and staffing. Each of these seven positions is filled by a qualified, experienced, nationally recognized human factors professional. The four technical subgroup areas include a broad spectrum of human factors concerns. They are not considered to be independent or isolated areas. Rather, they are key elements in an overall systems engineering context. The level of effort is approximately four professional person years.

The Study Group is responsible to the Executive Council of HFS.

Project Manager is Harry L. Snyder, Professor of Industrial Engineering and Operations Research, Virginia Polytechnic Institute and State University.

Technical Director is Charles O. Hopkins, Professor of Psychology and of Aeronautical and Astronautical Engineering, University of Illinois.

Agency Liaison Technical Officer is H. E. "Smoke" Price, Executive Vice President, Biotechnology, Inc., Falls Church, Virginia.

The area of human engineering is primarily the responsibility of Richard J. Hornick, Head, Human Factors and Systems Safety, Hughes Aircraft Company, Fullerton, California.

Operational procedures and performance aids are primarily the responsibility of Robert J. Smillie, U. S. Navy Personnel Research and Development Center, San Diego, California.

Training and training equipment are primarily the responsibility of Robert C. Sugarman, Director, Human Factors and Training Center, Calspan Corporation, Buffalo, New York.

Personnel and staffing are the primary responsibility of Robert R. Mackie, Vice President, Human Factors Research, Canyon Research Group, Goleta, California.

1.2.4 Project Plan

The project was carried out in three phases, referred to as tasks. Each task covered a period of four months. An additional three months were spent on NRC review and briefings prior to final report completion.

Task A - Survey of NRC Program Offices. The requirements of Task A were to determine the aspects of nuclear power plant safety that are impacted by or have an impact upon human factors issues and to describe the nature of these impacts. This was accomplished through a detailed survey of the NRC Program Offices, current reports resulting from investigations of the Three Mile Island accident, and other documents and reports relevant to regulation of human factors in the design and operation of nuclear reactors. The survey also included the organization and staffing of the Offices. At the completion of Task A, a briefing was made to the NRC by the Study Group and an informal report was submitted summarizing the findings.

Task B - Selective Check with Nuclear Industry. The findings of Task A were expanded as necessary and refined to ensure completeness and accuracy through selective checks with representative elements of the nuclear industry. Sectors of the industry involved in this task included utilities, architect-engineers, nuclear steam supply system vendors, the Electric Power Research Institute, Institute of Nuclear Power Operations, and other organizations. The Study Group also interacted with representatives of other professional organizations who have functional working groups concerned with human factors in the nuclear industry. Task B culminated in the preparation of a Tasks A and B report and the presentation of a briefing to the NRC.

Task C - Evaluate Current Activities and Recommend Courses of Action. During the work on Task C the Study Group evaluated current activities and programs for each of the regulatory functions identified as having human factors involvement. In light of the evaluation of what is being done and the determination of what needs to be done, the Study Group formulated recommendations regarding the problems to be addressed and suggested approaches. The recommendations are presented in the form of a plan to cover the next 10 years. The plan provides estimates of priorites, schedules, and resources. In addition to the final report the Study Group presented two briefings to the NRC staff at the conclusion of the work.

1.2.5 Method

At the very beginning of work on this project the NRC emphasized that, subject only to the broad constraints of fulfilling the contractual statement of work, the Study Group's operations were to be independent of NRC influence. NRC personnel were most helpful and cooperative in response to our requests for information, documents, and meetings. They have made constructive suggestions when we have solicited them. There were no attempts to discourage or hinder our review of any area or to manage our approach to getting information from any source either inside or outside the NRC. On the contrary, we were encouraged by the NRC to meet with some elements of the nuclear power community that we might not have contacted otherwise.

Task A. Task A was concerned with surveying NRC Program Offices and studying documents to determine those aspects of nuclear power plant safety with human factors implications. The majority of our activities and our contacts with the nuclear power community during the performance of Task A were focused upon the NRC. This was appropriate because, first of all, we needed to learn how human factors issues are being handled presently by the NRC. We also needed to learn about the NRC's plans for human factors activities, both for the short term and for a longer period. It was necessary for us to acquire an understanding of the regulatory role and the responsibility of NRC for insuring safety of nuclear power plant operations in terms of human factors considerations.

The HFS Study Group attended a two-day briefing program provided by NRC personnel in Bethesda on December 15-16, 1980. These briefings included summary presentations on responsibilities and operations of all five NRC Program Offices. More detailed briefings were provided by certain organizations whose responsibilities are directly concerned with human factors.

At the end of these briefings, the Study Group requested copies of relevant reports and documents for additional study. The NRC Project Officer arranged for the requested documents to be sent to appropriate team members.

In January 1981 the Study Group attended a special training program provided by the NRC Office of Inspection and Enforcement. This training program included (1) instruction at the NRC Training Center in Chattanooga on nuclear reactor fundamentals and effects of radiation, and (2) one week of operational training and experience on the Brown's Ferry control room simulator at the TVA Training Center near Soddy-Daisy, Tennessee.

In February, 1981 the HFS Study Group again met with individuals in various NRC organizations, and were given detailed briefings on the programs of the Division of Human Factors Safety of the Office of Nuclear Reactor Regulation and on the programs of the Operational Safety Research Branch and the Risk and Operations Research Branch of the Office of Nuclear Regulatory Research. As a result of these briefings and meetings, copies of additional NRC documents relevant to the work of the Study Group were requested.

Intermittently during this period, the Study Group personnel read and discussed the numerous NRC documents and reports, held formal meetings and informal conversations on this material among Study Group members and with NRC personnel, and held working sessions. A general framework for systematically addressing the overall human factors issues in the reactor regulation process was developed.

Liaison was established and maintained throughout the course of the project with Working Group 5.5 of the Reliability Subcommittee, Nuclear Power Engineering Committee of the Institute of Electrical and Electronics Engineers (IEEE). Working Group 5.5 includes three task groups. The problems being addressed by the task groups are development of a guide for human factors engineering requirements for systems, equipment, and facilities of nuclear power generating stations; development of a guide for evaluating human performance in a nuclear power plant environment; and development of a recommended practice for the use of color coding in nuclear power plant panels, controls, and displays. One member of the HFS Study Group participated in the bimonthly meetings of IEEE Working Group 5.5.

During the last month of work on Task A, the HFS Study Group visited the NRC Region I Office in King of Prussia, Pennsylvania and was briefed on the responsibilities and operations of that office. Formal presentations and discussions were concerned with the following topics: Region I organization, recruitment and training of inspectors, rotation of resident inspectors, region operation center, procedure reviews by inspectors for format and technical content, resident inspector reporting requirements and mechanisms, licensee event reports (LERs) and Regional follow-up, and licensee shift manning and operator duty hours.

Following the meetings with personnel in the Region I Office, site visits were made to two nuclear power plants in this region. Study Group members visited Salem II (Public Service Gas and Electric - New Jersey) and Peachbottom (Philadelphia Electric). These site visits included observations of control rooms and discussions of human factors requirements and problems with operational, engineering, and management personnel. Discussions were also held with NRC resident inspectors.

Some members of the Study Group attended the presentation on "Advances in Improving Human Performance Through the Use of Computerized Control and Surveillance Systems in Reactor Operations" given by staff representatives of member organizations of the Halden Reactor Project in Bethesda, Maryland on March 18, 1981.

The NRC Contract Officer made arrangements for two members of the Study Grouop to visit the NRC Emergency Operations Center personnel for detailed briefing on the rationale, planning, and functioning of the Emergency Operations Center.

Study Group members continued the acquisition and study of documents relevant to human factors issued by NRC, Department of Energy (DOE) laboratories and contractors, and professional and industrial organizations. A formal briefing on the accomplishments of Task A was presented to NRC personnel on April 14, 1981.

Task B. In the performance of Task B we were concerned primarily with checking selectively with representative elements of the nuclear industry the completeness and accuracy of our findings during the performance of Task A. During Task B our activities and contacts were almost exclusively with the nuclear power industry outside the NRC. The major purpose of our activities during Task B was to identify and understand the human factors issues and problems in nuclear power safety as they are perceived by elements of the nuclear community outside the NRC. A comprehensive long-range human factors plan will be useful to the degree that it takes into account the many operational, as well as scientific and technical, aspects of human factors. Extensive meetings with all elements of the nuclear industry and site visits helped ensure that the real world of nuclear human factors is adequately considered in the plan.

Although the long-range human factors plan is being developed for the NRC, under the sponsorship of the NRC, the activities of Task B are viewed as being crucial to the development of a realistic, effective plan. There was an explicit agreement between the NRC and the HFS Study Group that we would not approach any part of our work as a captive of the NRC. We selected the organizations to be visited and made our own contacts and arrangements for visits. In our contacts with the NRC and with industry we have tried to be unbiased in our information gathering, evaluation, and planning.

During Task B, the HFS Study Group held meetings with the following elements of the nuclear power industry: utilities, nuclear steam supply system (NSSS) vendors, architect-engineer firms, control room simulator manufacturers, industry sponsored organizations, professional organizations, human factors consulting firms and other nuclear industry service companies, and public interest groups.

In addition to site visits to nuclear power plants during Task A, meetings were held during Task B with human factors, engineering, operational, and management personnel from the following companies that have nuclear power plants:

Detroit Edison Company

Louisiana Power and Light

GPU Nuclear (General Public Utilities)

Commonwealth Edison

Tennessee Valley Authority (TVA)

Pennsylvania Power & Light Company

Duke Power Company

Illinois Power Company

The Study Group also met with human factors and other engineering and management personnel of all four nuclear steam supply system vendors:

Westinghouse

Combustion Engineering

Babcock & Wilcox

General Electric

Visits or meetings were conducted with personnel at Department of Energy national laboratories:

Idaho National Engineering Laboratory

Oak Ridge National Laboratory

Meetings with control room simulator manufacturers/vendors included:

Singer Corporation - Link Division

Westinghouse

Combustion Engineering

General Electric

The Study Group has met with the following industry-sponsored organizations:

Institute of Nuclear Power Operations (INPO)

Electric Power Research Institute (EPRI)

Nuclear Safety Analysis Center (NSAC)

Edison Electric Institute (EEI)

The Study Group has held meetings with three architect-engineer firms:

Bechtel Power Corporation, San Francisco Division

Gibbs and Hill

Ebasco

Contacts have been established by the Study Group with the following organizations:

American Nuclear Society (ANS)

Atomic Industrial Forum (AIF)

Institute of Electrical and Electronic Engineers (IEEE)

Meetings were held between the Study Group and aerospace human factors personnel with extensive experience and expertise in nuclear power plant control room design and plant design for maintainability:

Lockheed Missiles and Space Company

Meetings were also held with representatives of human factors consulting companies and other nuclear industry service companies that have worked in the area of nuclear human factors:

Essex Corporation

NUS

Torrey Pines

General Physics

BioTechnology

We made contacts with and held meetings with representatives of public interest and environmental concern groups:

Union of Concerned Scientists

National Resources Defense Council

Interspersed among the meetings and visits with the various elements of the nuclear industry, the HFS Study Group continued acquiring and studying documents and reports relevant to the broad areas of human factors in nuclear power generation. Working sessions were held intermittently. A report on the work accomplished during Tasks A and B was submitted to the NRC and a briefing was presented for NRC personnel on September 11, 1981.

Task C. The third phase of the planning project, Task C, was concerned primarily with an evaluation of the regulatory areas and activities that had been identified as having a human factors impact. Each area of human factors concern was treated in terms of the following factors: the requirement and any technological constraints, an evaluation of present status of the problem or area of development both within the NRC and in industry, an evaluation of planned activities for each of the areas of the NRC and in industry, identification of missing elements, assessment of technical feasibility and problems, interaction with other system requirements, and recommendations (technical, priorities, schedule, resources, implementation, and interaction). These evaluations are contained in Volume II.

Study Group members participated in the 1981 IEEE Standards Workshop on Human Factors in Nuclear Safety, August 30 - September 4, 1981. One member participated in the CSNI Specialist Meeting on Operator Training and Qualifications, October 12-15, 1981 sponsored by the Committee on the Safety of Nuclear Installations (CSNI), Nuclear Energy Agency of the Organization for Economic Cooperation and Development. A staff briefing on the results was presented on March 10, 1982, and a final briefing was presented to the Commissioners of the NRC on May 25, 1982.

1.3 The Human Factors Discipline

During the brief period since the publication of the reports of results of groups investigating the TMI-2 accident, "human factors" has become a much used and misused phrase. It is clear that many who use the phrase do not know much about it.

This brief account of the human factors discipline is provided as an introduction to those persons who are not familiar with the field. It should also be useful as a reminder to some persons whose education and professional experience have been in some other field that the human factors discipline is more than just the use of good (or bad) common sense in engineering design. It is hoped that this brief survey will help persons in both categories understand the necessity for explicit, competent consideration of human factors principles in the design, development, and operation of safe, effective, and efficient man-machine systems. Furthermore, this section of the report emphasizes the requirement for formal human factors activities as an integral part of the systems approach to the design and development of man-machine systems.

The human factors discipline in the United States has had about 40 years of growth, development, and experience in the analysis, design, development, testing, operation, and maintenance of man-machine systems. At least three kinds of products from this experience can contribute to the nuclear power community. These are:

(1) An approach to man-machine (M-M) system design. This includes both a philosophy of man-machine systems and methodologies for scientifically investigating human performance in M-M systems and for effectively integrating humans in M-M systems.

(2) Data, knowledge, and some scientific generalizations and principles relevant to human performance in M-M systems.

(3) A relatively small group of well-trained, qualified, and experienced human factors professional personnel.

The topics included in this brief survey of human factors are origins and objectives, growth and development of the field, fundamental concepts and misconceptions, methods, professional qualifications, and areas of specialization.

1.3.1 Origins and Objectives

Human factors is an interdisciplinary scientific-technical field concerned with the capabilities and limitations of humans in the design and use of tools, equipment, systems, and environments. Antecedents may be found in several fields of science and engineering but it is accepted generally that the field had its significant origins during World War II. It was born of the recognition of a variety of people-related problems and the attempts to solve them.

Several lines of scientific and engineering development of sophisticated military systems converged with military requirements for rapid preparation of relatively large numbers of people to operate and maintain the systems. Problems began to surface when equipments with advanced performance capabilities from an engineering point of view were either misused or could not be used in ways that would fully exploit their potential. It became apparent in many cases that there was not an appropriate match between the capabilities and limitations of the human operators and the physical characteristics of the equipment. In some cases the primary source of the mismatch was due to inappropriate design of equipment. In other cases it seemed to be due primarily to inappropriate or inadequate training of the human operator.

The recognition that some equipment which could not be used correctly was subject to modification to meet the capabilities of the human operators was not a single discovery with earth shaking consequences made by a single individual or group. Rather, many people representing a variety of formal scientific and engineering disciplines, working for different military organizations on different kinds of people-related problems, began taking human factors into account in research, development, and redesign aimed at solving the problems. A large proportion of the people who started working on human factors (the term was not used then) problems were experimental psychologists who by personal preference or necessity were working in applied research and training areas for the military services.

Early human engineering work during World War II was concerned mostly with specific problems of modification or redesign of individual displays and controls to make them more nearly match the sensory, perceptual, and motor capabilities of the human operators. Although much of the immediately required work was of the simple "knobs and dials" variety, the concepts of the man-machine system and of the systems approach to design quickly gained widespread acceptance.

The principle objective of human factors is to optimize overall system performance by taking into account the human's capabilities and limitations in the assignment of functions, design of the physical elements of the M-M interface, development of procedures, selection and training of personnel, provision of a safe, comfortable environment, and development and management of personnel policies and procedures such as shift manning, rotation, and duration.

1.3.2 Growth and Development

Following World War II, both the Army Air Corps and the Navy established human engineering laboratories responsible both for conducting research and development work and for monitoring contract work done by other organizations. Later, all three military organizations (Air Force, Army, and Navy) promoted the development of the human factors discipline through a large number of military laboratories and research management organizations.

A handful of universities had done human factors research and development work during the war. These included Brown University, Harvard University, The Johns Hopkins University, Tufts University, and the University of Wisconsin. Strong human factors programs continued at some of these universities following the war. Over a long period of years the programs at Hopkins and Tufts made significant contributions to the development of the human factors discipline.

In the years following the end of World War II, human factors laboratories and programs were established in several other universities. Among the earliest and most influential was the laboratory at the University of Illinois. Later a strong program was established at Ohio State University. Other universities that had prominent human factors programs at various times during the early development of the discipline were the University of Southern California and the University of Michigan.

University and government laboratories were prolific during the six to eight years following the end of the war. A solid foundation of theoretical formulation and experimental research-derived data was laid for the developing discipline. Also the results of thousands of experiments that had been performed previously in laboratories of experimental psychology and physiology were re-examined. The data were evaluated in the light of relationships between man and machine in operational situations. Some data were found to be useful in the form in which they had been presented originally. In other cases it was possible to replot the data or to present alternate functional relationships that would better serve to describe the man-machine interface. These materials were collated, interpreted, and published to serve as guides for equipment and system design. When gaps were found in existing knowledge, experiments were designed and conducted to provide the missing information. Also, a large amount of research that was done was suggested by new theoretical formulations.

During the late 1940s and early 1950s several small companies were established to provide human factors consulting, research, and development services. The primary sponsors of human factors activities were still the military services, but other agencies including the Civil Aeronautics Administration and the Federal Aviation Agency (later the Federal Aviation Administration) began to conduct and sponsor human factors research and development.

Beginning in the early 1950s large companies, primarily in the aviation and electronics fields, began to recruit and employ human factors personnel and to establish human factors groups within their organizations. By the end of the decade the importance of human factors had been recognized widely and applications were being made in a variety of fields outside the traditional ones of military, aviation, and electronics systems.

During the decade of the 1960s human factors activities became an integral part of the design and development of manned space vehicle systems, transportation systems, communication systems, medical systems, and others. Human factors also began to play an important role in the design of consumer products and in such diverse fields as architecture, computer design, and underwater operations.

During the 1970s more and more areas of man-machine system and equipment design, development, operation, and maintenance recognized the importance of human factors. By the end of the decade human factors activities could be found in almost every human endeavor, including the design of sports equipment, training of athletes, design of leisure time equipment and systems, and the design of toys and games.

Human factors personnel were employed by designers and manufacturers of industrial, business, and professional tools and equipment as diverse as chain saws, helmets, eye and ear protectors for foresters, tractors and related heavy equipment for farm and industrial use; dentists' and surgeons' instruments and operating room equipment; banking systems and equipment; powered hand tools for the tradesman, craftsman, and hobbyist or do-it-yourselfer; and mail sorting, processing, and handling systems.

The Bureau of Mines sponsored human factors research directed at improvement of the coal miner's personal equipment. Insurance companies employed a significant number of human factors professionals. Human factors professionals have made important contributions to the winemaking industry, to paper products manufacturing, to pharmaceutical production, and to the design of hospitals. A casual check of the Human Factors Society Directory and Yearbook shows that members are employed by organizations as diverse as the Central Intelligence agency, American Association of Retired Persons, National Fire Protection Association, Coca Cola Company, Smithsonian Institution, Price-Waterhouse, public school systems in several states, Sears Roebuck, Social Security Administration, the National Transportation Safety Board. In 1981 members of the Human Factors Society were employed by more than 1100 different companies, organizations, and institutions. Perhaps the only major industry that had not incorporated human factors considerations into its design, development, and operations by the end of the 1970's was the nuclear power industry.

The expansion of human factors activities during the period from about the mid-1950s to the present was paralleled by the growth of professional society activities and memberships. The Human Factors Society was founded in 1957 at a meeting attended by about 90 persons. The membership reached 500 in 1960 and exceeded 1000 in 1962. Between 1962 and 1969 the growth rate averaged about 5% per year. After a period of no increase during the period 1969-1971 the membership has now increased to approximately 3000. The Human Factors Society is the only scientific/technical organization in the United States concerned solely with human factors. Other scientific and technical societies and associations have established human factors subgroups within their organizations. One of the first of these was Division 21, The Society of Engineering Psychologists, in the American Psychological Association. The Institute of Radio Engineers (IRE), later to become the Institute of Electrical and Electronics Engineers (IEEE), established the Professional Group on Human Factors in Electronics in 1960. This professional group later became the IEEE Man-Machine Systems Group and subsequently the IEEE Systems, Man, and Cybernetics Society. Other professional societies such as the American Rocket Society (ARS), later to become the American Institute of Aeronautics and Astronautics (AIAA), the American Society of Mechanical Engineers (ASME), and the Society of Automotive Engineers (SAE) have had committees and groups concerned with man-machine relationships and human factors for many years. The American Nuclear Society (ANS) formed its Technical Group for Human Factors Systems in 1980.

1.3.3 Fundamental Concepts and Misconceptions

1.3.3.1 Introduction

A few simple tenets provide a working philosophy for the human factors disciplines. The design of any tool, equipment, device, or system should explicitly consider the people who are going to have to use, operate, and maintain it. More generally, it is necessary to consider the human in all phases of the system life cycle, from conceptual design through decommissioning of the system. Futhermore, the design decisions that involve the man-machine interface and all the decisions involving manning of the system should be made only with due consideration of human performance capabilities and limitations. Several basic human factors concepts facilitate the application of this philosophy. Two of the most fundamental concepts are those of (1) the man-machine system and (2) the human as an information processor.

1.3.3.2 Man-Machine System Concept

The central concept of the human factors discipline is that of the man-machine system. There may be almost as many definitions of "system" as there have been persons who have studied, designed, or written about systems. Some representative definitions of system by prominent system scientists may be found in the <u>System Engineering Handbook</u> (61). However, most system definitions differ only slightly and all of them include certain common concepts and characteristics.

For the purpose of this brief account of some of the major facets of the human factors discipline, the most complete and concise definition of system was one formulated by Fitts (42):

> an assemblage of elements that are engaged in the accomplishment of some common purpose(s) and are tied together by a common information flow network, the output of the system being a function not only of the characteristics of the elements, but of their interactions or interrelationships.

The essential characteristics of a system are encompassed by this definition. These are: purpose, components or elements, functions, organization, and interaction. When one or more of the elements in the assemblage is a human, we have a man-machine system.

The man-machine system concept can be represented by a general model. Various elaborations, refinements, and modifications of the model serve as the stimuli for theoretical formulations and experimental research, as well as for organizing, planning, and conducting human factors applications programs. The block diagram in Figure 1 is a simplified model of a man-machine system. It illustrates important relationships in terms of information transmission between the environment and the system and, within the system, between the plant and the human through the displays and controls that constitute the physical man-machine interface.

A more sophisticated block diagram could show, for a specific system, additional elements and information pathways. For example, many additional routes for feedback of information about the human's controlling responses are possible in addition to the single pathway implied by the block diagram. Also, the input of information from the environment may be displayed in relatively raw form as it is sensed or it may be highly processed or transformed before being displayed. In many systems some inputs from the environment may be sensed directly by the human operator.

Conceptualizing the human as an integral part of the man-machine system by means of this type of model fosters an awareness of interactions between the human and the machine. The competent career human factors professional routinely thinks in terms of man-machine relationships. He is alert to aspects of man-machine interactions to which professionals trained in other scientific/technical disciplines are often insensitive.

1.3.2.3 Concept of the Human as an Information Processing System

The human operator in a man-machine system is frequently and usefully characterized in terms of an information processing model in which conceptual subsystems are concerned with the functions of sensing, information processing and storage and responding. Included in the general category of information processing and storage are inferred operations such as identification, transformation, learning, short term and long term memory, time sharing, etc. This conceptualization of the human operator is shown by means of the block diagram in Figure 2. The diagram is based upon the model by VanCott and Warrick in Human Engineering Guide to Equipment Design (157).

The sensing subsystem consists of the various sense organs that have specialized receptors sensitive to different kinds and ranges of physical energy. A very large body of information from

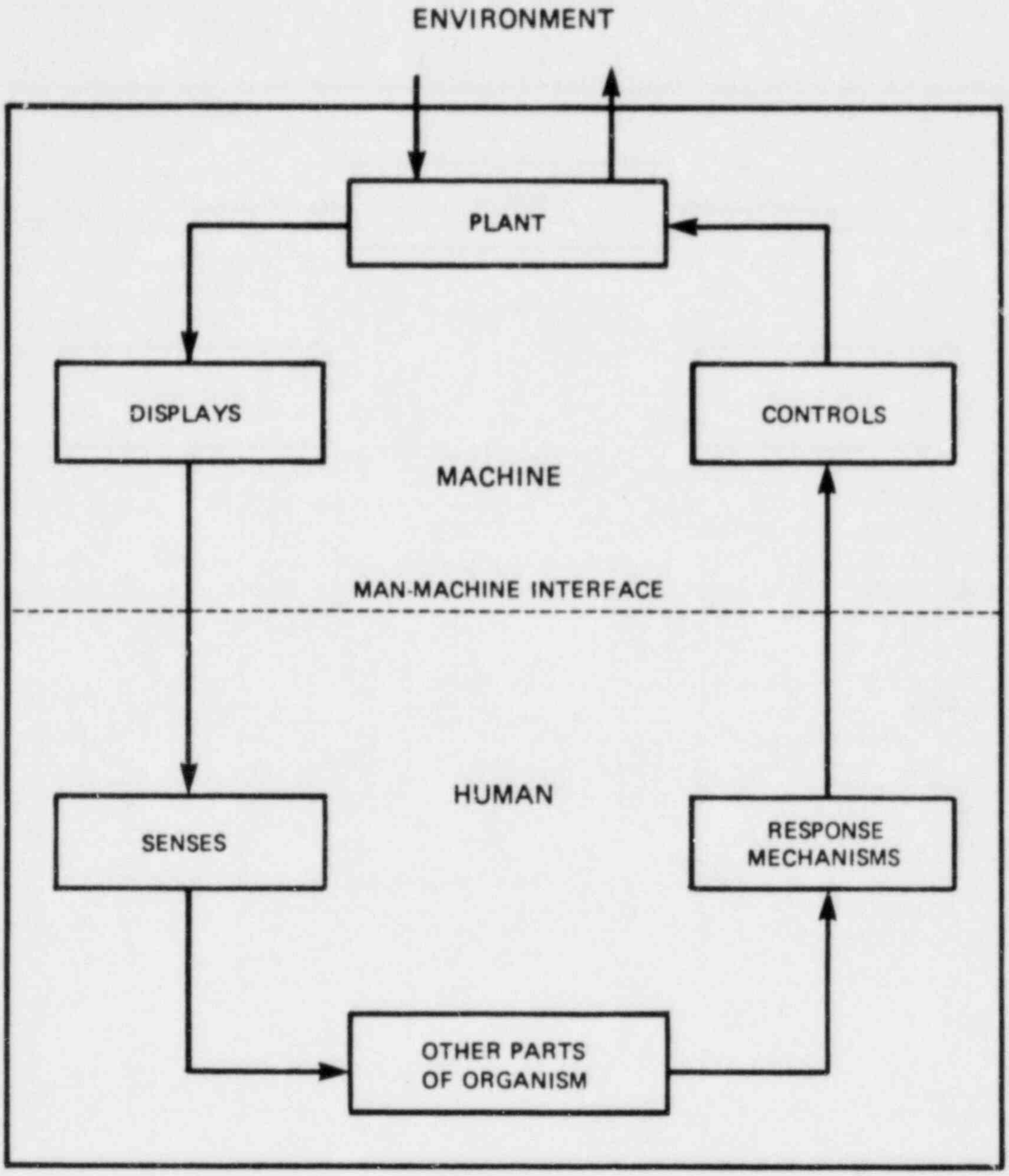

FIGURE 1. SIMPLIFIED BLOCK DIAGRAM REPRESENTING THE MAN-MACHINE SYSTEM CONCEPT.

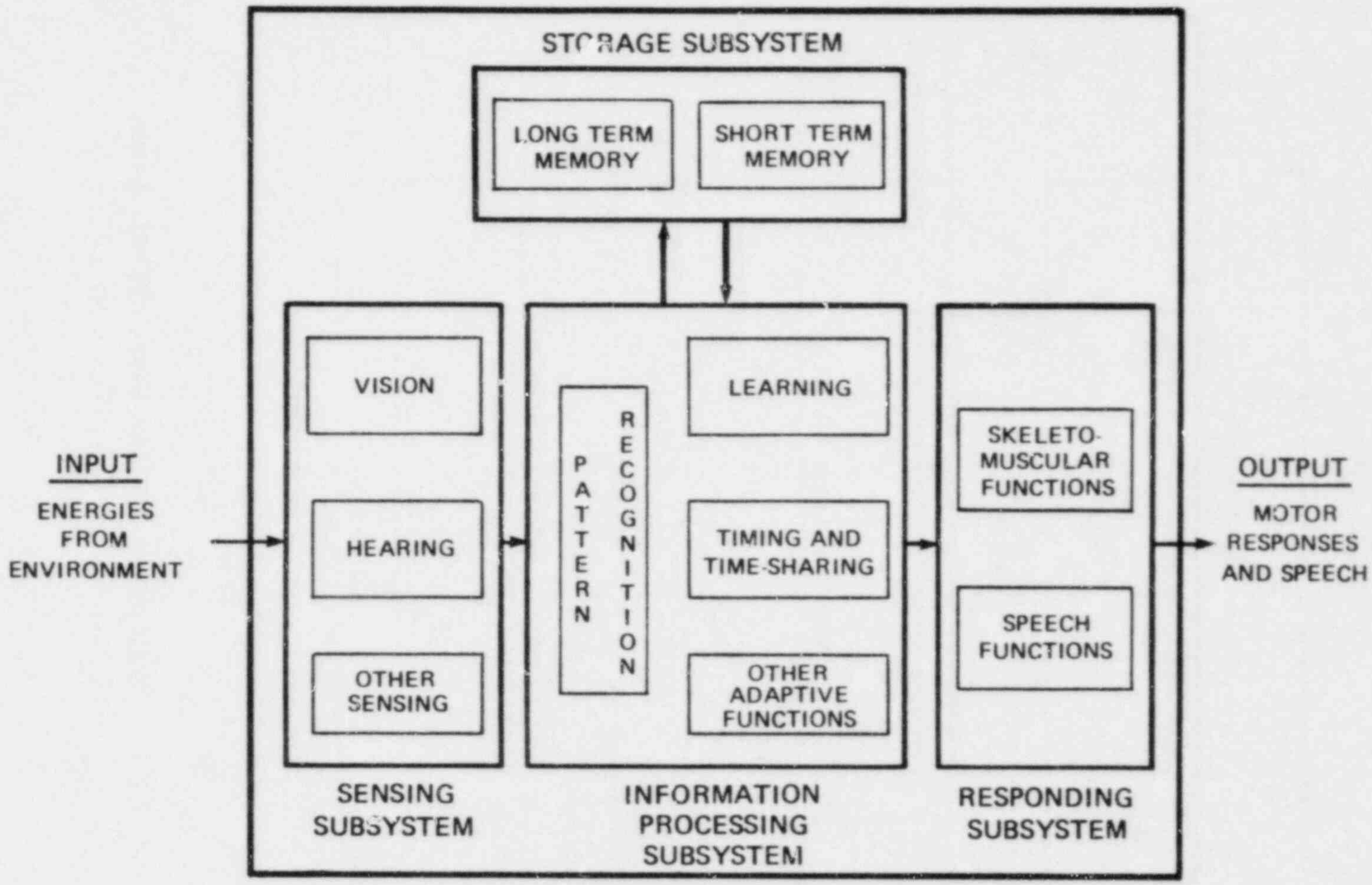

FIGURE 2. BLOCK DIAGRAM REPRESENTING THE CONCEPT OF THE HUMAN AS AN INFORMATION PROCESSING SYSTEM.

experimental psychology and neurophysiology is available regarding the sensory functions of detection and encoding in the visual and auditory senses. Less is known about the sensory mechanisms of the other sense organs.

Knowledge of the sensory dimensions and their physical correlates, the information transmission channel capacities, absolute and differential thresholds, adaptation characteristics, sensory illusions, subjective attributes, sensory interaction, masking, etc. of each of the major sensory modalities permits the human factors specialist to design the system for optimal transmission of information to the human operator. While much of our knowledge about sensory behavioral functions can be identified with anatomical structures and physiological processes, such is not the case with the inferred information processing and memory functions. It is probably true - but not very enlightening - to say that they are correlated with structures and functions of the central nervous system. Fortunately, it is not necessary to pinpoint precisely the neural loci of complex behavior such as verbal learning, for example, in order to understand the conditions under which it occurs - to induce it, facilitate it, control it, or eliminate it. Also, in the man-machine system context it is not productive to cast these behaviors in cognitive or mental terms. The results of many years of experimental study of the psychology of learning and memory and the translation of these results into training technology provide highly effective methods and techniques that are quite independent of neurophysiology and cognitive speculation. This rationale is also valid for other inferred functions of the conceptual information processing and memory subsystems.

The conceptual response subsystem consists of muscles and glands. Because information is transmitted to the rest of the man-machine system almost entirely by muscular activity through the medium of related skeletal structures (primarily limbs and speech apparatus), we are almost exclusively concerned with these parts of the response subsystem in the context of man-machine systems. Behavioral characteristics and anthropometric data are related to control design variables.

1.3.3.4 Concept of the Man-Machine (M-M) Interface

The concept of the man-machine interface is derived directly from the concepts of the man-machine system and the human as an information processing system. All human factors activities are concerned with some aspect of the M-M interface. The most obvious class of activities, particularly to one who is relatively unfamiliar with human factors, is the human engineering design of control rooms, cockpits, operator stations, and work places. However, the M-M interface consists of more than just the physical elements of displays and controls. It also includes behavioral elements such as procedures, operator aids, and trained operators (including all that this phrase implies in terms of operator selection, instructional system development and implementation, operator qualification and requalification, and design and development of training equipment). The M-M interface also includes a variety of conditions under which the system operators perform, ranging from environmental (noise, temperature, lighting, etc.) to administrative (shift staffing, duration and rotation, organizational characteristics such as management structure, promotional and other policies, etc.).

1.3.3.5 Misconceptions Regarding Human Factors

The most serious misconception regarding the human factors discipline is that it is nothing more than common sense in design. If this is true, then the staggering conclusion is that there was an uncommonly small amount of common sense exhibited by managers and engineers in the nuclear industry prior to TMI-2.

During the course of this project we have frequently heard some variant of the statement. "Human factors are important but just common sense." We most often heard this kind of statement from managers and engineers of utilities, AEs, and NSSS vendors when the topic of discussion was the absence of competent career human factors professionals on the staffs of their organizations, both prior to TMI-2 and, in most cases, at present. Most of them apparently failed to recognize, until it was pointed out to them either subtly or bluntly, that this kind of statement coupled with the knowledge of the gross deficiencies of control room designs in terms of human factors, was an indictment of someone's failure to use common sense in design. The significant point to be made here, of course, is that the integration of human factors considerations into design is not just common sense. Significantly, design in accordance with sound, accepted, and proven human factors scientific engineering principles often is counter to "common sense".

Common sense does not provide the specialized information regarding the physical characteristics of displays and controls necessary to provide a compatible match with the human's sensory, perceptual, and motor capabilities and limitations. Common sense, by itself, is worthless as a guide to the instrumentation and control engineer who tries to make design decisions that involve human behavioral processes such as stimulus detection and discrimination, complex response times, time sharing of responses, short term and long term memory, continuous tracking with system dynamics that require complex integration and differentiation operations, etc.

The nuclear industry has operated on the assumption, probably in most cases without even verbalizing it, that the human operator's flexibility, adaptability, and resourcefulness would permit him to safely control nuclear power generation processers, regardless of the deficiencies and defects in the man-machine interface. This misconception regarding the capacities of the human is also another example of the fallability of common sense as a guide to the design and operation of man-machine systems.

In summary, human factors is not just common sense in engineering design. Common sense is generally taken to mean an average ability to judge and decide with soundness, prudence, and intelligence without sophistication or special knowledge. Sophistication in man-machine relationships and specialized knowledge of human capabilities and limitations are basic ingredients of the human factors discipline.

It is also a misconception to believe that any good engineer can become a competent human factors specialist if he completes a human factors short course or reads a human factors textbook or buys some human factors handbooks for his bookshelf. All of these actions are useful and desirable for the engineer who wants or needs a better understanding of human factors. They will almost certainly increase the person's sensitivity to human factors and enhance the acknowledgement of human factors requirements as having the same status as other system requirements. They will not, however, produce a competent human factors professional.

Another misconception regarding human factors is that its products are largely cosmetic and can be applied to a finished system after the other "important" engineering features have been designed and developed. Costly changes and retrofits are often compromises leading to less-than-optimal design. In many cases, such "fixes" are beneficial but far less useful than a proper, less expensive original design. In many cases, retrofits are impossible because of structural, seismic, or electrical barriers. Thus, while after-the-fact fixes (e.g., "paint, label, and tape") should not be overlooked and can certainly be helpful, they are in no way substitutes for a properly done design job.

The preceding discussion is intended to set a perspective for the reader unfamiliar with the human factors engineering literature. It is within this general contextual background that the concept of human factors in system design can be applied to the design of nuclear power generating plants, as discussed in the next Section.

2.0 THE SYSTEM APPROACH TO HUMAN FACTORS IN NUCLEAR POWER REGULATION

2.1 Introduction

The system approach to incorporating human factors considerations into the life cycle of a man-machine system is a way of ensuring that human factors are adequate, appropriate, timely, and cost-effective.

2.1.1 System Concept and Philosophy

The system approach recognizes that a design or development decision regarding a particular aspect of the human's interaction with the rest of the system cannot be made in isolation. It almost always has implications for other aspects of man-machine interaction. Although a human operator is a single system element physically, the human functions typically as an integral part of many different subsystems, equipments, and components. Consideration of the human's potential interaction with all of the system in the light of human capabilities and limitations maximizes the likelihood of designing a system which can be safely and effectively controlled and maintained by human operators. The system approach provides a logical, rational sequence of development in which the results of each stage provide the requirements for the next stage. All human factors requirements (displays and controls design, procedures development, training, etc.) are derived from the system-mission requirements in terms of the system functions that are allocated to the human.

2.1.2 Background

The human factors discipline was one of the first to recognize the necessity for a system approach to the design, development, operation, and maintenance of complexes of humans and mechanical devices. As engineering psychologists and others began thinking in terms of the man-machine system concept, it was quite natural that they also should have started thinking in terms of an overall system approach to design and development.

One of the earliest examples of the application of the system approach to a large scale man-machine system is described in Human Engineering for an Effective Air-Navigation and Traffic-Control System (41). This project, carried out by a National Research Council working group that met at intervals during 1950, was done under a contract awarded by the Civil Aeronautics Adminstration. The working group consisted of A. Chapanis, F.

C. Frick, W. R. Garner, J. W. Gebhard, W. F. Grether, R. H. Hanneman, W. E. Kappauf, E. B. Newman, A. C. Williams, and P. M. Fitts.

With the spread of the fluence of human engineering from universities and government laboratories into industry, some companies began using a system approach to incorporate human factors into system design. As early as 1952, Hughes Aircraft Company adopted a system approach to the incorporation of human factors into the design of displays and controls of the MX-1179 (later to be designated MA-1) all-weather interceptor fire control system for the F-102 and F-106 aircraft.

Results of some man-machine system experiments on command and control operations, carried out by the RAND Corporation in the early 1950s and later by the System Development Corporation, were influential in emphasizing the necessity for including non-hardware related human factors considerations (procedures, training, team organization, etc.) in the overall system approach to design and development (113).

During the 1950s the Air Force was gaining experience with incorporating various aspects of human factors into large aircraft, command and control, and missile systems. It became increasingly apparent that closer coordination of the many personnel-related activities in system design, development, and operation was necessary. Accordingly, the management concept of "Personnel Subsystem" was the subject of a joint policy statement by Air Research and Development Command and Air Training Command in February 1960. After coordination with Air Material Command the policy became the official basis for application of human factors in the acquisition of new Air Force systems (AFL 375-5, Planning and Programming for System Personnel, 30 October 1961).

After some modifications and refinements based on experience with the concept, the Air Force published a regulation (AFSCR 80-16, Personnel Subsystem Program for Aerospace, Support, and Command and Control Systems, May 1963) that established a threefold objective of the personnel subsystem program:

(1) to promote the acquisition of functionally integrated systems and facilities which can be safely and reliably operated, maintained, and supported by USAF personnel;

(2) to provide personnel, training, and using agencies with timely planning and technical information concerning personnel, training and life support requirements which systems will impose on the Air Force personnel structure; and

(3) to assure development of training equipment, facilities, and protective equipment for support of system personnel requirements.

AFSCR 80-16 stated, "The development, documentation, test, and evaluation of the personnel subsystem will be integrated with procedures in effect for hardware portions of the system." This regulation also established AFSCM 80-3, Handbook of Instructions for Aerospace Personnel Subsystem Designers (HIAPSD). The handbook described six functional personnel subsystem areas as being essential in the development of a system. "In the conceptual phase, program definition phase, and periodically throughout the system acquisition phase, each listed functional area will be investigated and analyzed. The extent of effort required in each area at any given time will be affected by changes in system characteristics and proposed operating environment."

The personnel subsystem functional areas were:

a. personnel/equipment data analysis

b. human engineering

c. life support

d. system personnel requirements

e. system training requirements

f. personnel subsystem test and evaluation

The process of functionally integrating these various areas that previously had been, in some cases, the exclusive domains of different Air Force organizations and of different departments and divisions of the companies that were designing and building Air Force systems was not uniformly smooth and without organizational conflict. However, eventually the logic and utility of the concept came to be understood and appreciated. The HIAPSD was superceded in January 1969 by AFSC DH 1-3, Personnel Subsystems. This was one of a series of AFSC design handbooks published as a primary means of documenting and applying technical knowledge in support of system and equipment acquisition programs. General design criteria and guidance suitable for use in design and development of Air Force systems and equipment are published in these handbooks.

The system approach, as embodied in the USAF personnel subsystem concept and programs, became a routine part of system design, development, and operation for the Air Force and its contractors. There was always some opposition to the phrase "personnel subsystem". Many persons maintained that it was misleading in that "personnel subsystem" was not a subsystem in the ordinary sense of a hardware subsystem. The Air Force ceased using the title but retained the concept. AFSC DH 1-3 was retitled Human Factors Engineering. It still contains the same kinds of material that it contained when it was titled Personnel Subsystems. Chapters 2 through 6 are Human Engineering, Biomedical/Life Support, Personnel and Manning, Training and Training Equipment, Job Performance Aids, and Test and Evaluation.

2.2 Development Sequence for Human Factors Elements in the System Approach

2.2.1 General Considerations

Efficient development and safe operation of a man-machine system require explicit attention to human factors from the earliest stages of concept formulation and conceptual design through test and evaluation to operation to decommissioning. The nuclear power person unfamiliar with human factors frequently focuses upon the design of the control room as the starting point for consideration of human factors. Certainly, in some systems the control room design is the most visible manifestation of the need for human factors. Logically, however, the consideration of human factors cannot begin at this point. The information and control requirements that should determine the design and arrangement of displays and controls must be derived from some more basic considerations than just a designer's whims and idiosyncracies or the availability of a large supply of meters, dials, or switches manufactured by a division of the company that is responsible for design and construction of the control room. The logical starting point for consideration of human factors is the same as for any other activity important to the design of the system - the beginning.

2.2.2 Initial Steps in the System Approach

Our concept of an ideal sequence of development of the human factors in a nuclear power plant is shown in Figure 3. The flow diagram has been simplified by eliminating the lines that indicate interactions among blocks and feedback loops involved in successive iterations and refinements.

The development sequence described here is an ideal sequence. All of the major steps that are required for a system life cycle from preliminary design through development, construction, testing and evaluation, to operation and maintenance are included. This is only a model, however, and it should serve only as a guide. The emphasis and amount of activity

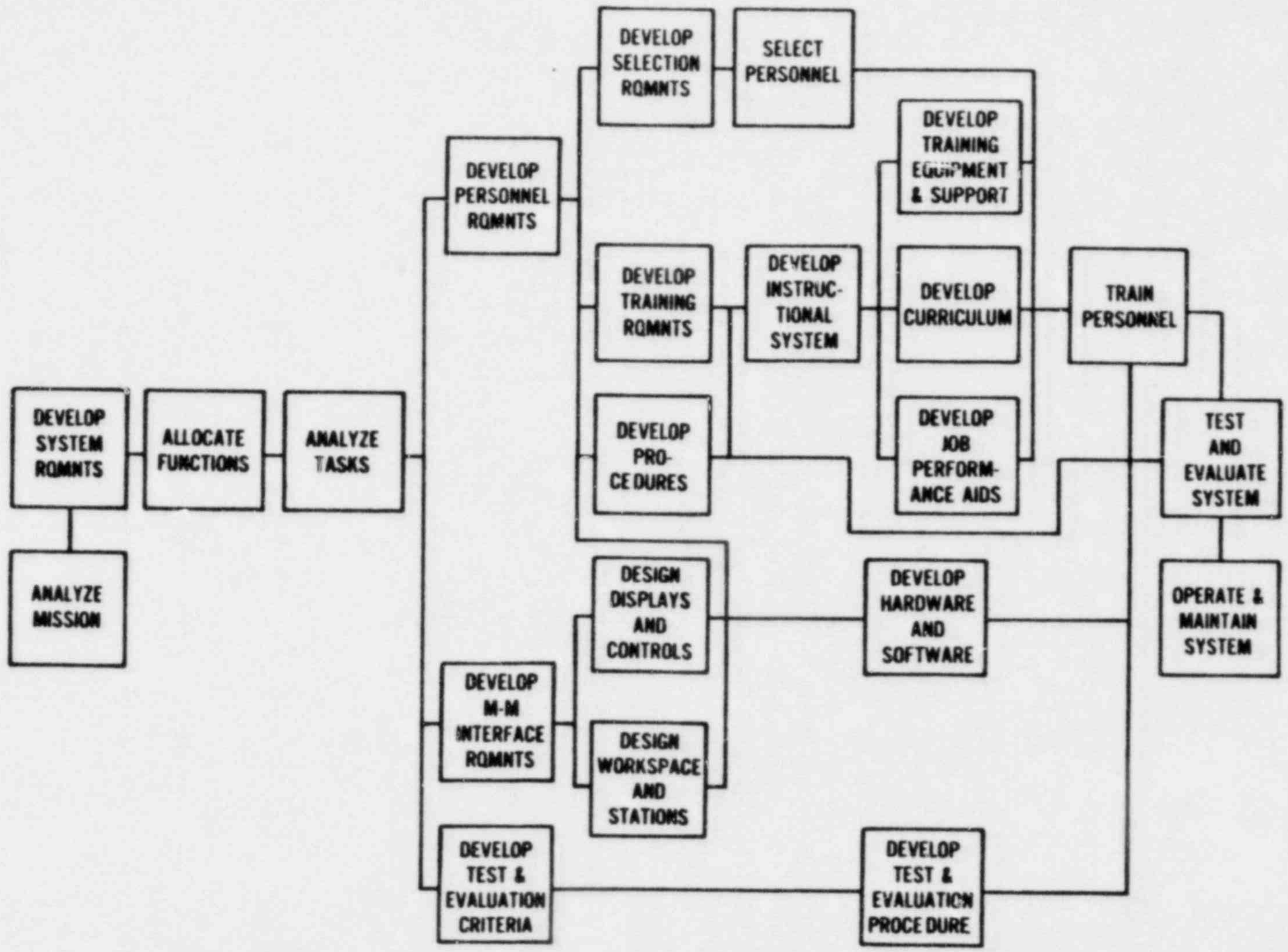

FIGURE 3. IDEAL HUMAN FACTORS SYSTEM APPROACH TO NPP DESIGN.

for each element will vary from system to system, but in one fashion or another all elements have to be addressed. The sequence almost certainly will be modified to meet the requirements of a specific system development. Sometimes certain steps may be performed informally, may be abbreviated or expanded, or may be modified in other ways. In almost all cases iteration of some of the steps will be required. There is reasonably widespread agreement on the general approach to be followed in the performance of human factors analyses. The standard approach closely follows the framework shown in Figure 3. There may be considerable variability in the details of the analytic procedures that are used depending upon the kind of system, its newness, the nature and completeness of human factors analyses that were done on earlier versions of the system if it is not a new type, as well as other factors.

All man-machine systems, whether they be nuclear power, military, intercontinental ballistic missile, civilian air transportation, industrial process, specialized or worldwide communication, information processing, recreational vehicle, or some other type, are designed and built to fulfill some purpose, or in the technical idiom, to perform some mission. The design of a system starts with a requirement or a projected requirement for some mission to be accomplished. An explicit formal statement of the mission is the starting point for the system approach to design and development. An important step in mission analysis is the identification of any assumptions and constraints associated with the design of a system to accomplish the mission.

System requirements are imposed by the nature of the mission, the assumptions, and the constraints. The system requirements may encompass considerations such as safety, dollar cost, development time, and environmental consequences as well as operational performance. One or more generic system configurations may be alternative candidates to meet the system requirements. Frequently human factors professionals can make significant contributions to the trade studies and comparative system concept evaluations. Sometimes an important factor in this process is the allocation of functions between humans and automatic devices.

Regardless of how much tentative function allocation may have been done prior to selection of a conceptual system design, this process must be done as one of the earliest steps of preliminary design. Function allocation occurs in the design of every system. It may be done deliberately and formally or it may not be recognized and occur as a result of other design decisions or by default. The requirement for function allocation may be explicitly recognized and it may be accomplished with timely participation of competent career human factors professionals. On the other hand, it may be done in ignorance of the value of participation by persons with educational and experience backgrounds in scientifically evaluating human capabilities and limitations. In cases where the latter has happened, functions have been allocated to human operators on the basis of tradition, prejudice, expediency, chance, ignorance, or simply because some functions were discovered to be necessary after the automatic systems had been designed.

Of all these unacceptable bases for function allocation, only the basis of tradition has any merit, and it has only limited merit in restricted situations. Tradition may provide efficient and reasonably useful guidelines for preliminary gross function allocation being accomplished for a system that represents an evolutionary design change from an old model to a newer one. It is not a reliable or valid guide when there are revolutionary changes in system design (as, for example, in the change in design from use of fossil fuel heated boilers to nuclear steam supply systems).

Function allocation should be accomplished with full knowledge and recognition of human capabilities and limitations within the context of state-of-the-art characteristics of automatic devices and equipment, and the performance and reliability characteristics of these devices.

In summary, the allocation of functions to the human is the most fundamental system design activity for which there is a requirement for major participation by competent career human factors professionals. All of the human factors considerations in a system depend either directly or indirectly upon the functions that the human has to perform in system operation and maintenance.

2.2.3 Systematic Development

A detailed presentation of the methodologies and techniques for carrying out the steps of the system approach to incorporate human factors is ouside the scope of this report. However, the steps, as represented by the blocks in Figure 3, are summarized for readers who are not familiar with this technology.

After appropriate system functions have been assigned to humans, it is possible to identify and analyze specific tasks that the humans will have to perform. The results of the task analyses are used to develop requirements for three major general areas of the human factors program in system design, development, and operation. These are personnel requirements, man-machine interface requirements, and man-machine system test and evaluation criteria. Design and development activities resulting from these sets of requirements proceed in parallel. The requirements for other major human factors programs such as development of procedures, job performance aids, and training equipment are derived subsequently from the detailed specifications, analyses, designs, and interactions that are the logical consequences of the personnel requirements and the man-machine interface requirements.

2.2.3.1 Human Factors System Evaluation Criteria

It is necessary that the criteria, although not the detailed procedures, for test and evaluation of the human factors design and development be based upon the system requirements/function allocation/task analysis results. The reason for this is simple. If the evaluation criteria are to be used to determine objectively whether the results of the human factors programs meet the system requirements, then the establishment of the criteria must be independent of the manner in which the human factors programs are conducted. The detailed methods and techniques for test and evaluation are developed later in the cycle, and are dependent upon the results of the design and development of the man-machine interface, the instructional system, and the operational procedures.

2.2.3.2 Man-Machine Interface Requirements

The overall man-machine interface requirements provide the basis for design and selection of displays and controls and the design and arrangement of crew stations and workspaces. These general man-machine interface requirements are concerned with items such as the specifications of (1) information to be displayed, (2) system events, sequences, and processes to be initiated, controlled, and terminated, (3) distribution of tasks among operators, and (4) time constraints for sequences of events to be monitored and controlled.

In addition to providing the basis for development of the man-machine interface hardware and software, the results of the displays, controls, and crew stations design activities are used in conjunction with personnel requirements information to begin development of operational procedures.

2.2.3.3 Personnel Requirements

The overall personnel requirements provide the primary inputs for developments of personnel selection requirements and training requirements. General personnel requirements are concerned with items such as numbers and types of personnel, special behavioral and physical characteristics qualifications, and levels of experience, knowledge, and skill.

The personnel selection requirements and the training requirements, respectively, guide the development and management of personnel selection procedures and the development of the instructional system.

The results of the analysis of training requirements combined with information from the procedures development activity, referred to in Section 2.2.3.2, provide a rational basis for instructional system development. The major areas of work constituting instructional system development are curriculum, training equipment including simulators, and job performance aids.

The instructional system development activities converge with the personnel selection sequence to permit the beginning of the program to train operational and support personnel.

2.2.3.4 System Test, Evaluation, and Operation

While the instructional system is being developed and personnel are being trained, the development, construction, and assembly of the man-machine interface hardware continue in parallel. After the displays, controls, crew stations, procedures, and trained personnel characteristics have been specified in detail, the methods and techniques for testing and evaluating the operating man-machine system can be developed. The results of the tests are evaluated against the criteria that were developed earlier (Section 2.2.3.1). Any significant deficiencies, deviations, or discrepancies may be corrected by iteration of work in the appropriate areas.

In the interest of clarity of an overall view of the systematic integrated approach to incorporation of human factors into system design, development, and operation this summary has been greatly oversimplified. Neither the narrative summary nor the diagram (Figure 3) indicates of the extensive crossfeed of information that occurs between major human factors activities that are occurring in parallel. There is also continuous information crossfeed with the other areas of engineering design, development, and construction of the system. Furthermore there are numerous feedback loops within the sequences and networks represented in Figure 3. As is the case in any engineering design and development program, the feedback of results of human factors activities produces numerous iterations of steps and sequences. The end result is a man-machine system that is designed to be operated and maintained safely, effectively, and economically.

2.3 Significance of the System Approach for Nuclear Reactor Regulation

The system approach to incorporating human factors has evolved as part of the design and development process for man-machine systems. Its effectiveness and its value are well established.

There are no indications that new nuclear units will be built in the U. S. beyond those for which construction permits have already been issued. It is reasonable to question whether the system approach has value for incorporating human factors into systems that have already been designed and constructed. We believe that it does. To be sure, some of the elements of the system approach cannot be applied. Unfortunately, some of the most fundamental elements have already been determined, for better or for worse. And some of the elements of the system approach can be applied only partially. Nevertheless, even for an after-the-fact analysis of human factors the system approach provides a valuable organizing framework. It also provides a systematic context within which dependencies and interactions can be identified and solutions to problems and deficiencies can be developed. Working within the framework of the system approach fosters and enforces the awareness of the ramifications of human factors decisions and other design decisions upon other functions of the system and upon total system performance.

We have used a system approach to the identification and evaluation of human factors requirements in nuclear power plant design, operation, and maintenance. Early in the course of our work we drew upon our individual system analysis, design, and development experiences, and jointly developed our concept of an ideal sequence of development of the human factors elements in a nuclear power plant. This ideal sequence not only delineates sequential dependencies of design requirements and information flow, but it also permits identification of interactions among human factors elements and feedback loops involved in successive iterations and refinements.

The very fact that this kind of approach is systematic, is analytical, and does include all aspects of the human in relationship to the rest of the system minimizes the probability that some human factors consideration or requirement will be overlooked or not be given adequate consideration.

One of the conclusions and recommendations of the NRC Special Inquiry Group regarding stronger project management applies equally well to the human factors area.

> In addition, one of the obvious lessons learned from the Three Mile Island accident is the critical need for overall plant and systems analysis. There is as much or more of a chance that safety matters will "fall in the cracks" between two or more highly proficient technical groups as there is for a safety error to be made in any one of the specific groups (123, Vol. 1, page 119).

3.0 HUMAN FACTORS ACTIVITIES IN NUCLEAR POWER

This section contains a description and evaluation of the principal human factors research or development programs and activities in nuclear power. The programs and activities described here are those sponsored activities which generally apply to all commercial nuclear power plants. No attempt is made to address R&D activities being performed by individual organizations for their own specific use. The type of sponsored R&D discussed here is that which would lead to policy decisions, standards, or widespread design practices.

There are three major organizational groups sponsoring or performing human factors activities in nuclear power: the U. S. NRC, the nuclear industry, and some professional organizations. Each of these groups and the suborganizations within them is addressed in turn. The following format has been adhered to whenever possible.

1. ORGANIZATIONAL GROUP (Name)

   - Mission
   - Organization

1.1 HUMAN FACTORS RESPONSIBILITY OR INTEREST

   - HF Related Mission
   - Organization for HF

1.2 SIGNIFICANT ORGANIZATIONAL CHANGES (If Necessary)

1.3 PROGRAMS AND ACTIONS

1.3.1 Sub-Organization (If Necessary)

1.3.1.1 Program/or Project Title

A. Description

   (1) Need

   (2) Objective

   (3) Work Effort (over the entire project)

B. Performing Organization: (Prime + Subcontractors

C. Status -

(1) Schedule/Priority: (Start and End; Any Stated Priority)

(2) Resources: (PMY or $)

(3) Cost/Benefit

(4) Quality of Work to Meet Objective (If Known)

Sometimes the format above could not be followed because of lack of information or the fact that the format was simply inappropriate. As a minimum, an attempt was made to (1) describe the program or activity sufficiently for the reader to understand what was being done and why; and (2) provide some evaluation of the appropriateness of the effort.

Every attempt was made to be accurate in describing programs and projects. In most cases, this was accomplished either by using excerpts from project statements of work or by including descriptive information exactly as it was provided to us by the organization. Additionally, all major organizations were given rough drafts of the descriptive portions of their activities to review for technical accuracy.

The evaluations presented here are, of course, strictly the assessments of the project Study Group. The evaluations were arrived at in general by a three-step process. First, products or publications resulting from or related to the program were reviewed. Second, discussions were held with the sponsors and/or the performers. Third, interactive sessions were held among the members of the project Study Group to arrive at a consensus.

In brief, we have made every attempt to provide technically accurate project descriptions and objective, rational evaluations representing a consensus of the project study team.

3.1 The United States Nuclear Regulatory Commission (NRC)

The NRC is responsible for licensing and regulating nuclear facilities and materials and for conducting research in support of the licensing and regulatory process, as mandated by the Atomic Energy Act of 1954, as amended, the Energy Reorganization Act of 1974, as amended, and the Nuclear Non-proliferation Act of 1978; and in accordance with the National Environmental Policy Act of 1969, as amended, and other applicable statutes. These responsibilities include protecting public health and safety, protecting the environment, protecting and safeguarding materials and plants in the interest of national security, and assuring conformity with antitrust laws. Agency functions are performed through standards-setting and rulemaking; technical reviews and studies; conduct of public hearings; issuance of authorizations, permits, and licenses; inspection, investigation, and enforcement; evaluation of operating experience; and confirmatory research. The Commission itself is composed of five members, appointed by the President and confirmed by the Senate, one of whom is designated by the President as Chairman. The Chairman is the principal executive officer and the official spokesman of the Commission.

The top-level organization of the NRC as of September 3, 1981 is shown in Figure 4. A brief statement of the function of the Executive Director for Operations and the four principal technical offices is provided below.

The Executive Director for Operations directs and coordinates the Commission's operational and administrative activities and the development of policy options for Commission consideration.

The Office of Nuclear Reactor Regulation licenses nuclear power, test, and research reactors under a two-phase process. A construction permit is granted before facility construction can begin and an operating license is issued before fuel can be loaded. NRR reviews license applications to assure that the proposed facility can be built and operated without undue risk to the health and safety of the public and with minimal impact on the environment. NRR monitors operating reactor facilities during their lifetime through decommissioning. NRR also reviews the financial responsibility of each applicant for a construction permit, confirms that each applicant is properly indemnified against accidents, and verifies that the applicant(s) is not in violation of antitrust laws.

The Office of Nuclear Material Safety and Safeguards is responsible for ensuring public health and safety and protecting of national security and environmental values in licensing and regulation of facilities and materials associated with the processing, transport, and handling of nuclear materials. NMSS reviews and assesses safeguards against potential threats, thefts, and sabotage, and works closely with other NRC organizations in coordinating safety and safeguards programs and in recommending research, standards, and policy options necessary for their successful operation.

The Office of Nuclear Regulatory Research plans and implements research programs of nuclear regulatory research which are deemed necessary for the performance of the Commission's licensing and regulatory functions. Research programs cover reactor safety areas such as materials behavior, site safety, systems engineering, and computer code development and assessment. Research is also performed on safeguards, health effects associated with the nuclear fuel cycle, environmental

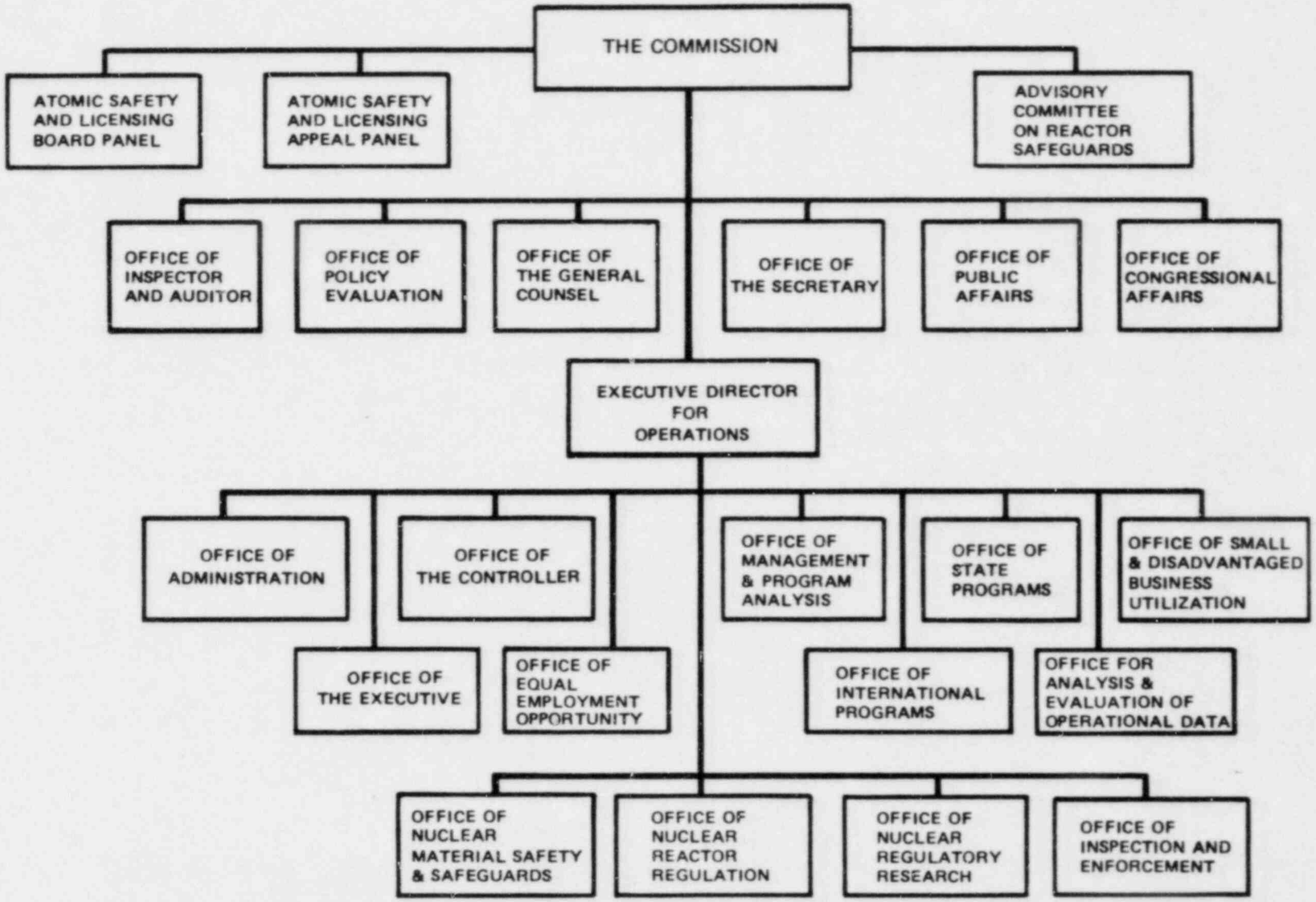

FIGURE 4. THE NRC ORGANIZATION.

impact of nuclear power, waste treatment and disposal, and transportation of radioactive materials.

The Office of Research also develops regulations, guides, and other standards needed for regulation of facilities and materials with respect to radiological health and safety and environmental protection, for materials safeguards and plant protection, and for antitrust review. The Office also coordinates NRC participation in national and international standards activities.

The Office of Inspection and Enforcement inspects nuclear facilities and materials licensees to determine whether facilities are constructed and operations are conducted in compliance with license provisions and Commission regulations, and to identify conditions that may adversely affect the protection of nuclear materials and facilities, the environment, or the health and safety of the public; inspects applicants and their facilities to provide a basis for recommending issuance or denial of licenses; investigates accidents, incidents, and allegations of improper actions that involve nuclear material and facilities; and enforces NRC regulations and license provisions. IE, on behalf of NRC, manages and directs the Commission's five regional offices, located in Philadelphia, PA, Atlanta, GA, Chicago, IL, Dallas, TX, and San Francisco, CA.

3.1.1 Human Factors Responsibility or Interest

The NRC is not only responsible for licensing and regulating nuclear facilities and materials, but is also responsible for licensing and regulating those personnel who actually operate nuclear power plants (that is, manipulate controls in the control room). Thus, their regulatory and research functions span the cycle of design, construction, and operations. Prior to TMI, there were no programs or activities dedicated to human factors issues in regulations, with, of course, the exception of the operator licensing process. Similarly, there were essentially no human factors programs or activities in research, with the exception of some human reliability studies performed by the Sandia National Laboratories.

As of September 30, 1981 the NRC organization included two principal activities dedicated to human factors: The Division of Human Factors Safety in the Office of Nuclear Reactor Regulation; and The Human Factors Branch, in the Division of Facility Operations, Office of Nuclear Regulatory Research. A brief description of these two activities follows.

3.1.1.1 Regulatory Human Factors

The Division of Human Factors Safety (DHFS) is one of five operating divisions in the Office of Nuclear Reactor Regulation (NRR), as shown in Figure 5. The responsibilities of the Division are:

- to direct and administer evaluations in the operational, administrative, and people-oriented disciplines for nuclear reactor applications, and for reactor facilities licenses for operations.
- to develop and administer related programs, policies, and procedures governing these aspects of the licensing and operation of nuclear reactors.

There are four branches within DHFS, as shown in Figure 6. The responsibility of each of the branches is delineated below:

1. <u>The Human Factors Engineering Branch</u> performs multidisciplined reviews and evaluations of the interaction of systems and equipment with humans in the design and operation of nuclear reactors; reviews and evaluates the type, quality, and quantity of critical process and safety parameter information provided to control room operators; evaluates information and control systems such as display panels and computerized diagnostic systems; participates in the development of guides and regulations pertaining to human factors engineering.
2. <u>The Operator Licensing Branch</u> prepares, administers, and grades licensing examinations for reactor operators and senior operators, certification examinations, and annual requalification examinations; develops testing techniques and standards for evaluating candidates in coordination with the Licensee Qualifications Branch; accredits training programs and facilities, and audits operator training programs on simulators.
3. <u>The Licensee Qualifications Branch</u> establishes requirements and qualifications standards for licensee management, licensed operators, and other plant personnel; reviews and evaluates the technical and managerial qualifications for constructing and operating the plant and handling accidents; evaluates the qualifications and training of all utility and key plant personnel, including licensed

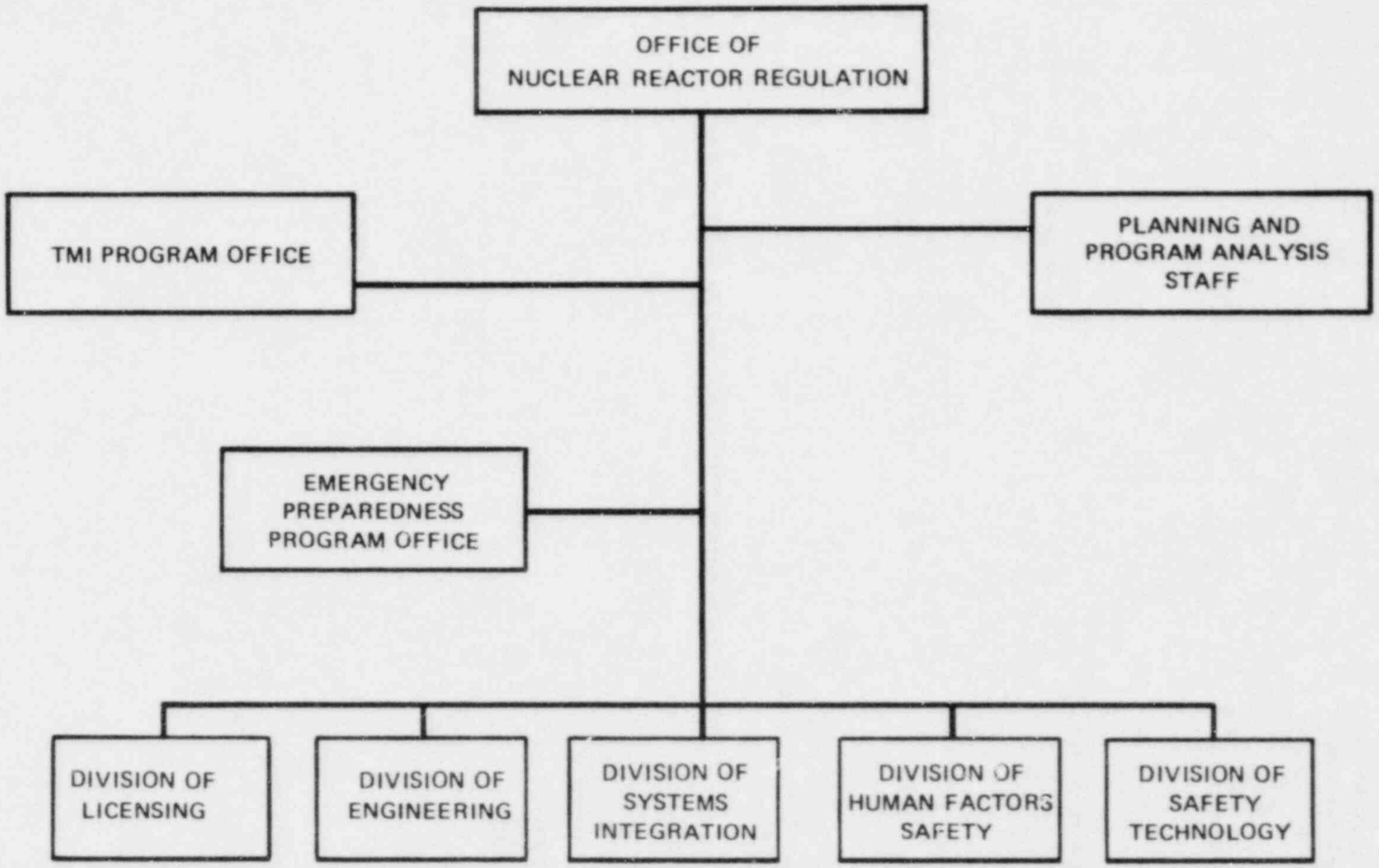

FIGURE 5. NRR ORGANIZATION.

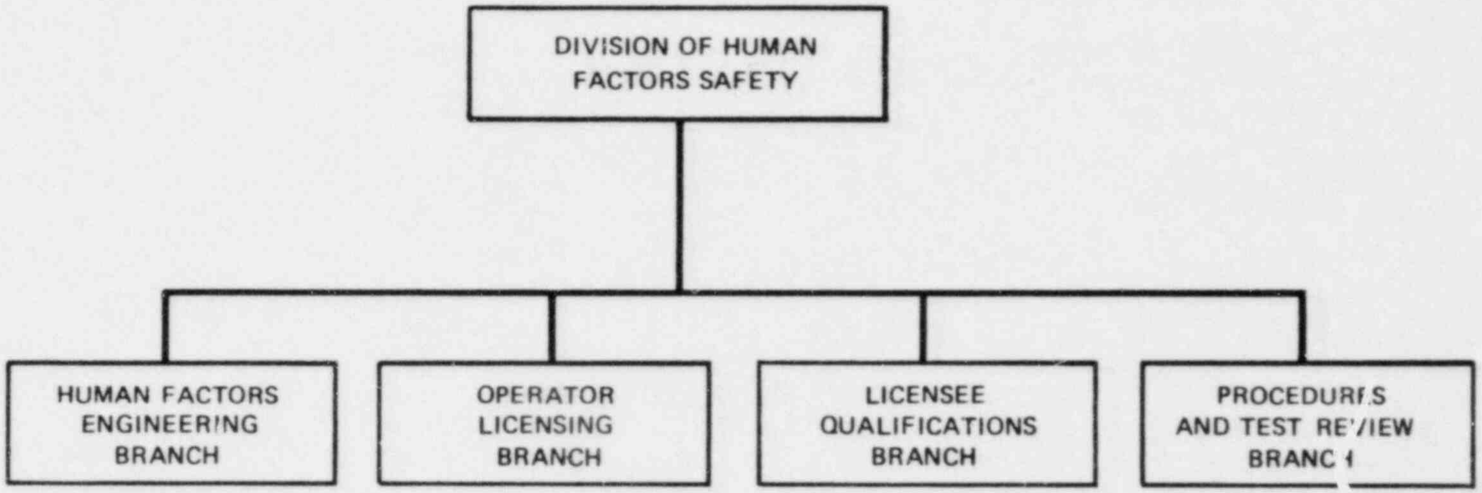

FIGURE 6. DHFS ORGANIZATION.

operators; coordinates with the Operator Licensing Branch.

4. The Procedures and Test Review Branch reviews and evaluates selected preoperational, startup, operational, and emergency operating procedures with respect to design, engineering, and operational aspects; evaluates results of significant tests to assure conformance with design and operational requirements; develops guidance on format and content of test procedures and reports.

3.1.1.2 Research Human Factors

The Division of Facility Operations is one of five divisions within the Office of Nuclear Regulatory Research (RES), as shown in Exhibit 7. The Division responsibilities are:

1. Plans, develops, and directs comprehensive research standards programs for nuclear safety in the design, qualification, construction, inspection, testing, operation, and decommissioning of nuclear power plants, nuclear reactors and fuel cycle facilities, and for nuclear materials safety with emphasis on human factors, instrumentation and control, safeguards, and occupational radiation protection aspects of these facilities and materials.

2. Establishes or recommends policy, planning, and procedures for the research and standards program as required to carry out the functions of the Division.

3. Coordinates these research and standards programs with other NRC offices to ensure that the programs are responsive to their needs.

4. Provides technical assistance within NRC regarding resolution of generic issues and the development and application of research and standards to the solution of specific safety problems.

5. Provides funding guidance to NRC contractors, DOE laboratories, and other government agencies within the Division budget and consistent with NRC policy.

6. Maintains liaison and provides technical input to other Federal agencies, ANSI, professional societies, international agencies, and other organizations in assigned areas.

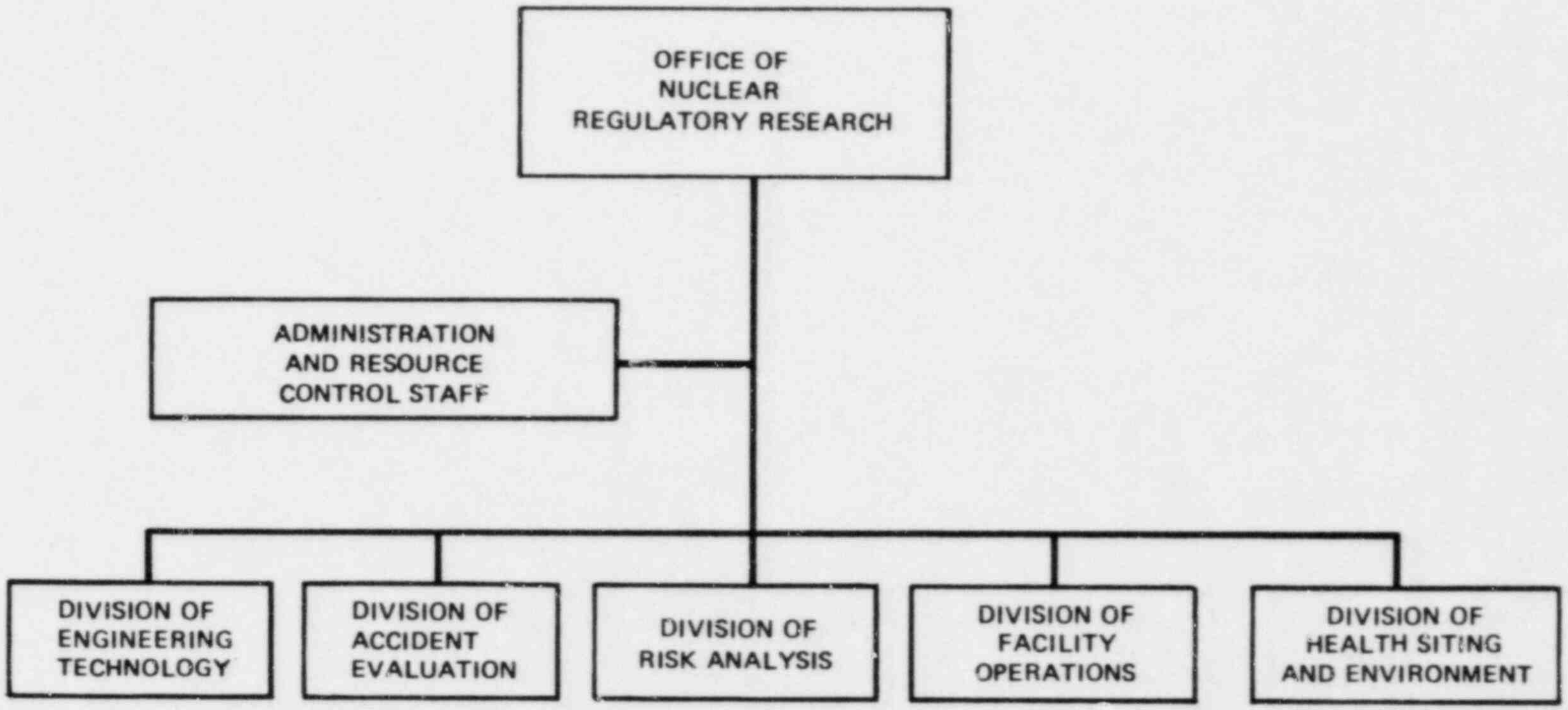

FIGURE 7. RESEARCH ORGANIZATION.

Human factors research is under the cognizance of the Human Factors Branch, one of four branches in the DFO, as shown in Figure 8. The branch has the charter for human factors in the safe operation of nuclear facilities, including all aspects of quality assurance in their design, construction, and operation. These activities deal with safety-related aspects of the man-machine interface; risk analysis and human reliability; plant procedures and tests; qualifications, training, and licensing of persons in certain functions; and the organization and management of the plant operating staff and the licensee corporate staff as a whole. The pursuit of these activities requires close coordination with the Division of Human Factors Safety, the Quality Assurance Branch in NRR, and the Office of Inspection and Enforcement. Within the Human Factors Branch, human factors research is the responsibility of the human engineering section .

3.1.1.3 Significant Organizational Changes

As previously stated, there were no activities dedicated to human factors within the NRC at the time of Three Mile Island, but there was some human reliability research being conducted as part of an overall risk assessment program. Two significant organizational changes have occurred since then, which affect the recognition of human factors within the NRC.

The first change was the establishment of the Division of Human Factors Safety in the Office of Nuclear Reactor Regulation. This division was originated in April 1980. There were approximately 50 professionals assigned to the Division, but none of these was a career human factors professional. All of the professionals were engineers transfered into the Division from other parts of the NRC.

A second, non-organizational, change was the establishment of two separate human factors research programs. The first program was concerned with human reliability research and was primarily a continuation of work already underway. Human reliability research was conducted as part of the Risk and Operations Research Branch in the Division of Systems and Reliability Research. The second program of human factors research was concerned with man-machine integration, and was assigned to the Operational Safety Research Branch in the Division of Reactor Safety Research. Neither of these human factors research activities had a career human factors professional as part of the staff when the activity was initiated. However, one senior human factors research analyst was hired shortly after this organizational change and was assigned to the Risk and Operations Research Branch.

The next significant organizational change occurred again within the Office of Research in April 1981. At the top level, the Office of Standards was merged into the Office of Research, thus making one major organizational entity responsible for both

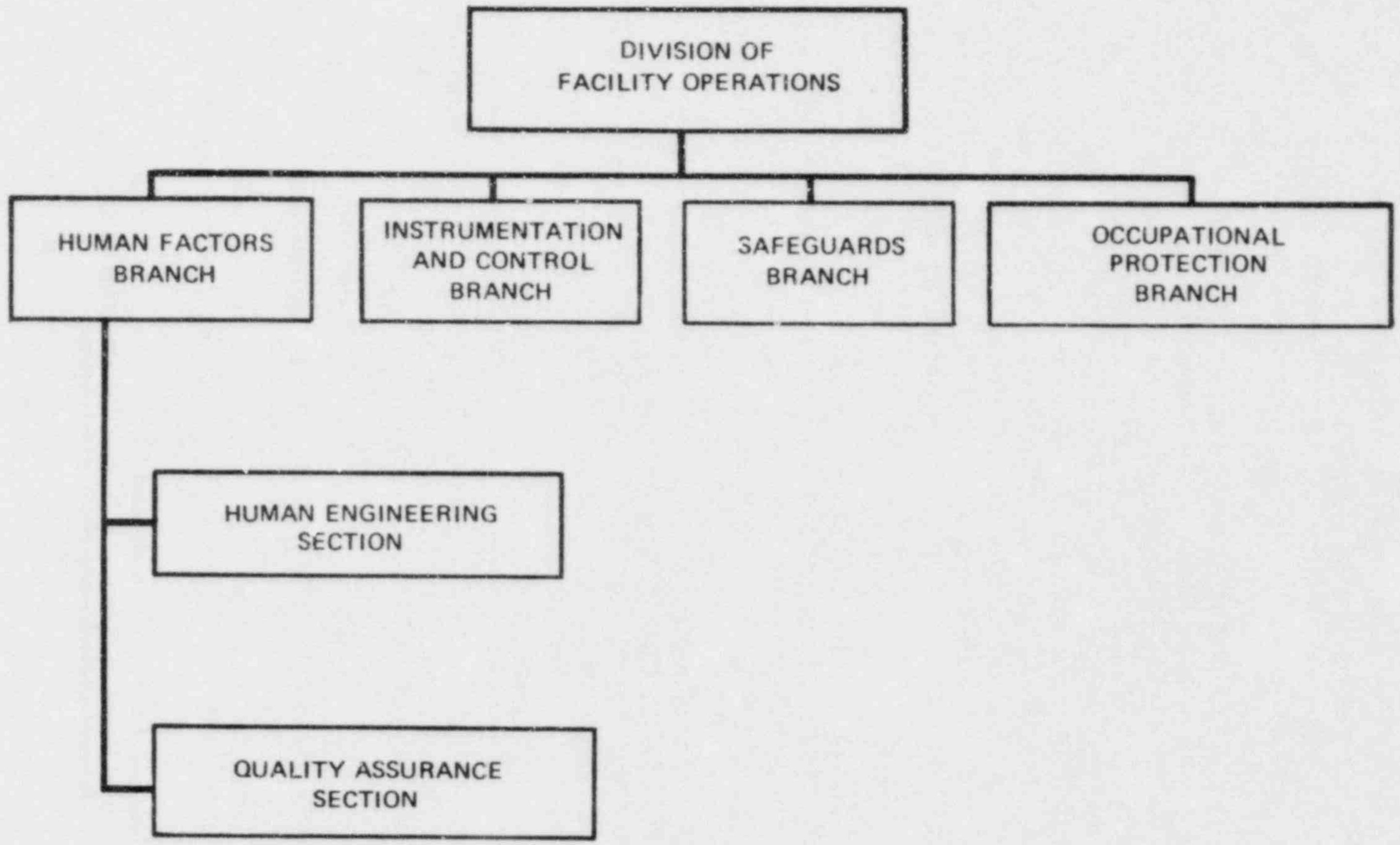

FIGURE 8. FACILITY OPERATIONS ORGANIZATION.

research and development of necessary standards. Of more importance to human factors was the establishment of a Human Factors Branch within the Division of Facility Operations in the new Office of Research. The key people responsible for human factors research in the prior organization were consolidated in one branch. However, neither the Division Director, the Branch Chief, nor the section leaders are career human factors professionals.

The most recent and perhaps significant organizational change occurred in November 1981 when the Director of the Division of Human Factors Safety, NRR was transferred to another division. The Deputy Director, a career human factors professional was appointed Acting Director. However, within a few weeks, this decision was reversed and an Acting Director was assigned from the staff of the Office of NRR. The job for a permanent Division Director was posted in December 1981 for an engineering manager, not necessarily for a career human factors professional. It was anticipated that the Director's job will be filled sometime early in 1982, but has not been filled as this report goes to printing.

In the opinion of the authors of this report the removal of the original Division Director was very untimely, since the major human factors activities of the Division (e.g., NUREGs 0700, 0801, and 0799) were about to be presented to the NRC Commissioners for a rulemaking decision. The ultimate effect of this change is of course unknown, but the removal of the original director (with no immediate permanent successor) at such a crucial time interpreted by this Study Group as an apparent reduction in emphasis on human factors within NRR.

The most recent organizational event that may affect human factors considerations both within NRC and in the entire nuclear power community was the establishment in November 1981 of the Committee to Review Generic Requirements (CRGR). This Committee, under the chairmanship of the Deputy Executive Director for Regional Operations and Generic Requirements (DEDROGR), has the responsibility to review and recommend to the Executive Director for Operations (EDO) approval or disapproval of requirements to be imposed by the NRC staff on one or more classes of reactors. The CRGR will develop means for controlling the number and nature of the requirements placed by NRC on licensees.

As a result of CRGR meetings on December 3 and 10, 1981, a memorandum was issued by DEDROGR stating basic requirements for emergency implementation of them. Facilities, equipment, and actions specifically dealt with were the Safety Parameter Display System (SPDS), Control Room Design Review (CRDR), upgraded Emergency Operating Procedures (EOP), Regulatory Guide 1.97, Technical Support Center (TSC), Operational Support Center (OSC), and Emergency Operations Facility (EOF).

It is unfortunate that the control room design review was inappropriately grouped with the other items, all of which are diectly concerned with emergency response and related facilities. This creates the impression, reinforced by the language and provisions of the document, that control room modifications should be made only in the context of emergency response. This approach ignores the importance of good human engineering design of displays and controls in normal operation. A control room design review that results in needed control room modifications will enhance safety of operation in emergencies, but more importantly, good human engineering design minimizes the probability of an emergency situation arising through operator decisions and actions.

The memorandum was circulated for comment prior to formulating a recommendation to the EDO. The overall impression created by the memorandum was one of downgrading the importance of or even denying the necessity for human factors consideration in nuclear power plant control rooms.

Three members of our Study Group met with the DEDROGR and were told that the contents of the memorandum were not intended to imply a weakening of the importance attached to human factors considerations, except in the specific case of the SPDS, the requirement for which is established by executive decision. We were told several times that SPDS is a given - not subject to justification in terms of an analytically derived scientific or engineering requirement - and that <u>any</u> SPDS, no matter how it is designed or implemented, will <u>be</u> better than no SPDS. Subsequent to this meeting, the HFS Study Group expressed its continuing concerns in a letter to DEDROGR.

The NRC Staff (DEDROGR) recommendations on the requirements for emergency response capability were presented to the Commissioners in a document dated March 10, 1982 (SECY 82-111). The HFS Study Group evaluated this document and identified the following shortcomings:

(1) de-emphasis of importance of human factors.

(2) elimination of requirement for approval of CRDR plan.

(3) denial of the logical and functional priority of operator task analysis.

(4) weakening of the requirement for correction of human engineering design deficiencies.

(5) assignment of unwarranted and potentially detrimental priority to SPDS.

Before presenting the details in support of these evaluations, it is important to stress the support of the HFS Study Group for the stated intent and purpose of the activity of the CRGR. We strongly support the emphasis on coordination and integration of all the initiatives that have developed as a result of TMI-2. One of our recommendations (4.2.9 - System Engineering of the Regulatory Requirements) that comprise the comprehensive long range human factors plan presented in Section 4.0 of this volume is directed specifically at definition and integration of regulatory requirements. Unfortunately, the content of SECY 82-111 does not promote the achievement of this goal.

The overall impression conveyed by SECY 82-111 does not differ substantially from that of the earlier version. In some respects there is a reduction of emphasis upon the importance of human factors in the wording of the SECY 82-111 version. The following statements which appeared in the first paragraph of December 29, 1981 version were deleted: "studies that followed the accident at TMI identified the need to improve the on-site and off-site capability for responding to accidents. The fundamental weakness revealed during these studies was the lack of attention devoted to the "man" in the "man/machine" equation. We must not detract from this finding."

By deleting these statements it appears that the NRC staff is not stressing to licensees the importance of human factors as an overall concern in emergency response capabilities.

Some statements such as "accepted human factors principles shall be taken into account" were inserted in the document. Although these statements provide some positive recognition of human factors, they do not constitute a particularly strong emphasis and are not likely to ensure that licensees devote more than minimal attention to human factors. In some cases the impacts of these statements are more than offset by the implications of other recommended requirements and adjunctive statements.

It is misleading to state, as is done more than once in the document, "in some cases a good SPDS may obviate the need for large scale control room modifications." In fact, there is greater validity to the reverse form of this statement, namely, "a well-designed existing or modified control room would obviate the need for the SPDS." More to the point, however, is the simple recognition that the extent of control room modifications required for safe, efficient operation is independent of the existence of SPDS. The safety purpose and safety result of good human factors engineering design of control rooms is to minimize the likelihood that operators through their actions will contribute to the initiation or exacerbation of "abnormal and emergency conditions" and to maximize the likelihood that if these conditions do occur operators will respond quickly and correctly.

There is a realistic recognition in SECY 82-111 on page 7, paragraph 2, that "the SPDS is used in addition to the basic components and serves to aid and augment these components"; and, in the same paragraph, "after the SPDS has been installed operating procedures should be available that will allow timely and correct safety status assessment when the SPDS is not available." These latter statements provide the basis for a strong case that if appropriate improvements are made to the basic components of the control room the presumed need for SPDS would not exist. The statements clearly imply that the SPDS is not intended to be a primary source of information for operators to perform their duties. Yet the possibility remains that necessary changes in primary instrumentation and control may not be made because of the more highly emphasized incorporation of an SPDS and the NRC implied importance of it relative to the more basic modification of the control boards.

Priorities assigned to the initiatives in SECY 82-111 are inappropriate. The document emphasizes that licensees should develop and propose an integrated schedule for implementation in which SPDS design is an input to the other initiatives. There are two serious problems with the latter part of this recommendation and the associated suggested sequencing of steps for integrating the initiatives.

First, it is suggested on page 5, paragraph 8.a(1) that the SPDS program should be initiated by "reviewing the functions of a nuclear power plant operating staff that are necessary to recognize and cope with rare events that (a) pose significant contributions to risk, (b) could cause operators to make cognitive errors in diagnosing them, and (c) are not included in routine operator training programs." This cannot be done without having available the results of some kind of task analysis as suggested to be a part of the control room design review in NUREG-0700. For example, one cannot examine events which can cause operators to make cognitive errors in diagnosing them without knowing the expected task requirements, including data about the existing displays and controls. The need for function analysis and task analysis should be stated more explicitly.

Second, it is suggested on page 6, paragraph 8.c(1) that the results of the control room design review be applied to "verify SPDS parameter selections, data display and functions." However, according to the suggested integration sequence, the SPDS will already have been designed, built, and installed in the control room (page 6, paragraph 8.a.3). Rather than specify the SPDS design as an input to the other initiatives, it would be more meaningful from a systematic, logical, engineering, and operational point of view to recognize that a control room design review, including the very basic element of a function/task analysis, is the most basic requirement for initiating human factors safety improvements in nuclear power plant operation. The result of this analysis may or may not indicate a requirement for SPDS.

The position of the HFS Study Group regarding the SPDS is not unique. The same conclusion was reached by a working group at the 1981 IEEE Standards Workshop on Human Factors and Nuclear

Safety held at Myrtle Beach. Task Group 3, "Short Term Control Room Evaluation, Enhancements, and Procedures" was composed of a well-balanced cross section of organizations and experiences, including primarily 20 representatives of utilities, 10 human factors professionals, 7 representatives from NSSS vendors and AEs, 5 DOE National Laboratory and industry organization representatives, and 3 NRC staff members.

The summary of the work and conclusions of Task Group 3 included the following statements concerning the relationship of the SPDS to the Control Room Review:

> The Task Group felt that a safety parameter display system (SPDS) should not be introduced into the control room independent of the control room review, but should be integrated to the control room review process to assure adequate human factors considerations. It was agreed that the goal of the SPDS should be included in the control room review objectives and that this review process could be used to identify the parameters, methods of display, added instrumentation, etc., necessary to implement the SPDS goal. The approach to meeting the SPDS functions and goal would be specific to the control room under consideration. It may be possible in some control rooms to incorporate the SPDS functions within existing instrumentation and displays. Other control rooms will require the addition of displays and instrumentation to implement the SPDS functions. On this basis, the following consensus position was developed.
>
> The ongoing process of control room reviews and procedure upgrade would help define the need for the addition of another device in the control room called an SPDS.
>
> The goal of an SPDS should be part of a control room review goal. An additional device in the control room called an "SPDS" per se may not be needed.
>
> This consensus statement does not imply that the need for an SPDS is in question. Rather, the intent was to require justification of an analysis of the functions to be performed to meet the goal of an SPDS. This analysis should take place as an integral part of the control room review.

The HFS Study Group is greatly concerned that there is no requirement for approval by NRC of the plan for the control room design review. We stressed this point in our letter of January 12 concerning an earlier version of the staff recommendations. This requirement is necessary to help insure that the review (1) will be directed at relevant human factors aspects of control room design, (2) will be conducted with the active participation of competent human factors professional personnel, and (3) will maximize the probability that modifications proposed as a result of the review will be planned and executed in accordance with accepted human factors principles. If control room design reviews are planned, conducted, and evaluated by the same type of engineering personnel that were responsible for the original control room designs, little or no improvement can be expected. We strongly recommend that the control room design review plan as described in NUREG-0700 be required and be reviewed and approved by the NRC in accordance with the general guidance of NUREG-0801, and that feedback be provided to the licensees about areas of concern in the plan.

The language of SECY 82-111 reinforces a position that human engineering deficiencies in the control room may be left unchanged even though they may produce higher than necessary human error rates in the use of primary instrumentation and controls. For example, the language used in the Functional Statement of paragraph Section 5, Detailed Control Room Design Review does not properly emphasize the importance of review and modification. It has the effect of making the importance of control room design reviews and subsequent modifications subordinate to SPDS and the upgraded emergency operation procedures. In the context of a systematic, integrated human factors approach, the results of a human factors analysis of design of displays and controls, although bearing a somewhat complementary relationship to procedures development and training program development, nevertheless maintain a priority position both logically and in terms of application. Procedures cannot be specified in the absence of the design of those objects with which one is to proceed and operator training cannot be specified meaningfully unless the objects that are to be operated and the procedures governing those operations are known.

The HFS Study Group is also concerned about the likely results of a loose interpretation of the statement "flexibility is considered in the control room design review because certain control board discrepancies (design deficiencies) can be overcome by techniques not involving control board changes. These techniques could include improved procedures, improved training, and the SPDS." Although the first sentence is true, it refers to relatively minor errors in human factors engineering design. The fundamental concept of the human factors discipline is to design the equipment/system to match the capabilities and limitations of the human operator. If the design target cannot be achieved then one may consider tradeoffs involving training in special procedures. Unfortunately, these tradeoffs usually are not easily accomplished in an already operational system as opposed to a system in design. Therefore, at the very least, it should be incumbent upon a licensee that might propose an alternative to correcting a control board design deficiency to demonstrate that a proposed alternative is a completely adequate substitute.

The Study Group concurs with the view expressed on page 10 in the Functional Statement: "Decisions to modify the control room would include consideration of long-term risk reduction and any potential temporary decline in safety after modification resulting from the need to relearn maintenance and operator procedures." This kind of consideration is standard practice for a human factors evaluation of proposed changes in operating systems. We have observed during the course of our study of the human factors requirements for nuclear reactor regulation that far too much emphasis has been placed upon the possible decline in safety that might result from control room changes which would require operators to learn new task performance techniques. For the most part, persons with no competence in the psychology of human learning have attempted to use the concepts of negative transfer and interference in an effort to argue against making control room modifications. Significantly, we have heard reference to possible "negative transfer" only in conjunction with discussions of control room modifications - never in conjunction with the discussion of upgrading (i.e., changing) of emergency operations procedures. Both would require relearning on the part of the operators. However, it seems that negative transfer is a matter for concern only if it is seen as resulting from an activity that involves appreciable costs.

We do not consider a potental for negative transfer resulting from having to learn to use new or modified control boards to be a problem of any practical operational or safety significance. There are several reasons for our position. First, many of the changes that need to be made on control boards are of the type that permit the displays and controls to be used in conformance with population stereotypes. Such changes, rather than interfering with learning and correct responses, will soon enhance the probability of correct operator performance. Any initial interference from old habituation can be easily eliminated. Second, new operating techniques on modified control boards will be learned quickly because they will be practiced frequently. Third, any assessment of the possible negative transfer resulting from control room modifications has to consider the high replacement rate of control room personnel. In this context concern about possible negative transfer is largely irrelevant.

With regard to the initiative to upgrade emergency operations procedures (page 15, paragraph 7) we concur with the recommended requirement that analysis to identify operator task and information and control requirements for these must be performed. However the need for integrated task analysis to support all initiatives (including SPDS) should be clearly specified.

We support the recommended requirements for submission of the emergency operating procedures technical guidelines and of the writer's guide for acceptance by NRC. However, we emphasize that the required acceptance of this document is no more important than would be the acceptance of the detailed control room design review plan discussed previously.

All of the emergency response facilities are mandated without requiring specific analysis of their use, task performance requirements, decisions to be made, and information required to support the expected human performance. The recommended requirements are concerned primarily with physical features rather than functional requirements.

On April 15, 1982 the Commission was briefed by NRC staff on the recommendations contained in SECY 82-111. The Chairman identified several questions related to the issue including the comments made by the HFS Study Group. The Commission took no action, pending inquiry of the Advisory Committee for Reactor Safeguards (ACRS) regarding their comments.

Subsequently, the HFS Study Group presented its evaluation of SECY 82-111 to a meeting of the ACRS Subcommittee on Human Factors on May 5, 1982 and to a meeting of the ACRS on May 7, 1982. We also discussed our evaluation of SECY 82-111 with the Commissioners when we presented our final briefing to them on May 25, 1982. At the time this report is being typed in final form we do not know what action will be taken regarding SECY 82-111, but we have received no additional information in any of these meetings to cause us to temper or change the evaluations and opinions expressed above.

3.1.2 Programs and Actions

The programs and actions discussed in this section include those that were initiated prior to the end of fiscal year 1981 (30 September 1981), but generally do not go back further than the time of the accident at Three Mile Island. Details of programs and actions will be described as part of the branches or divisions responsible for them. However, for the purpose of providing some historical perspective, Tables 1, 2, and 3 summarize the general status of NRC programs and actions which were presented at the 1981 IEEE Standards Workshop on Human Factors and Nuclear Safety, August 30 - September 4, 1981.

The status of NRC programs and actions as of December 1979 is shown in Table 1. This was nine months after the Three Mile Island accident and it can be seen that some major initiatives in human factors were planned.

One year later, December 1980, the status of NRC programs and actions had changed significantly as indicated by the items in Table 2. One of these items is the initiation of the contract with the Human Factors Society to develop a comprehensive plan for human factors. This contract was started in December of 1980. Also significant is the assessment of current and near-term operating license (NTOL) control rooms which began in February 1980, and included some 21 human engineering audits as of the end of September 1981.

Finally, as another milestone, Table 3 summarizes significant programs and actions as of September 1981. Completed, current, and future programs and actions will now be described more fully under a description of the appropriate Office, Division, or Branch.

TABLE 1

NRC STATUS - DECEMBER 1979

ANNOUNCEMENT OF A HUMAN FACTORS SAFETY DIVISION IN OFFICE OF NUCLEAR REACTOR REGULATION : EFFECTIVE APRIL 1980

INITIAL HUMAN ENGINEERING RESEARCH BEGUN AT LOFT FACILITY AND PLANS FOR MAN-MACHINE INTERFACE RESEARCH PROGRAM STARTED

TMI-2 LESSONS LEARNED TASK FORCE REPORT, NUREG-0585, RECOMMENDED YEARLY REVIEW OF CONTROL ROOMS, INCLUDING PROCEDURES AND TRAINING: ISSUED OCTOBER 1979

PROBABILISTIC ANALYSIS STAFF/RES POSITION ANNOUNCED FOR A SENIOR RESEARCH PSYCHOLOGIST FOR HUMAN RELIABILITY RESEARCH PROGRAM DIRECTION

TABLE 2

NRC STATUS - DECEMBER 1980

RESEARCH PROGRAM IN HUMAN FACTORS FUNDED WITH TASKS TO:

A. DEVELOP A COMPUTER-BASED DISPLAY FACILITY AT INEL TO SUPPORT LOFT AND OTHER RESEARCH PROGRAMS;

B. USE CURRENT DISPLAY TECHNOLOGY TO SUPPORT LOFT EXPERIMENTS AND ANALYSIS FOR LOCA SITUATIONS;

C. PUBLISHED HUMAN ERROR RISK ASSESSMENT AND MODELS FOR USE IN IREP, IN NUREG/CR-1278;

D. BEGAN CONTRACT WITH THE HUMAN FACTORS SOCIETY TO REVIEW NRC REQUIREMENTS AND PREPARE 5-10 YEAR PLAN FOR HUMAN FACTORS USES AND RESEARCH; AND

E. ESTABLISHED A NEW HUMAN FACTORS PROGRAM AT OAK RIDGE NATIONAL LABORATORIES.

HUMAN FACTORS SAFETY DIVISION ESTABLISHED WITH HUMAN ENGINEERING, OPERATOR LICENSING, PROCEDURES AND TEST REVIEW, AND LICENSEE QUALIFICATIONS BRANCHES WITH 50 PROFESSIONALS.

TASK ACTION PLAN, NUREG-0660, MAY 1980, TO PROVIDE A COMPREHENSIVE AND INTEGRATED PLAN TO CORRECT DEFICIENCIES: RESULTED IN:

A. ASSESSMENT OF CURRENT AND NTOL CONTROL ROOMS, BEGINNING IN FEBRUARY AND CONTINUING TO DATE;

B. DRAFT HUMAN FACTORS GUIDELINES NUREG/CR-1580, PUBLISHED IN AUGUST 1980 FOR COMMENT;

C. REQUIREMENT FOR SHIFT TECHNICAL ADVISOR TO CONTROL ROOM STAFF;

D. UPGRADED PASS/FAIL CRITERIA FOR LICENSING EXAMS AND ADDITIONAL KNOWLEDGE REQUIREMENTS ISSUED, MAY 1980;

F. NEW TRAINING AND PERSONNEL REQUIREMENTS DESCRIBED IN NUREGS-0660 AND 0737;

Table 2 (continued)

NRC STATUS - DECEMBER 1980

F. LIMITS PLACED ON OPERATOR OVERTIME AND DEFINITION GIVEN OF A MINIMUM SHIFT MANNING, JULY 1980; AND

G. PROCEDURE UPGRADED AND MADE PART OF THE FIELD REVIEW PROCESS, JANUARY 1980.

TABLE 3

NRC STATUS - SEPTEMBER 1981

DIVISION OF HUMAN FACTORS SAFETY ISSUED PUBLIC COMMENTS TO DRAFT HUMAN FACTORS GUIDELINES, AS NUREG-0659, AND PLAN FOR FINAL GUIDELINES, AS NUREG-0700, TO BE PUBLISHED IN LATE 1981. EVALUATION CRITERIA, NUREG-0801, DUE IN LATE 1981.

UPGRADED EDUCATIONAL AND TRAINING REQUIREMENTS FOR ROs AND SROs UNDER SCRUTINY.

METHODS FOR CHECKLIST AND PROCEDURE EVALUATION OF MAINTENANCE AND CALIBRATION ISSUED, NUREG/CR-1868 AND 1869 (I & E).

STUDY OF LICENSING NON-OPERATORS NEARLY COMPLETED.

NEW GUIDELINES ON CONTROL ROOM PROCEDURES ISSUED AS NUREG-0799.

MAJOR NRR HUMAN FACTORS RESEARCH REQUIREMENTS ESTABLISHED IN MARCH AND RES PROGRAMMATIC RESPONSE PROVIDED IN JULY.

APPLICABILITY OF LICENSEE EVENT REPORTS TO HUMAN ERROR IN MAINTENANCE TASKS DESCRIBED IN NUREG/CR-1879 AND 1880.

PILOT TASK ANALYSIS OF PWR ACCIDENT SEQUENCES COMPLETED.

OTHER RESEARCH PROGRAMS IN EFFECT PRIOR TO SEPTEMBER 30, 1981:

- HUMAN PERFORMANCE MODELING AND VERIFICATION
- HUMAN ERROR RATE ANALYSIS
- AUGMENTED OPERATOR CAPABILITY STUDY
- CRT DISPLAY DESIGN AND EVALUATION
- SAFETY RELATED OPERATOR ACTION STUDY
- OPERATIONAL AIDS FOR REACTOR OPERATIONS
- MAINTENANCE ERROR MODEL

Table 3 (continued)

PERSONNEL SELECTION AND TRAINING

BEHAVIORAL RELIABILITY PROGRAM

STANDARDS FOR PSYCHOLOGICAL ASSESSMENT

3.1.2.1 Division of Human Factors Safety, NRR

The Division of Human Factors Safety was established in April 1980. It has the responsibility to direct and administer evaluations in the operational, administrative, and people-oriented disciplines for nuclear reactor applications, and for reactor facilities licenses for operation; develop and administer related programs, policies, and procedures governing these aspects of the licensing and operation of nuclear reactors. The DHFS does not conduct any research, but has a substantial technical assistance program which is comprised of four decision units. These are:

1. Operator Licensing - The process of licensing reactor operators and senior reactor operators. This is by staff and contract support.

2. Operating Reactors - Reviews of selected areas or items in operating reactors for safety implications. This includes emergency operating procedures, control rooms and operating facilities, management and organization structure and attitude, and training programs.

3. Case Work - Specific reviews or audits of near-term operating licensees. This includes control room design reviews, emergency operating procedures reviews, training program reviews, and special or low power test programs.

4. Safety Technology - The application of state-of-the-art knowledge to current concerns of licensing and regulation. This includes such actions as development of the requirements for the safety parameter display system (SPDS), development of human engineering guidelines for control room review (NUREG/CR-1580 and NUREG-0700), and development of guidelines for preparing emergency procedures (NUREG-0799). Since the programs and actions are carried out by the four branches of the DHFS, they will be described separately, by branch.

3.1.2.1.1 Human Factors Engneering Branch

3.1.2.1.1(a) Guidelines for Control Room Design Reviews (NUREG 0700)

Description

(1) Need

One of the potentially beneficial consequences of the TMI-2 episode has been to focus the attention of everyone concerned with nuclear energy on the human factors in power plant design and operations. One of the most direct inferences from the several post-mortems that were done on TMI-2 was that the configuration of the control room was far from ideal and that the deficiencies in control room human engineering contributed to improper actions and delays in coping with the emergency.

Task I.D.1 of NUREG 0660, the NRC Action Plan developed as a result of the TMI-2 accident, specifies that the Commission's Office of Nuclear Reactor Regulation will require that operating reactor licensees and applicants for an operating license perform a detailed control room design review to identify and correct design deficiencies. This review will include an assessment of control room layout, the adequacy of the information provided, the arrangement and identification of important controls and instrumentation displays, the usefulness of the audio and visual alarm systems, the information recording and recall capability, lighting, and other considerations of human factors that have an impact on operating effectiveness. Prior to the initiation of the detailed reviews, NRR will formulate design review guidelines to be used by each licensee and applicant to assist in the identification of design weaknesses.

(2) Objective

The primary objective of this effort was to develop guidelines that the NRC staff believes should be followed to accomplish the control room design review described in NUREG-0660.

(3) Work Effort

Draft guidelines for the detailed control room design review were published for public review and comment in July 1980. The guidelines were identified as NUREG/CR-1580, Human Engineering Guide to Control Room Evaluation. A supplement to the guidelines, NUREG-0659, was subsequently published in March 1981. This supplement responded to comments on NUREG/CR-1580. Two public meetings were held in April 1981 to discuss comments on NUREG-0659, and to review the staff's plans for publishing the complete set of guidelines for control room design reviews. The final development of NUREG-0700 had two major tasks.

> Task 1. Reorganize, reformat, and revise NUREG/CR-1580. This major task required an in-depth review of the specific human engineering guidelines/criteria presented in NUREG/CR-1580 for consistency, validity, and relevance. The public comments, together with the results from previous human factors engineering audits of the control rooms of applicants for operating licenses, were analyzed to prepare revised guidelines/criteria, checklists, and instructions for measurements and observations in the control room. In addition, guidance was developed for analysis of system functions and tasks, to provide a frame of reference for assessing the potential performance impacts of interference deficiencies identified in the existing control room design.

> Task 2. Develop a recommended format for licensee reports and evaluation criteria and procedures to be used by the NRC to assess the performance and results of the control room design reviews.

Status

(1) Schedule/Priority: NUREG-0700 was issued in September 1981

(2) Resources: Not known

(3) Products/Publications: NUREG/CR 1580
NUREG 0659
NUREG 0700

Evaluation

Development of guidelines for control room reviews is highly desirable. The sequence of development for NUREG-1580, 0659, and 0700 was proper, though the timing between them was severely tight due to the pressure of TMI-2 and the lack of a previous similar requirement. Consequently, some professional elements of the Human Factors community find some portions of NUREG-0700 to be unnecessary or unreasonable in terms of required documentation. The application of this effort is timely for both existing plants and for NTOLs.

The cost of CR reviews will be great (on the order of several person-years). However, the benefits are great in terms of the significant reduction in operator error that will be achieved by elimination of design-induced error features, any of which can have the same financial impacts as TMI-2.

In these early stages, where utilities are seeking competent human factors evaluation support, a caution is in order. Several competent individuals and consulting firms can perform the reviews. However, other individuals and firms may claim such expertise, but are without proper qualifications.

3.1.2.1.1(b) Human Factors Control Room Case Reviews

Description

(1) Need

Various internal and external studies of the Three Mile Island Unit 2 accident have found that the nuclear industry has given too little attention to human factors in the design, operation, and safety analysis of nuclear power plants. The Human Factors Engineering Branch is responsible for the implementation of human factors principles to the man-machine interface which exists in nuclear power plant control rooms. In the NRC Task Action Plan (NUREG 0660), Section I.D identifies a number of tasks relating to control room design reviews, which are the primary responsibility of the HFE Branch. Specifically, Task I.D.1 requires that control room design reviews be completed for near term operating license applicants. This review is required to be completed prior to issuance of a full power license.

(2) Objective

The contractor shall provide consulting and site measurement support to assist NRC in the review of near term operating license casework reviews.

(3) Work Effort

To perform casework reviews, a control room audit review must be conducted. This review involves measurements of ambient environment, instrument and control arrangement, control room design, and selected emergency operating procedures under simulated emergency conditions in order to ascertain the adequacy of control room layouts.

The review shall be performed using checklists and guidelines that will be provided by the NRC. Specifically, the reviews will encompass annunciators and alarms, process computers, controls, displays, labeling, control-display relationships, sound levels, lighting, communications in the control room, and a walk-through of selected emergency procedures to observe accessibility, completeness, operator traffic patterns, and requirements for switch manipulation and instrument displays.

The identification of specific plants will be scheduled. For each specific plant the following subtasks shall be performed.

a. Preparation and familiarization for control room audit review.

b. Perform a five-day control room audit review.

c. Prepare and submit to the NRC audit team leader a first draft of audit report.

d. Resolve comments and submit second draft of audit report to NRC team leader.

e. Audit team meeting with licensee to evaluate proposed modifications to control room.

f. Prepare and submit to the NRC team leader a draft Safety Evaluation Report.

g. Participate in a preliminary review for incomplete control rooms and in all hearings related to work performed.

Performing Organization

Lawrence Livermore National Laboratory/BioTechnology, Inc.

Status

(1) Schedule: Begin in FY80 and continue as necessary

(2) Resources: FY80-$91K; FY81-$664K; FY82-$663K

(3) Products/Publications: a. Control Poom Evaluation Kit

b. Safety Evaluation Report (SER) input for specific plants

Evaluation

These case reviews are intended to assist a utility in passing the final CR review by generation of proposed changes and in the preparation of a Safety Evaluation Report. The objectives are highly desirable.

The earlier that such a review can be completed, the greater is the likelihood that an operating license can be obtained without delays required or later retrofit. It is highly cost effecive to perform such audits as early as possible. The timeframe of FY80 through FY82 is appropriate.

The subcontractor selected through Lawrence Livermore National Laboratory - BioTechnology, Inc. - is well qualified to perform such audits, and is so recognized in the professional human factors community.

3.1.2.1.1(c) Final Report of NUREG-0801, Evaluation Criteria for Detailed Control Room Design Review

Description

(1) Need

The objective of Task I.D, "Control Room Design", is to "improve the ability of nuclear power plant control room operators to prevent accidents or cope with accidents if they occur by improving the information provided to them." Item I.D.1, "Control Room Design Reviews", describes the NRC actions and licensee actions necessary to accomplish the objective. The licensee and applicant for operating license is required to perform a comprehensive review (Detailed Control Room Design Review - DCRDR) using NRC human factors design guidelines and evaluation. To aid the NRC staff and the licensee/applicant in judging the acceptability of the review performed and the design modifications implemented, NUREG-0801, Evaluation Criteria for the Detailed Control Room Design Review, was developed in draft and issued for public comment. The public comment period ended in December 1981.

(2) Objective (1982)

To complete and issue NUREG-0801, Evaluation Criteria for Detailed Control Room Design Review, taking into account public comments.

(3) Work Effort

Assist the HFEB staff in the preparation of responses to public comments received on the draft version of NUREG-0801, Evaluation Criteria for Detailed Control Room Design Review, and in the revision of NUREG-0801 in response to the comments. In addition, assist the HFEB staff in the development and operation of instructional workshops for the licensees and applicants who are using the guidance presented in NUREG-0700 and NUREG-0801 to perform detailed control room design reviews (DCRDRs).

This work will be based upon work performed in FY81 in the preparation of NUREG-0700 and NUREG-0801, and upon experience gained in the control rooms of license applicants.

Task 1. Work Plan Development

Task 2. Resolution of Public Comments on NUREG-0801

a. Collate and prepare summaries of public comments received by the NRC on NUREG-0801. The summaries should identify public concerns and be presented to the NRC at a meeting with the HFEB staff.

b. Review the collated public comments on NUREG-0801 and prepare a draft of responses to the comments.

Task 3. Revision to NUREG-0801

a. Prepare a draft version of NUREG-0801 that incorporates modifications reflecting NRC responses to public comments.

b. Prepare final report of NUREG-0801 which reflects HFEB review of the preliminary draft.

Task 4. Conduct Workshops with Industry

Develop the content and presentation format of instructional workshops that will be held to provide additional guidance to the licensees and applicants on the performance of the DCRDRs.

Task 5. Participate in Workshops

Participate, as required, in a maximum of five Regional instructional workshops as developed under Task 4. Participation will be under the direction of an NRC workshop leader(s) who will be responsible for presenting official NRC policy.

Performing Organization

Lawrence Livermore National Laboratory

Status

(1) Schedule: Complete in FY82

(2) Resources: FY82-$100K

(3) Products/Publications:

(a) NUREG-0801, Evaluation Criteria for Detailed Control Room Design Reviews, draft issued in FY81

(b) Responses to public comments to be issued

Evaluation

The objective of this effort is to produce NUREG-0801. The objective of that document is to assist the NRC in evaluating the competency of the conduct of the CR reviews. Both objectives are highly desirable. A secondary result of such a document will be the guidance given to the utilities in terms of the appropriate qualifications a review team should possess.

Since NUREG-0700 is already issued, it would have been desirable that 0801 would have been issued concurrently. However, its immediate scheduling is appropriate and should not be delayed.

The cost of producing this document and its attendant workshop is well worth the benefits in assisting both the NRC and the industry.

It is important that the final document and its subsequent workshops be prepared in part by competent human factors professionals.

3.1.2.1.1(d) Final Report of NUREG-0835, Human Factors Acceptance Criteria for the Safety Parameter Display System

Description

(1) Need

Task Action Plan I.D.2, Plant Safety Parameter Display Console, requires each applicant and licensee to install a safety parameter display system (SPDS). The goal of the system is the display of a minimum set of plant parameters from which the operator determines the safety status of the plant. The functional criteria for the display system are defined in NUREG-0696, Functional Criteria for Emergency Response Facilities, Final Report. The acceptance criteria for the display system are defined in a draft report issued for comment, NUREG-0835, Human Factors Acceptance Criteria for the Safety Parameter Display System.

(2) Objective (1982)

To resolve public and industry comments on NUREG-0835 and to prepare a final report. Also, generic reviews of SPDS design proposals are to be conducted using the acceptance criteria defined in NUREG-0835, Final Report.

(3) Work Effort

The regulatory staff seeks the assistance of Lawrence Livermore National Laboratory (LLNL) in the conduct of this work based on experience gained by LLNL in the control room design review audits and work performed in the preparation of NUREG-0700 and NUREG-0801. The two main phases of work are: (1) prepare a final report, suitable for publication, on the human factors acceptance criteria for the SPDS; and (2) conduct generic reviews of SPDS design proposals using the pre-defined acceptance criteria and report the results of the review. Each phase of work will focus only on the human factors elements of the SPDS. All work for the effort shall be completed by September 1, 1982. The main products of this effort shall consist of:

a. A final draft of NUREG-0835 suitable for publication.

b. Technical Evaluation Reports on the generic review of SPDS design proposals.

Task 1. Work Plan Development

Task 2. Resolution of Public Comments on NUREG-0835

a. Collate and prepare summaries of public comments received by the NRC on NUREG-0835. The summaries will identify industry concerns and point out any discrepancy that may exist between NUREG-0835 and NUREG-0696.

b. Review the collated public comments and prepare draft responses to the comments.

Task 3. Prepare a Draft Revision of NUREG-0835

a. Prepare a draft revision of NUREG-0835 which updates the report to integrate the results of Task 2.

b. Respond to NRC comments and modify the report.

Task 4. Pilot Review of Two SPDS Designs

Review two generic SPDS design proposals, as designated by HFEB. The reviews of the SPDSs are to evaluate conformance of the display system to the NRC approved human factors acceptance criteria.

Performing Organization

Lawrence Livermore National Laboratory

Status

(1) Schedule: This project started in FY81 and will continue through FY84

(2) Resources: FY81-unknown; FY82-$100K; FY83-unknown

(3) Products/Publications: (a) NUREG-0696

(b) NUREG-0835

(c) NUREG-0814

Evaluation

The objective "to develop evaluation criteria for the review of the SPDS" is not appropriate. The objective assumes that an SPDS is necessary or desirable. No functional requirements analysis has been performed to suggest that a separate SPDS is a required feature in control rooms. In addition the criteria in the draft version of NUREG-0835 are not substantially different from those of NUREG-0700.

Producing such a document is premature. It should not be initiated until a valid need for an SPDS is demonstrated. Indeed, if such a document is produced, it may be counter-productive in that design modifications may be initiated by utilities which will be disruptive to the design criteria reasonably imposed by NUREG-0700.

3.1.2.1.1(e) System Status Verification Guidelines

Description

(1) Need

TMI Action Plan Item I.C.6 (Procedures for Verification of Correct Performance of Operating Activities) requires that licensee procedures be reviewed and revised, as necessary, to assure that an effective system of verifying the correct performance of operating activities is provided as a means of reducing human errors and improving the quality of normal operations. Item I.D.3 (Safety System Status Monitoring) states, "NRR will study the need for licensees and applicants not presently committed to the requirements of Regulatory Guide 1.47, 'Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems', to monitor and verify operations, test, and maintenance activities by means of an automatic status monitoring system, such as that described in Regulatory Guide 1.47." This study is to be performed following a review of procedures and other nonautomatic actions to verify these activites, as required in Item I.C.6, and installation of the Safety Parameter Display System (Item I.D.2). In addition, consideration should be given to the impact of other control room modifications on the need for automatic monitoring (Item I.D.1).

Regulatory Guide 1.47, Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems, provides general guidance on safety system status monitoring. However, it concentrates on the hardware aspects of safety system monitoring. Therefore, additional guidance is needed concerning the person/machine interface of safety system status monitoring. Further, after the development of a requirement for a Safety Parameter Display System (SPDS), owners' groups and vendors have expressed an interest in integrating the safety status monitoring and the SPDS into a computer-based CRT display. Guidance is required concerning the evaluation of the effectiveness of the display of safety system status to the human operator. This statement of work covers the person/machine interface aspects of status monitoring and the interaction among procedures, the SPDS, and status monitoring.

(2) Objective

To develop and recommend guidelines for licensing actions regarding needed improvements to safety system status verification systems. The near term objectives are to recommend a regulatory position concerning the need for automatic safety system status monitoring systems, and to develop interim guidelines for areas of urgent concern and for improvements that can be readily accommodated in existing systems.

(3) Work Effort

This task focuses on the near term objective of interim technical guidelines plus a plan for longer term guidelines development. Seven principal subtasks are involved: (1) define current utility practices for designs through services of related work at LLNL and visits to selected plants and simulators; (2) define related industry and foreign (DOD, aerospace, and foreign utilities) activities; (3) assess the effectiveness of the various approaches utilized concentrating on the safety advantages and disadvantages of each; (4) develop preliminary guidelines for near term improvements; (5) pilot test the preliminary guidelines at one (or more) plants, if appropriate; (6) develop final interim guidelines; and (7) develop a program plan for establishing longer term guidelines as necessary.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Start in FY81, complete in FY82

(2) Resources: FY81-$45K; FY82-$105K

(3) Products/Publications: Unknown

(4) Related Activities: RES-NRC is supporting system status research at INEL.

Evaluation

Irrespective of the need or lack thereof for a distinct SPDS (see 3.1.2.1.1(d)), the objective for this effort is excellent. Technical direction is needed by the NRC regarding potential improvements in the development of safety status indication systems. This is particularly relevant in CRT computer-based displays. Interim as well as long range guidelines are desirable. This research effort represents a systems analysis approach to the problem.

It is the kind of study approach that should precede the assumption-based adoption of SPDS. The results of this study should serve to define whether the SPDS is uniquely required or whether a more integrated and systematic status verification system is appropriate to the needs.

The funding level is inordinately low, should be increased in FY82, and extended out through FY84. An effort for FY82 should be approximately 4 person-years, with 4-6 in FY83.

3.1.2.1.1(f) Advanced Display Technologies

Description

(1) Need

There is increasing emphasis in NPP control rooms on the preparation of information and data by means other than the traditional analog devices. As advanced display technologies, primarily computer-generated interactive displays, are introduced, two basic issues must be addressed: (1) the content of the information and data to be displayed, and (2) the format of the information to be displayed. This project is directed at providing a systematic analysis of these issues for a single, narrowly defined control room function. This effort will provide assistance to the Human Factors Engineering Branch in the review of display issues which arise from licensees' detailed control room design reviews, and the development of criteria for and subsequent evaluation of Safety Parameter Display Systems.

(2) Objective

To provide preliminary guidance concerning advanced display technologies and identification of tasks required to provide full regulatory guidance concerning advanced display technologies.

(3) Work Effort

There are two major tasks to be performed in this effort:

(1) development of a comprehensive work plan, and

(2) implementation of the work plan.

Task 1. Work Plan Development

The initial task of this effort is the development of a comprehensive work plan, including costing estimates, for the systematic analysis of a single control room function. The primary objective of this analysis is to provide the technical basis upon which design and acceptance criteria for advanced control room displays will be developed. A secondary objective of the analysis is to provide information which will assist HFEB in reviewing licensee perforance of the system review component of the Guidelines for Control Room Design Reviews (NUREG-0700). The work plan should address the following items, identified here as subtasks.

a. Selection of the Function to be Analyzed

The system function chosen for analysis should be: (a) one which requires a high degree of interaction between the operator and hardware subsystem, (b) well-defined and relatively narrow in scope, and (c) common to the range of reactor types and vendors.

b. Procedures for Determining the Information and Data Requirements for the Selected Function

Essentially, this procedure will define a limited-scope function and task analysis which will provide specification of the information needed for accomplishing the tasks associated with the selected function.

c. M[illegible] for Defining Display Format

The work plan should specify the approach which will be used to proceed from knowledge of the necessary information content to specification of appropriate information formats and display design criteria.

Task 2. Implementation of the Work Plan

Upon concurrence by the HFEB technical monitor and cognizant manager the analysis work plan developed in the preceding task will be implemented. A report should be prepared summarizing the results of those portions of the analysis effort completed during FY82.

Performing Organization

Lawrence Livermore National Laboratory

Status

(1) Schedule/Priority: Complete in FY82

(2) Resources: FY82-$50K

(3) Products/Publications: Unknown

Evaluation

The general objective stated is a desirable one - providing guidance regarding advanced display technologies. However, the scope of this effort is poorly defined and severely limited - asking the contractor to select only a single control room function for systematic analysis. At best, results of the study will only be suggestive.

The effort is scheduled in an appropriate time frame. However, the limited scope and budget promise only meager benefits. Either the effort should be expanded to include several representative control room functions or it should be cancelled.

The quality of the objective as stated is excellent. For results to have any significance, the study should be expanded in funding and duration. A sample of six functions is suggested. Using the $50,000 per function base, 2 person-years in 1982 and 3 person-years in 1983 appear to be appropriate.

3.1.2.1.1(g) Annunciator System Guidelines

Description

(1) Need

Since TMI, it has become increasingly apparent that improved operator performance can be obtained through better use of the control room annunciator system. For example, annunciator systems at various plants are based on differing philosophies with different designs. Simulator observations indicate that during major transients too much information is being provided by the annunciator system. Annunciator panels often have lighted annunciator display windows for known reasons, e.g., a piece of machinery has been taken out of service for maintenance, thereby downgrading its effectiveness as an alarm system.

(2) Objective

To develop and recommend technical guidelines regarding annunciator system improvements. The near term objective is to recommend interim guidelines for areas of concern on near-term operating license applicant facilities and for improvements that can be readily accommodated in existing systems.

(3) Work Effort

This project focuses on the near term objective of interim guidelines plus a plan for longer term guidelines development. Six principal sub-tasks are involved: (1) define current plant designs and practices through a review of ongoing work at ORNL and LLNL and through visits to selected plant control rooms and site-specific simulators; (2) based on these data, assess the effectiveness of current annunciator systems; (3) develop preliminary guidelines for near-term improvements; (4) pilot test the revised guidelines of one (or more) nuclear plants; (5) develop final interim guidelines for near-term improvements to annunciator systems; and (6) develop a program plan for longer term guidelines.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Start in FY82 and continue to FY84

(2) Resources: FY82-$150K

(3) Products/Publications: Guidelines and acceptance criteria will be developed.

(4) Related Activities: RES-NRC is supporting annunciator research at INEL; EPRI is sponsoring an annunciator study.

Evaluation

The objectives of this effort are excellently suited to the problem. It has the near-term objective of providing interim guidelines for annunciator licensing actions and for providing a plan for longer term guidelines development.

Timeliness is appropriate, with results being directed to current operating plants, NTOLs, and potentially for plants with advanced control rooms. Near and interim guidelines dates (6/82 and 5/83) appear realistic, as does that for development of the plan for longer term improvements (3/83).

The budget appears to be realistic, assuming the contracted study with PNL will be supplemented by NRC staff personnel for guideline document processing. Benefits are well worth the relatively small cost of this study.

It is essential that a competent career human factors professional be involved in the study effort.

3.1.2.1.1(h) Plant Maintenance Program Plan

Description

(1) Need

Maintenance has been identified by the NRR-DHFS and the

ACRS as an essential and critical function in the safe operation of nuclear power plants. Numerous interrelated factors appear to improve the efficiency and effectiveness of nuclear power plant maintenance. Among these factors are the equipment's inherent maintainability; the availability and adequacy of maintenance facilities, tools, and spare parts; the adequacy of personnel selection and training; the availability, adequacy, and use of maintenance procedures; as well as maintenance organization and policies. Although some research has been done, current knowledge of nuclear power plant maintenance problems is insufficient to permit development of clear, constructive guidelines for licensing actions in the maintenance area.

(2) Objective

The overall objective of this task is to develop recommended guidelines for nuclear power plant licensing actions related to maintenance. The near term objective is to develop a recommendation for a program plan to accomplish the overall objective.

(3) Work Effort

This task is focused on the near term objective to develop a program plan and involves three principal sub-tasks: (1) review existing studies (NRC, INPO, EPRI, and others) and related data on current industry maintenance practices through visits to selected utilities, vendors, and A-E firms; (2) define related industry practices and their applicability to the nuclear industry through selected visits to and/or a survey of domestic and foreign firms; and (3) develop a program plan to formulate recommendations for NRC licensing actions.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Begin in FY82 and continue through FY87

(2) Resources: $280K in FY82; at least $1,000K in FY83-87

(3) Products/Publications: Program plan scheduled for FY82

Evaluation

Both the near term and the overall objective (to develop recommended guidelines for nuclear power plant licensing actions related to maintenance) are appropriate and properly ordered.

Timeliness of the effort is also appropriate, and the fact that current planning extends the effort into FY87 demonstrates that the NRC has a proper appreciation for the magnitude and importance of the problem.

Since there is substantial evidence regarding the severe impact of maintenance error on plant safety, the costs of this effort are well worth the benefits to be realized.

It is essential that career human factors professionals with substantial experience in maintainability, equipment design, training, and procedures development be involved in the effort.

3.1.2.1.1(j) Standard Review Plan for HFEB

Description

(1) Need

The Standard Review Plan (SRP) provides guidance to staff reviewers in the Office of Nuclear Reactor Regulation who perform safety reviews of applications to construct or operate nuclear power plants. The SRP is intended to assure the quality and uniformity of the staff reviews. The current SRP for the Human Factors Engineering Branch (HFEB) does not cover the various branch review responsibilities in sufficient detail to assure the desired quality and uniformity of staff reviews. Recently published documents address many of the review criteria and should be referenced in or incorporated into the SRP as appropriate. These documents are: NUREG-0700, Guidelines for Control Room Design Review; NUREG-0801, Evaluation Criteria for Detailed Control Room Design Review, Draft Report for Comment; and NUREG-0835, Human Factors Acceptance Criteria for the Safety Parameter Display System, Draft Report for Comment. The current SRP also identifies the need to develop numerous Branch Technical Positions (BTPs) for inclusion in the SRP. The list of BTPs identified needs revision and development of required BTPs should be initiated.

(2) Objective

The objective of this work order is to revise the HFEB SRP so that it will provide guidance to HFEB reviewers that assures the quality and uniformity of staff reviews.

(3) Work Effort

There are five principal tasks required for this effort:

Task 1. Review NUREG-0700

Identify appropriate portions of NUREG-0700 which should be referenced or incorporated into the SRP.

Task 2. Review NUREG-0801

Identify appropriate portions of NUREG-0801 which should be referenced or incorporated into the SRP.

Task 3. Review NUREG-0835

Identify appropriate portions of NUREG-0835 which should be referenced or incorporated into the SRP.

Task 4. Review Current BTPs and Recommend Modifications

Review the BTPs identified in the current SRP and recommend a revised list of BTPs which need to be developed. This task should take into account those BTPs which are adequately addressed in NUREG-0700. Recommendations should be made regarding the urgency with which the various BTPs should be developed.

Task 5. Prepare a Revised SRP Chapter 18

On the basis of subtasks 1-4, prepare a revised SRP which can be adopted by HFEB. The revised SRP should provide guidance to the HFEB staff which will assure the uniformity of HFEB reviews in the following areas: the design of NPP control rooms; the design of control stations outside the main control room, e.g. remote shutdown panel; and evaluations of Safety Parameter Display Systems.

Performing Organization

Lawrence Livermore National Laboratory

Status

(1) Schedule: Complete in FY82

(2) Resources: $50K

(3) Products/Publications: Revised SRP in October 1982

Evaluation

Updating of the HFEB's Standard Review Plan is desirable in the light of NUREGs 0700 and 0801. The objective is appropriate with one possible exception. Without adequate requirements analysis, the incorporation of SPDS factors is ill-advised. However, should 0835 be adopted without adequate justification, the Review Plan, unfortunately, would have to accommodate its provisions.

The effort is scheduled for completion by October 1, 1982. It would be desirable if it could be completed earlier, since control room audits are being conducted currently and full CRDR's are imminent.

Funding level is meager, but not too low, and a reasonable benefit will be realized to the NRC.

The effort requires the services of a competent career human factors professional.

3.1.2.1.2 Procedures and Test Review Branch

3.1.2.1.2(a) Review of Emergency Procedures for Licensing Reviews

Description

(1) Need

The Procedures and Test Review (P&TR) Branch is responsible for reviewing and evaluating plant procedures in all modes of plant operation. Initial and special test programs and procedures are also reviewed for those plants in the OL & CP review stage. In the NRC Task Action Plan (NUREG-0660) Section I.C identifies a number of tasks relating to operating procedures which are the primary responsibility of the P&TR Branch. Specifically, Task I.C.8 requires that a pilot monitoring program be initiated for selected emergency procedures for near-term operating license applicants. This review is required to be completed prior to issuance of a full-power license.

(2) Objective

Review, analyze, evaluate, and report on the adequacy of selected emergency procedures for nuclear power plants expected to be ready for full-power operation in 1980 and 1981.

(3) Work Effort

This review will provide an evaluation of the adequacy of emergency procedures from the perspective of human factors information transfer, operator usability, and the correctness of technical content for the following postulated events: Inadequate Core Cooling, Small Break LOCA, Loss of Main Feedwater, and Steam Generator Tube Rupture. This effort will involve a team approach and will also review the training related to the symptoms of the postulated transients. For guidance as to proper technical content, PNL will utilize vendor procedure guidelines previously approved by the NRC, as well as the applicable plant Safety Analysis Report. The review process will also involve observation of a simulator walk-through for each of the procedures, performed by the plant operating personnel, and a plant walk-through of one or more procedures, observing such factors as procedure/control board interface, technical support center operation, and general sufficiency of the procedures for actual plant use.

Concurrent with the above work, the contractor will also assist the staff in developing a long-term program plan that will integrate and expand on current efforts in writing, reviewing, and monitoring nuclear power plant procedures using human factors principles. The plan will define the work effort and studies which will provide a basis in writing plant procedures to assure that the wording of procedures is clear and concise; that the content of procedures reflects both engineering thinking and operating practicalities; and that the format of procedures is clear including diagnostic instructions for identifying the particular abnormal conditions confronting the operator.

The estimated level of effort per plant is three person-months. Specific plants and the schedule for their procedures review will be provided separately. A typical set of subtasks for a specific plant is as follows:

Subtasks

a. Review, analyze, and evaluate emergency procedures.

b. Following any necessary revisions to the procedures by the utility which result from the review under Subtask a., observe a simulator walk-through of each procedure, performed by plant personnel, and a plant walk-through of one or more procedures. Identify any further revisions that are needed for follow-up audit by I&E.

c. Prepare and submit to the cognizant Branch Chief a Safety Evaluation Report (SER).

d. As required, prepare and submit an SER supplement.

e. As required, appear on behalf of the staff at ACRS meetings and public hearings.

Performing Organization

Pacific Northwest Laboratories (PNL)

Status

(1) Schedule/Priority: This project was initiated in FY80 and may continue for several years as NTOLs develop their procedures

(2) Resources: FY80, $154K; FY81, $531K; FY82, $250K est.; FY83 and beyond -- unknown

(3) Products/Publications: No reports are known to have been published yet, other than Safety Evaluation Reports for each unit.

Evaluation

Since emergency procedures are the most critical procedures in a nuclear power plant, it is appropriate to initiate a study with an objective to review and evaluate them. The objective includes not only review and evaluation for technical accuracy, but also for incorporation of appropriate human factors design and information transfer principles, and from the perspective of operator usability. Vendor technical guidelines will be used as criteria to evaluate the technical content. Unfortunately, criteria needed to evaluate the human factors design, information transfer, and operator usability aspects are not defined. With no definition, it cannot be determined how these principles will be used for the review and evaluation of emergency procedures.

Without the establishment of specific criteria for the review and evaluation, the timeliness of this effort is questionable. If criteria are established, these plants may be subjected to another review and evaluation.

Even considering the concurrent activity of assisting the NRC staff in the development of a long range plan for improving all plant procedures, the $54.3K per plant is an extremely high price for validation of emergency procedures.

The effort is scheduled to be labor intensive during the first year and will require a team of career human factors professionals, technical writers, systems engineers, and subject matter experts with operational experience. Both NRC and PNL have expertise in these areas, but the availability of the additional resources needed to accomplish this effort may be severely limited.

3.1.2.1.2(b) Criteria for Preparation of Emergency Operating Procedures

Description

(1) Need

As required by the TMI Task Action Plan, NUREG-0660, and TMI-Related Requirements for New Operating Licenses, NUREG-0694, the NRC staff has been conducting pilot monitoring of emergency procedures for near-term operating license (NTOL) applicants. In these reviews the staff has surveyed existing methods of developing and implementing Emergency Operating Procedures at nuclear power plants. In this project NRC staff has coordinated: (1) information gained from the pilot monitoring program and from the reanalysis of transients and accidents that was required by Task Action Plan Item I.C.1(3) and clarified in NUREG-0737, Clarification of the TMI Action Plan Requirements, Item I.C.1; (2) the NRC survey of human factors criteria applicable to Emergency Operating Procedures; and (3) the application of these criteria to the near-term operatng license reviews.

(2) Objective

The objective of the project was to identify the elements necessary to prepare and implement a program of Emergency Operating Procedures that will mitigate the consequences of a broad range of initiating events and multiple equipment failures. Although all of the events and conditions identified in Appendix A of Regulatory Guide 1.33 should be covered by appropriate procedures, only those that fall within the definition included in this document should be designated Emergency Operating Procedures. Application is limited to Emergency Operating Procedures so designated, and specifically does not address emergency preparedness or emergency planning.

(3) Work Effort

No specific work statement for this project was available. However, the work effort can be inferred from material in the Introduction of the resulting document, NUREG 0799. This document has drawn upon a wide range of expertise and literature to identify the best available information related to preparation of procedures in general and to Emergency Operating Procedures in particular. This review also identified a large body of information that was not directly applicable because of the difference in technologies involved or the difference in constraining factors, such as time response. This information, as well as the applicable information, has been included in Appendix 2, References and Bibliography. Comments on this document should be supported by references and field experience to the greatest extent possible and additional alternatives should be identified.

In this document the staff attempted to accommodate a broad range of acceptable programs being developed in response to NUREG 0737, Item I.C.1. Although it was recognized that there are necessary differences dictated by variations in plant designs, the approaches to be taken should be as similar as possible. This is intended to facilitate the most efficient development of Emergency Operating Procedures at utilities with multiple reactor sites and to reduce the impact on operators transferring from one station to another.

NUREG 0799 represents the first step in developing a plan for upgrading of plant procedures, as required by TMI Action Plan, Item I.C.9. Future staff actions related to normal and abnormal operating procedures, maintenance and test procedures, and surveillance procedures will be addressed as new regulatory guides, revisions to existing regulatory guides, or revisions to the Standard Review Plan (SRP).

Performing Organization

Pacific Northwest Laboratories

Status

(1) Schedule/Priority: Draft completed in April 1981

(2) Resources: Unknown

(3) Products/Publications: NUREG 0799
NUREG/CR 1999
NUREG/CR 1977
NUREG/CR 1875

Evaluation

Although only in draft form (for comment), NUREG-0799 does provide the first step in establishing specifications and guidelines required for the development of nuclear power plant procedures, specifically emergency procedures in this document. It is not sufficiently integrated with NUREG-0700 to insure complete coverage when applying the systems analysis methodology. Function allocation and task analysis are not adequately defined in NUREG-0799 to permit the detail needed to delineate the system requirements for emergency procedures. The revision to the draft will need to address these issues and will have to be integrated into an overall plan for improvements in procedures that considers general (non-plant-specific) specifications and plant-specific guidelines.

The timeliness of the effort is consistent with the task action plan guidelines. The effort, however, should be concurrent with the improvement of all plant procedures.

The cost of the work is unknown. NUREG-0799 was compiled by the staff, but included work from two contract studies.

The effort required input from both career human factors professionals and nuclear engineers and thus represents a balanced approach.

3.1.2.1.3 Licensee Qualifications Branch

3.1.2.1.3(a) Guidelines for Utility Management Structure and Technical Resource (NUREG-0731)

Description

(1) Need

In the aftermath of the Three Mile Island nuclear plant accident, a number of studies and investigations conducted by the industry, the NRC, and others recommended changes in the numbers, qualifications, and organization of personnel operating and providing support for nuclear power plants. The principal studies have been conducted by the President's Commission on Three Mile Island, the NRC Special Inquiry Group, the NRC staff's Lessons Learned Task Force, and the Atomic Industrial Forum. Collectively, these studies have called for an upgrading of utility capabilities for handling routine plant operations and especially for coping with accident conditions. As might be expected, the recommendations of these diverse groups are not completely compatible; what is clear, however, is that all of these studies have called for upgrading, at least in certain areas, of management oversight and technical competence.

(2) Objective

The objective was to promulgate guidelines for nuclear plant staffing which are generally in accordance with the various recommendations and which describe an acceptable organizational structure and competence level for nuclear power plant operations.

(3) Work Effort

This project was performed by the NRC staff and no separate statement of work is available. The project resulted in publication of NUREG-0731 and the abstract from that document follows.

Guidelines are presented for the staffing levels and technical expertise that are considered to be essential within a utility to properly support nuclear power plant operation under both routine and accident conditions. Acceptable structures for both the utility corporate organization and the plant staff are described. Desired qualifications of plant staff and utility support personnel are indicated. The need for a subjective evaluation is acknowledged.

Two other documents relating to this same general area have previously been issued for public comment. One, NUREG/CR-1280, Power Plant Staffing, was issued in April 1980. The other, NUREG/CR-1656, Utility Management and Technical Resources, was issued in September 1980. The intent is to consider both the substance of and the comments received on NUREG/CR-1280 and NUREG/CR-1656 in conjunction with the comments received on this document. NRC then re-issued this document, revised as necessary, at the end of December 1980, for an additional comment period. Guidance was scheduled to be promulgated in final form during the Spring of 1981, after the second round of comments was received.

Performing Organization

NRC staff

Status

(1) Schedule/Priority: Completed in September 1980 and issued for public comment.

(2) Resources: Unknown

(3) Products/Publications: NUREG-0731
NUREG-0654
NUREG/CR-1280
NUREG/CR-1656

Evaluation

NUREG-0660 (I.B.1.1) calls for the development of evaluative criteria for on-site and off-site organizations, both management and technical, that will assure the safe operation of the plant during normal and abnormal conditions, and their capability to respond to accident situations. NUREG-0731 represents a first attempt to establish guidelines in this area but it is recognized that the evaluation of a utility's organizational structure and technical resources, even with those guidelines, has to be made on a largely subjective basis. It is thereby appropriate that efforts be made to develop a more objective, technical basis for making these assessments.

The current NRC review process is scheduled to be reviewed, revised, and pilot-tested during the first six months of 1982. Interim revisions to NUREG 0731 will also be developed during that time. Final management and organization evaluation guidelines are to undergo development starting in July 1982 and are to be completed in recommended final form by February 1, 1983. Promulgation of the final guidelines is scheduled for October 1983. This time frame appears appropriate in view of the development objectives and magnitude of the task.

The total program funding of $235,000 relates well to the objectives. The potential benefits are substantial.

A contract has been established with Battelle Pacific Northwest Laboratories (Human Affairs Research Center) for research leading to the development and recommendation of guidelines for licensing actions regarding manpower and staffing of nuclear power plants. It is too early to assess the progress of this effort. The need to demonstrate the reliability and validity of the evaluation procedures appears to be recognized. Success will clearly depend on the ability of the contractor to develop intermediate criteria of organizatic al effectiveness that not only can be employed by those who engage in the assessment process but which are fundamentally related to operational and maintenance effectiveness and thus to plant safety.

3.1.2.1.3(b) Utility Management and Organization Guidelines

Description

(1) Need

The TMI accident indicated a need for a more thorough assessment of utility management structures and utility technical resource bases, as well as the operating staff at nuclear power plants. The Licensee Qualifications Branch (LQB) developed guideines for desired utility management structures, technical capabilities, and plant organizations which were published for interim use and comment as NUREG-0731. These guidelines have been used as a partial basis for LQE review of utilities with applications pending for operating licenses.

The guidelines contained in NUREG-0731 are considered to be too prescriptive. Guidelines are needed which identify the principal aspects of an acceptable utility organization and management process and controls that will provide the necessary assurance of plant safety. The guidelines should allow individual approaches to organizational structures to account for differences in plant size, number of operating units, number of plant sites, and the individual utility approach to providing technical support, whether by in-house or contract resources.

(2) Objective

To develop a technical basis for NRC licensing actions related to the evaluation of utility management and organization for nuclear power plant construction and operation.

(3) Work Effort

There are three principal tasks involved: (1) improve the current process for evaluating utility management and organization, (2) prepare an interim revision of NUREG-0731, and (3) prepare final guidelines for the evaluation of utility management and organization. Each of these tasks has several subtasks.

Task 1. Improve Management and Organization Evaluation Process

This task involves assessing the current NRC review process, developing a revised format for the process, testing the revised format, and recommending an improved format. The product of this task will be a format for the review process which assures reliability through consistent, standardized methods and interview guides.

Task 2. Prepare Interim Revision to NUREG-0731

This task involved the review of existing documentation relative to NUREG-0731, incorporation of the views of management assessment specialists, and preparation of a document which can be tested in future efforts. This task assumes the use of consultants who are subject matter specialists in the assessment of management and organizational structure in industry.

Task 3. Prepare Final Management and Organization Evaluation Guidelines

This task incorporates the results of the efforts of Tasks 1 and 2, with an in-depth review of the field of managerial and organizational assessment into the development of guidelines for the evaluation of utility management and organization. This will include both a revised NUREG-0731 and an improved review process format.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Started in FY82; complete in FY83

(2) Resources: FY82-$185K; FY83-$50K

(3) Products/Publications: NUREG-0731, Guidelines for Utility Management Structure and Technical Resources.

(4) Related Activities: RES-NRC is supporting related research

Evaluation

The development of a sound technical basis and standardized procedures by which to evaluate utility management structures, technical resources, and organizational effectiveness is clearly a desirable objective considering the central role of management in maximizing safety of operations. Guidelines that will permit a diversity of approaches reflecting plant-specific variables and yet provide evaluative criteria that reflect universally applicable principles of management and organizational effectiveness are clearly needed and may represent a considerable technical challenge. The focus on formats leading to assessment techniques that are standardized and reliable (in the sense of interjudge agreement) is particularly desirable.

In view of the recognized limitations of NUREG-0731, which offers the only existing guidance in this area, the current support of this program with its scheduled completion in FY83 is quite timely.

The budget appears to be well in line with the stated objectives. If the technical objectives can be reached, the benefit to cost ratio should be high.

It is too early to evaluate progress in this program although it appears that the contractor clearly recognizes the difficult technical problems associated with the reliability and validity of the assessment process. For example, they have addressed such questions as the extent to which different evaluators use similar processes and arrive at the "same" evaluations of a given management structure and resources. They also appropriately raise questions concerning evaluative criteria and the relationship of these criteria to empirically tested theory as well as to other methods of validation. They appear sensitive to practical issues that may face the utilities if the criteria that are found to be desirable call for substantial changes in industry practice. In sum, it appears that the contractor has recognized the critical issues. There will be considerable technical challenge associated with their ability to meet all of the stated objectives.

3.1.2.1.3(c) Feasibility of Licensing Nuclear Utility Managers and Officers in Accordance with Public Law 96-295 Section 307(b)

Description

(1) Need

LQB has been charged with the responsibility of determining the feasibility of licensing nuclear power plant managers and other senior officers. In order to accomplish this, reports which address licensing matters have been reviewed. However, the precise question of licensing managers has not been studied to the depth which would allow for definitive decisions regarding such licensing.

(2) Objective

The objective of this effort is to obtain technical assistance from ORNL to assist NRC in determining the feasibility and value of licensing, under Section 107 of the Atomic Energy Act of 1954, plant managers of utilization facilities and senior licensee officers responsible for operation of such facilities. This is to be done in accordance with Public Law 96-295 Section 307(b).

(3) Work Effort

The contractor will plan and conduct interviews and analyze relevant information gathered from individuals having expertise in or experience with executive assessment techniques, from among utility management, and from NRC and other appropriate federal agency staff. This effort will require the contractor to personally contact representatives from each of these groups to elicit responses to questions such as: what are the technical and managerial/administrative task/job elements of targeted personnel; what criteria can be imposed to evaluate performance on these job elements; is such licensing needed, practical, effective; and which of the targeted positions should be licensed?

Performing Organization

Oak Ridge National Laboratory with Science Management Corporation as subcontractor

Status

(1) Schedule: Start in FY81, complete in early FY82

(2) Resources: FY81-$90K

(3) Products/Publications: Unknown

Evaluation

The objective is to determine the feasibility and benefits of licensing plant managers and senior officers of nuclear power plants who are responsible for operation of the facility. This is to be done in accordance with Public Law 96-295, Section 307(b). The appropriations authority act (June 1980) directed NRC to undertake a study of the feasibility and value of such licensing. Thus the appropriateness of the program effort is mandated by law.

This effort started on June 1, 1981, and was to have been completed on November 30, 1981. The results of the project will provide the basis for DHFS recommendations to the Commission. Depending on the Commission decision, follow-up efforts will be initiated to assist in generating license requirements. The timing of this effort appears appropriate.

The fiscal year 1981 budget for this effort was $90,000. No funds have been budgeted for subsequent years pending outcome of the feasibility study. The cost of the effort appears conservative in relation to the benefit of resolving this issue one way or the other.

A contract was let to Oak Ridge National Laboratories for the performance of this study. A progress report given to the Safety Technology Program Workshop (October 29-30, 1981) identified four key issues:

(1) Would the licensing of nuclear power plant managers and other senior utility personnel have value in terms of public health and safety?

(2) What job related technical and managerial requirements should be included and which utility officers should be subject to the process?

(3) What should be the most valid and practical processes by which the requirements, both managerial and technical, might be assessed?; and

(4) If a licensing program is to be set in place who should be responsible for the design and administration of the program?

To answer these questions, interviews were conducted with representatives of the nuclear power industry, including INPO and eight utilities; representatives from NRC, including resident inspectors and representatives at regional offices and headquarters; and personnel and companies who are professionals in assessment techniques. It appears that this approach has generated a number of important perspectives that must be taken into account in reaching a decision on the desirability of licensing and has identified both similarities and differences of opinion between representatives of NRC and representatives of the industry. It is recognized, for example, that necessary management attributes may be difficult to define and measure and that there is a need for management assessment procedures to be linked to task analyses of the specific positions and to training and development programs. There appeared to be general agreement that whatever licensing/certification program is adopted it should be developed, administered, and policed by industry as opposed to the NRC, although NRC would have an audit function.

In general, this feasibility study appears to have been effective in identifying major points of view, areas of concensus, areas of disagreement, and steps that would have to be taken should a decision be reached that licensing or certification of nuclear power plant managers and other senior personnel is to be implemented. The actual benefit of such an effort has not been established, however, and it is evident from the work reported so far that considerable difference of opinion remains concerning that benefit. The question will remain moot since there are no objective criteria by which to validate the concept.

3.1.2.1.3(d) Independent Safety Engineering Group Role and Responsibility

Description

(1) Need

Each applicant for an operating license, as part of the ongoing license application review, is being required to establish an cn-site Independent Safety Engineering Group (ISEG) that is independent of the plant staff, but assigned on-site to perform reviews of plant operations.

The draft Guidelines for Utility Management Structure and Technical Resources, NUREG-0731, states that the review functions of the ISEG will, as a minimum, include the following: evaluation for technical adequacy and clarification of all procedures important to the safe operation of the facility, evaluation of plant operations from a safety perspective, evaluation of the effectiveness of the quality assurance program, comparison of the operating experience of the plant with plants of similar design, assessment of the plant performance regarding conformance to requirements related to safety, assessment of the plant safety program, and any other matter involving safe operation of the nuclear power plant that an independent reviewer deems appropriate for consideration.

NUREG-0737 provides clarification regarding the ISEG. It states that the ISEG shall not replace the Plant Operations Review Committee (PORC) or the utility's independent Safety Audit Group (SAG). It is an additional, independent group consisting of a minimum of five dedicated, full-time engineers, located on-site, but reporting off-site to a corporate official who holds a high level, technically oriented position that is not in the management chain for power production.

An ISEG has been required at each new operating plant with the intent that the NRC would review the ISEG performance and effectiveness after about a year of plant operation to determine whether such a group should be a requirement for all operating plants.

(2) Objective

The objective of this project is to develop and recommend guidelines for licensing actions regarding the Independent Safety Engineering Group. Following an assessment of the merits of the ISEG, guidelines will be developed to determine what should be the ISEG functions, membership composition, organizational role, and relationship to other independent review and auditing groups during plant construction, startup, and operation.

(3) Work Effort

This project involves three princip.` tasks: (1) define current independent review practices of utilities with and without ISEGs, (2) assess the advantages and disadvantages of ISFGs and their relationships to other review and audit groups, and (3) develop revised ISEG guidelines for incorporation in NUREG-0731.

Task 1. Define Utility Experience

This task involves visits to selected utilities with and without ISEGs to collect pertinent data on ISEGs (where appropriate) and on-site and off-site review committees (PORCs and SARs).

Task 2. Assess Utility Experience

This task involves assessing the overall utility experience with ISEGs, with particular emphasis on the advantages and disadvantages of ISEGs, why these exist, and the effectiveness of the relationship of ISEGs to PORCs and SARs.

Task 3. Develop Revised ISEG Guidelines

This task involves developing and recommending, as appropriate, revisions to the NUREG-0731 ISEG guidelines. These guidelines will be based on the results of Task 2 in conjunction with an overall assessment of the independent audit and review functions, and consideration of eliminating any of the review groups or combining their responsibilities.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Start in FY82, conclude in FY83

(2) Resources: FY82-$100K, FY83-$30K

Evaluation

NUREG-0737 requires that each applicant for an operating license have an independent safety engineering group (ISEG) consisting of a minimum of five dedicated full-time engineers, located on-site, who report off-site to a corporate official who holds a high level, technically oriented position that is not in the management chain for power production. The objective of this effort is to assess the merits of the ISEG, develop guidelines concerning ISEG functions, membership composition, organizational role, and relationships to other independent review and auditing groups during plant construction, start-up, and operation. The study appears highly appropriate since the cost of ISEGs would be considerable and their necessity to safety of operations should be firmly established.

Work on this task began on November 1, 1981, and is to be completed by October 1, 1983. This schedule suggests that there is no particular urgency in the completion of this task. Its timeliness clearly depends on the criticality of the ISEG function for operating plants and the number of plants that will be in various phases of construction or start-up during the next two years.

Total program fun ing is in the amount of $130,000, most of which is budgeted for FY82. In view of the considerable cost of an ISEG as presently defined, and the importance of its tentative responsibilities, this appears to be a modest investment for settling the issue of its need, role, membership composition, method of operation, and so forth.

A contract has been let to Battelle Pacific Northwest Laboratories (Human Affairs Research Center) to perform this task. It is too early in the program to assess progress. Visits will be made to selected utilities to define current independent review practices of utilities that do, and do not, have ISEGs. Based on utility experience, the advantages and disadvantages of ISEGs will be assessed and ISEG guidelines specifying roles and responsibilities will be developed if the Commission rules that ISEGs are required for all operating reactors. The major technical concern with this plan relates to the question of evaluative criteria. Success of the effort will depend upon what objective criteria, if any, can or will be brought to bear in determining the advantages and disadvantages of ISEGs.

'.1.2.1.3(e) Manpower and Staffing Criteria

Description

(1) Need

Reviews of utility license applications require an assessment of the adequacy of plans to staff the nuclear operation with on-site plant staff and corporate management including technical support. Information is needed to determine the minimum requirements for numbers of people, types of jobs, and configuration of staff to maintain safe construction, transition, and operation of a nuclear plant. The TMI Action Plan indicated the need to evaluate the necessary personnel to man nuclear plant shifts (I.A.1.3). Some work on this issue is being performed by NRC-NRR, NRC-RES, INPO, the nuclear power industry, and others.

Manpower requirements focus on the entire organization constructing and operating the plant - managers, engineers, shift staff, maintenance staff, auxiliary staff, technical advisors, technicians, and others. There is a need to establish desired staffing levels for those types of positions, recognizing differences in requirements for different types of utilities and plants and for different phases of plant development (construction-operation).

(2) Objective

To develop and recommend guidelines for licensing actions and/or the establishment of a regulatory position regarding manpower and staffing of nuclear power plants. This includes consideration of on-site and off-site staff requirements including contractual personnel with emphasis on numbers of people by type of job, staff qualification, work schedules, and overtime requirements. The on-site staffing includes attention to control room shift and nonshift staff.

(3) Work Effort

Task 1. Evaluate Current Knowledge

This task involves reviewing and evaluating available literature pertaining to staffing of nuclear power plants, including past and current NRC reports, guidelines and regulations, and recent and ongoing work of NRC-Research, INPO, AIF, and other industry groups. In this review, particular attention will be paid to staffing level information, the basis on which it was generated, and its applicability to other nuclear plant situations, e.g., transients, off-normal events, accidents, variability in standards and patterns and what determines that variability, and general extent of current application and problems attributed to staffing practices.

Task 2. Define Utility Practice

This task involves obtaining additional data on utility manpower and staffing practices to augment, as necessary, data determined to be available in Task 1.

Task 3. Refine Initial Program Plan

This task involves further assessment and refinement, as appropriate, of the planned approach for development of manpower and staffing guidelines. This assessment will be based on the results of Task 1.

Task 4. Define Foreign Practices

This task involves collecting, reviewing, and reporting on manpower and staffing practices in selected countries. Incorporate results of NRC (RES) survey of foreign operations and other literature as available.

Task 5. Assess Effectiveness of Current Practices

This task involves assessing the data collected in Tasks 1 through 4 emphasizing the advantages and disadvantages of the various manpower and staffing practices employed.

Task 6. Prepare a Technical Report on Recommendations for Guidelines

This task involves preparing a technical report to assist in the establishment of a regulatory position and/or guidelines to address manpower and staffing issues identified in Tasks 1 through 5. Emphasis will be on establishing a firm technical basis for near-term guidelines for assessing applications for operating licenses.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Started in FY82; continue to FY83

(2) Resources: FY82-$23K; FY83-$200K

(3) Products/Publications: Unknown

(4) Related Activities: Unknown

Evaluation

Research leading to the development of sound guidelines for licensing actions regarding manpower and staffing of nuclear power plants is obviously appropriate to the objective of maintaining public safety. This effort includes consideration of both on- and off-site staff requirements and consideration of how the numbers and types of required personnel are affected by work schedules and overtime requirements.

This project began in November 1981, and is scheduled for completion on September 30, 1982. The schedule is timely. However, performance of the work in such a comparatively short period appears to assume that it will not be necessary to correlate manpower and staffing variables with objective criteria of operating effectiveness or safety, since the latter measures probably will not be available in this time frame.

Total funding for this project is $431,000. This budget appears generous in view of the project objectives and proposed methodology. The key to both cost and benefit hinges on how the effectiveness of current staffing practices are to be "assessed".

A contract has been let to Battelle Pacific Northwest Laboratories (Human Affairs Research Center) to perform this work. It is too early to comment on progress. The key issue as noted concerns the criteria by which various staffing configurations, work schedule alternatives, structures for work flow, communications and control, and so forth, will be judged to be effective or not. The time schedule of this project does not seem to allow for an empirical approach to these potentially important questions.

3.1.2.1.3(f) Shift Technical Advisor Guidelines

Description

(1) Need

Shift Technical Advisors (STAs) have been required at all operating plants since January 1, 1980. STAs are required to have engineering expertise and special training in plant dynamic response so they can provide immediate on-shift advice and assistance to the Control Room Supervisor and other control room personnel in the event of an accident. When the STA requirement initially was established, the industry was told (NUREG-0737) that the need for the STA would be further evaluated and that the STA position may be eliminated when operator qualifications and control rooms are suitably upgraded.

(2) Objective

To develop and provide recommendations regarding the role and responsibility of the Shift Technical Advisors. The near-term objective is to define the preferred role for the STA including consideration of STA functions, responsibilities, qualifications, organizational relationship, integration with other operating staff, and need for licensing. The long term objective is to define whether the STA is required or the role should change in light of potential future changes in operator qualifications, responsibilities, and on-site staffing requirements.

(3) Work Effort

Task 1. Define Utility Experience

This task involves surveying utilities having STAs to obtain information on their current practices and experiences including the qualifications, selection, training, and job activities of STAs. Utility management, STA, and operator evaluation of the advantages and disadvantages of the STA position will also be obtained.

Task 2. Assess Effectiveness of Current Practices

This task involves assessing the data collected in Tasks 1 and 2, emphasizing the advantages and disadvantages of the various roles assigned to STAs or STA alternatives.

Task 3. Define Foreign Experience

This task involves collecting, reviewing, and reporting on alternative programs involving the use of engineering expertise on-shift at nuclear plants in other countries. The requirements for control room crews will be identified and foreign utility evaluations of the use of engineering expertise on-shift will be obtained as available. Incorporate results of NRC (RES) survey of foreign operations.

Task 4. Develop Interim STA Guidelines

This task involves developing and recommending interim NRC guidelines for the STA position. These guidelines will be based on the results of Task 3 in conjunction with the INPO job/task analysis of the STA position and any work completed by NRC/RES on the STA job task analysis.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Begin FY81; end FY83

(2) Resources: FY82-$120K

(3) Products/Publications: Unknown

(4) Related Activities: INPO Job Task Analysis

Evaluation

NUREG-0737 directed that the need for the STA be further evaluated after operator qualifications and control rooms were suitably upgraded. It is fully appropriate that the role, responsibilities, qualifications, integration with other operating staff, and need for licensing of the STA be the subject of research investigation. A longer term objective is to define whether the STA is required at all or, if he is, what role he should play in view of other changes that are taking place.

This project began in mid-November 1981, and is scheduled for completion on October 1, 1983. This schedule provides time for the development of interim STA guidelines and industry feedback. The timing is probably appropriate in view of the other changes (operator qualifications upgrading and control room design reviews) that may impact the role and necessity of the STA position.

This project has been funded in the amount of $120,000. In view of the controversy over the role and benefit of STAs, the benefit of this project in relation to costs should be substantial if the STA's role, qualifications, and necessity can be established on the basis of objective evidence of his contribution to operational safety.

A contract has been let to Battelle Pacific Northwest Laboratories (Human Affairs Research Center) to perform this work. It is too early to evaluate progress. The key to success lies in the methods by which the effectiveness of various STA roles and qualifications are "assessed", and how the question of his acceptance by other plant personnel in these roles is resolved. It may be difficult to establish an objective basis (criterion) for this assessment.

3.1.2.1.3(g) Analysis, Conclusions, and Recommendations Concerning Operator Licensing

Description

(1) Need

A vital component of the operational safety of nuclear power plants is the employment of qualified personnel. As a part of a major program to reassess its requirements regarding nuclear power plant personnel, the U. S. Nuclear Regulatory Commission (NRC) contracted to conduct an independent study of requirements and practices regarding the selection, screening, training, licensing, requalification, and performance of nuclear power plant operators and the training and qualifications of non-licensed operations and maintenance personnel.

(2) Objective

The objectives of this study were to evaluate the adequacy of current requirements and practices and provide recommendations in the following areas:

(a) selection, screening, and training of licensed operators,

(b) evaluation of operator qualifications (certification) by utility management,

(c) licensing of operators by the NRC,

(d) regulations, procedures, and practices employed by the NRC and utility management to assure continued competency of licensed individuals,

(e) adequacy of current regulatory requirements and NRC implementing guidance regarding selection, training, licensing, and requalification of operators,

(f) motivation and job satisfaction of nuclear power plant operators and relative compensation and status of these individuals compared to those in other high-technology fields where similar responsibilities are exercised,

(g) upgrading of all present operators to meet proposed program improvements,

(h) training and qualification of non-licensed operating, maintenance, and technical support personnel, and

(i) selection, training, and retraining of NRC examiners and staffing of the operator licensing organization.

(3) Work Effort

Field survey trips consisting of document research and personal interviews at the following locations were conducted:

(a) 9 nuclear power stations,

(b) 6 vendor- and utility-operated training centers,

(c) Institute of Nuclear Power Operations (INPO),

(d) NRC, Operator Licensing Branch (OLB),

(e) NRC, Region I Office of Inspection and Enforcement

(f) NRC, Headquarters Offices of Nuuclear Reactor Regulation (NRR) and Inspection and Enforcement (IE), and

(g) Office of 2 NRC Resident IE Inspectors.

Analysis, conclusions, and recommendations are provided in the following areas:

(a) Selection, training, and certification of control room operators,

(b) Effectiveness of the NRC operator licensing program,

(c) Method to assure continued competence of operators,

(d) Method for maintaining a highly motivated and dedicated operator work force,

(e) Upgrading of presently licensed operators to meet proposed requirements,

(f) Training and qualification of non-licensed, operating, maintenance, and technical support personnel,

(g) Qualifications of Operator Licensing Branch (OLB) examiners, and

(h) Organization of the OLB.

Performing Organization

Analysis and Technology, Inc.

Status

(1) Schedule: Work initiated May 1980; report completed 1 November 1980

(2) Resources: Insufficient data

(3) Products/Publications: NUREG-1750, Analysis, Conclusions, and Recommendations Concerning Operator Licensing, January 1981.

Evaluation

Each of the objectives is of high importance to the problem area. This is also the first comprehensive summary of the status of licensing and training in the nuclear power system.

This study was carried out in time to have a significant impact on NRC and INPO current programs. Insufficient research is available, however, to provide the data needed to complete the evaluations that were attempted.

This report provided a generally high quality compilation of information in a very short performance period.

The summary of current practices is of very high quality. The attempt to correlate supervisor ratings with other descriptive and performance measures (Section 2.3 of NUREG/CR-1750), however, was methodologically unsound. The conclusions from that analysis should not be trusted. The conclusions and recommendations presented throughout the report are mixed in quality. None should be accepted without reexamining the premises, data, and analysis on which they are based. The Job/Task Analysis was, in fact, incomplete as a Task Analysis, since the latter typically includes performance criteria for each task. The analysis included in the report is adequate for many of the objectives of the study, but caution is in order if one assumes that this analysis can be used to generate training requirements or licensing examinations. Volume II of our report discusses the data and research needed to conduct the evaluations of current practices.

3.1.2.1.3(h) Reactor Operator and Senior Reactor Operator Examination Validation

Description

(1) Need

NRC Task Action Item I.A.2.1 is directed at the improvement of the capability of operators to understand and control complex reactor transients and accidents. In order to bring about the types of improvements indicated in the Task Action Item, it is necessary to examine carefully the entire qualification process by which operators are selected, trained, and examined. Each of these three components constitutes a necessary and interrelated portion of the process, and each must be evaluated not as an entity unto itself but as a part of the overall process. The ideal operator is one who moves successfully through each component thereby becoming adequately trained to operate a nuclear power plant as determined by performance on NRC's licensing examination. At issue is whether the licensing examination reflects the adequacy of training and predicts the adequacy of performance.

(2) Objectives

The basic objectives of this effort are to produce some preliminary recommendations on how to increase the efficiency of the existing examination process and to gain some preliminary understanding of how the examination relates to performance. ORNL is to provide the following technical assistance to the NRC in support of these objectives:

(a) an analysis of the way in which the examination is administered,

(b) a statistical analysis of a sample of the examination scores for the oral and written parts and the written sub-parts,

(c) the development of some preliminary approaches to performance measurement, and

(d) an analysis of a sample of examination scores against the preliminary performance measures.

(3) Work Effort

Task 1. Evaluate Data Sources and Refine Validation Design

The purpose of Task 1 is to determine the availability of the data and the adequacy of methodologies required to complete the following tasks. Execution of Tasks 2 through 9 is dependent upon availability of operator and examination data, sizes of populations to be sampled for interviews, cooperation from industry and regulatory authorities, and the appropriateness of validation methodologies for the proposed study.

Task 2. Develop a Data Base on Reactor Operators

The purpose of this task is to secure from NRC files the operator-related data which are essential for completion of the validation effort. Because of the number of operators a sample will have to be selected. The scope of the information to be gathered for each operator and the size of the sample are to be decided after NRC files can be examined to determine the amount of information that is available and to determine the efficiency with which it can be retrieved. The ideal data base would contain examination scores for the licensing examination, the oral and written components of the examination, and the scores on the written subsections. Other data necessary for performing subsequent tasks would include identification of the examiner, the utility, the training program, and an indication of the operator's prior employment experience, level of education, and years of operating experience. The data will be entered into a newly created data base from NRC records via a computer program. The data base is to be designed so that it can be expanded and so that new information can be entered as it is gathered. A letter report will be provided to the NRC indicating the components of the data base.

Task 3. Perform a preliminary content and skill analysis of existing examination

An important step in the validation process is an analysis of whether the oral and written portions of the NRC licensing examination tap the knowledge and skills needed to operate a nuclear power plant. As an initial step for determining this relationship, ORNL will perform a content and skill analysis of a representative set of written questions and gather information on the content of the oral exam. Substantive areas covered in the examination will be identified, as well as whether content is generic or plant specific, and what skills are needed to answer various types of questions (e.g., rote memory, facility with mathematical formulas, etc). A content analysis of the examination is needed for any subsequent validation whether that validation is based on job performance or job content or both.

Task 4. Develop a description of the oral and written examination process

Review and document how the written and oral portions of the examination are developed, administered, and scored. An analysis of these processes is needed to better understand the validity of the current examination as well as to contribute to the development of recommendations for procedural changes which would streamline the examination process. These recommendations will be designed to help decrease the cost of administering the examination.

Task 5. Perform a statistical analysis of examination scores

Before attempting to validate the examination, it is necessary to understand how the various parts and subparts of the examination interrelate. This will give some clues to the range of skills, abilities, and knowledge that the examination taps. It is also essential to know how factors such as licensee background, the utility, and the examiner influence examination scores. Substantial variation in scores among examiners would be an indication of reliability problems.

Task 6. Provide NRC with recommendations for interim measures for the licensing examination process

Provide a report to the NRC recommending interim measures the NRC could adopt for the licensing examination process. These measures will aim at increasing the cost-effectiveness of the process without the sacrifice of any institutional or procedural credibility. Among the major thrusts of the effort will be an examination of possible ways to shorten the current examination and/or to develop more efficient means of administering the examination. These recommendations will be predicted on the findings available at that point from the NRC data base on operators, the analysis of NRC examining procedures, the content and skill analyses of existing examination questions, and the analysis of examination scores.

Task 7. Identify selected measures of operator performance on skill and knowledge dimensions which relate to the content of the examination.

Performance measures are used to determine whether a person is performing a job adequately. Such measures can range from a single rating of overall performance to a series of ratings for a wide variety of specific dimensions of performance. Performance dimensions can be subdivided according to type of behavior, and different types of behavior may be measured by different instruments. This kind of distinction makes it possible to differentiate between adequate performance on one dimension and inadequate performance on another. Performance categorized in terms of dimensions also makes it possible to determine whether job performance as an operator is related to performance on the examination. Relevant dimensions of performance would include skills, abilities, and knowledge specific to the ability to operate a nuclear plant, as opposed to dimensions of performance which would be generally applicable in any employment situation. This task is aimed at measuring dimensions of performance which are specific to the operations of a nuclear plant.

Task 8. Perform Pilot Validation Work

Once the preliminary list of dimensions of performance have been identified and instruments found or developed to measure as many performance dimensions as possible, the next step is to validate the relationship between job performance and examination performance. A complete validation procedure would require more time and resources than are contained in the scope of the present prject. However, a preliminary determination of the relationship between job performance and examination performance can be had by obtaining ratings of a sample of operators on the performance measurement instrument developed in Subtask 7.7. A pilot validation study of this type could be particularly useful for determining important areas of job performance which are not covered in the examination.

Performing Organization

Oak Ridge National Laboratory

Status

(1) Schedule: Begin FY82; end TBD

(2) Resources: FY81-$85K; FY82-$205K

(3) Products/Publications: Unknown

Evaluation

The many questions concerning the scope, reliability, and validity of current RO and SRO examinations makes the research objectives of "increased efficiency" of the examination process and "preliminary" understanding of how the examination relates to performance of unquestioned appropriateness.

The period of performance for this project is from October 1, 1981 to December 31, 1982. In view of the impact of examination content and procedures on operator licensing decisions, immediate and concentrated effort to resolve the many issues involved should be a matter of high priority.

This project has been funded in the amount of $290,000. The adequacy of this budget appear to hinge on the project objectives of developing "preliminary" recommendations for increasing the efficiency of the examination process, and preliminary understanding of how the examination relates to performance. The realized benefits from such "preliminary" project objectives may not be proportional to the investment. However, the budget is probably insufficient for a thorough program of alternative examination procedures development and validation against operational criteria whose relevance to actual on-the-job performance is well established.

A contract has been established with Oak Ridge National Laboratories to perform the required work. The project is too new to evaluate progress thus far. The work statements leave doubts about the varieties of examination formats that will be selected for study and the purposes behind some of the statistical analyses proposed (e.g., the use of factor analysis on the intercorrelations of scores on the subparts of the written examination). The validation effort evidently will employ only subjective appraisals of operator performance. A significant question that appears not to be addressed concerns the effects of (currently used) cutoff scores on the various parts of the examination and the impact of those cutoffs on the desired objective (i.e., assuring that the licensed candidate is fully qualified in all important respects).

3.1.2.1.3(j) Training and Examination Program Development

Description

(1) Need

NRC's primary mission is to ensure that nuclear power plants are operated in such a manner that public health and safety are protected. One of the key mechanisms for achieving this mission is to assure that qualified persons are licensed to operate reactors. NRC Task Action Item I.A.2.1 is directed at improving the capability of operators to deal with emergency situations.

In order to bring about the types of improvements indicated in the Task Action Plan, the entire process by which operators are selected, trained, and examined must be investigated and this process must in turn be related to job performance. At the present time the examination is the critical component of this process because it is the point at which the NRC determines an operator's capability. Major questions exist regarding the degree to which the training process adequately prepares operators in the skills and capabilities necessary to operate a reactor and the extent to which the present NRC licensing examination provides a valid prediction of operator performance. Better definition of the skills, knowledge, and capabilities required to perform the reactor operator tasks will be an integral part of the development and validation of an improved examination, as well as an investigation of the use of simulators in both the training and testing of operators.

This statement of work focuses on defining and validating the mechanisms essential for enabling the NRC to carry out the mission of examining reactor operators. Specifically, it is concerned with providing a state-of-the-art examination process and recommendations regarding acceptance criteria to be utilized for training programs and training centers.

(2) Objective

The two basic objectives of the effort are: (1) develop a validated NPP operator examination and examination process, and (2) develop guidelines and acceptance criteria for training programs at utilities and training centers.

(3) Work Effort

Task 1. Baseline - Problem Definition and Design of Methodology

This task involves the clarification and operationalization of objectives and the identification of processes and procedures to assist in directing the overall program.

Subtasks

a. examination data base development including analysis of present examination process and test items
b. develop criteria to be utilized in developing and using the data base in item analysis
c. design input and output program for analyzing the examination item bank
d. evaluate alternatives, select a data analysis program, perform item analysis, and establish individual item difficulty

e. define data needs for licensing examination and administration
f. clarify the operationalized objectives for this project and the related Examination Validation project
g. define the methodologies to be developed and utilized in preparing training program and training center guidelines
h. define and assess the appropriate validation methodologies for examination development and validation
i. assess the feasibility of the various validation methodologies
j. define data requirements for the validation process
k. establish criteria for test development and test validation
l. identify, define and establish requirements for those properties of the tests projected to be statistically analyzed.

<u>Task 2</u>. Develop and Identify Performance Measurers and Generate a Data Analysis Plan

This task involves a large amount of data acquisition from the industry to be utilized in assessing the adequacy of the current examination process and all proposed revisions to this process.

<u>Subtasks</u>

a. develop sampling frames and design sampling plan
b. define data needs
c. identify data sources and compile readily available information
d. develop data collection instruments and procedures
e. consult other potential sources of information (i.e., training manuals, expert opinion, researchers at places like TVA, persons knowledgable about practices in Europe, etc.) for information about performance measurement
f. Synthesize the input from various sources and use these materials to obtain additional input from experts in the field
g. collect job-audit data on the operator job activities
h. analyze job-audit data to identify major dimensions of job performance to be assessed
i. review operator training programs to identify key skills and knowledge content areas related to major dimensions of job performance

j. conduct a workshop for 10-12 persons (supervisors and other knowledgables) to identify dimensions of operator performance
k. identify job performance criteria for each content area
l. develop a list of performance criteria that should be measured in the examination process
m. develop criterion measures for each content area
n. develop procedure for establishing operator performance measures
o. develop methodology for obtaining operator performance measures
p. develop a data analysis plan addressing training, validation and performance measures to focus remainder of program effort.

Task 3. Develop Training Program and Training Center Guidelines/Acceptance Criteria

This task is concerned with an analysis of training programs, training center wit! regard to the relationship among the content of training programs, the key job-related knowledge, skills and abilities (KSAs) required of operators, the operator license tests, and training program assessment procedures.

Subtasks

a. collect data on content and procedures of training programs
b. analyze data to identify major KSA content areas, training methods, and evaluation procedures employed
c. assess discrepancies in licensing examinations and training programs' interface
d. assess relationship among training programs, training centers, and licensing examinations
e. collect data from NRC, operators, and industry personnel on problems with existing examinations
f. provide recommendations regarding major KSAs to be included in training programs to improve the fit between program content, training, and licensing examinations
g. develop interim evaluation criteria

Task 4. Develop a Reactor Operator Examination Process

This task is directed to the resolution of the use of simulators and the overall examination process.

Subtasks

a. review literature on methods for evaluating performance on simulators

b. inventory the use of simulators in examinations and evaluaton in non-nuclear industries and in the nuclear industry in foreign countries
c. evaluate the necessity of doing an analysis of the impact of examiner-examinee interaction in the simulator examination
d. develop an interaction analysis scoring form for scoring examiner and examinee interaction
e. using trained observers and the interaction scoring form developed in the previous task. observe all or part of 50-75 oral examinations and score examiner-examinee interactions
f. combine the data from the interaction scoring forms and examination results and then perform an analysis of the data
g. develop recommendations for improving the existing simulator examination
h. develop dictionary of knowledge, skills and abilities (KSAs) critical to each content area to be examined (both cognitive and psychomotor or cognitive only, depending on the scope)
i. develop test items for each KSA and construct paper & pencil tests
j. develop alternate administration and scoring procedures for cognitive tests (e.g., mail-out, on-site, computer-scored, etc.)
k. develop alternate procedure for psychomotor test (walk-through, simulator, etc.)
l. construct long-form alternate tests for pilot testing

Task 5. Pilot Testing of Preliminary License Examination

Subtasks

a. select samples of operators for inclusion in the pilot study
b. administer alternate tests and procedure to samples of operators
c. collect data on job performance of operators
d. collect data on test performance

Task 6. Analyze Pilot Test Data

Subtasks

a. statistically analyze relationship between test performance and job performance ratings (regressive criterion validation)
b. compare results of analyses for alternate tests and procedures; compare results from various training centers
c. factor analyze to validate test construction (construct validation)

d. perform statistical analyses of test reliability, internal consistency, item discrimination, etc.
e. based on data analyses, recommend tests and procedures that meet requirements of validity, reliability, length, labor intensity, respondent burden, etc.
f. provide recommendations regarding effective training mechanisms

Task 7. Provide Final Recommendations Regarding Operator Licensing Examination and Training Center/Program Criteria

Subtasks

a. provide final recommendations regarding guidelines for training program content, methods, and assessment procedures
b. provide final recommendations with supporting data on new RO and SRO examinations with regard to content, form, administration, scoring, and interpretation

Performing Organization

Oak Ridge National Laboratory

Status

(1) Schedule: Begin FY82; complete FY84

(2) Resources: FY82-$376K; FY82-$300K; FY84-$300K

(3) Products/Publications: None at present

Evaluation

The objectives of this program are considered to be of high priority by the Study Group. This effort represents a systematic approach to the intertwined problem areas of selection, training, and examining.

A key element of the work effort is the task to "develop and identify performance measures and generate a data analysis plan." This task is totally dependent on the existence of an acceptably comprehensive task analysis and training programs which would be forthcoming from other current programs within the NRC and INPO. This dependency creates some risk in the timing of this program.

If the necessary data are available for the analysis, then this program is appropriately funded for the potential outputs.

This program is highly dependent on the quality of the data supplied to it from other sources. The background information supplied to us for this assessment, however, indicates a very high level of understanding of the total problem, so that we feel confident that the input data will be adequately evaluated and that the technical quality will be properly monitored.

3.1.2.1.3(k) Plant Operator Qualifications

Description

(1) Need

Several attempts have been made to establish appropriate educational, training, and experience requirements for licensed operators of nuclear power plants. The most recent presentation to the Commission was made on June 18, 1981. As a result of that meeting, the Commissioners directed the staff to formulate a peer review panel, hold workshops, solicit comments from the industry, and report on progress to the Commission, scheduled for January 1982.

(2) Objective

To assist the NRC in developing alternative approaches for establishing reactor operator qualifications.

(3) Work Effort

Task 1. Establish Peer Review Panel

This task involves establishing a peer review panel of federal employees with selected outside consultants. The panel will meet to evaluate and act on the alternatives developed by the NRC and industry, the results of the workshop, and on the input provided by other interested entities. The panel will be asked to review past proposals and reports on foreign experience, propose workshop participants, be represented at workshop(s), review new proposals from the NRC, industry, or others, review the recommendations from the workshop, and develop a recommended course of action.

Task 2. Conduct Workshop

This task involves developing and conducting a workshop involving various affected parties, i.e., operators, utility management, and other representatives of the nuclear industry, with training professionals and academicians, in a forum to discuss the pros and cons of operator qualification issues.

Task 3. Synthesize Overall Position

This task involves identifying and analyzing the state of the art with regard to qualifications of personnel in jobs similar to that of the reactor operator. Alternative approaches will be presented to the peer panel and the workskhop for their consideration. An overall synthesis will also be made of the state of the art combined with panel and workshop results.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: FY81 to FY83

(2) Resources: FY81-$150K; FY82-$50K; FY83-$50K

(3) Products/Publications: Unknown

Evaluation

Since current qualification standards for operator personnel involve various proposed mixes of prior power plant experience, education, and training, the objective of this task, which is to assist NRC in developing alternative approaches to establishing reactor operator qualifications, is highly appropriate.

The period of performance for this work extends from August 10, 1981 to December 31, 1982. This seems to be more than ample time for a problem of some urgency.

This program has been funded to the extent of $250,000. There are major issues concerning tradeoffs between "experience" and formal education requirements for operator personnel that need to be resolved. If this program is successful in achieving an objective basis for the resolution of such issues, the benefit related to the costs involved will be substantial.

A contract has been let to Battelle Pacific Northwest Laboratories (Human Affairs Research Center) to perform this work. Success of the project appears to depend heavily on inputs from a peer review panel and a workshop of industry representatives from various affected groups. The fundamental difficulty in establishing operator qualifications so as to reflect acceptable mixes of formal education, training, and prior operational experience stems from the lack of objective criteria against which to validate these variables, either independently or in combination. One of the most difficult aspects of the problem is the matter of defining "experience" in terms that are operationally meaningful. A solution to the problem of evaluating alternative proposals, or formulating new ones, fundamentally depends on the ability of the contractor to deal with this issue as well as the matter of optimum weighting of various proposed qualification variables. It seems unlikely that this can be done satisfactorily in the absence of objective criterion measures of operator effectiveness.

3.1.2.1.3(1) Operator Feedback Workshops

Description

(1) Need

The NRC Task Action Plan indicates that the Office of Nuclear Reactor Regulation should develop a Commission paper on NRC training workshops for licensed personnel. The Division of Human Factors Safety has received information comments from operators and others, including the Commissioners, that indicate the desirability of conducting such workshops. There is clearly a need to determine the effectiveness of workshops in obtaining feedback from operators, and also to determine whether there may be more effective ways of obtaining this feedback.

(2) Objective

To conduct four workshops in order to obtain feedback from plant operating staff on issues of concern to the NRC.

(3) Work Effort

Task 1. Conduct Workshops

This task involves developing and conducting four workshops, varying the size, participation, and format, as appropriate. The letter reports on each workshop will address both the issues of the workshop and the effectiveness of the workshop process in obtaining feedback.

Task 2. Assess Workshop Effectiveness

This task involves assessing the overall effectiveness of workshops for obtaining operator feedback, including recommendations, as appropriate, on size, participation, format, and other parameters affecting the success of this approach.

Task 3. Assess Alternative Approaches

This Task involves a summary evaluation of other approaches to obtaining feedback to determine whether any alternative appears more promising than workshops.

Evaluation

The objective of having an effective feedback mechanism to NRC from plant operating staff on issues of concern to NRC, and the development of methods whereby valid, representative feedback can be obtained is of unquestioned value to the NRC's mission.

Work on this project started on September 1, 1981, and is to be completed December 1, 1982. In view of the many critical problems whose solution would appear to benefit by candid feedback from operator personnel, the time frame might well be indefinite, if the technique proves successful.

A total of $150,000 has been allocated to this project. This should be more than enough to reach the stated objectives. Provided a feedback mechanism is established which has continuing value not only to the NRC but to the entire industry, the benefits could far outweigh the costs.

A contract has been let with Battelle Pacific Northwest Laboratories (Human Affairs Research Center) for the performance of this work. Feedback is sought from operators on issues affecting safety, staffing, and plant drills. It is expected that the procedure will serve as a "sounding board" for future policies and actions and provide for participation of the personnel who may be most affected by proposed solutions to these operational problems. Alternative approaches to workshops are also to be considered and evaluated.

It is clear that whatever the operator feedback mechanism is it should be beneficial not only to the interests of NRC but to the industry if it is to be a program of continuing benefit. Behavioral theory relating to innovation acceptance would suggest that participation of the affected personnel is a key ingredient to their acceptance of change. It is important therefore that those responsible for this program recognize that it is likely to succeed only to the degree to which it benefits all parties involved.

3.1.2.1.3(m) Plant Drill Guidelines

Description

(1) Need

The NRC Task Action Plan (Item 1.A.2.5) indicates that guidelines are needed for dealing with in-plant drills to be conducted by plant shift operating personnel. The conduct of these in-plant drills is limited by the practical restrictions of not interfering with the safe and reliable operation of the facility. However, these restrictions can be adequately addressed by varying the types of plant drills: perform, walk-through, observe, and discuss. Drills will also be required to test the adequacy of plant procedures -- operating, abnormal, and emergency (73, Recommendation 1.3).

(2) Objective

To develop and recommend guidelines for licensing actions regarding the implementation of an effective program of plant drills. These guidelines will consider types of drills required, their practicality, frequency, and timing depending upon plant operating mode.

(3) Work Effort

Task 1. Define List of Drills

This Task involves developing a list of drills which should be conducted, and categorizing the drills into those that can be performed at the plant, those that can only be performed at a simulator, and those that involve both plant and simulator operations.

Task 2. Develop Preliminary Guidelines

This Task involves developing preliminary guidelines for the conduct, evaluations, and frequency of each recommended drill, including which plant personnel should be involved and the use of simulators, as available.

Task 3. Pilot Test Guidelines

This Task involves assessing the effectiveness of the preliminary guidelines in implementing a drill program at representative nuclear plants.

Task 4. Develop Final Drill Guidelines

This Task involves developing final guidelines based on the pilot test experience and industry comment.

Performing Organization

Battelle Pacific Northwest Laboratory

Status

(1) Schedule: Start in FY82; complete in FY83

(2) Resources: FY81, $75K; FY82, $105K

(3) Products/Publications: None known.

(4) Related Activities: This program interacts with procedures development with licensing and training program development

Evaluation

The objectives have an apparent deficiency in the lack of a task to define an objective procedure in which drills should be selected or designed and the evaluation criteria for performance. The work effort appears to indicate that drills will be selected on the basis of prior practices in related endeavors (e.g., U. S. Navy, foreign utilities, etc.). Drills should be based on an objective analysis of the job requirements, and should also be an integral part of an Instructional System Development program for refresher training.

This project may be premature in the absence of an adequate data base for an objective analysis. The results may be adequate on an interim basis for the evaluation of current procedures.

Considering the inadequacy of the currently available data base, the early-years investment is not likely to lead to a long-term solution. For an interim solution, this program is overfunded.

3.1.2.1.4 Operator Licensing Branch: Program for the Administration of Reactor Operator (RO) and Senior Reactor Operator (SRO) Examinations (Typical Contractor Effort)

Description

(1) Need

In order to carry out an effective program of reactor regulation, the Nuclear Regulatory Commission (NRC) examines not only the safety aspects of the design, fabrication, and functioning of plants and components, but also the qualifications and organization of personnel associated with quality assurance and safety. Of obvious importance in the "human element" of reactor operations are the qualifications of those who handle the controls, all of whom must be licensed individually by the NRC.

The NRC presently issues two types of operating licenses. In general, anyone who manipulates reactor controls must be licensed as a reactor operator, while those who direct the activities of licensed operators must be licensed as senior reactor operators. Practically speaking, the reactor operator would be the control room operator, and his immediate supervisor would normally be the senior reactor operator.

(2) Objective

The objective of this effort is to assist NRC in the process of licensing commercial reactor operators. The scope of the task will include examination preparation, the conduct of examinations in the utility facility (both written and oral), grading examinations, and making pass or fail recommendations to the NRC regarding applicants for operator and senior operator licenses pursuant to 10 CFR Part 55.

(3) Work Effort

Task 1. Orientation

Extensive orientation will be required to prepare personnel for conducting the examinations. During FY81, the goal was to completely staff this task and complete their orientation program. (The complete staff for this effort will consist of a manager, secretary, 10 full-time examiners, and 2 half-time afternative examiners.) The orientation of persons selected will begin with a review of nuclear reactor theory conducted by the Office of Inspection and Enforcement (OI&E) personnel. Following completion of the initial orientation, these personnel will be sent to the simulator training school to train on specific Westinghouse and General Electric (GE) reactor systems for a one-week period. The personnel will then spend four weeks in an operating commercial plant (to be arranged by NRC). The NRC will provide a one-week orientation regarding the overall conduct of the licensing procedures. Personnel will then be assigned to prepare an examination to be critiqued by NRC personnel. In-plant orientaton will be accomplished in two parts: (1) a visit to a plant to observe a qualified examiner conduct while being observed by a qualified examiner. Upon satisfactory completion of the orientation period, the contractor will make a recommendation regarding the readiness of its employees to conduct tests on its own for the NRC. The NRC will then conduct its examination. The candidates, upon successful completion of the NRC's examination, will then be considered qualified to conduct operator examinations on their own.

Task 2. Examination Grading

During the process of completing Task 1, assistance will be provided by the NRC. This assistance will consist of grading the written part of operator examinations conducted by NRC personnel.

Task 3. Operator Examinations

The contractor will complete up to 100 operator examination trips per year to facilities designated by the NRC for the purpose of conducting operator testing. Examiners will be responsible for preparation, administration, and the grading of examinations for operators from facilities assigned by the NRC.

The Nuclear Reactor Regulation (NRR) question bank for test preparation will be provided to the contractor for inclusion in its word processor. Funding will be provided to implement and maintain the question bank.

Task 4. Maintenance of Staff

Two alternative examiner candidates per year will be selected and oriented in a program similar to that conducted in Task 1. These people will provide backup to compensate for turnovers in the organization.

Performing Organization

The following organizations administer licensing examinations under contract to the NRC: Idaho National Engineering Laboratory; Oak Ridge National Laboratory; Pacific Northwest Laboratory; Rockwell International; United Nuclear; and Energy Technology Engineering Center.

Status

(1) Schedule: Operator licensing is a continuing process. Each year approximately 20 percent of all ROs and SROs will receive a written examination and 100 percent of all ROs and SROs will receive a simulator examination. Every licensed operator has to requalify every five years on the written examination. Licensing examinations are also given to initial applicants, both hot and cold or NTOLs, and replacement applicants who transfer from one facility to another.

(2) Resources: The cost for administering license examinations has been on the increase for several years and will probably continue to do so unless the examination procedure is streamlined, or the number of examinations given is reduced. For FY82 the cost is $4,040K; FY83 is in excess of $4,000K.

(3) Products/Publications: Each examiner prepares annually an evaluation of his experience with the licensing process and may make a presentation to the Operator Licensing Branch (OLB)

Evaluation

Periodic administration of knowledge and competency examinations is a critical requirement for continuing quality control of RO and SRO performance. Increased emphasis on examinations conducted in the simulator is viewed as a positive step toward achieving a more operationally relevant balance between required theoretical knowledge and demonstrated skill in performing functions required for normal, off-normal, and emergency situations. Obviously, the quality of the examiner personnel is critical to the success of this program. They should not only have extensive backgrounds in control room operations but appreciation for test theory, including an understanding of all of the issues associated with examination scope, reliability, objectivity, item construction techniques, scoring procedures, components of variance in developing composite measures of performance, and so forth.

The extensive examining load necessitated by the requirement to administer written exams to 20% of all ROs and SROs annually and, more particularly, simulator exams to 100% of all such personnel, makes the matter of qualifying adequate numbers of examiners a matter of considerable urgency.

The costs of this program are high. However, if the examinations are developed and administered in a fashion that guarantees their effectiveness as diagnostic instruments of operational skill and knowledge deficiencies that need to be corrected before licensing, then the benefits in terms of increased probability of safe operations are immeasurable.

The ability of this program to reach its objectives will depend heavily on the criteria employed for the selection of examiner personnel, the quality and scope of the training program administered to them by the NRC, and the skill brought to the process of utilizing simulators as a vehicle for examination. The administration and scoring of practical performance examinations in simulated operational systems requires considerable sophistication if comprehensive and reliable results are to be achieved. Particular difficulties arise in the judgement of whether specific aspects of performance were "satisfactory." There is room for considerable subjectivity in these processes and many of the advantages of simulator testing could be lost if different examiners employ different standards of evaluation or are differentially selective of test tasks because of their own particular technical backgrounds. Some members of industry report that in the past it has been easy for an operator to "snow" an examiner in the simulator. Clearly, if simulator examinations are to play their proper role, and they potentially are a highly important key to improved operator qualifications, the examiner must be as sophisticated in control room operation as is the operator being examined.

There are also technical problems to be solved concerning the scope of the simulator examination, the number of "items" (tasks or elements of performance) that must be used to get reliable performance data and possible problems in translating operator responses irto satisfactory performance metrics. The criterion for "pass-fail" will be a particularly critical decision and considerable attention needs to be directed toward this and the other measurement problems associated with performance testing in simulators during the training and qualification of the examiner personnel.

3.1.2.2 Division of Facility Operations, Office of Nuclear Regulatory Research

3.1.2.2.1 Human Factors Engineering Research

Human factors research programs, as of the end of September 30, 1981, were consolidated under the cognizance of the Division of Facility Operations, Office of Nuclear Regulatory Research. Almost all of the human factors research is developed by the Human Engineering Section of the Human Factors Branch. Two past projects were sponsored by the Safeguards Branch. Many of the projects were started under a different organizational structure, but the historical origins will not be traced in the project descriptions which follow, unless there is some importance to the historical perspective.

The Human Factors Branch currently has approximately 8 employees, of which one is a career human factors professional, although there are presently several jobs open. The research budget has grown from less than $1 million at the time of the TMI accident, to approximately $3 million for FY81 and an estimated $5 million for FY82. A projection of future funding is shown in Figure 9. Almost all of the work is done under contract, predominantly to the Department of Energy National Laboratories, who in turn use many subcontractors. It appears that the amount of work contracted by the NRC will increase beginning in 1982, although the DOE National Laboratories will be the predominant resource of organizations for human factors research.

Research can be either confirmatory or exploratory. Confirmatory research is undertaken to confirm a regulatory requirement or position which has been adopted because of some safety concern. Thus, many actions are initiated on the basis of the opinion of the NRC technical staff and later confirmed

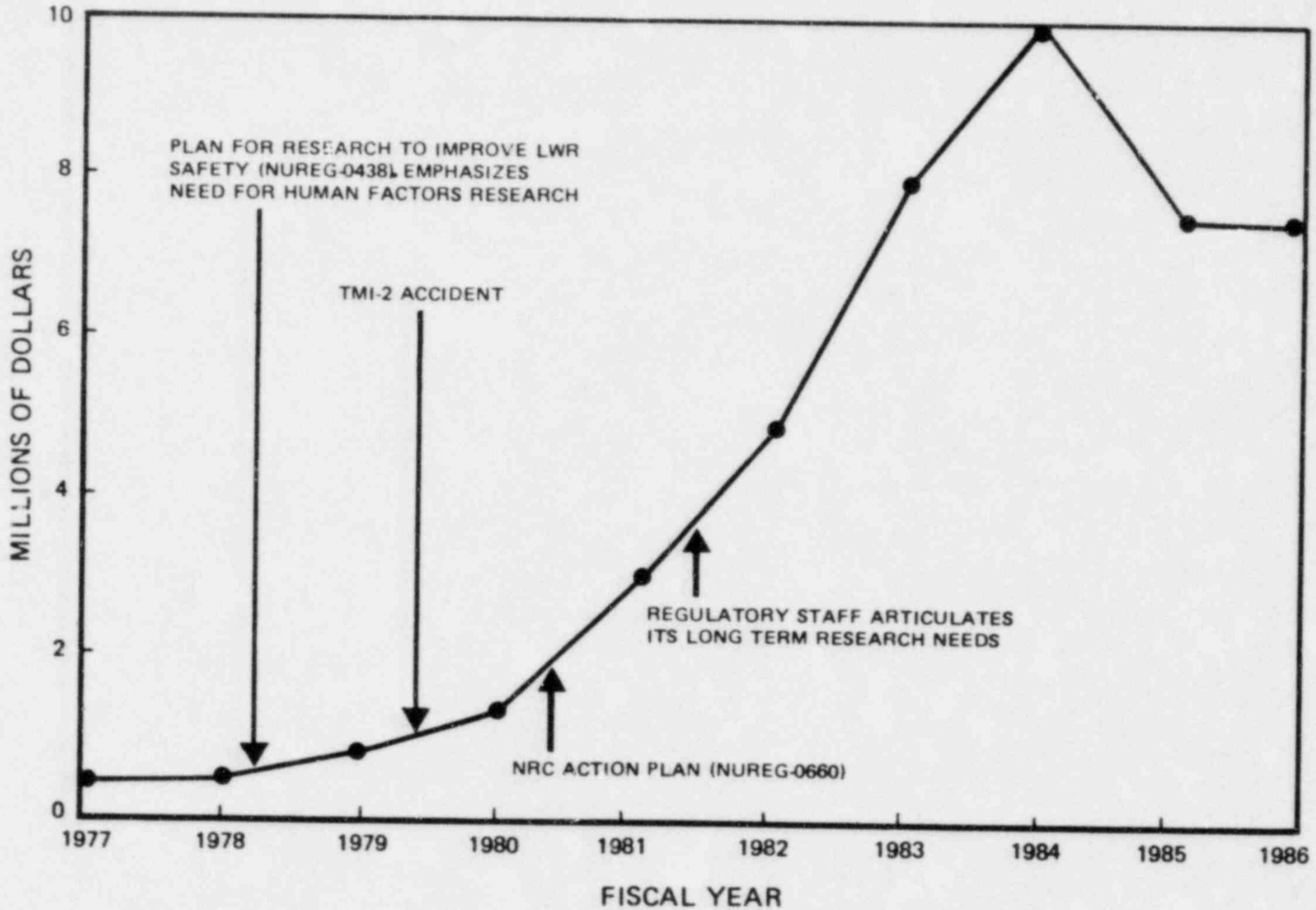

FIGURE 9. SIGNIFICANT INCREASE IN HUMAN FACTORS RESEARCH IS UNDERWAY.

by research. Exploratory research is done in anticipation of a regulatory requirement, and thus can provide evidence prior to the establishment of regulatory requirements. No basic research is performed at NRC, as this is the province of the Department of Energy in areas related to nuclear power.

The majority of the research projects have to be endorsed by one of the other NRC Offices (NRR, IE, NMSS). This research is usually confirmatory research. Projects of an exploratory nature can be originated within the Office of Nuclear Reactor Research, but are usually coordinated with some "user" group in one of the other offices. The biggest sponsor of research is the Office of Nuclear Reactor Regulation, specifically the Division of Human Factors Safety. In March 1981, NRR research needs for human factors safety were transmitted to the Office of Nuclear Regulatory Research. In November 1981, the latest priorities for these research needs were established and the needs were classified into three groups. Group A needs were high priority and designated for initiation in FY81, if possible. Group B needs were medium priority and were designated in FY82. Group C needs were lower priority to be carried out in the period from FY83 to FY87. The NRR research needs and their priorities are listed in Table 4.

Research projects are not carried out on a one-for-one basis with the NRR research needs identified above. Many of the research needs are being satisfied through one or more projects. The project descriptions which follow account for the research work as it is funded and contracted. Occasionally project names have changed, and in such cases the latter title is used and reference is given to the former project title if it is important. Projects are described in sufficient detail to give the reader adequate understanding of the project to be able to review the evaluation made of that project by the authors of this report. Each project is presented separately on the pages which follow.

3.1.2.2.1(a) Plant Status Monitoring

<u>Description</u>

(1) Need

The need of the control room crew to be aware of plant status at all times was dramatically revealed during the TMI accident. The information available to the operators should be as direct as possible and require minimum interpretation or inference. One key ingredient to determining the necessary information requirements is to analyze accident signatures in

TABLE 4

NRR RESEARCH NEEDS

Priority Ranking	
	Group A - FY81
1	Task analysis
2	Plant procedures
3	Operator examinations
4	Validation of SS, SRO, STA & RO education and training requirements
5	Organization and management
	Group B - FY82
6	Capability of training simulators
7	Shiftwork and overtime effects on operator performance
8	Evaluation of human factors engineering data
9	Validation of control room modifications
10	Plant maintenance
11	Effects of post-TMI requirements on operators
	Group C - FY 83-87
12	Research dependent on advanced simulators
13	Automatic plant operations
14	Task analyses for operations support activities
15	Code applications for startup test programs

detail to permit unambiguous definition of system status during accidents. Procedures and instrumentation can then be reviewed for adequacy and requirements established for new ways to augment operator capability.

(2) Objective

To improve the ability of reactor operators to prevent, diagnose, and properly respond to accidents.

(3) Work Effort (FY81)

<u>Task 1</u>. Develop Diagnostic and Action Aid Algorithms

(a) Identify key parameters and acceptable bounds (i.e., if key parameters are all within bounds, normal operation is expected and no operator action is necessary). These key parameters are analagous to inputs to the plant protection system.

(b) For each key parameter, indicate the significant upset conditions (i.e., reactor water level, rapid drop below level A, slow drop to level C, etc.).

(c) For each of the upset conditions, identify the potential initiating events which could be the cause (e.g., small LOCA, steam line break, steam generator tube rupture, overcooling, all can cause initial RCS pressure drop).

(d) Identify the additional information the operator would need to unambiguously discern the initiating event (i.e., more detailed behavior of key parameters which indicated upset, additional parameters, etc.).

(e) Develop the logical decision process the operator should take to diagnose initiating events. This would take the form of: Given that RCS pressure is dropping, look at parameters B, C, D, and E. If B is within normal bounds, the initiator cannot be in LOCA. If parameters C and D are rapidly rising, it must be either initiator 12 or 13. If parameter E is dropping, then it must be 13.

(f) Develop the logical decision process the operator should take at each of the branch points in the event trees developed in FY79 and FY80.

<u>Task 2</u>. Review and Evaluate Existing Operating Procedures

(a) Select a specific plant, preferably one for which the sequence evaluations were performed.

(b) Review specific operating procedures to determine operator response to events associated with import¯nt sequences.

(c) Interface with plant operators to obtain a thorough understanding of operator actions and concerns in response to events of risk significant sequences.

(d) Utilize plant status monitoring methodology (logic structure of operator action event trees and systematic sequence evaluation to assess the effectiveness of existing procedures).

(e) Prepare a report which summarizes the methods for examining procedures and recommendations for improvement of the: (1) procedures per se, and (2) presentation and organization of procedures.

<u>Task 3</u>. Develop Detailed Accident Signatures Suitable to Allow Unambiguous Definition of System Status During Accidents

The objective of this task is to determine the time dependent behavior and interrelationships of key plant parameters for selected accident sequences. The results of this task will provide the necessary input to allow completion of Task 1. Accordingly, the extent and required detail of the analysis will be defined by the informational needs identified in the performance of Task 1. The subtasks listed below represent the continuation and composition of efforts initiated in FY80:

(a) Identify and prioritize the specific accident sequences for which accident signatures are required. This list will be comprised of those sequences identified in Task 3a of the FY80 workscope as well as additional accident sequences identified as requiring signatures in Task 1 of FY81.

(b) Using the results of Task 3b and 3c of the FY80 work (in which the applicability and availability of appropriate computer codes were assessed and already existing analyses were used to develop a limited number of the required accident signatures) as a starting point, develop complete accident signatures identified in Task 3a above.

(c) Review the results of Task 3b and identify any overlapping accident signatures (this will have been performed in FY80 for the limited number of available signatures identified). This involved the determination of key parameters that behave in a very similar way (including considerations of uncertainties for one or more accident conditions, thereby making unambiguous diagnosis of the plant state based on these parameters impossible). Identify alternative parameters whose behavior could be used to differentiate these accident conditions. Also, review results to assure that signatures would not be significantly affected to small changes in the input assumptions or data.

(d) Incorporate the knowledge gained into sample operational aids which might assist reactor operators to prevent, diagnosis, and respond properly to reactor accidents.

Performing Organization

INEL

Status

(1) Schedule/Priority: started in FY80; complete in FY81

(2) Resources: FY80 unknown; FY81-$450K

(3) Products/Publications: (a) NUREG/CR-1440
(b) NUREG/CR-2100
(c) NUREG/CR-2278

Evaluation

The objective of this effort is appropriate because the results should help determine diagnostic and decision aids that will facilitate the operator during normal and off-normal situations. Properly developed decision aids will allow the operator to recognize a problem or potential problem sooner and provide guidance on verified actions that mitigate the situation. Reviewing existing procedures and soliciting operator concerns should help describe the user population and help determine user acceptance criteria. The procedure review should also identify areas where improved formats would be useful, as well as provide input to NRR's overall plan for improving all procedure types. The final task area will provide sample operational aids that can be evaluated in an operational plant. If successful, the methodology used to develop the operator aids can be used by other nuclear power plants to develop operational aids once requirements for such aids have been established. This effort, however, should be coordinated with the other INEL efforts that have implications for improving operator performance, specifically the augmented operator capability and the CRT display design programs. An overall objective should be established and definitive task areas prioritized.

This is a timely effort because existing, as well as new, power plants are being required to perform a system review (NUREG-0700) of the control room. When completed, the need for operator aids, if any, will be identified.

If the effort is completed as described, the results will benefit all nuclear power plants and more than justify the reasonable investment cost. Unfortuntely, if this effort and the other two aforementioned efforts are not coordinated, redundant and unnecessary research will be performed.

With the effort being performed at INEL, additional resources (other than those presently available at INEL) will be required. The effort represents a 4-6 person-year resource comprising career human factors professionals, system analysts, decision science analysts, psychometricians, and subject matter experts with operational experience.

3.1.2.2.1(b) Augmented Operator Capability

Description

(1) Need

The man-machine interface in nuclear power plant control rooms, especially the visual display techniques, designs, and characteristics, is changing. The change emanates from two major events: recognized human factors problems surfaced because of the Three Mile Island accident and newly specified requirements for control room information, such as the Safety Parameter Display System, technological changes in computer based data management systems, and new display techniques as represented by CRTs and video terminals. It is necessary to investigate long-term strategies for improving the display and integration of diagnostic information in reactor control rooms and for developing experimental facilities to assess the impacts of these changes.

(2) Objective

Analyze new man-machine operational display concepts and their effectiveness in enhancing operator capability.

(3) Work Effort (FY82)

Task 1. Effects of Control Room Modifications

1.1: Complete a literature survey and critical review of the basic data indicating the effects of changes in instrumentation and control board modifications on operator performance especially emphasizing high stress situations.

1.2: Report on the results of this review by February 1982, including recommendations on the need for and nature of experiments to resolve outstanding issues.

Task 2. Advanced Display Concepts

2.1: Investigate the applicability of advanced graphic display concepts for assisting reactor operators during accident conditions. Concepts to be investigated include:

(a) JANUS displays (which combine plots of historical trend informaton on the left half of the CRT with plots of predicted trend information on the right), and

(b) Response trees (which present to the operator the availability of flow paths for delivering water to the core).

2.2: Demonstrate these concepts on the ODDS-II system. (Note that the development and implementation of an experimental design to evaluate these displays is not covered in this Statement of Work. Such activity, if performed, is within the scope of A6308.)

2.3: Report on the results of this task by March 1982.

Task 3. Graphic Display Research Facility

3.1: Define the functional requirements of a research facility intended to satisfy the NRC's needs to:

(a) Develop and/or confirm the adequacy of design and evaluation criteria for computerized graphic displays and other information presentation methods, and

(b) Assess the effects of various display concepts on operator performance.

3.2: Develop a Systems Requirement Document for such a facility. The document should consider the objectives of the facility; the necessary hardware, software, and personnel capabilities; and the potential costs of construction and operation. Special care should be given to avoid tailoring the Systems Requirement Document to any specific currently existing capabilities.

3.3: Report on the results of this task by January 1982.

Performing Organization

INEL (with Georgia Tech, Boeing, SAI, and Hartford Graduate Center)

Status

(1) Schedule: Started in FY80; completion in FY82

(2) Resources: Prior to FY82 unknown; FY82-$300K

(3) Products/Publications:
- (a) NUREG/CR 2147
- (b) NUREG/CR 1995
- (c) Nelson, W. R., "Response trees for emergency operator action at the LOFT facility," CONF-800403, Proceedings of the ANS/ENS Topical Meeting on Thermal Reactor Safety, Knoxville, TN, EG&G/Idaho, Inc., April, 1980
- (d) Kline, M. E., "LOFT system design description: operational diagnostics and display system." EG&G/Idaho, Inc., January 1980.
- (e) Nelson, W. R., "Response trees for detection, diagnosis, and treatment of emergency conditions at the LOFT facility." Master of Science Thesis, University of Washington for EG&G/Idaho, Inc., October 1980.

Evaluation

Most of the described need is well-stated and realistic; however, the need to develop a distinct research facility is questionable. The stated objective to analyze candidate display concepts is desirable.

In general, the tasks are sufficiently described and the effort would be timely if the tasks were completely valid.

Task 1 may not reveal much in the way of usable empirical data, especially for high stress situations, but an attempt to find such data is desirable. The funding level is not great, so if no pragmatic data are uncovered, the financial risk is small.

Task 2 is highly appropriate, though it assumes graphic displays are an optimal solution. They may be, but other candidate formats should not be excluded from study. The funding level is realistic.

Task 3, calling for specification of a research facility, is not necessary. Substantial research facilities exist at various national laboratories as well as at academic and industry locations. Research into the stated problem/objective area does not need to be conducted at a singular facility. Basic facility requirements, such as computers, display terminals, research staff, accessibility to test subjects, etc., are not mysterious and no Systems Requirements Document seems necesary. Funding for this task is not necessary or desirable.

3.1.2.2.1(c) Operational Aids for Nuclear Power Plant Operators

Description

(1) Need

Beginning with WASH-1400 and continuing through several analyses, investigatory findings and research results is the theme: the entire subject of man-machine interaction must be treated holistically with the operating crew included as a system element. It is necesary to not only define reactor crews' organization and responses to the work environment, but also to build on a number of seemingly disparate research results, methods and techniques, and man-machine interface models. It is necessary to develop and assess the allocaton of functions between operating crews, crew aided display and control systems, and fully automatic systems. The research program should focus on the development of criteria for evaluating the effects of different mixes of allocations between man and machine, analyze the impact of automation on the human component in the nuclear power plant, review and assess operational aids under development by industry, and continue feasibility studies of modeling the operator-plant interface.

(2) Objective

Provide the technical basis for developing design requirements, developing review criteria, and assessing the impact on safety of methods to enhance the capability of reactor operators.

(3) Work Effort

Oak Ridge National Laboratory will continue the function allocation development and analysis, and evaluate automated systems and operational aids.

Task 1. Evaluate Engineered Safety Features for level of automation, man-machine interaction, and decision points for operator control. Perform analysis with selected PWR and BWR nuclear power plants. Document the analysis for each plant, include the results of a survey of automation in different ESF systems.

Task 2. Complete the development and documentation of criteria for allocation of task or function. Apply the criteria to a selected ESF system. Document the approach used, criteria identified, and application.

Task 3. Perform a survey of domestic process industries and selected foreign nuclear power plants to determine the impact of changes and degrees of automation on operator selection, training, qualification, performance requirements such as vigilance, skill maintenance, or information requirements and attitudes. Document the findings for the subject areas surveyed and such changes as might have occurred in operator monitoring and control.

Task 4. Complete the review and assessment of operational aids. Include a description of the aid, ORNL's perspective of its adequacy and effectiveness, safety implications regarding its use in a control room, new developments since the last report and progress notes. Document the findings.

Task 5. Report the findings and recommendations of the feasibility and need study of a man-machine interface model. Continue investigations in accordance with a plan to be approved by NRC.

In FY81 the project focused on the following tasks.

Task 1. Define the operating crew requirements (role) for a nuclear power plant.

Task 2. Define the functional and safety design requirements placed on operator aids.

Task 3. Develop methods to characterize operator aid systems as to their potential safety impact.

Task 4. Develop a repeatable procedure for assuring consistency in application of methodology described in Task 3.

Task 5. Monitor and assess the development of an operational aid system such as the DOE/EPRI DASS development and the SRL disturbance monitoring system.

Task 6. Characterize maintenance and testing aids as to their impact on safety.

Task 7. Investigate the feasibility of developing and applying an integral analytical model of the operator-machine interface in nuclear reactor control rooms.

Performing Organization

Oak Ridge National Laboratories/BioTechnology (allocation of functions), BBN (man-machine interface modeling).

Status

(1) Schedule/Priority: This project started prior to FY81 and will continue beyond FY82. NRR priority 13, Automatic Plant Operations, is related to this project.

(2) Resources: FY80 unknown; FY81-$500K; FY82-$300K; FY83-$300K

(3) Products/Publications:

(a). W. H. Sides and J. L. Anderson,"Trip Report - Automatic Diagnosis of Alarms: A System to Improve Operator Emergency Response at Savannah River Laboratory Reactors," Oak Ridge National Laboratory, August 1980.

(b). W. H. Sides, et al., "A Survey of Proposed Functional Requirements for a Disturbance Analysis and Surveillance System," NUREG/CR-1762, Oak Ridge National Laboratory, October 1980.

(c). A. A. El-Bassioni, et al., "Review of Standards and Requirements Affecting Human Factors in Nuclear Power Plant Control Rooms," SAI #1-245-08-124-00, Science Applications, Inc., for Oak Ridge National Laboratory, October 1980.

(d). R. A. Kisner and G. F. Flanagan, "A Systems Approach to Defining Operator Roles," IEEE Conference, Orlando, Florida, November 1980.

(e). C. B. Oh, et al., "Analysis of the Operator's Role During the Onset of an Emergency," TEC No.

R-81-004, Technology for Energy Corporation for Oak Ridge National Laboratory, February 1981.

(f). Price, H. E., Maisano, R. E., Van Cott, H. P., "The Allocation of Functions in Man-Machine Systems: A Perspective and Literature Review, BioTechnology, Inc., Falls Church, VA for Oak Ridge National Laboratory, November 1981.

Evaluation

This effort appears to be extremely complex in its myriad of tasks and subtasks. The overall objective is appropriate to the development of operator aids, but the appropriateness of some of the sub-objectives and their relationship to the overall objective are questionable. The first five tasks appear to be loosely related to and a follow-on to the seven FY81 tasks. In Task 1 (FY81), the definition of the role of the operating crew, evaluation of NRC and industry regulations, specifications, and standards relating to the operator, as well as descriptions of legal restrictions on the operator may be useful in understanding team interactions but they have little bearing on defining the functional requirements for operator aids that will enhance performance. Task 2 should define design restrictions that would affect development of specific mechanical or electronic operator aids. It does not, however, address hard-copy JPAs. Tasks 3 and 4 seem premature, since no functional requirements have been established. Task 5 will provide information, but its usefulness cannot be determined from the task statement. Task 6 extends the vaguely defined program to maintenance and testing aids. Task 7 may be useful for future applications, but the compilation of reliable input data and human behavior algorithms are not presently within state-of-the-art capabilities. These efforts should be combined with the INEL efforts and a single objective established for researching and developing operator and maintenance aids.

It appears that the research results from this effort will provide input to a long range study and thus will not provide any immediate timely solutions.

With seven FY81 tasks at $500K and five FY 82 tasks at $300K, the level of effort on any one task cannot be too extensive. Little benefit, however, is readily recognizable. If it is input to a long range effort, there may, indeed, be some future payoff.

Based upon the objective, many resources would be required that are presently unavailable at ORNL, most notably a sufficient number of career human factors professionals and behavioral scientists.

3.1.2.2.1(d) Human Factors Reviews

Description

(1) Need

Many minor control room changes are being contemplated and their effects on crew performance need to be determined. Specifically, it is necessary to ascertain whether enhancements through labeling, demarcation, color coding, and other surface improvements will improve performance or lead to confusion (increased error rate). Also, the effects on crew performance of minor changes in meter and control arrangements that might be made to meet human engineering conventions (e.g., rearranging meters from an A, C, B configuration to an A, B, C configuration) need to be answered. The thrust of this would be to ascertain whether such changes lead to negative training transfer under stress.

(2) Objective

Generate data on human performance in nuclear power plants to assist in the validation of minor control room modifications.

(3) Work Effort

Task 1. Complete a human factors review of current practices involving annunciators in the two nuclear power plants reviewed during FY80.

Task 2. Initiate collection of human performance data through a survey of EG&G maintenance and instrument adjustment/calibration activities of INEL. Analyze data to determine:

(a) The feasibility of using this technique for use in estimates of probability for human performance reliability.

(b) The priorities for human performance problems in maintenance.

(c) Estimates of probability of successful human performance for areas covered by the survey.

Task 3. Initiate a research project using as subjects operators of the INEL test reactors, simulators, and/or mockups to collect data on human performance reliability or performance degradation. The study would utilize pretest and post-test conditions to determine the effects of control room design modifications. Initially operator performance related to changes in display color and color relocation would be considered. Using the recommendations made following control room assessment performed during FY80 at ATR and ETR, repeated performance testing would be used to:

(a) Establish reactor operator reaction time and error on current design.

(b) Determine whether any increase/decrease would result following design modification.

(c) Identify the training techniques that could be used effectively to establish an acceptable level of performance following design modification.

(d) Recommend the changes that will tend toward compliance with established principles as identified in MIL-STD-1472 and at the same time support system acceptable human performance. Conclusions will be limited to the data, but will be based on statistical significance and will establish a strong basis for generalization so long as the basis for the data is recognized.

Task 4. Provide consultation on other human factors programs as requested by NRC within available funding limits.

Performing Organization

Idaho National Engineering Laboratory

Status

(1) Schedule/Priority: This effort was started in FY80 and will conclude in FY81. It is related to NRR priority 9, validation of control room modifications (minor).

(2) Resources: FY81 obligation is $10^k.

(3) Products/Publications: (a) L. M. Potash, "Analysis of Licensee Event Report (LER) and Noncompliance Data Related to Licensee Performance Evaluation," EGG-SSDC-5223, EG&G/ Idaho, Inc., August 1980.

(b) W. W. Banks and M. P. Boone, "Nuclear Control Room Annunciators: Problems and Recommendations," NUREG/CR-2147, EG&G/ Idaho, Inc., September 1981.

Evaluation

The task descriptions in support of the objective are vague and overly ambitious. Given the very limited data source described, the generalizations that are being sought would have very limited validity. The goal of assessing performance effects of design modification is desirable. Any hope to gather human reliability data, probability data, and training techniques effectiveness data is not well founded.

The FY81 expenditure of $100K is insufficient to accomplish all that is stated.

The effort should be descoped to focus on the specific measurement of human performance as a result of design modifications. Even that more limited project will require far greater resources in terms of scenario development, hours of testing time needed, numbers of test subjects, software development, etc.

The research task statements appear to be too loosely worded to offer any hope for significant results to be realized.

3.1.2.2.1(e) CRT Display Design and Evaluation

Description

(1) Need

The man-machine interfaces in nuclear power plant control rooms, especially the visual display techniques, designs, and characteristics, are changing. The change emanates from two major events: recognized human factors problems surfaced because of the Three Mile Island accident and newly determined requirements for control room information, such as the Safety Parameter Display System, technological changes in computer-based data management systems, and new display techniques as represented by CRTs and video data terminals. It is necessary to compare various data display methods to provide a technical basis for regulatory actions, to develop design criteria for NRC standards and guidelines, and to provide proven evaluation methods to ensure valid and reliable results for the NRC uses. The research will focus on providing data on the effectiveness of various forms of industry designed or potential man-machine displays and information systems and on different methods of display evaluation.

(2) Objective

Develop human factors display evaluation methods and evaluate their effectiveness in enhancing operator capability.

(3) Work Effort

Idaho National Engineering Laboratory will develop man-machine display evaluation methods and evaluate the effectiveness of operator displays and enhancing operator capability.

Task 1.a. Evaluate four potential safety parameter display formats. These are:

a. Deviation bar diagram

b. Circular plot or star diagram

c. Clustered meters

d. Trend plots.

Task 1.b. Several methods will be used in parallel for these display evaluations. These include:

a. Rating scales

b. Tachistoscope performance oriented tests

c. Real-time performance oriented tests using interactive simulation and reactor data inputs.

Task 1.c. Document report as a result of the evaluations.

Task 2.a. The effectiveness of the methods used in Task 1 will be evaluated and a separate report issued which will include comparisons of the effort involved for each method and the results obtained (pros and cons) from each technique.

Task 3.a. Review existing human factors data to identify display design criteria and gaps in such criteria, as related to nuclear power plant applications.

Task 3.b. A report on this review and findings which point out areas of CRT display and other state-of-the-art visual display techniques which may need criteria will be published.

Previous FY81 effort was to develop and evaluate advanced diagnostic graphic displays for enhancing reactor operator capability, and explore applications of real-time modeling for aiding the operator to analyze and predict plant behavior.

Performing Organization

Idaho National Engineering Laboratory

Status

(1) Schedule/Priority: This project was initiated earlier and will continue beyond FY81. It is related to NRR priority 9, Validation of Control Room Modifications.

(2) Resources: FY81-$500K; FY82-$500K; FY83-$700K; FY84-$1M; FY85-$1M

(3) Reports/Publications:

(a) W. W. Banks, "Some Suggestions for Human Engineering Design Guidelines Relating to CRT Displays and Software Development," SD-D-80-002, EG&G/Idaho, Inc., April, 1980

(b) M. M. Danchak, "Techniques for Displaying Multivariate Data on Cathode Ray Tubes with Applications to Nuclear Process Control," NUREG/CR-1994, Hartford Graduate Center for EG&G/Idaho, Inc., April 1981.

(c) J. A. Mahaffey, "Availability of Hardened Computer Systems," NUREG/CR-2118, Georgia Institute of Technology for EG&G/Idaho, Inc., April 1981.

(d) W. W. Banks, et al., "Human Engineering Design Considerations for CRT Generated Displays," Draft Report, EG&G/Idaho, Inc., September 1981.

(4) Related Activities: EPRI and NSAC are conducting experimental evaluations of SPDS and DASS programs. EPRI is also expected to initiate a project on annunciator evaluation and internal communications systems evaluation.

Evaluation

Some of the needs and objectives described are desirable; some are not. Research into advantages of different display methods and formats for CRTs is necessary and should be well-sponsored toward advanced control room design concepts. The other stated "needs" and objectives are premature at best. Regulatory actions and positions are not necessary for these display formats at this time. Premature adoption of standards and guidelines may well inhibit creative research and development of better displays as technology progresses. For example, steam pressure changes may be better for an operator in scheme "B" vs. scheme "A"; if the NRC imposes "B" on the industry, schemes "C" and "D" which ma, superior to "B" may never be identified through subsequent research.

Further, the need to provide "evaluation methods" is not a true need. Evaluation methodology for comparative assessment of alternative displays is a common tool of the behavioral research scientist and is readily available in the literature.

The proposed research is timely. Though it may be some lengthy time before advanced control rooms with large use of CRTs are seen in the nuclear industry, there are a great number of display functions worthy of investigation and many candidates for each function. It is appropriate that the research activity has been initiated. Such research is lengthy in its nature.

Budgetary planning information beyond FY81 is reasonable. It is desirable that a high level of funding be anticipated for the next several years for research prior to any NRC regulatory actions.

The currently planned work is being performed at INEL. Some mix of good to mundane research capability in personnel talents are evidenced there. Good facilities do exist and should be utilized. Excellent, more developed and more specialized facilities for this type of research also exist elsewhere, as do suitable technical talents. It is essential that if INEL continues future work in this area that INEL add competent career human factors research professionals to its staff.

3.1.2.2.1(f) Halden Reactor Project

Description

(1) Need

The United States has been a signatory of the Halden Reactor Project. The NRC has established a resident delegate to provide technical support to the Halden staff and to act as the NRC representative. In prior years the primary emphasis was on monitoring fuel rigs in reactors. The technical emphasis under the FY82 statement of work is directed toward human factors research. The development of computer-based information and display systems by the Halden staff provides technical results which assists the NRC in developing design criteria and evaluating the safety implications and performance of such systems.

(2) Objective

Provide USNRC representation in the Halden Reactor Project primarily in research on human factors, man-machine interfaces, and computer-based display systems, and to a lesser extent in research on fuel behavior.

(3) Work Effort

INEL will provide (as an NRC delegate) a technical delegate to the Halden Reactor Project. The duties of the resident are as follows:

<u>Task 1.</u> Participate in Halden human factors and computer-based display research.

1.1: Provide approximately 70% of the delegate's time in staff support to human factors research on new display concepts; experiments and test programs, identification of unique human engineering characteristics of man-machine systems; development of human performance models and data; procedure development and data presentation methods; identification of personnel manning and training requirements; types of emergency operations; and training simulators and devices.

1.2: Fulfill requests for information by the NRC technical monitor and contractor personnel.

<u>Task 2.</u> Data collection for fuel behavior codes.

2.1: Monitor the NRC's fuel behavior rigs in the reactor.

2.2: Provide data to develop and assess the FRAP-T and FRAPCON fuel behavior codes through application of approximately 20% of the delegate's time.

2.3: Fulfill requests for information by the NRC technical monitor and contractor personnel.

<u>Task 3</u>. European Research Analysis

3.1: Provide a resource for description and analysis of human factors and display technology development in Europe by attendance at relevant technical meetings and visits to selected European research facilities. About 10% of the delegate's time will be spent in this task.

<u>Performing Organization</u>

INEL

Status

(1) Schedule/Priority: Continuing participation

(2) Resources: $500K/year for sponsorship; $100K/year for delegate

(3) Products/Publications: Various reports from Halden participants are available. A yearly report is prepared by the NRC delegate.

Evaluation

The overall objectives appear meaningful, although very generally described. They do not appear to follow directly from any control room systems or task analyses and therefore may or may not have direct applicability to issues which are defined by subsequent task analysis studies.

The only exposure the HFS Study Group had to the Halden Project was in an early orientation briefing from NRR and in a Halden Project briefing on March 18, 1981. The briefing from NRR was intended to be an overview, while the Halden Project briefing was also superficial and decidedly oriented toward generating continued funding support rather than providing detailed technical information.

The original HFS proposal for this contract included funding and plans for a visit to Halden. It was deleted from the contract due to an NRC policy against foreign travel, however relevant. Subsequent requests for approval were also denied, the last after the March 18, 1981 Halden Project briefing. Meetings with NRC staff members who have visited Halden have yielded little meaningful technical information.

On the basis of the above limitations, it is difficult to evaluate, in depth, the utility of the Halden Project from a human factors viewpoint. However, several conclusions appear warranted and well supported.

First, while FY82 emphasis is to be on "human factors", much of the work appears to be proceeding with little or no human factors planning and with little or no human factors professional staff expertise. Research on CRT display techniques, in the absence of useful information or task analyses, may be of little or no value.

Second, the absence of a controlled experimental approach in previous Halden work suggests that current and future work may suffer from similar faults. Thus, the results may be more like "demonstrations" than experiments.

Third, the cost appears quite high compared to the results received thus far. The same level of support, if spent in a dedicated simulator, for example, might produce far more useful information.

In summary, it is questionable whether continued support of the Halden work will prove useful to nuclear human factors issues. Unfortunately, we have been prevented from obtaining adequate information to fully support anything other than this qualified conclusion on this very costly project.

3.1.2.2.1(g) Evaluation of Human Factors Engineering Data

Description

(1) Need

Major compilations of human factors engineering data, based mainly on military and aerospace applications, are being used to develop guidance for nuclear power plant programs, e.g., control room reviews. A critical review is needed to determine applicability and validity of these data and the need for additional research.

(2) Objective

Critically evaluate the technical basis, i.e., data, supporting the available HF criteria for their reliability, validity, and applicability to NPP. Identify major gaps and problems in applying criteria. Recommend specific research.

(3) Work Effort (under consideration)

Critically evaluate all major compilations/sources of human factors engineering data which appear to be related to the generation of nuclear power. The process of critical evaluation will provide NRC a better understanding of what data are good and directly related - the need for validation, what data are bad - the guidance for needed research, and what are the gaps - again, guidance for needed research. The need is to evaluate the scientific basis/underpinning of the source data which led to the development of current standards, guides, handbooks, and texts.

Performing Organization

Undetermined

Status

The initiation of this project is pending until the results of related EPRI work (see 3.3.2.1.12, Human Engineering Guidelines for Operations) in 1982 as known.

Evaluation

The stated "need" to determine and evaluate the reliability, validity, and applicability to nuclear power plants is highly questionable. The vast majority of human engineering data found in recognized texts and documents such as MIL-STD-1472 are well founded on empirical research and years of judgmental application to a wide variety of systems - from lawn mowers to spacecraft.

This proposed activity is not needed nor meaningful. No real benefits are to be realized. No budgetary information is currently available for this proposed effort, but the cost/benefit tradeoff is not a positive one.

It is true that some human engineering data are more strongly substantiated than others. But that is where the skills of a qualified career human factors professional are important - in making interpretive judgements about the interactive importance in each of the human engineering criteria areas.

3.1.2.2.2 Personnel, Staffing, and Training Research

3.1.2.2.2(a) Safety Related Operator Actions

Description

(1) Need

This program is intended to provide information which will assist in the assessment of the performance of nuclear power plant (NPP) operators in responding to emergency conditions. The primary effort, which has been in progress since FY78, is a program to collect and assess data on operator performance in order to support development of design criteria for safety-related operator actions and ANSI N660. In addition to this, work is planned to investigate the applicability of task analysis techniques as a method of providing data for assessing a variety of human factors issues related to NPP operation under emergency conditions, e.g., operator training and certification requirements and adequacy of procedures.

(2) Objective

Collect and assess data and information on nuclear power plant operator performance to support NRC efforts relevant to safety related operator actions.

(3) Work Effort

Task 1. Operator Response Time

1.1. Publish reports on the BWR simulator data collected in FY81 and the simulator-to-field data calibration.

1.2. Prepare a preliminary outline of criteria for safety related operator actions and identify the data needed to validate the criteria and a data collection program which will satisfy this need.

Include as part of this data collection program a discussion of the dependent (e.g., response time, error rate) and the independent variables (e.g., performance shaping factors, accident sequence, plant). Identify the performance shaping factors which have a significant impact on operator performance and identify simulator experiments that can be used to validate and quantify these performance shaping factors.

1.3. Coordinate with Sandia National Laboratory (SNL) to collect simulator and field data which will, if possible, satisfy both the needs established in Task 1.2 and the SNL program to validate the handbook and workbook on human reliability.

1.4. Investigate the use of additional data collection techniques such as eye motion monitoring, pulmonary monitoring, voice recording, voice taping, etc.

Task 2. Task Analysis Pilot Study

2.1. Publish the PWR task analysis pilot study conducted in FY1981.

2.2. Perform task analyses for the BWR events used in FY81 calibration studies. Validate the task analyses using simulator data and publish a report summarizing the results.

Performing Organization

Oak Ridge National Laboratory

Status

(1) Schedule: Started in FY78. Training-related tasks will continue in FY82 as "Personnel Selection and Training," FIN No. B0466.

(2) Resources: FY82-$600K

(3) Products/Publications: (a) NUREG/CR-1482, "Nuclear Power Plant Simulators: Their Use

in Operator Training and Requalification," July 1980, ORNL//NUREG/TM-395.
(b) NUREG/CR-2353, "Specification and Verification of Nuclear Power Plant Training Simulator Response Characteristics." Vol. 1: "Part I: Summary of Current Practices for Nuclear and Non-Nuclear Simulators." ORNL/TM-7985. Vol. 2: "Part II: Conclusions and Recommendaations," ORNL/TM-7986.
(c) NUREG/CR-1908, "Criteria for Safety-Related Nuclear Plant Operator Actions: Initial Pressurized Water Reactor (PWR) Simulator Exercises," September 1981.
Other products may exist, but were not identified. Planned products are human performance data to support functional allocation decisions; assessment of simulator practices.

(4) Related Activities: (a) Fin No. B0466 to commence in FY82 will that were encompass training-related tasks initiated in B0421.
(b) Task 1.3 will coordinate with Sandia National Laboratory to exchange data related to Human Reliability.
(c) Prior tasks made use of the Performance Measurement System described in EPRI Report NP-783.

Evaluation

This activity has been a collection of several loosely-related tasks. In general, the tasks attacked the very important, but very difficult task of developing tools and procedures for evaluating operator performance variables. The FY82 objectives, which are satisfied by publishing prior results and investigating the utility of measurement and evaluation techniques, are considered to be appropriate. It has been concluded by us elsewhere in this study report (Volume 3, Section 1.7) that data related to human response time, for the purpose of determining human error rates, is unwarranted at this time. That conclusion, plus the enormity of the related problem of quantifying the factors that affect specific error rates and response times, gives us concern with the appropriateness of Tasks 1.2 and 1.3 for inclusion at this time.

Except for Tasks 1.2 and 1.3, the prior and planned activities of this program are necessary to bring the best practices of research in human performance to the nuclear plant operator research community. The specific activities contemplated in Task 1.2 would need to be known to evaluate its timeliness (cf. Volume 3, Section 1.8, Evaluation Criteria). Task 1.3 is not warranted at this time.

Insufficient data are available to determine the magnitude of funds devoted to each of the several tasks completed to date or the allocation of funds to the FY82 tasks. Considering the costs of collection of simulator and field data, the budget appear to be appropriate for FY82.

In general, the work to date in this area is of acceptable quality, but ranges from creative applications of task analysis techniques, to development of interesting measurement techniques (but in the absence of answerable research questions), to what amounts to little more than the discovery of Instructional System Development techniques that have been standard practice in the military environment for nearly a decade. As long as the effort is well-directed toward formulating the right questions and bringing the best research tools to bear on them, this program shows promise in advancing the quality of nuclear operator research.

3.1.2.2.2(b) NPP Personnel Selection and Training

Description

(1) Need

Historically, nuclear power plant personnel selection and training requirements have been developed largely on the basis of best judgment. This program is intended to develop a systematic approach to establishing training requirements similar to those used successfully by other industries. This method will provide the technical basis for nuclear power plant personnel selection, qualification, and training requirements including simulator use and fidelity.

(2) Objective

Provide a plan to develop and validate NPP operator selection, qualification, and training requirements using established techniques such as SAT/ISD.

(3) Work Effort

Oak Ridge National Laboratory will assemble and evaluate the necessary background information, establish the feasibility of applying the systematic approach to nuclear power plant operator training, and develop a comprehensive program plan.

Task 1. Program Plan

a. Define the elements and performance shaping factors related to selection and training of reactor operators, senior reactor operators, shift supervisors, and shift technical advisors.

b. Assess the applicability of existing methods such as Systems Approach to Training and Instructional System Design (SAT/ISD) to the area of selection, qualification, and training of nuclear power plant operators.

c. Using the INPO job/task analytic data demonstrate the methods used to determine selection, qualification, and training program requirements. This should include at least one illustrative example that traces a skill or knowledge requirement all the way to a simulator fidelity requirement. The adequacy of the existing data to fully define the training program should also be addressed.

d. Provide a comprehensive program plan for development, validation, and application of a system such as the SAT/ISD method of establishing operator selection qualification and training requirements.

Task 2. Evaluation and Upgrading of Nuclear Power Plant Training Simulators

a. Develop and demonstrate a technique to select malfunctions which should be required for NPP training simulators.

b. Develop a comprehensive program plan for research and assessment necessary to specify and validate NPP training simulator requirements.

Possible Task. Also under consideration for inclusion in this program are efforts for simulator validation of licensing examinations and education and training requirements in response to request NRR-81-2.

Performing Organization

Oak Ridge National Laboratory

Status

(1) Schedule: Start in FY82

(2) Resources: FY82-$300K; FY83-$200K.

(3) Products/Publications: Evaluation and criteria for RO, SRO, SS, and STA selection and instructional system development, including criteria for evaluating training simulators.

(4) Related Activities: This is a continuation of work accomplished in FY81 under "Safety Related Operator Actions" (B0421).

Evaluation

The objective was given a high priority by the HFS Study Group. It is appropriate for this program to be conducted at this time.

The budgeting may be high considering that there is little new knowledge to be generated in this effort.

Prior work in this area under B0421 (Safety Related Operator Actions) showed a good understanding of the problem, as does the INPO Job/Task Analysis Model. There is a good likelihood of success for this effort.

Proposed Add-On Task

An additional task is under consideration by RES for inclusion as part of B0466, entitled Validation of Licensing Exams and Education and Training Requirements in Response to Research Request NRR-81-2. Licensing exam scores (written, oral, simulator) and education and training background (amount of high school, technical training, or college, college technical degree, years of operating experience and NPP operating experience) would be correlated with performance measures, including training examination scores, simulator evaluations (error rate, action time, instructor's rating) and on-the-job factors (supervisor's and peers' ratings, reactor outages avoided).

It is estimated that the records of no more than 10% of licensed operators would need to be surveyed, with an expenditure of about ten person-years of labor.

Evaluation

Although we are in agreement with the objectives of validating the requirements for licensing, we do not believe that this effort addresses that objective in a meaningful way. While it may be possible that the independent variables are significantly correlated with the performance measures, that is not a sufficient test of the validity of examinations or of the education and training requirements for a variety of methodological problems. Likewise, a lack of correlation does not mean that the examinations or requirements are not valid, but may simply have been "overwhelmed" by other factors that affected the data. It is pointed out in Section 1.8 of Volume 3 of this report that subjective performance measures (e.g., ratings) are risky measures, and certainly the close relationship between the training process and the licensing examinations make it doubtful that such measures can be relied upon to give valid results. It is, in fact, recommended in Section 1.8 of Volume II that objective (criterion-referenced) performance measures be developed and that research should also be pursued "to define useful secondary criteria such as progress through training, licensing examination scores, supervisory ratings on various dimensions of performance, frequency of involvement in 'events' or critical incidents, and turnover rate." Until valid performance measures are defined for use as evaluation criteria, we cannot support the inclusion of this task.

In a review elsewhere in this report (Section 4.0, Volume 3) of a similar correlational study performed as part of NUREG/CR-1750, the comment was made that "it is quite possible that unreliable and fallible predictors were correlated with unreliable and fallible criteria." Without first determining the reliability of the measures proposed, the same comment would apply to the results of this effort.

3.1.2.2.2(c) Management Qualifications

Description

(1) Need

The Commission is responsible for determining whether or not a utility is technically qualified to build and operate a nuclear power plant and for assuring that operating plants are managed and operated safely. The process of assessing the capability of a utility organization to effectively and safely manage a nuclear power plant is quite subjective. There is need for guidelines and methods for making such assessments in a valid manner. There is a body of data which can contribute; but, for the most part, it is related to such factors as efficiency, productivity, attitudes, and the like in non-nuclear areas. There is little data dealing with the attitudes of nuclear power plant management toward safety. There is need for systematic study of those elements of management and those indicators of effectiveness which are important to deciding utility management qualifications from the standpoint of assuring safe operations.

(2) Objective

Develop and validate a comprehensive set of performance measures that could be used to determine the ability of a utility organization to effectively and safely manage a nuclear power plant.

(3) Work Effort

Task 1.

a. Develop a comprehensive list of actions, results, policies, attitudes, etc., that may indicate the ability of a utility to manage a nuclear power plant in a safe and effective manner (e.g., LERs, civil penalties, radioactive releases, personnel exposure to radiation, industrial accidents, material condition of the plant, percent of scheduled maintenance completed on time, quality of machinery history records, percent of operators that pass the licensing examination on the first try, percent of operators achieving scores above the national average, availability, capacity, forced outage rate, etc.).

b. Determine which of the performance measures identified can be measured quantitatively, and which are limited to subjective judgement.

Task 2.

a. For each of the performance measures identified in Task 1, produce a rationale and the best supporting information available to prove the validity of that measure as an indicator of the ability of a utility organization to manage a nuclear power plant in a safe and effective manner.

b. Rank the performance measures in the order of their relative importance to management quality and weight the performance measures within the order of importance (e.g., if number 1 is twice as important as number 2, indicate this fact).

Task 3.

a. Collect data on each performance measure identified in Task 1 and validate the ranking and weighting assigned to each performance measure in Task 2.

b. Correlate the data collected on each performance measure with:

1. The other performance measures.

2. An overall rating of the utility's ability to manage a nuclear power plant in a safe and effective manner using the results of the performance measures as a whole.

3. An overall rating of the utility's ability to manage a nuclear power plant in a safe and effective manner using a more subjective method of rating such as the approach described in NUREG-0731.

Task 4.

a. Draw conclusions from the results of Task 3 and provide recommendations on the use of performance measures for establishing a utility organization's competence.

Performing Organization

Undecided

Status

(1) Schedule/Priority: FY82 and FY83; NRR Priority #5.

(2) Resources: FY82-$100K; FY83-$200K

(3) Products/Publications: Eventual guidelines for assessing management qualifications.

Evaluation

The objective of developing indicators of management effectiveness and techniques whereby management structure, practices, and attitudes can be assessed in relation to public health and safety is obviously appropriate to NRC responsibilities. This project appears to complement to the LQB project in this area (see 3.1.2.1.3(a), Guidelines for Utility Management Structure and Technical Resources).

No information on the schedule for this project was available. It is assumed that it will be contemporary with a contract to be performed by Battelle Pacific Northwest Laboratories (Human Affairs Research Center) on "Utility Management and Organization Guidelines".

The benefits are potentially very large if the technical objectives can be achieved.

This project brings into focus the need for objective criteria by which management practices can be evaluated (for fuller discussion see Volume 3, Section 1.8 and Section 4). The success of the effort will depend on the contractor's ability to develop intermediate criteria, related to operatonal safety, by which to validate the guidelines and methods of assessing utility management structure and practices. It is possible that some "extant" measurement approaches from the field of organizational effectiveness will be found useful but the real value of the work will depend upon the contractor's success in developing intermediate criteria that reflect management practices that are in fullest accord with operational safety. The requirement for objective criteria is particularly evident in the long term objective of this project which calls for ". . . model linking of multiple management elements with safety criteria and model validation through continued collection of data . . ." that reflect effective and ineffective management behaviors.

3.1.2.2.2(d) Independent Spent Fuel Storage Installations (ISFSI) Operator Task Analysis

Description

(1) Need

The decision to indefinitely defer spent fuel reprocessing has resulted in an additional step in the fuel cycle, the Independent Spent Fuel Storage Installation. In order to ensure that the operators of these ISFSIs have adequate training, a Regulaory Guide entitled "Certification and Training Requirements for Independent Spent Fuel Storage Installation Operators" is being prepared. The task analysis described is intended to serve as the technical basis for the regulatory guide.

(2) Objective

Prepare a task analysis which will provide the technical basis for establishing certification and training requirements for ISFSI operators.

(3) Work Effort

The task analysis is to be performed for the General Electric Morris Facility. The work will entail about one staff year performed in 3 to 4 months.

Task 1. Program Planning

Further develop the objectives of the program and the specific actions necesary to satisfy them. Items to be addressed include identification of:

a. The ISFSI operators for which task analyses will be done and the extent of analysis needed to define interfaces and interactions with support personnel who may be involved in routine and emergency decision making.

b. Definition of the operating conditions (routine and emergency) that must be analyzed to reach the basic objectives of the program.

Task 2. Prepare for Data Collection

Develop plans for data collection.

a. Define the particular systems to be analyzed including their functions and components (e.g., handling equipment, control station, operating crew, equipment and personnel interfaces).

b. Describe the allocation of tasks between humans and machines in the system's current configuration for the following functions: Handling Casks, Handling Fuel, Fuel Unloading and Cask Turnaround, Basin Cooling, Water Purification, Normal Operation, and Infrequent or Abnormal Operations.

Task 3. Data Collection.

Collect data by such means as:

a. Administering questionnaires to operating crew and management.

b. Extracting materials from procedures and other sources.

c. Walk-throughs and talk-throughs of simulated events.

d. Conducting interviews with operators and management.

e. Observing facility operations to verify or modify the pre-site-visit data.

Task 4. Suitability for Data Analysis.

Use the task analysis information to develop findings and recommendations relative to certification and training requirements for ISFSI operators.

New Tasks. Under consideration are several new tasks funded to study other human factors problems in fuel cycle facilities.

Performing Organization

Sandia and a subcontractor to be determined by competitive bid in FY82.

Status

(1) Schedule/Priority: Start in FY82

(2) Resources: FY81-$76K

(3) Products/Publications: A Regulatory Guide for certification and training requirements for Independent Spent Fuel Storage Installation Operators.

Evaluation

The objective of this project is appropriate to the existing need for establishing certification and training requirements for ISFSI operators.

The timeliness of this project has to be evaluated in terms of two different time references. As is the case with most nuclear power installations and operations, the proposed task analysis would have been timely several years ago. It should have been performed as a part of the design and development of the General Electric Morris Facility. However, within the present time reference of the world as it actually exists, the proposed project remains timely. Although the results of the task analysis most likely would have been more valuable had it been done earlier, we are now faced with a case of "better now than later". It should provide a rational basis for determining certification and training requirements for ISFSI operators.

The potential benefits of this project greatly outweigh the modest personnel requirement of one staff year.

No quality evaluation can be made. The subcontractor to Sandia has not been selected.

3.1.2.2.2(e) The Effects of Post-TMI Requirements on Operators

Description

(1) Need

Since the TMI accident, the turnover rate of licensed shift personnel has increased. There is need for data on the turnover rate (present and projected), and the root causes of the turnover. There is some indication that the psychological impact of the

TMI accident and post-TMI operator licensing and enforcement practice may be a significant factor in causing increased turnover. Such data would be of material assistance in planning and projecting the work of the NRC operator licensing personnel and in finding practical ways of minimizing the impacts of TMI-related stress on licensed plant personnel.

(2) Objective

Develop data on key personnel turnover from 1975 to date and expected turnover for 1983-1990; define likely causes and recommend methods for minimizing NRC associated causes; provide feasibility study of job stress effects on performance.

(3) Work Effort

In coordination with INPO, develop a methodology and conduct a comprehensive survey designed to ascertain the turnover rate of licensed plant personnel and the associated causative factors, particularly those related to the TMI accident and TMI requirements. Recommend methods for minimizing the impact of such requirements on the career paths and job performance of licensed plant personnel. If feasible, develop a non-intrusive method for identifying serious degradation in performance capability because of job related stress.

Performing Organization

Undetermined

Status

(1) Schedule/Priority: Under consideration for future NRR priority 11.

(2) Resources: Not planned

(3) Products/Publications: Survey of RO, SRO, and key personnel turnover

Evaluation

There are two distinctly different objectives of this program, both of which are highly appropriate to NRC objectives. The importance of minimizing personnel turnover, from whatever causes, is discussed in detail elsewhere (see Volume 3, Section 4). The study of job stress effects on performance is a major research issue in its own right which may or may not be reflected in turnover rates. (This is also discussed in Volume 3, Section 4).

Whether the program objectives are viewed as independent or part of the larger single effort, the problem is one that demands immediate attention because of the likely adverse consequences of personnel attrition in the face of increased manpower needs in the industry. RES has developed a preliminary plan with a desired start in FY82. However, it is evident that related efforts by EPRI and INPO are being relied upon as the primary source of information related to these problems. The INPO output, which results from plant evaluations, can be considered a more or less continuous source of insights into the effects of post-TMI requirements. The EPRI study of "Work Structure and Performance" is scheduled for a start early in calendar 1982 and will continue through 1985. The sooner that useful insights are provided from any of the programs, the better.

No information was available on the NRC's budget for this program. The benefits of reducing the attrition of highly trained personnel and minimizing the effects of stress on performance effectiveness are extremely high. It does not appear that budgeting has been in proportion to the potential benefits. The EPRI budget is $120,000 for the first year.

The collaborative efforts among NRC, INPO, and EPRI to ascertain the causative factors of personnel attrition and to identify methods for minimizing those influences call for comparatively straightforward survey methodologies. The task of developing a non-intrusive method for identifying degradation in performance related to job stress is, however, a far greater technical challenge and one requiring considerable investment that appears not to be reflected in the budgeting for this program (for further discussion of this point see Volume 3, Section 1.8 and Section 4).

3.1.2.2.2(f) The Effects of Shift Work and Overtime on Operator Performance

Description

(1) Need

The Commission has issued guidance to the utility industry on shift length and the use of overtime (see NUREG-0737). This guidance resulted from "common-sense" recognition of the deleterious effects of excessively long work shifts and too much use of overtime work on operator performance. In some cases this guidance has created hardship for utilities. There is a need to establish a more rigorous scientific basis for deciding what is acceptable from the standpoint of shift length, shift rotational schemes, and the use of overtime at nuclear power plants (circadian desynchronosis).

(2) Objective

Develop guidance on acceptable and unacceptable shift lengths, types of shift rotation, and overtime practices. Establish basic methods, procedures, practices, and data base associated with minimizing the deleterious effects of shift rotation, excess shift length, and overtime (more than ten hours) on operator performance in NPPs.

(3) Work Effort

An in-house study has been underway to analyze LERs for human error and time of day. Further work will depend on results available from the EPRI study on Work Structure and Performance (see 3.3.2.1.17). NASA work on fatigue and pilot performance is also being closely monitored. If future work is necessary it would probably be similar to the tasks identified below.

Task 1. Critically evaluate what is already known about the effects of shift length, shift rotation, and overtime use on operator performance and provide for interim guidance a report on what is clearly acceptable or unacceptable with respect to shift work management.

Task 2. Conduct basic research with human subjects to determine the optimum methods for minimizing the deleterious effects of shift rotation, shift length, and overtime on operator performance.

Performing Organization

Undetermined

Status

(1) Schedule/Priority: No planned schedule; NRR Priority #7

(2) Resources: Undetermined

(3) Products/Publications: Data correlated with detrimental effects of shift work and overtime.

Evaluation

Shift duration, extent of overtime, and shift rotation schemes potentially represent some of the most important performance shaping variables that influence operator effectivness. The objectives of this task are appropriately directed at identifying and evaluating the magnitude of these effects.

Other than work that is already largely completed, in which LERs were examined for time-of-day effects, the schedule for work on this problem appears overly tentative. The RES plan stipulates that prior to the implementation of experimental work in this area, assurance is desired that the effects of working hours are "dominant" performance shaping factors. It seems unlikely that this can properly be established in the absence of empirical work directly on work-rest schedules and control room tasks characteristic of the nuclear power industry.

The benefits of satisfactorily resolving the questions of acceptable shift length and optimal rotation schemes are incalculable. The costs of satisfactory research in this area also are likely to be high since there are many technical problems to be solved (see also Volume 3, Section 4). The estimated budget ($400,000 to $600,000) is probably appropriate, assuming industry cooperation.

EPRI's proposed study of "Work Structure and Performance" is to identify some key performance shaping factors including problems related to work schedules and shift duration. However, that effort will not necessarily provide the empirical research required to identify the conditions under which there is measurable performance deterioration and the time course of that deterioration as a function of the many variables possibly affecting it. Further discussion of the research requirements in this area will be found in Volume 3, Section 4.

3.1.2.2.2(g) Standards for Psychological Assessment of Nuclear Facility Personnel

Description (Abstract of Final Report)

The subject of this study was the development of standards for the assessment of emotional instability in applicants for nuclear facility positions. The investigation covered all positions associated with a nuclear facility. Key findings were that emotional instability is a multi-dimensional concept; no single instrument by itself is capable of measuring emotional instability; few studies have been conducted in a nuclear setting aimed at determining the predictive validity of various selection instruments with respect to emotional stability; and standard criteria for evaluating instruments require careful considerations. Conclusions reached in this investigation focused on the ingredients of an integrated selection system including the use of personality tests, situational simulations, and the clinical interview; the need for professional standards to ensure quality control; the need for a uniform selection system as organizations vary considerably in terms of instruments used; and the need for an on-the-job behavioral observation program. In terms of key recommendations, the selection system would vary as a function of the demands of the position and the degree and frequency of access to vital or protected areas in the facility associated with the position. More specifically, for positions of considerable on-the-job stress, the selection system would include the Minnesota Multiphasic Personality Inventory, the Sixteen Personality Factor Questionnaire, the clinical interview, and, in the case of some positions, situational simulations. For other positions, because of a lack of on-the-job related stress, and limited access to vital or protected areas, no screening for emotional instability would be necessary. When situational simulations are to be included for a given position, these instruments would need to be specifically tailored to the given position. Research needs to be conducted on the predictive validity of the aforementioned instruments, as well as others available, within a nuclear facility setting.

Performing Organization

Assessment Designs, Inc.

Status

(1) Schedule/Priority: Completed in FY81

(2) Resources: Unknown

(3) Products/Publications: NUREG/CR-2075, "Standards for Psychological Assessment of Nuclear Facility Personnel"

Evaluation

NUREG-0660 (I.A.3.3) calls for the development of regulations to provide assurance that applicants for operator and senior operator licenses are psychologically fit (emphasis on stress and malevolence), and to prohibit licensing of persons with histories of drug or alcohol abuse. The objective of NUREG/CR-2075, namely developing standards whereby emotional instability in applicants for nuclear facility positions can be identified, is clearly in line with this requirement. Reports of "critical incidents" reflecting unstable performance on the part of operator personnel in the face of stressful operating circumstances occur with sufficient frequency for this to be a major area of concern. The possibility of malevolent behavior is also a matter of obvious concern though it is rot at all clear that the present state of the art in predicting such behavior is adequate for meeting this objective.

This work was completed in FY81. No budgetary information was available. The study was probably cost effective in the sense that it raised critical questions concerning the current state of the art and the need for validation of psychological assessment techniques as they may apply to personnel in the nuclear power industry.

This study involved a detailed analysis of traditionally used psychological and psychiatric screening procedures and an assessment of those procedures in terms of their reliability, content validity, construct validity, and "criterion-oriented" validity. For positions that may involve considerable on-the-job stress, specific recommendations were made for the use of the Minnesota Multiphasic Personality Inventory, the 16PF (personality factor) questionnaire, a clinical interview, and in some cases situational simulations. These recommendations were made in the absence of any empirical evidence of the predictive validity of these screening techniques in the nuclear power industry. The authors properly conclude, however, that criterion-oriented validity studies should be carried out to identify relationships between various predictors and behavioral indices of emotional instability on the job. It is recognized that it will be necessary to develop criteria of on-the-job emotional stability before this can be accomplished. It is also noted that in the past such validation studies have not been particularly successful for other types of personnel who perform under high stress conditions (e.g., air traffic controllers, pilots, and law enforcement officers). It is appropriately concluded that researchers in these areas have not been able to develop instruments that are reliable and valid predictors of stability as it relates to on-the-job performance, and more importantly, that criterion measures of emotional instability on the job have not been identified.

To accomplish the needed validation studies it is suggested that use should be made of situational simulations which would "approximate" the specific elements and conditions surrounding key positions which may contribute to the manifestation of emotionally unstable on-the-job behaviors. It is also recommended that effort be directed toward developing and implementing on-the-job behavioral observation programs to supplement information obtained during the hiring process (see Section 3.1.2.2.2(h)).

There is a long history of failure to demonstrate criterion-oriented validity for personality inventories of the types recommended as well as other psychological and psychiatric screening techniques. Probably all are effective in identifying seriously disturbed individuals, but we are unaware of evidence of their predictive utility in identifying less obvious cases of individuals who may break down in the face of job stress, particularly as it occurs in the power industry. In fact, one recent well-executed study (28) failed to show any validity for a variety of psychological tests in predicting degree of emotional stability as reflected in the ratings of operators by supervisory personnel. It seems likely that further research and development work will be necessary before confidence can be generated that either the criterion measure (of stability) or the predictor measures have sufficient validity to meet the important objective of the program. It is possible that a needed criterion of ability to perform under stressful conditions can be developed in the simulator but this would require a study of considerable scope and technical sophistication or, if the behavioral reliability program (see 3.1.2.2.2(h)) is successful, it may be that in time a sufficient data base will be developed whereby various predictive measures can be validated. But the work to date in this area leaves the objective far from achieved.

3.1.2.2.2(h) Behavioral Reliability Program for the Nuclear Industry

Description (Abstract of Final Report)

The subject of the study was the development of standards for a behavioral observation program which could be used by the NRC licensed nuclear industry to detect indications of emotional instability in its employees who have access to protected and vital areas. Emphasis is placed on those observable characteristics that could be assessed by supervisors or peers in a work environment. The behavioral reliability program, as was defined in this report, encompasses the concept and basic components of the program, the definition of the behavioral reliability program, the definition of the behavioral reliability criterion, and a set of instructions for the creation and implementation of the program by an individual facility.

Performing Organization

Personnel Decisions, Inc.

Status

(1) Schedule/Priority: Completed in FY81

(2) Resources: Unknown

(3) Products/Publications: NUREG/CR-2076, "Behavioral Reliability Program for the Nuclear Industry"

Evaluation

The detection of emotional instability in employees who have access to vital areas of nuclear power plants and the development of standards whereby behavioral indices of instability might be recognized by superiors or peers in the work environment is an objective that is clearly in the interest of safety of operations. The basic requirement is for personnel in appropriate positions to watch for signs of unreliability, poor judgment, behavior change, or inability to cope with job stress. Thus, behavioral reliability programs are aimed at detecting aberrant behaviors or behavioral change within the context of the everyday routine. If there is any reservation about the appropriateness of this objective, it would stem from concern about the ability of peer and supervisory personnel to be satisfactorily trained to perform this function in a reliable and valid manner, and whether the program might be subject to misuse in the case of personality conflicts.

This program was completed in FY81 with the publication of NUREG/CR 2076.

No information was available on the costs of this program. If its implementation were successful, the benefits obviously would merit a substantial investment.

The authors of NUREG/CR-2076 identified five broad criteria of behavioral unreliability:

a. Argumentative hostility toward authority

b. Irresponsibility

c. Defensive incompetence

d. Reaction to stress

e. Emotional and personal adaptability

A variety of illustrative examples of behaviors falling under each of these major categories is provided for guidance to personnel who would be responsible for a behavior reliability program. This is supported by an analysis of 158 "critical incidents" gathered during job analysis interviews at power generating sites. In this respect, the study has a convincing empirical foundation.

A panel of experts convened for the purpose agreed that the supervisors of nuclear power plant employees would find some cues of behavioral unreliability quite easy to detect. Included among these were energy level, hostility, anger, insubordination, frequent errors, and other indices of the quality of work performance. It was cautioned, however, that the supervisor must be convinced that his reporting of such behavior will be helpful, not harmful, to his subordinates. Further, he should serve as an observer and referral source only, not as a diagnostician or counselor. A further restriction on the approach is that it is aimed primarily toward individuals who are experiencing emotional instability because of personal adjustment problems or the stresses of the job. It was agreed that even the most comprehensive assessment and observation program would be hard pressed to detect the determined saboteur.

Despite the evident complexities of implementing a behavioral reliability program, the authors of NUREG/CR 2076 conclude that such a program should be an integral part of safeguarding a nuclear facility. It is further concluded that no existing behavior reliability program in either the public or private sector can be "lifted" as is and installed in nuclear facilities. Further, it is admitted that there is no body of research that has demonstrated the effectiveness of ineffectiveness of such a program in the nuclear power industry.

It is reported that some nuclear power generating facilities have begun pilot behavioral reliability programs. The authors of NUREG/CR-2076 report that some of these programs have been characterized by a lack of interrater reliability due to an inadequate definition of the behaviors to be assessed and lack of specificity concerning how often and under what circumstances observers should report their observations. This suggests that even with the improved criteria for behavioral observation generated by this program, there may well be problems of implementating and maintaining the program at a quality level within industry. Unfortunately, it is a methodology that would appear to require continuing reinforcement and which, as noted above, may be vulnerable to abuse. If the program is successful in its implementation, however, not only would it generate immediate benefits in identifying significant personnel problems but it might also provide the criterion data needed for validating personnel selection procedures in the area of emotional stability (see 3.1.2.2.2(g)). Continuing study aimed at the validation and assessment of behavioral reliability programs, as well as the practical difficulties involved, clearly seems essential.

3.1.2.2.3 Procedures and Operator Aids Research: Operating Procedures Effectiveness Technical Assistant Upgrading

Description

(1) Need

Item I.C.9 of NUREG-0660 requires a long term program for updating all operating procedures. A pilot project is needed to produce the guidance necessary to reproduce pilot project results for other plants. In addition to providing procedures that follow proper style and format, this work also is to address the need for providing operating procedures that are correct technically for the components and systems to which they apply. This activity is intended to be part of a program in which: (1) well-thought-out, step-by-step approved and validated operating procedures exist in each operating plant; and (b) operating procedures are prepared so that specified evolutions can be performed in strict compliance with the procedures so as to prevent incidents that can lead to accidents.

(2) Objective

Structure a pilot project to produce, for an NRC-selected pilot plant, upgraded operating procedures (i.e., procedures for emergencies, abnormalities, normal operation, and maintenance) that fulfill the requirements of NUREG-0660, "NRC Action Plan Developed as a Result of the TMI-2 Accident," Item I.C.9, which requires a long-term program for upgrading all operating procedures.

(3) Work Effort

Task 1. Devise a method (perhaps based on risk assessment data) to limit the number of procedures subjected to pilot project review and approval to those that are reasonably important to safety. Define this method and limit in a way that can be applied to any plant.

Task 2. Attempt to further limit the number of procedures subjected to pilot project review and approval to a sample of sufficient size to allow remaining tasks to be performed with a high degree of confidence.

Task 3. Establish and define the proper level of detail that operating procedures should contain.

Task 4. Produce a model set of upgraded operating procedures for the pilot plant procedures identified in Task 2.

Task 5. Based on duplicating the pilot project, prepare a handbook that outlines the method and defines resources needed to conduct a complete operating plant procedures upgrading at other operating plants.

Task 6 a. Quantify the reduction in operator error rate that would be expected from using the model set of upgraded procedures as compared to the procedures existing before upgrading.

Task 6 b. Quantify the reduction in error rate that would be associated with applying the method used to develop the model set of procedures prepared in the pilot project to all plant operating and maintenance procedures.

Performing Organization

To be determined

Status

(1) Schedule/Priority: This is a planned effort which is scheduled to begin in FY82 and go through FY84.

(2) Resources: FY82-$100K; FY83-$200K; FY84-$200K

(3) Products/Publications: Unknown

Evaluation

The objective is poorly conceived and defined, and almost devoid of human factors concern. No consideration is made of the systems approach required to identify all plant tasks/procedures and the task analysis needed to describe these tasks. Combined requirements. ,he level of detail for procedures can then be defined. J performance aids for operations and maintenance also need to be identified.

Tasks 1 and 2, performed as described, will not provide any meaningful or useful data. Tasks 3 and 4 would only be useful for the participating power plant. Task 5 could be accomplished if the overall effort were better defined. Methods and documentation already exist, however, in other system applications that can be applied to the objective of this task. Task 6 is impossible within the present state-of-the-art techniques. Little benefit can be expected from the $500K cost.

3.1.2.2.4 Risk Analysis and Human Reliability Research

3.1.2.2.4(a) Human Performance Data Bank and Analysis

Description

(1) Need

Human error models, prediction techniques, and human performance data related to nuclear power plant operations were developed from data sources such as aircraft pilot performance on indicator discriminations. The authors of those human error performance prediction techniques at Sandia National Laboratories made expert judgments about the applicability and reliability of these data and models to nuclear power plant operations. In October 1980, a cohesive statement of human error performance was published with the issuance of NUREG/CR-1278. The validation of data and human performance models by independent means through simulation studies and experiments was not available at the time. The need to validate both the human error data values and the underlying human performance models was recognized to the final edition of NUREG/CR-1278.

(2) Objective

Verify human error data and model; prepare and teach verified human error analysis techniques; recommend human error data bank parameters.

(3) Work Effort

a. Survey and analyze the available human performance data that have been generated in representative NPP simulators primarily and other simulators to verify the human error values in NUREG/CR-1278.

b. Survey ongoing simulator research programs to determine the nature of available simulators, types of data collection ongoing, and possible requirements for future validation studies.

c. Based on Tasks a and b, determine which aspects of human error data and models are most in need of further research and the facilities available to conduct the research. Evaluate the analysis and decide if further validation studies are needed. A peer review group will be established for this purpose.

d. Prepare a data collection and experimental program, if required.

e. Issue a report on the validation and survey results.

Performing Organization

Sandia National Laboratories with General Physics as a subcontractor.

Status

(1) Schedule/Priority: Work on this project started several years ago and was continued through FY81. There is no NRR priority associated with this task.

(2) Resources: The resources prior to FY81 are unknown. $350K was obligated in FY81.

(3) Products/Publications: NUREG/CR-1278, "Human Reliability Analysis with Emphasis on Power Plant Applications," April 1980 (Draft)

Evaluation

The objective of this work is well defined. Unfortunately, the realization of the objective may well be infeasible, for the amount of research, data collection, and data analysis needed to verify/modify the HER values in NUREG/CR-1278 is extraordinarily large. While such a task is theoretically possible, its cost may be prohibitive. To determine the feasibility of such data collection and analysis, however, the activities proposed in Tasks a, b, and c are appropriate.

This task, as stated in the work effort, is quite timely and should precede any data collection effort. However, it appears that some data collection by the subcontractor is already ongoing, and that the level of effort is more compatible with an HER data collection and data analysis effort than with a determination of the requirements for such.

The selection of the subcontractor is of questionable suitability. General Physics, while selected in a competitive procurement, has a vested interest in the recommendation to continue HER data collection research due to its involvement in the Chattanooga facility training program. Other potential subcontractors have much greater experience in simulator evaluations, human performance measurement in simulators, and non-obtrusive embedded performance measurement. Presentations made on a previous, related General Physics effort at the NRC-sponsored Gaithersburg, MD meeting were not technically impressive.

In summary, the HFS Study Group is not convinced of the value of this effort, especially in relation to its cost.

3.1.2.2.4(b) Human Performance Modeling for Nuclear Power Plant Operations

Description

(1) Need

Efforts have been under way since the Reactor Safety Study (1974) to develop a standardized methodology and database for the modeling of human errors in nuclear power plant system analyses. These efforts have resulted in the publication of NUREG/CR-1278, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Application" (Draft). A draft of the NUREG/CR 2254 workbook to guide the use of NUREG/CR 1278 was developed in FY81. These documents are currently in the process of being evaluated by human factors experts to determine their suitability, reproducibility, and applicability for ascertaining human error probability for use in reliability and risk assessment type analysis. Efforts in FY82 will be directed towards the update of and validation, as possible, of the human error models and probabilities used in the handbook.

(2) Objective

To provide a source to guide reliability or human factors experts in modeling and quantifying human reliability analyses related to nuclear power plant facilities.

(3) Work Effort

Sandia National Laboratory will provide for the research, analysis, report preparation, and the human factors support necessary to accomplish the following activities.

Task 1. Prepare the final version of NUREG/CR-1278 which is to include:

a. Incorporation of the relevant comments from the various peer reviews which have been performed on the draft version.

b. An evaluation of HEPs with respect to other relevant sources of human error data, including but not limited to the generic and specific human error rates developed from LER reports by Brookhaven National Laboratory, the Simulator Program #1, and the simulator studies done for the NRC by Oak Ridge National Laboratory.

c. A review to insure compatibility with NUREG-0700, "Guidelines for Control Room Design Reviews," provided that NUREG 0700 is made available in sufficient time to permit an adequate review and to incorporate the changes.

Task 2. Prepare a final version of the Workbook to accompany NUREG/CR-1278 which incorporates the relevant review comments.

Task 3. Develop a detailed set of procedures for the use of expert judgment to derive human error probabilities where actuarial data do not exist. These procedures will be used to select the appropriate psychological scaling method for the task under analysis. Provide for an evaluation of the proposed procedure and modify the program as required.

Task 4. Perform a final evaluation and prepare a report on the results of the Handbook exercises which were performed by experts in human factors to evaluate the repeatability of human error task assessments.

Task 5. Develop a program plan for establishing a human performance data bank.

Task 6. Prepare and conduct a 4½ day training course on "Effects of Human Performance on Nuclear Power Plant Operations."

Task 7. Continue the development and design of a program and method to collect human performance data on nuclear power plant simulators and to reduce and analyze data from previous simulation data collected by Oak Ridge National Laboratory. During this fiscal year begin the collection of and the analysis of data by operators undergoing training. A progress report is to be provided the NRC during this fiscal year describing activities completed.

Task 8. Provide consulting to the Human Factors Branch or to other NRC professionals as agreed to by the NRC program manager. Sandia personnel will participate in meetings of the NRC Human Engineering Review Group, in other NRC meetings, or in other human factors meetings in support of NRC requirements.

Performing Organization

Sandia National Laboratories

Status

(1) Schedule/Priority: Ongoing; no NRR priority assigned.

(2) Resources: Prior to FY82 unknown; FY82-$700K

(3) Products/Publications: NUREG/CR-1278 (Final Version)
NUREG/CR-2254
NUREG/CR-2255, "Use of Expert Opinion to Estimate Human Error Probability: A Review of Probability Assessment and Psychological Scaling Literature"
NUREG/CR (TBD), "A Procedure to Use Expert Opinion to Derive Estimates of Human Error Probabilities"

Evaluation

For reasons stated previously, the objectives of this effort are questionable. The effort assumes the utility and feasibility of HER measurement for the variety of tasks involved in NPP operations. Presentations of courses on this material reinforces the approach. Preliminary analyses of a peer review study suggest low reliability in the interpretation of the NUREG-1278 "data" and in the consistency with which the approach can be applied.

Most critical is the basic question of the desirability of conducting this type of program, as discussed in Section 1.7 of Volume 3 of this report. Specifically, we believe this work is of limited utility for several reasons. First, there are well-established, empirically determined human factors engineering principles which have been shown to minimize HERs for most applicable tasks in both operations and maintenance.

We, therefore, advocate using these well-established principles in lieu of awaiting the results of HER validation studies. Secondly, the number of new plant designs (new starts) which could benefit from these data is small, and perhaps zero. With the present economy and outlook, there may be no near-term application of these HER data to new plant design. Thirdly, and most importantly, the application of HER data and, by similar logic, probabilistic risk analysis models, to new plant design or to existing plan modifications, presumes the application of traditional system engineering/system integration approaches to that design and/or modification. As pointed out in section 1.3 of Volume 3, there is no evidence that a system integration approach is being or has been taken in any plant design or modification.

Thus, the constraints to obtaining valid HER data are substantial, and the application of such data, under current conditions at least, is virtually impossible.

While we seriously doubt, for the above reasons, the value of this effort, we find no fault with the qualifications of the personnel or the level of funding (assuming the work continues). It should also be noted that the doubtful validity of HER "data" in no way is meant to detract from the NRC commitment to the PRA approach. Rather, we urge caution in permitting PRA results to be driven by HER estimates.

3.1.2.2.4(c) Maintenance Error Model

Description

(1) Need

Both reports from nuclear power plants in LERs and research findings have documented the human performance error attributable to maintenance activities. The type of human error models and human performance data as documented in NPP operations and published in NUREG/CR-1278, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," were not intended to predict errors to maintenance for correction of component faults or to preventative maintenance tasks. U. S. Navy experience and methods of human reliability prediction of electrical and electronic maintenance have demonstrated the feasibility of this application of human error analysis. A computer-based performance model was developed as well as a manual model and both have been validated through field trials. However, the applicability of these models and methods to NPP maintenance has not been demonstrated. It is necessary to determine the limit of these techniques as well as to quantify human reliability of maintenance tasks in NPP applications to complete the total human performance prediction portion for probabilistic risk assessment. This task can provide a technical basis of human error determination for regulatory action, as well.

(2) Objective

Develop and validate quantitative human error models, risk prediction techniques, and methods of utilization for nuclear power plant (NPP) maintenance.

(3) Work Effort

Task 1. Survey of user requirements for models and methodology.

a. Identify potential users in the NRC, national laboratories and other risk assessment groups with respect to specific information needs.

b. Define the required output for a (the) selected method from the Task 2 effort.

Task 2. Review and analyses of existing models and methodology

a. Document available quantitative methods for predicting human performance for maintenance tasks.

b. Define the advantages/disadvantages of each method for NPP applications.

Performing Organization

Sandia National Laboratories with Applied Psychological Services, Inc. as subcontractor.

Status

(1) Schedule/Priority: This effort is scheduled to be completed in FY81. There is no NRR priority associated with this effort.

(2) Resources: FY81 obligation is $150K

(3) Products/Publications: The final report, due in December 1981, will document the results of surveys and define a comprehensive plan for NPP maintenance, human error model development, data base and schedule/cost. The maintenance task analysis will also be documented in the final report.

Evaluation

This program assumes the same logic that is inherent in the previous two programs, namely that a quantitative model, with supporting data, will be useful in improving design, operations, and maintenance of NPPs. For the reasons described and discussed previously, we believe that careful adherence to well-founded human engineering principles will maximize maintenance capability, and that knowledge of related HERs, if obtainable, will add no useful improvements. Thus, the objective of this task suffers from the same logic as do the objectives of the previous two tasks.

Disregarding, for the moment, our disagreement with the objectives and utility of the effort, we feel the personnel, schedule, and funding are suitable.

3.1.2.2.4(d) Human Error Rate Analysis

Description

(1) Need

The contribution of human error on nuclear power plant unreliability and the resulting contribution to risk was highlighted by the Reactor Safety Study, again in later IREP-type studies, and in operating occurrences at the nuclear power plants. However, given the importance which human error is purported to play, the human error data base remains essentially the same as the used in the Reactor Safety Study, a data base derived from non-nuclear data or the expert judgment of human factors specialists based upon their knowledge and experience. The data base, to the extent possible, must be validated by the operating experience at nuclear power plants. BNL has performed prior validation efforts on human errors related to valves and pumps and reported in NUREG/CR-1280. This work led to the development of a methodology to determine the opportunity for errors related to hardware components which is an essential element in the determination of human error rates. This research will focus on the validation of human error rates.

(2) Objective

To develop realistic human error models and data to aid in the quantification of human errors in reliability and safety studies of nuclear power plants and other nuclear facilities.

(3) Work Effort

Task 1. Data Analysis

1.1. Continue efforts currently in progress in the analysis of Licensee Event Reports (LERs) for the development of human error rates. This analysis is to be expanded to include electrical plant power systems. Analysis is to include both standby and operating components and the effects of testing and maintenance. Utilizing the performance shaping work accomplished in FY81, the errors will be classified into basic man-machine interface categories. Analysis of the LERs will be performed to assure that all human errors are identified and included. Other data sources, including simulator studies, will be reviewed to expand the statistical basis for the developed human error rates.

1.2. Scoping studies and statistical analyses will be performed on LERs and other appropriate data bases to examine the effects of several performance shaping factors on human performance. The contribution of maintenance errors to risk will be examined.

Task 2. Data Identification, Storage and Retrieval Feasibility Study

BNL will perform a feasibility study of the optimum methods for the coding, storing, and retrieval of human errors reported by the LER system. The purpose is to reduce the time required to sort through and classify by types the various forms of human error.

Task 3. Human Error Data Needs

BNL will study and identify the accuracy requirements of human performance data in the performance of risk on other quantitative type assessments. Applicability of different data sources will be evaluated for areas or uses most sensitive to variations in human error or the various forms of tasks, i.e., calibration, maintenance, operator action, etc.

Task 4. Common Mode Errors

Perform a re-evaluation of common mode human errors using the common mode human error model developed in FY81. Identify the dominant contributors to risk.

Task 5. Human Factors Conference

Initiate planning for an NRC sponsored conference on human factors in nuclear safety to be held in early 1983.

Performing Organization

Brookhaven National Laboratory

Status

(1) Schedule/Priority: Start in FY79; Continue through FY82

(2) Resources: Prior to FY82-unknown; FY82-$200K

(3) Products/Publications: NUREG/CR-1879; NUREG/CR-1880

Evaluation

While the study group is generally opposed to designing and conducting training-environment simulator experiments to generate human error rate data on the bases of cost-benefit ratio and validity, we recognize that meaningful information can be obtained from careful analysis of critical incident (e.g., LER) documentation. Therefore, this effort appears useful and should be continued, although improvement in LER data formats and information could greatly assist this effort as well.

The level of funding appears generally meaningful, especially when spread across the several (often unrelated) tasks. The personnel at BNL have already demonstrated their technical competence in this area.

3.1.2.2.5 General Human Factors Research

3.1.2.2.5(a) Human Factors Program Plan

Description

(1) Need

One of the consistent findings of the various groups that investigated the accident at Three Mile Island was the inadequacy of human factors considerations in the nuclear regulation process. NRC has taken actions to address some of the significant Three Mile Island human factors-related deficiencies. However, a long range plan for incorporating human factors into all significant aspects of nuclear power generation is required.

(2) Objective

Develop a comprehensive plan for the next ten years that will meet requirements imposed by regulatory functions and responsibilities of the NRC offices.

(3) Work Effort

The development of the plan will require approximately 4 professional person years over a period of 12 months.

Task 1. Identify aspects of nuclear power plant safety related to human factors issues and describe them. Survey NRC Offices and activities and review reports and documents relevant to regulation of human factors in nuclear power plants.

Task 2. Develop a preliminary account of problem areas, requirements, and priorities which document the human factors issues.

Task 3. Survey the nuclear industry, including utilities, architect-engineers, NSSS vendors, EPRI, INPO, and others relative to human factors issues.

Task 4. Prepare a draft report and final report.

Performing Organization

The Human Factors Society, Inc.

Status

(1) Schedule/Priority: The project started December 15, 1980 and will be completed with the submission of this report to the NRC in Spring 1982.

(2) Resources: The planning project has been carried out with the part-time services of seven senior human factors professional personnel possessing expertise over a broad range of human factors areas. The project cost is $528K.

(3) Products/Publications: The product of the project is a three-volume report (including identification of human factors problem areas in the nuclear industry, evaluation of current human factors activities and a comprehensive long-range human factors plan for nuclear reactor regulation).

Evaluation

The members of the HFS Study Group performing this planning project believe the objective to be appropriate and the project to be timely. Evaluations of the cost/benefit and the quality of work to meet the objective must be made by those whose job it will be to incorporate and manage human factors activities in the nuclear reactor regulatory process over the next several years.

3.1.2.2.5(b) Reactor Operator Task Analysis

Description

(1) Need

The Nuclear Regulatory Commission needs data and information to accurately and quantitatively define the role of the reactor operating crew and the various influences which tend to either support or hinder their performance. To acquire the data required to analyze operator performance, it is necessary that a task analysis be performed. This provides a description of the behavior pattern of operators when interfacing with procedures, training, control room hardware, management, etc., particularly under off-normal conditions. The term "task analysis" is used in its textbook definition; that is, the application of systematic methods for describing tasks, subtasks, and elements and their inter-relationships.

(2) Objectives

The objective of the proposed research is to prepare a task analysis which will provide data for evaluating:

a. human engineering designs of new control rooms and retrofitting of current control rooms;

b. the numbers and types of control room operators required with requisite skills and knowledges;

c. operator qualification and training requirements;

d. normal, off normal, and emergency operating procedures;

e. job performance aids; and

f. communications.

(3) Work Effort

Task 1. Program Planning.

Further develop the objectives of the program and the specific actions necessary to satisfy them. Furnish, within

90 days of contract approval, a detailed Program Plan. Items to be addressed include identification of:

a. The number of nuclear power plants to be analyzed based upon analysis of current trends, the types of accident scenarios to be used, and the total number. A minimum is one PWR of each NSSS vendor and one BWR.

b. The control room crew members for which basic task analyses will be done (ROs, SROs, Shift Supervisors, AOs, and others who may be directly involved in plant operations control) and the extent of analysis needed to define interfaces and interactions with support personnel (e.g., STAs, engineering) who may be involved in emergency decision making.

c. Definition of the minimum set of operational sequences that must be analyzed to reach the basic objectives of the program, e.g., normal evolutions pertaining to plant maneuvers, FSAR Chapter 15 postulated accidents, abnormal situations not covered in Chapter 15 but requiring attention because of LERs or TMI related requirements.

Task 2. Prepare for Data Collection.

Develop plans for data collection.

a. Define the particular systems being analyzed including their functions and components (e.g., process equipment, control room, crew, equipment, and personnel interfaces).

b. Describe the allocation of tasks between humans and machines in the system's current configuration for the following functions: Reactivity Control, Core Cooling, Reactor Cooling, Containment Integrity Control, Reactor Startup, and Reactor Shutdown.

c. Develop the format and methods to be used, including computer-based storage, analysis, and retrieval requirements, to analyze the tasks.

d. Review each plant's normal operating, transient, and emergency procedures.

Task 3. Data Collection.

Collect necessary data by such means as:

a. Observing control room activities over an extended period of time.

b. Conducting interviews and administering questionnaires with operating crew and management.

c. Walk-throughs and talk-throughs of simulated events.

d. Extracting material from procedures and other sources.

Performing Organization

General Physics Corporation/BioTechnology, Inc.

Status

(1) Schedule/Priority: Start in FY82; complete in FY83; NRR Priority #1

(2) Resources: FY82-$700K

(3) Products/Publication: Unknown

(4) Related Activities: INPO Job and Task Analysis (see 3.3.2.3.1)

Evaluation

The objectives of this research are highly appropriate to a wide range of human factors requirements. The information to be derived from the task analysis is fundamental to such human factors activities as control room design, development of operator qualification and training requirements, instructional system development, and determination of shift staffing requirements.

Nuclear power plant operator task analyses should have been performed during the past two decades. Because they were not performed, there were no sound bases for the decisions that were made regarding the man-machine interface. Most current and near-term planned human factors activities are concerned with attempts to ameliorate the existing deficiencies and defects. If it is recognized that, regardless of what should have been done during the past twenty years, significant human factors activities are only now beginning in the nuclear power community, then it can be said that this work on task analysis is timely. Certainly, it is timely in the sense that it is among the first group of human factors programs sponsored by the NRC.

This program ranks high in terms of the benefits to be derived relative to the cost. The results of the work are prerequisite for effective human factors programs in many areas ranging from control room design to training.

At the time this evaluation is being made, no products of the task analysis have been reviewed by the Study Group. However, a general evaluation of the capabilities of the organizations doing the work can be made. On the basis of professional qualifications, past performance, and familiarity, both with human factors analysis techniques and with nuclear power generating systems, it may be expected that the quality of work to meet the objectives will be of the highest order.

3.1.2.2.5(c) Human Factors Research for Liquid Metal Fast Breeder Reactors

<u>Description</u>

(1) Need

This is a new project under consideration in the event there is a definite go-ahead for the LMFBR.

(2) Objective

Develop a human factors technical basis for regulatory requirements related to control room design, procedures, controls and displays, staffing, personnel qualifications, and training for LMFBRs.

(3) Work Effort

Compare the design, construction, operation, and maintenance of LMFBRs to LWRs with the aim of identifying those LMFBR features which merit particular consideration with respect to human factors safety, identify criteria for man/machine functions, and prepare a task analysis program plan.

<u>Task 1</u>. Particular attention to the following systems and design features will be provided in considering LMFBR human factors safety:

a. Method of reactivity control

b. Secondary heat removal system

c. Sodium fire detection and control system

d. Data display and status indicators of core and coolant loops

e. Unique maintenance design relative to use of sodium coolant

f. Fuel handling system

<u>Task 2</u>. Prepare a functions analysis to identify LMFBR system functions to be performed by man, machine (hardware and/or software), or by some combination of man and machine. The analysis will identify the criteria applicable from

other NRC functions allocation studies which are used herein. The task effort and results will be documented as a NUREG.

Task 3. Prepare a task analysis program plan which will provide data and recommendations for evaluating:

a. Human engineering aspects of the LMFBR control room

b. Numbers and types of licensed and unlicensed personnel for operators and maintenance

c. Control room crew qualifications and training requirements

d Maintenance crew (I&C, machinists, electricians) qualifications and training requirements

e. Normal, off normal and emergency operating procedures unique to LMFBRs

f. Job performance aids

g. Communications systems inside of and interfacing with the control room

h. Unique LMFBR control and display requirements

Performing Organization

Undetermined.

Status

(1) Schedule/Priority: under consideration

(2) Resources: possibly $200K in FY82.

(3) Products/Publications: Function Analysis and Allocation Study

Evaluation

The objectives of this proposed research are both appropriate and timely. Completion of the research and incorporation of the results in the design and development of the LMFBR would provide benefits to safety and efficiency of operation that far outweigh the expected cost. No estimate of quality of work can be made at this time.

3.1.2.2.5(d) Human Factors Research Review Group

Description

(1) Need

The increasing emphasis on human factors research has caused the need for research review groups. Such groups in NRC are established to enhance communication and bring to the research program management a wide range of technical viewpoints, including views from NRC representatives that use the research results.

(2) Objectives

a. To provide reviews, technical recommendations, comment, and analysis of the research program and products related to human factors of the Human Factors Branch, Division of Facility Operations, RES.

b. To identify new human factors research needs.

c. To recommend redirection of existing tasks based on evaluation of priorities and progress.

d. To review the completeness and quality of human factors research products and assess their appropriate utilization in the regulatory process.

e. To facilitate coordination of related activities of human factors research among the NRC, ACRS and public, equipment suppliers, INPO, EPRI, IEEE, ANS, and other interested domestic and international organizations.

(3) Work Effort

The Human Factors Research Review Group will address the following major technical fields and principal functions:

1. Human Factors Systems Engineering - research products and standards relevant to the operator-machine interface. This research emphasizes criteria development and focuses on the consequences of functional allocation and control room designs.

2. Human Reliability - research dealing with modeling and estimation of human performance and its contribution to risk and to design and safety requirements and standards.

3. Plant Procedures - research products and standards needed to develop and implement clear, concise normal and emergency operating procedures.

4. Licensee Qualifications - research products and standards relevant to selecting, training, and licensing plant personnel, including simulator technology development; and research products and standards relevant to management of plant operations.

Performing Organization

Human Factors Branch, DFO, RES

Status

(1) Schedule/Priority: formed in summer 1981; Meet 3 or 4 times per year

(2) Resources: N/A

(3) Products/Publications: Unknown

Evaluation

The formation of the Human Factors Research Review Group was both appropriate and timely. The designation of representatives from other divisions in RES, NRR, and I&E as members of the group should provide a wide range of administrative and technical perspectives. The benefits to be derived from the activities of this group should far outweigh the cost of the time required to the members. It is too early to evaluate the quality of work of the group.

3.1.2.2.6 Long Range Research Plan

The material included under this topic is taken directly from the Long Range Research Plan for Human Engineering in the Division of Facility Operations. Evaluative comments are provided by the authors of the present report after the complete statements of planned long-range research.

Description

The plan for human engineering is directed toward the resolution of long-term issues related to human factors safety. Research and standards efforts to date have focused on the operators and the control rooms of light water cooled reactors and these efforts are expected to continue well into the planning period. However, increasingly greater emphasis will be placed on personnel and sytems outside the control room and on fuel cycle facilities other than light water reactors. Integral to the planning is continual assessment of the safety significance of human performance as derived from reviews of documented operating experience and risk analysis. These reviews help set priorities for research and standards activities.

3.1.2.2.6(a) Human Factors Engineering

This subelement generates information, data, methods, and standards relevant to evaluating the operator-machine interface of nuclear facilities. Prior to the planning period, this subelement will have generated significant bodies of data on reactor operator response times during simulated accidents on the effects of computerized display systems on operator performance. Task analyses for reactor operating crews will have been substantially completed.

During the planning period, a task analysis for reactor operators will be reported. The products will include data on performance requirements of the crew in normal, transient, and accident sequences, the information required by operators to perform tasks, and probable sources of human errors. A software package will assist the NRC staff in using the task analysis results to confirm or develop requirements for staffing, equipment design, and training. Completion: FY84.

Functional allocation studies will produce data and criteria to assist the staff in evaluating the proposed degree of automation of engineered safety features and other plant systems. The products will include the effects of automation on operator motivation, vigilance and attitude, and an assessment of the need to preserve manual operation as a backup to an automatic system. Completion: FY86.

The methods, equipment, and effectiveness of computerized aids will be evaluated by laboratory experimentation, field trials, and analysis. The currently available graphic display research capability will be enhanced in 1983 and utilized thereafter to perform this task. The NRC will continue to participate in the Halden Reactor Project through 1987. The products will be data and information to help develop functional requirements and evaluation criteria for alarm filtering systems, disturbance analysis systems, computerized procedure manuals, artificial intelligence systems, and other computerized systems currently being considered for implementation in commercial reactors. Completion: FY88.

Human engineering analysis will help develop or validate standards for equipment used or maintained by operators and support personnel of advanced nuclear power plants and fuel cycle facilities. The results of this research will assist the staff in preparing guidelines for future human engineering standards and in assessing the operation and maintenance of new designs. Completion: FY88.

Supervisory control models will be developed, validated, and applied to facility operations. The products will assist the staff in confirming and developing regulatory requirements for and value/impact assessment of equipment design and operational and maintenance aids. The scope of this task includes conventional and advanced plants and fuel cycle facilities. Completion: FY88.

3.1.2.2.6(b) Licensee Qualification

This subelement generates information, data, methods, and standards relevant to evaluating the training and licensing of plant personnel and the management of design, construction, and operation of nuclear facilities. Prior to the planning period, this subelement will have generated sufficient informaton to arrive at interim regulatory positions on reactor operator education, training and licensing. Performance measures which define long-term data gathering efforts to confirm regulatory criteria will have been developed. Task analysis for support personnel of reactors and other nuclear facilities will have been initiated.

During the planning period, a primary goal is to validate the education, training, and licensing requirements for licensed operators. The product of this work will be either a confirmation that current requirements are appropriate, or detailed recommendations for changes that should be made to these requirements such that they become appropriate. Completion: FY85.

Pending its successful application to reactor operators, the Instructional System Development (ISD) method, a technique proven in use by the military, will be used to establish training requirements for instrument and control technicians (completion FY85), maintenance technicians (completion FY86), fuel cycle facility operators (completion FY87), and selected nuclear power plant support positions (completion FY88). This work will serve as a portion of the technical basis for planned regulatory guides such as "Qualifications and Certification of Instrument and Control Technicians in Nuclear Power Plants", and "Qualification of Maintenance Personnel".

Studies will be conducted and data collected to support three regulatory efforts. The first is the revision of Regulatory Guide 1.149, "Nuclear Power Plant Simulators for Use in Operator Training." This regulatory guide addresses the similarity that should exist between a simulator and the facility it simulates; simulator fidelity, testing, and upgrading requirements; and overall simulation capabilities (completion FY84). The second is the planned development of a regulatory guide on "Nuclear

Power Plant Simulator Training Programs," which will address the similarity that should exist between a simulator and the facility the operator is being trained to operate and effective use of part-task, concept, and full-scope high-fidelity simulators (completion FY85). The third is validation of the requirements for determining appropriate manual versus automatic function allocation which will be developed based on ANSI-N660.

Data will be collected to validate criteria established for evaluating the ability of a utility organizaton to effectively and safely manage a nuclear power plant. Completion: FY86.

A systematic method of evaluating the effects of errors in design or construction on the ability of an operator to safely operate the plant will be developed. This will include criteria which could be used to evaluate whether additional training is an acceptable means of compensating for the operational problems that result from a particular design or construction error. An attempt will be made to define the point at which design or construction errors make a system too challenging to operate correctly. Completion: FY87.

3.1.2.2.6(c) Plant Procedures

This subelement addresses research and standards relevant to developing and implementing sound procedures. Prior to the planning period, this subelement will have generated sufficient information to draft a proposed regulation and supporting regulatory guides aimed toward assuring that technically accurate, human engineered, step-by-step, approved, and validated operating procedures exist and are followed in each operating plant. Data based on quantifying the reductions in operator error rate from use of the upgraded procedures will be under development to confirm the benefits of these proposed regulatory requirements.

During the planning period, a pilot study will be completed to confirm the necessity and adequacy of the proposed requirements. Completion: FY84.

Data will be provided to allow preparation of regulatory requirements that address operating procedures for all equipment important to safety, not just equipment covered by narrow historic definitions of importance to safety. As part of such research, data will be generated as necessary to acknowledge that as plants become more automated, the burden of proper equipment operation may shift from the reactor plant operator to the software programmer and maintenance personnel.

As detailed technical upgrading commences for each operating plant, gather sufficient data to validate, refine, and optimize published regulatory requirements in FY86 through FY88.

From the experience and insight of procedure upgrading programs, research projects will be conducted in FY85 through FY88 that study and provide data to show the strong ties between design conservatism or margin and equipment complexity, particularly control equipment complexity, and the resulting demands on operating procedures, and the education and training of operators.

In conjunction with functional allocation studies and computer aid evaluations, research will be conducted leading to procedure preparation and use that adequately recognizes and addresses the balance that must exist such that new computer diagnostic equipment does not cause the operator to have an unsafe dependence on it, and that as the operator is placed more and more "out of the loop" by automation he does not become less prepared to handle unanticipated emergencies. Completion: FY88.

Once the fundamental deficiences in operating procedure systems have been corrected, research may be desirable to explore and test alternate ways of presenting procedures to operators to optimize comprehension and response. In particular, studies related to functional criteria and design criteria of computer-based CRT displays may be necessary.

3.1.2.2.6(d) Human Reliability

This subelement develops and verifies models of human performance and quantitatively assesses the human contribution to risk. Prior to the planning period, this subelement will have generated methodologies, guidelines, and a data base suitable for constructing models of human performance to assess human reliability, ("Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications," NUREG/CR-1278), principally in those areas involving skill and rule-based behavior (stimulation and response) as opposed to cognitive behavior. Assessment will have been performed to determine if these methods and models, when utilized by different users, produce repeatable results.

The human performance models presented in NUREG/CR-1278 will, in part, be validated by two activities to be performed. First, the licensee event reports will continue to be assessed to determine gross human error rates, and to the extent possible, the cause of human error. Secondly, a current program to record the actions taken by reactor operators, corresponding response times, and the action sequences for selected accident scenarios during simulator runs will be continued. These activities should reduce the uncertainties in human reliability assessments that will be performed to estimate the benefits of proposed regulatory requirements. Completion: FY84.

Simulator evaluations will be conducted of the ability of operators and operating teams to deal successfully with selected accident sequences. The results of this data collection program will be the development of models and data requirements for modeling and evaluating the ability of operators or operating teams to perform cognitive tasks. Such tasks consist of the recognition of off-normal conditions, the interpretation of these data to ascertain reactor status, and the determination of the action required to bring the reactor to and maintain it in a safe state. The product of this effort will be the development and experimental validation of cognitive models for performing reliability assessments of the operator involved in decision making tasks. Completion: FY86.

A human performance data bank will be established (FY85) and maintained to serve as a repository of information for use by human reliability analysts.

Models will be developed to determine the reliability of plant personnel in performing maintenance and test activities correctly and to determine those design and operational factors which most affect the mechanic's or technician's ability to accomplish the intended tasks. This work will form a basis for determining the reliability improvement which could be expected from various changes or improvements in work environments, job aids, training, etc. Improved modeling capability will also improve the determination of risk contribution resulting from maintenance and test errors. Completion: FY86.

An event report investigation group will be established to demonstrate the feasibility and effectiveness of applying classical methods, such as the critical incident technique, to determine, from appropriate event reports, the root causes of human error. Factors which influenced the operator either to take incorrect action or to respond correctly will be determined and used to validate operator and maintenance activity reliability models. Completion: FY86.

Reportable human errors, defined as those which result in event reports, provide a currently available human error data base; however, this is believed to be a small percentage of those which occur but which are detected and corrected promptly and therefore do not exist for a sufficient period of time to require reporting. A better understanding of human error potential could be determined if all such human errors were reported for analysis. A reporting system similar in nature to the Aviation Safety Reporting System which NASA provides the Federal Aviation Agency will be considered. Plans for instituting such a reporting system and subsequent report analysis will be developed by FY84 and, if acceptable, implemented by FY85.

3.1.2.2.6(e) Evaluation of Long Range Research Plan

A detailed evaluation of this long range research plan in the format used for other research projects and tasks would be neither appropriate nor useful at this point. The problem areas addressed by the plan are considered at length in other parts of this final report (Volume 3, Human Factors Areas of Concern). Our best evaluation of long range research that is needed, beyond that already in progress, is represented by the comprehensive long range plan we recommend (Section 4.0, Volume I). Although we were provided and took into consideration earlier, and, in some cases, quite different, versions of the RES long range research plan summarized here, this most recent version reached us after we had completed the development of the plan recommended in Section 4.0. We see nothing in the RES long range plan that would cause us to modify the plan we recommend.

Differences between the two plans are obvious. Some of these are due to differences in scope. Our long range plan is not limited to research. In addition to research it includes regulatory and organizational recommendations. More important than these, however, are some major differences resulting from the perspectives and experience of the persons developing the plans. Although there are some general areas of agreement regarding the appropriateness and timing of research tasks, there are major differences in the relative importance and emphasis accorded some proposed tasks (noteably, those concerned with human reliability)

We concur with the position that although research focused on operators and control rooms should continue, increasingly greater emphasis should be placed on human factors outside the control room. Because many activities of auxiliary operators and maintenance personnel are critical for safe and efficient plant operation it is necessary to ensure that the equipment design, procedures, and personnel training conform to accepted human factors practice. Also the application of human factors science and technology to other fuel cycle activities will become more urgent during the next few years.

3.1.2.3 Office of Inspection and Enforcement

The Office of Inspection and Enforcement (IE) uses regulatory requirements (Code of Federal Regulations), USNRC regulatory guides, industry standards, and its own internal guidelines to inspect nuclear related activities for violations of health and safety that may endanger the general public. IE has a planned program for inspection that covers the life of a nuclear power plant. The functions of IE are:

1. Inspection of
   (a) applicants for licenses
   (b) licensees and other organizations
   (c) vendors

2. Investigation of suspected or alleged unsafe practices

3. Enforcement of the regulatory requirements, regulatory guides, and industry standards

4. Evaluation of problems

5. Notification to licensees of generic problems through issuance of bulletins, circulars, and information notices

6. Incident response

Regulated activities include:

1. Nuclear reactors
   (a) under construction (both commercial and research),
   (b) in operation, and
   (c) related activities of contractors and vendors

2. Nuclear materials
   (a) fuel fabrication, processing and reprocessing plants, and
   (b) by-products, e.g., radiography, etc.

IE uses resident inspectors supported by regional offices to provide continuous evaluation of nuclear power plants for compliance.

Among the numerous aspects of a nuclear power plant that IE inspects is the evaluation of procedures for technical accuracy and adequacy. Having no evaluation technique to determine what a "good" procedure looks like, IE contracted out two technical efforts to develop checklists that resident inspectors could use to assess procedures. These efforts are described on the following pages.

3.1.2.3(a) Development of a Checklist for Evaluating Maintenance, Test, and Calibration Procedures in Nuclear Power Plants

Description

(1) Need

Based upon an evaluation of the inspection process it was determined that maintenance, test, and calibration procedures are high risk procedures and should be assessed in a consistent manner. Without a checklist, inspectors made inconsistent subjective judgments about the adequacy of procedures.

(2) Objective

To develop a checklist that can be used by IE inspectors during their evaluations of procedures and serve as an aid for identifying procedural characteristics that can lead to human performance deficiencies.

(3) Work Effort

The work was performed in three phases:

(a) Evaluate maintenance, test and calibration procedures used in a sample of reactors to identify procedural characteristics that can lead to performance deviations.

(b) Develop a list of checklist items for identifying procedural deficiencies, weighted according to their contribution to performance deviations.

(c) Develop a method for IE inspectors to use the checklist to identify procedural deficiencies during their evaluations of procedures.

Performing Organization

Sandia National Laboratories with Human Performance Technologies, Inc. as subcontractor.

Status

(1) Schedule/Priority: Completed

(2) Resources: Unknown

(3) Products/Publications: NUREG/CR-1368, "Development of a Checklist for Evaluating Maintenance, Test and Calibration Procedures Used in Nuclear Power

Plants," R. L. Brune and M. Weinstein, May 1980.
NUREG/CR-1369, "Procedures Evaluation Checklist of Maintenance, Test and Calibration Procedures," R. L. Brune and M. Weinstein, May 1980.

Evaluation

At the time this effort was initiated the NRC was not too interested in human factors (this effort began prior to TMI); thus, the objective was very appropriate for the needs of IE. It was timely because it filled a gap in the IE inspection process. Cost information is unavailable.

The effort produced a checklist that was based upon a development process that considered data from many sources including performance data. Unfortunately, the checklist is not tied to specific criteria (specification and guidelines) established by the NRC. Guidance is provided to identify deficiencies, but no guidance is given to determine what deficiencies require complete correction.

3.1.2.3(b) Development of a Checklist for Evaluating Emergency Procedures

Description

(1) Need

After TMI, the effectiveness of emergency procedures came under scrutiny. Thus, prior to the creation of the Division of Human Factors Safety, IE determined that the resident inspectors needed an evaluation technique to assess the adequacy of emergency procedures.

(2) Objective

To develop a checklist to aid IE inspectors in identifying procedural deficiencies that can result in operator performance deviations.

(3) Work Effort

A sample of emergency procedures was gathered from four plants participating in the study. The plants were selected to represent as many factors as possible that might affect the design of procedures. During the plant visits, discussions were held with training personnel and operators regarding operator training programs. In addition, operators performed walk-throughs of the emergency procedures with members of the study team. Data pertaining to the training of operators for emergencies, the format and content of emergency procedures, and the use of procedures in emergencies were obtained. LERs were also analyzed.

Performing Organization

Sandia National Laboratory with Human Performance Technologies, Inc. as subcontractor.

(1) Schedule/Priority: Completed

(2) Resources: Unknown

(3) Products/Publications:

NUREG/CR-1970, "Development of a Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants," R. L. Brune and M. Weinstein, May 1981.

NUREG/CR-2005, "Checklist for Evaluating Emergency Procedures Used in Nuclear Power Plants," R. L. Brune and M. Weinstein, May 1981.

Evaluation

The objective of the development effort is appropriate because it provides the IE inspectors with a technique to assess the adequacy of the emergency procedure according to a standard implied by the checklist. It was timely because it filled a gap in the IE inspection process. Cost information is unavailable.

The checklist was generated from an extensive development effort. It incorporated proven information presentation principles. Unfortunately, as with the previous effort, criteria for emergency procedures have not been established. The NRC has just recently issued draft criteria for developing emergency procedures. In addition, since the initiation of the effort, the Procedures and Test Review Branch has been formed and is requiring all emergency procedures to be rewritten as symptom-based procedures.

3.1.2.4 Office for Analysis and Evaluation of Operational Data: The Assessment of Operational Safety Data in the Nuclear Regulatory Commission

Description

(1) Need

One result of the accident and the associated studies and investigations of Three Mile Island was that it became abundantly clear that improvements were required in the way that the NRC and the nuclear community used operating experience to help identify and resolve problems which could jeopardize public health and safety.

One of the NRC's responses to that need was to establish the Office for Analysis and Evaluation of Operational Data, or AEOD. The Office reports directly to the NRC's Executive Director for Operations, and is specifically dedicated to the tasks associated with the collection, assessment, and feedback of operational data from all NRC-licensed activities.

(2) Objective

The mission of the Office is to analyze and evaluate operational safety data. The Office also provides coordination for the overall NRC operational data program, and serves as the focal point for interaction with outside and foreign organizations performing similar work.

(3) Work Effort

Basically, AEOD screens and analyzes significant operational events, implements necessary supporting activities, and develops the procedures and tools needed to help assure that the NRC's program is defined, systematic, and effective. The Office issues no direction or requests for action to licensees; instead, the end product from studying an event is normally one or more recommendations to the NRC program office responsible for determining the need for an issuance for corrective action.

The principal source of data used in the assessment of operating experience has been the Licensee Event Report, or LER. A serious shortcoming of the present system is the fact that the reporting forms and the computerized files do not readily accommodate multiple failures or sequential happenings which may be part of a single reported event. The present system is also inadequate with respect to analysis of any human factors problems (see discussion in Volume 3).

A more complete description of the AEOD system, and the implications for human factors will be found in Volume 3 of this report. While there is no documented indication that LERs work to provide human error rate data, almost all attempts to study the role of human performance have relied heavily on the LER files.

Performing Organization

The NRC with support from the Nuclear Safety Information Center (NSIC) at the Oak Ridge National Laboratory.

Status

(1) Schedule/Priority: This is a continuous effort with a current rate of about 4,200 LERS per year entering the system.

(2) Resources: The AEOD has about 30 people.

(3) Products/Publications:

Since 1967, LERs have been abstracted and stored in the computer file of NSIC, with key words used as the primary means of retrieval. Since 1973, LERs have also been stored in a computer at the NRC. Searching these data bases is done with key words and coded fields plus the use of a search feature for words of interest in titles and abstracts. During 1981 a Sequence Coding and Search (SCS) procedure was developed to permit reconstruction of the chain of occurrences noted in the LERs. Each LER is also assigned one or more "Watch List" categories. This categorization is an automated tool for linking events having similar characteristics or sequences.

Evaluation

The assessment of operational safety data is a very important and appropriate objective; however, the current reporting and analysis system is unsatisfactory for determining human error causal factors or for use as a data base for evaluating the effects of human factors related changes.

Changes to the system to accommodate human performance data collection and analysis are long overdue. At present, it is not feasible to judge the quality of human performance data analysis since the general system design is inadequate to perform such analyses.

3.2 Department of Energy National Laboratories

The Department of Energy has extensive scientific, engineering, technology, and production facilities dispersed nationwide. These facilities support commercial nuclear power R&D in a variety of ways, from very fundamental research programs in the physical and life sciences to the most advanced goal-oriented design and development plans in nuclear energy technology. Of primary concern to the present report are the multiprogram laboratories, familiarly known as the National Laboratories. As indicated earlier in this report, both the Division of Human Factors Safety and the Human Factors Branch in the Office of Research contract extensively to these laboratories for the performance of technical assistance and research programs related to human factors. The twelve multiprogram laboratories are listed below:

1. Ames Laboratory, Ames, Iowa
2. Argonne National Laboratory, Argonne, Illinois
3. Brookhaven National Laboratory, Upton, Long Island, New York
4. Hanford Engineering Development Laboratory, Richland, Washington
5. Idaho National Engineering Laboratory, Idaho Falls, Idaho
6. Lawrence Berkeley Laboratory, Berkeley, California
7. Lawrence Livermore Laboratory, Livermore, California
8. Los Alamos Scientific Laboratory, Los Alamos, New Mexico
9. Oak Ridge National Laboratory, Oak Ridge, Tennessee
10. Pacific Northwest Laboratory, Richland, Washington
11. Sandia Laboratories, Alburquerque, New Mexico
12. Savannah River Laboratory, Aiken, South Carolina

The strength of the National Laboratories is based both on the excellence of their technical staffs and the excellence of their physical facilities. While no attempt will be made in this report to describe in detail either the staff or the facilities, the importance of these laboratories with respect to human factors is their unique facilities and the ease with which contracts can be initiated with the laboratories. With one or two exceptions, the staff of the National Laboratories does not include career human factors professionals. (A clear distinction is here between researchers in the social sciences and life sciences from career human factors professionals.) The programs being carried out by the National Laboratories have been presented elsewhere in this report under the sections dealing with the NRC sponsor, usually the Division of Human Factors Safety, NRR; or the Human Factors Branch in the Office of Research. Therefore, no further elaboration of those programs will be provided. For the reader's convenience, we have provided a table which identifies the human factors programs being performed by each laboratory, the NRC sponsor, and the paragraph number where these programs are described in this report.

Table 5. Human Factors Programs Being Performed for the NRC by the Idaho National Engineering Laboratory

PROGRAM	NRC SPONSOR	PARAGRAPH
Administer RO and SRO Licensing Examination	DHFS OLB	3.1.2.3
Plant Status Monitoring	DFO-HFB	3.1.2.2.1 (a)
Augmented Operator Capibility	DFO-HFB	3.1.2.2.1 (b)
Human Factors Reviews	DFO-HFB	3.1.2.2.1 (d)
CRT Display Design and Evaluation	DFO-HFB	3.1.2.2.1 (e)

Table 6. Human Factors Programs Being Performed for the NRC by the Lawrence Livermore National Laboratory (LLNL)

PROGRAM TITLE	NRC SPONSOR	PARAGRAPH
Guidelines for Control Room Design Reviews (NUREG-0700)	DHFS-HFEB	3.1.2.1.1 (a)
Evaluation Criteria for Detailed Control Room Design Review (NUREG-0801)	DHFS-HFEB	3.1.2.1.1 (c)
Human Factors Control Room Case Reviews	DHFS-HFEB	3.1.2.1.1 (b)
Human Factors Acceptance Criteria for the Safety Parameter Display System NUREG-0835)	DHFS-HFEB	3.1.2.1.1 (d)
Advanced Display Technologies	DHFS-HFEB	3.1.2.1.1 (f)
Standard Review Plan for NFEB	DFHS-HFEB	3.1.2.1.1 (j)

Table 7. Human Factors Programs Being Performed for the NRC by the Oak Ridge National Laboratory

PROGRAM TITLE	NRC SPONSOR	PARAGRAPH
Feasibility of Licensing Utility Managers and Officers	DHFS-LQB	3.1.2.1.3 (c)
Reactor Operator and Senior Operator Examination Validation	DHFS-LQB	3.1.2.1.3 (h)
Training and Examination Program Development	DHFS-LQB	3.1.2.1.3 (j)
Administer RO and SRO Examinations	DHFS-OLB	3.1.2.1.4
Safety Related Operator Actions	DFO-HFB	3.1.2.2.2 (a)
Personnel Selection and Training	DFO-HFB	3.1.2.2.2 (b)
Operational Aids for Reactor Operations	DFO-HFB	3.1.2.2.2 (c)

Table 8. Human Factors Programs Being Performed for the NRC by the Pacific Northwest Laboratories (PNL)

PROGRAM TITLE	NRC SPONSOR	PARAGRAPH
System Status Verification Guidelines	DHFS-HFEB	3.1.2.1.1 (e)
Annunciator System Guidelines	DHFS-HFEB	3.1.2.1.1 (g)
Plant Maintenance Program Plan	DHFS-HFEB	3.1.2.1.1 (h)
Review of Emergency Procedures of License Applicants	DHFS-PTB	3.1.2.1.2 (a)
Criteria for Preparation Emergency Procedures (NUREG-0799)	DHFS-PTB	3.1.2.1.2 (b)
Utility Management and Organization Guidelines	DHFS-LQB	3.1.2.1.3 (b)
Independent Safety Engineering Group Guidelines	DHFS-LQB	3.1.2.1.3 (d)
Manpower and Staffing Guidelines	DFHS-LQB	3.1.2.1.3 (e)
Shift Technical Advisor Guidelines	DHFS-LQB	3.1.2.1.3 (f)
Plant Operator Qualifications	DHFS-LQB	3.1.2.1.3 (k)
Operator Feedback Workshops	DHFS-LQB	3.1.2.1.3 (l)
Plant Drills Guidelines	DHFS-LQB	3.1.2.1.3 (m)
Administer RO and SRO Licensing Examination	DHFS-OLB	3.1.2.1.4

Table 9. Human Factors Programs Being Performed for the NRC by the Sandia National Laboratory

PROGRAM TITLE	NRC SPONSOR	PARAGRAPH
Human Performance Data Bank and Analysis	DFO-HFB	3.1.2.2.4 (a)
Human Performance Modeling for NPP Operations	DFO-HFB	3.1.2.2.3 (b)
Maintenance Error Model	DFO-HFB	3.1.2.2.4 (c)
Independent Spent Fuel Storage Installation Task Analysis	DFO-HFB	3.1.2.2.4 (d)

Table 10. Human Factors Programs Being Performed for the NRC by the Brookhaven National Laboratory

PROGRAM TITLE	NRC SPONSOR	PARAGRAPH
Human Error Rate Analysis	DFO-HFB	3.1.2.2.4 (d)

3.3 Industry

This section will identify, describe, and evaluate the principal human factors activities of the nuclear power industry. The section is subdivided into major units concerned with Utilities, Industry Sponsored Organizations (e.g., EPRI, INPO, NSAC, EEI, AIF), Architect-Engineer firms, Nuclear Steam Supply System Vendors, and Human Factors Organizations and Consultants.

Much of the information in this section was provided by the individual organizations in the form of written materials, or was obtained through discussions with them during the project. Every effort has been made by the authors of this report to obtain complete, accurate, and current information about industry human factors activities, particularly of an R&D nature, but of course some activity may have been left out, although not deliberately. In any event, the activities described in this section are believed to be representative of the nuclear industry.

One further point is the matter of evaluation of the programs and actions. As in the previous material, these evaluations are the exclusive opinions of the authors and are based on the information made available to us.

3.3.1 Utilities

Utilities that are either operating or constructing nuclear power plants cannot be characterized as a group by a small number of general descriptive statements. They differ greatly in size, type of ownership, corporate structure, ownership-management relationship , population and geographical size of area served, number of nuclear units, mix of hydro-fossil-nuclear generating units, and number of years experience in nuclear power generation. Less obvious to the casual observer are the major differences among utilities in operational philosophy. In view of large differences along these and other dimensions, it is not surprising to find that there has been no common approach to contracting for the design and construction of plants. Furthermore, these consideration, in conjunction with minimum NRC requirements for standardization, have resulted in different plant designs for practically every nuclear power generating unit in the United States.

Prior to TMI-2, there was almost no recognition of the importance of human factors in the design, construction, operation, and maintenance of nuclear power plants. Representatives of some utilities have claimed, after the fact, that "human factors type" activities were carried out in the design of their control rooms prior to TMI-2. This usually amounted to asking experienced operators to participate in control room design or design reviews and what was described in many instances as "using good engineering common sense in the layout of displays and controls". Certainly, both of these are desirable adjuncts to good human factors design. However, to confuse them with the approach, techniques, methods, principles, and knowledge that a competent human factors professional uses in solving design problems is to portray a gross lack of comprehension of human factors. Unfortunately, in spite of the widespread use of the phrase "human factors" since TMI-2, there is good evidence that many people who use the phrase do not have any real understanding of what is involved. More to the point, however, is that recent reviews of control room design do not even support the contentions of having used good engineering common sense in their designs.

Since TMI-2, perhaps in keeping with the diversity described previously, utilities have shown a great deal of variability in their acknowledgement of the requirements, express and implied, for belatedly incorporating human factors in their operations. Some utilities have employed persons with human factors education and training. Others have chosen to retain human factors consultants and human factors consulting firms. Some utilities have annointed employees from some other discipline with a human factors title or have in some cases assigned responsibility for human factors concerns to an employee whose training and experience are in some other field.

Most utilities, in spite of their great differences otherwise, have responded defensively to the spotlighting of previous and current human factors deficiencies. There are good indications that most have only a superficial understanding of the human factors discipline and of the implications of standard human factors principles and practices for improved safety and efficiency of operations. Although there are very few exceptions, most utilities' attitude toward human factors is to do the minimum possible to meet NRC regulations and guidelines.

3.3.2 Industry Sponsored Organizations

Industry sponsored organizations which provide research, development, or technical assistance to utilities with nuclear power plants are funded by those same utility companies. Each of these organizations has member utilities who sponsor the organization and receive the benefits of its efforts, although most of the data and information developed by these industry sponsored organizations is available to the public. Not every utility is a member of every organization, but in general the vast majority do participate. There are five principal industry sponsored organizations with some responsibility or interest in human factors in commercial nuclear power operations. These are

(1) The Electric Power Research Institute (EPRI),

(2) The Institute for Nuclear Power Operations (INPO),

(3) The Nuclear Safety Analysis Center (NSAC),

(4) The Edison Electric Institute (EEI), and

(5) The Atomic Industrial Forum (AIF).

Not all of these organizatons are dedicated solely to nuclear power; INPO and AIF are. The organizations have a staff of permanent professionals but also have members of the utilities working on loan or perhaps on a voluntary basis. While these organizations obviously represent the interest of the commerical industry, they tend to cooperate with the NRC in order to avoid unnecessary adversarial confrontations. Each of the five organizations identified above will be discussed separately in terms of its: (1) mission and organizaton; (2) human factors responsibillity or interest; and (3) projects and activities. The project descriptions will not be at the same level of detail as those described for the Nuclear Regulatory Commission, but an attempt will be made to provide sufficient detail to allow the reader to judge the evaluation made by the authors of this report.

3.3.2.1 The Electric Power Research Institute (EPRI)

EPRI was founded in 1972 by the nation's electric power utilities to develop and administer a coordinated national electric power research and development program. Through selection, funding, and management of research projects conducted by contracting organizations, EPRI promotes the development of new and improved technologies to help meet the public's present and future electric energy needs in environmentally acceptable ways.

EPRI has six technical divisions and approximately 40 program areas. Each technical division makes specific recommendations on R&D projects within its assigned areas. Funded projects are then managed by the EPRI staff. More than 1,600 technical reports have been published to date. The six technical divisions are as follows:

* Advanced Power Systems Division

* Coal Combustion Systems Division

* Electrical Systems Division

* Energy Analysis and Environment Division

* Energy Management and Utilization Division

* Nuclear Power Division

The human factors activities, initiated in 1975, are conducted almost exclusively in the Nuclear Power Division, which has a program manager who is a career human factors professional. Figure 10 is the current organizational structure at EPRI, emphasizing the human factors activity.

The objective of the Systems Performance Program is to support utilities in achieving maximum utilization of their investment in nuclear equipment. Improvement is needed in performance and reliability of plant components and subsystems, and this program is addressed to that need.

The program is organized to develop and validate generic remedies to current and projected problems which will affect plant reliability and operations. It is composed of three subprograms and generally provides projects in five areas: Component Reliability, Human Factors, Data Systems, Valves, and Refueling and Outage Improvements. The last three are combined in the plant Outage Data and Improvements Subprogram.

The objectives of the Human Factors Subprogram are the application of human engineering principles and criteria to design, improved training and performance evaluation of operations, and the development of diagnostic aids for operations. As these more critical needs are fulfilled, the emphasis will shift to other important residual needs, such as the total man/machine interface, protection against adverse environmental conditions, improved procedures and communications, operational climate, and problems of stress and fatigue. In order to increase nuclear plant availability and safety, the major causal factors that result in human error and degraded performance capabilities need to be identified and remedial actions taken.

Technical Performance Targets. Equipment will be developed such as cooling suits for maintenance work in hot environments. Modifications to control rooms will enhance the performance of operators and supervisors. Maintenance procedures will be developed using the job performance aid method for nonrepetitive tasks of a complex nature. Human engineering guidelines and anthropometric data will be developed for use in design trade-off decisions both in new plants and backfit of existing plants. Other areas such as training and maintenance will be investigated to establish behavior principles. Human performance guidelines will be established and guidance provided as to how they may be met.

Subprogram Strategy. The approach to be followed in selected areas of investigation is to conduct in-depth exploratory studies to identify the range, severity, and priority

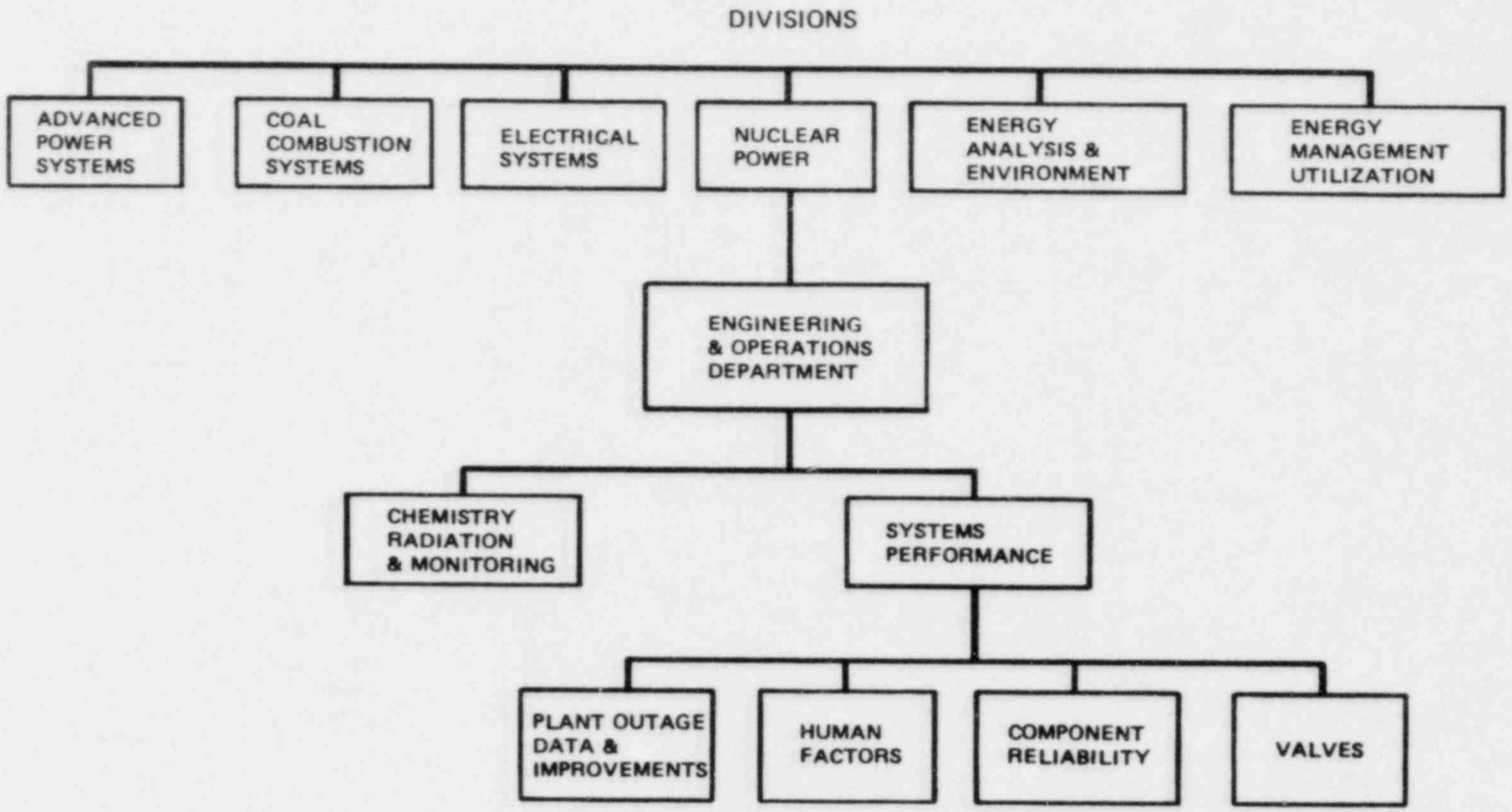

FIGURE 10. EPRI CORPORATE ORGANIZATION.

of problems. Next, solutions to these problems, through empirical investigations, are obtained and implemented. Extensive use will be made of existing technology and data bases from the DOD and other sources. Major areas of investigation include the design of plants and control rooms, training, maintenance, procedures, communications, and diagnostic aids for operations. By working directly with utilities in developing methods and technologies to meet each of the above needs, EPRI will be able to provide information which can be used by the industry to improve plant availability and safety and to satisfy forthcoming NRC requirements.

Technical Impediments. Despite improvement in awareness of the importance of the man-machine interface, human factors is still misunderstood conceptually because the approach calls for a mix of objective and subjective data. Human factors problems cannot be handled entirely by a common-sense approach, but require a specialized discipline. These misconceptions are influencing factors on the kind of R&D that is acceptable to the user/sponsor.

Interrelation to Other EPRI Research. This program continually interfaces with other EPRI projects. For example, the application of panel layout and job performance aid procedures is being applied to a program to enhance location of leaks in utility plant condensers. Human factors support is being given to the Disturbance Analysis Safety System project and also to the development of a system safety panel. Human engineering principles are important adjuncts to EPRI work in reliability and safety.

EPRI is concerned with human factors because of the impact on safety of nuclear power plant operations. It first sponsored human factors studies of control rooms in 1977, and has enlarged its activities since TMI-2; however, total funding is still marginal, and the emphasis on human factors does not seem to be growing. In some respects, this reflects what the utilities feel their needs are, since task forces of utilities' representatives approve all projects. Descriptions of projects follow.

3.3.2.1.1 Human Factors Review of Nuclear Power Plant Control Room Design (RP 501)

Description

(1) Need

Over the past 15 years, several investigators have pointed to the need for the application of human factors engineering principles to the development of nuclear power plant control rooms. The need for optimum man-machine relations in the nuclear power industry is no less acute than that for military and space programs. While the nuclear industry can take great pride from its enviable safety record, the adverse public reaction to radioactive releases that could be caused by operator error makes it essential that the operator-control room interface be optimized. Also, less than optimal man-machine interfaces can lead to costly equipment damage and serious losses in utility revenues.

(2) Objective

The Electric Power Research Institute sponsored this study in response to technical criticisms regarding the lack of attention to human factors in nuclear power plants. This 16-month study was designed to provide a thorough evaluation of representative control rooms.

(3) Work Effort

The human factors aspects of five representative nuclear power plant control rooms were evaluated using such methods as a checklist guided observation system, structured interviews with operators and trainers, direct observations of operator behavior, task analyses and procedure evaluation, and historical error analyses. The human factors aspects of design practices are illustrated, and many improvements in current practices are suggested. The study recommends that a detailed set of applicable human factors standards be developed to stimulate a uniform and systematic concern for human factors in design considerations.

<u>Performing Organization</u>

Lockheed Missiles and Space Company/NUS Corporation

<u>Status</u>

(1) Schedule/Priority: Completed in 1977

(2) Resources: Unknown

(3) Products/Publications: EPRI NP-309: Seminara, J. L., Gonzales, W. R., and Parsons, S. O., "Human Factors Review of Nuclear Power Plant Control Room Design," EPRI Project 501, March 1977.

<u>Evaluation</u>

The RP-501 series of studies was begun in 1976 with the initial objective of identifying the basic human engineering design deficiencies in control rooms. A Summary Report was proposed in November 1976, and the first complete study was published in March 1977. Performed by human factors personnel at Lockheed MSC, these represented an excellent start on the understanding of the severe magnitude of human engineering design problems. Additional studies in this series are evaluated in subsequent sections of this Volume.

Begun before TMI-2, the studies were timely and served as excellent warnings of design induced error of the type which occurred at TMI-2.

Funding levels were moderate and could have resulted in substantial cost benefits if the NRC and industry had been sensitive to the need to correct such deficiencies. It is fortunate and desirable that this research project is continuing.

3.3.2.1.2 Performance Measurement System for Training Simulators (RP 769-1)

Description

(1) Need

This program was motivated by three reports:

a. Reactor Safety Study, WASH 1400, section on human reliability analysis

b. EPRI NP-309 Project RP501, "Human Factors Review of Nuclear Power Plant Control Room Design"

c. EPRI Technical Services Agreement 75-26 with the Singer Company, Simulation Products Division for a PMS feasibility study.

The first two reports identified the need for an automated system to record human performance on nuclear reactor simulators. The third report determined the feasibility of such a system.

(2) Objective

This project has the following objectives: (1) to provide an empirical data base for statistical analysis of operator reliability and for allocation of safety and control functions between operators and automated controls; (2) to develop a method for evaluation of the effectiveness of control room designs and operating procedures; and (3) to develop a system for scoring aspects of operator performance to assist in training evaluations and to support operator selection research.

(3) Work Effort

To meet these objectives, a performance measurement system has been developed which is capable of automatic recording of statistical information on operator actions and plant response. During the conduct of a simulator response exercise, all control room data (gauges, annunciator lights, switch positions) are collected on magnetic tape, which can be evaluated by a computer after the exercise is completed.

Exercises consist of both normal operational procedures, such as startup and shutdown, plus a number of emergency procedures for both PWR and BWR plants which were selected based upon consultation with industry representatives. In addition, a number of casualty identification and control drills (CICDs) are included. The purpose of the CICDs is to obtain a measure of operator performance in dealing with discrete off-normal events that can be diagnosed and responded to by the operator relatively quickly.

The three principle criteria used in the performance measurement system are safety, economic, and personal consequence of errors.

Performing Organization

General Physics Corporation

Status

(1) Schedule: Approx. January 1978 to December 1981

(2) Resources: budget unknown; access to Browns Ferry and McGuire simulators.

(3) Products/Publications: An Interim Report was published as EPRI NP-783, Project 769, May, 1978. As of that report, a prototype PMS was developed for the Browns Ferry simulator. Data were collected in a pilot study to demonstrate the PMS capabilities. Further results are unknown to us; however, the Interim Report mentions several research programs at varying stages of formulation and development:

a) Potential errors associated with man-machine design factors.

b) Control action sequence analysis.

c) Continuous process control performance analysis.
d) Performance modelling.
e) Operator selection criteria development

Evaluation

This objective was given a high priority by the HFS Study Group. Additional work in this area must be coordinated with research aimed at defining objective (criterion-referenced) performance measures. The work to date is certain to benefit simulator instructors who have access to the PMS and are appropriately trained in its use. Judging only from the Interim Report, this effort appears to be well conducted and of good quality.

3.3.2.1.3 The Role of Personnel Errors in Power Plant Equipment Reliability (TPS 77-715)

Description

(1) Need

The power generation industry commits enormous resources and efforts to optimize power plant equipment efficiency and reliability. Considerably less effort has been spent on reducing personnel errors which contribute to equipment unavailability. The need exists to determine the impact of personnel error on the availability of power plants.

(2) Objective

The primary objective of this study was to quantify the role and impact of personnel errors on equipment availability. This would serve as a guide to the specific type and level of effort in human factors analysis (research, engineering, design, and training) which would be appropriate to power plant analysis and design.

(3) Work Effort

Three approaches were used to reach these objectives. First, representatives of nine utilities and three vendors were interviewed to obtain the opinions of experienced personnel on the frequency, type, and impact of personnel errors. Second, written reports of system failures were obtained from two utilities and analyzed to quantify the personnel error involvement and impact. Third, a questionnaire was designed for a telephone survey to collect data from 38 of 55 utilities surveyed, to expand the base of data, and to obtain information not available in the existing data.

The study indicates that the number of personnel errors in power plant generation systems are at least as high as those in non-utility systems, contributing at least 20% to 25% of all failures. This finding suggests strongly that human factors analysis and design should be a part of the reliability analysis of any proposed new system. Further, the level of effort put into human factors work can be high, considering the potential impact of availability and cost. More work is recommended to verify these conclusions and to establish more precisely the optimum approaches to develop and implement human factors engineering. Other findings of a questionnaire and telephone survey of 38 utility companies include suggestions for reducing personnel errors and list the equipment most frequently affected by personnel and the types of errors made.

Performing Organization

Failure Analysis Associates

Status

(1) Schedule/Priority: Completed in 1979

(2) Resources: Unknown

(3) Products/Publications: AF-1041: Finnegan, J. P., Rettig, T. W., and Rau, C. A. Jr., "The Role of Personnel Errors in Power Plant Equipment Reliability," EPRI Technical Planning Study 77-715, April 1979.

Evaluation

This "technical planning study" had as its objective the preliminary quantification of the impact of personnel error on the availability of fossil fuel power plants. It was directed at identifying personnel errors associated with both operation and maintenance of the plant as well as their causes and ways in which they might be reduced. Estimates of the annual costs of personnel error were made in terms of loss in power generation capability; thus, the appropriateness of the study objectives is beyond question although the criterion used to assess the consequences of personnel error was less appropriate to the NRC's interests than to those of industry.

This project has been completed and a final report was issued in April 1979. The costs of this study are unknown. The potential benefits in terms of reducing the average cost of personnel errors per unit per year, which was estimated as in excess of 110,000 lost megawatt hours per average 300 megawatt unit, clearly justifies considerable research effort directed at reducing the types of personnel errors responsible for this loss. The methodology of the study, however, (see below) did not permit pinpointing specific root causes.

This study was limited to the type of information that can be generated through personnel interviews and survey techniques and served to emphasize the inadequacy of these methods for identifying the root causes of operator and maintainer errors. It was speculated that improved training reduced personnel turnover, and improved equipment designs would reduce the personnel errors with obvious economic benefit to the utilities. It is noteworthy that the degree of concern and belief among utility representatives concerning their ability to reduce human error varied considerably, and that all utilities felt that personnel-related failures were not documented with sufficient thoroughness to permit the root cause of failure to be identified. This is probably a key study in pointing directions toward more definitive work on the impact of personnel error and their economic (if not safety) consequences.

3.3.2.1.4 Human Factors Methods for Nuclear Control Room Design

Description

An earlier review of the control rooms of operating nuclear power plants uncovered many design problems having potential for degrading operator performance. As a result, the formal application of human factors principles was found to be needed.

This task demonstrates the use of human factors in the design of power plant control rooms. The approaches shown in the report can be applied to operating power plants, as well as to those in the design stage.

This study documented human factors techniques required to provide a sustained concern for the man-machine interface in the control room, from concept definition to system implementation. It goes far beyond present control board design practices. However, control board designers intending to use this report as a design model should be aware of three limitations of the study. First, although design engineers supported the human factors analyses, the depth of the study was limited by the lack of their participation as an integral part of a design team. Second, the use of only three selected subsystems limited the study scope, so that overall control room layout and systems integration aspects were scarcely addressed. Third, the designs were based on analyses of startup, change of power level, and shutdown operations, and were modified by less detailed analyses of a few emergency sequences. A more thorough design approach would include detailed analyses of all events shown to be significant by safety and reliability studies and by reviews of plant operating histories.

The reports will be of interest to anyone involved in control room design, operator performance, or designers of other types of control rooms, such as dispatch centers or process plants.

Performing Organization

Lockheed Missile and Space Company

Status

(1) Schedule/Priority: Completed in June 1979

(2) Resources: Unknown

(3) Products/Publications: (a) NP 1118: Seminara, J. L., et al., "Human Factors Methods for Nuclear Control Room Design," EPRI Research Project 501-3, (Summary Report), June 1979.
(b) Ibid., Vol. 1, "Human Factors Enhancement of Existing Nuclear Control Rooms," Nov. 1979.
(c) Ibid., Vol. 2, "Human Factors Survey of Control Room Design Practice," Nov. 1979.
(d) Ibid., Vol. 3, "Human Factors Methods for Conventional Board Design," Feb. 1980.
(e) Ibid., Vol. 4, "Human Factors Considerations for Advanced Control Board Design," March 1980.

Evaluation

Section 3.3.2.1.1 identified the highly desirable nature of control room design assessment and methodology. The objective of the 501-3 study was to demonstrate the kinds of human factors analyses and design fixes which could be achieved in existing control rooms. Excellent examples and illustrations are provided in the four volumes and the summary report of NP-1118, Project 501-3, all published between June 1979 and March 1980.

Project cost is not known, but the benefits to industry in the reality of the adoption of NUREG-0700 and the imminent publication of NUREG-0801 are great.

As mentioned in 3.3.2.1.1, it is highly desirable that this research project be extended.

3.3.2.1.5 Human Factors Review of Power Plant Maintainability

Description

(1) Need

Prior EPRI human factors reviews of the control rooms of operating nuclear power plants identified several design problems having the potential to degrade operator performance and reduce plant efficiency. Based upon a similar concern for plant and equipment designs from the standpoint of maintainability, a human factors review was conducted of nine representative nuclear and fossil plants.

(2) Objective

This study examines the man-equipment-environment interfaces that influence the performance, safety, effectiveness, and reliability of maintenance personnel. The objective is to establish the adequacy with which human factors engineering principles and considerations have been applied to the design of power plants from the standpoint of maintainability.

(3) Work Effort

The human factors aspects of five nuclear power plants and four fossil fuel plants were evaluated using such methods as a checklist guided observation system, structured interviews with maintenance personnel, direct observations of maintenance tasks, reviews of procedures, and analyses of maintenance errors or accidents by means of the "critical incident" technique. This study reveals that a great deal can be done to improve the design of power plants and operational procedural practices to facilitate maintainability. Insufficient attention has been given to the role of maintenance personnel, and this deficiency is exacting a penalty in the form of degraded effectiveness and reduced plant reliability and safety. The economic implications of a degraded maintenance capability are obvious and extensive. A major problem is the difficulty of access to the equipment to be maintained. Other problems include deficiencies in coding and labeling, communications problems of varying types and severity, overcrowded workshops, multistress environmental problems, ineffectual internal coordinations, and frequent inadequacies in training. The report also identifies design deficiencies which should be avoided in future designs and furnishes information which can be used to upgrade existing plants.

Performing Organization

Lockheed Missiles and Space Company

Status

(1) Schedule/Priority: Completed in October 1980

(2) Resources: Unknown

(3) Products/Publications: NP-1567: Seminara, J. L., et al., Human Factors Review of Power Plant Maintainability, EPRI Research Project 1126, October 1980.

Evaluation

This RP was initiated in response to concern with man-equipment interfaces influencing performance, safety, effectiveness, and reliability of maintenance personnel. Emphasis was on the design characteristics of equipment from a human factors engineering perspective. The objective was (and still is) excellent in light of the high probability that design-induced maintenance errors significantly affect plant safety and control room decisions and operations.

Cost of the study as reported in the Final Report (EPRI NP-1567, Project 1126, February 1981) is unknown. However, the validity and significance of the reported observations and recommendations make this effort a desirable one.

The design for maintainability analyses should continue and EPRI plans to do so. Planned and on-going study efforts are evaluated in subsequent sections of this volume addressing RP-1126-1 and RP-2166.

3.3.2.1.6 Disturbance Analysis and Surveillance System (DASS)

Description

(1) Need

The DASS study was to determine the requirements for a computer-based information system that would process plant data and display results to control room operators in a prioritized order of importance such that plant safety and availability are improved.

(2) Objective

Assess the scope and feasibility of a plant-wide DASS which would build upon the short-term fixes being considered by the industry.

(3) Work effort

Two contract teams were selected for nine-month studies to:

(a) define the goals and functions for a plant-wide DASS,

(b) develop engineering procedures necessary to design a DASS,

(c) establish the feasibility and costs for a plant-wide DASS, and

(d) provide an example application of the design and engineering procedures developed in the study.

In addition, a Technical Advisory Group (TAG) was formed to provide review and guidance for both projects. Results were summarized and evaluated. Based upon the results, the TAG arrived at a consensus and an endorsement for the next phase of DASS development.

Performing Organization

Under a contract sponsored jointly by the Electric Power Research Institute and the Department of Energy, two contract teams performed the scoping and feasibility studies:

(1) Babcock and Wilcox with Duke Power, Burns and Roe, and General Physics, and

(2) Westinghouse with Commonwealth Edison, Sargent and Lundy, and Systems Control.

The TAG comprised experts from utilities, vendors, national laboratories, NRC, human factors organizations, and foreign and non-nuclear organizations.

Status

(1) Schedule: Completed

(2) Resources: Unknown

(3) Products/Publications: (a) EPRI NP-1684 (Project 891-3), "Summary and Evaluation of Scoping and Feasibility Studies for Disturbance Analysis and Surveillance Systems (DASS)." December 1980.
(b) E. F. Dowling, et al. "Disturbanceance Analysis and Surveillance System Scoping and Feasibility Study." Babcock and Wilcox Final Report BAW 1632, September, 1980.

(c) J. M. Gallagher, et al. "Process for Design of a Plant-Wide Disturbance Analysis and Surveillance System." Westinghouse Final Report, September 1980.

Evaluation

The objective is appropriate because the NRC is leaning towards a future requirement for a DASS in the control room. Before control rooms simply add hardware, a need has to be established and the feasibility of that need determined. The human factors review of the two contract projects considered the function of DASS integrating plant data for presentation to the operator to be advantageous. Overall, however, human factors concerns were poorly addressed in both designs, in particular the inadequate human factors basis for DASS.

The effort is timely because the results of this study can guide future DASS efforts, the applicability of which to control rooms has to be resolved.

No cost data are available.

The research teams and TAG comprised an extensive range of professionals, all of which were needed for this effort.

3.3.2.1.7 Operator Decision Analysis

Description

(1) Need

The NRC task action plan (NUREG-0660) required specific improvements in the control room that related to monitoring critical safety functions (SPDS), a near-term goal, and assisting operations of plant disturbances which could compromise safety or impact availability (DASS), a long-term goal. NUREG-0696 augmented the near-term goal by requiring a system that can display plant information to assist operators in monitoring the safety status of the plant. These requirements prompted EPRI's Nuclear Power Division in conjunction with NSAC and DOE to initiate a series of projects to improve the process-operator interface at nuclear reactors. The operator decision analysis study was to determine how the outcome of the decision-making process could be improved by changes in staffing, training, control room layout, and computerized support systems.

(2) Objective

Develop a descriptive model characterizing factors influencing the operator decision-making process in order to help identify and prioritize potential improvements.

(3) Work Effort

The effort required:

(a) Developing an illustrative model to provide insight into the decision-making process;

(b) Utilizing the model and retrospective analysis techniques to evaluate specific recent off-normal incidents; and

(c) Estimating the potential impact of various proposed changes on operator decision making, based upon the studied incidents.

Performing Organization

Bolt Beranek and Newman, Inc.

Status

(1) Schedule: Completed

(2) Resources: Unknown

(3) Products/Publications: EPRI NP-1982 (Project 891), "Evaluation of Proposed Control Room Improvements Through Analysis of Critical Operator Decisions." R. W. Pew, D. C. Miller, and C. E. Feehrer, August 1981.

Evaluation

The objective is appropriate because any JPAs that are going to be developed to assist the operator's decision-making process have to consider the factors that affect that process. The shortcomings of the approach and suggested improvements are provided in the conclusions.

The study is timely because it is a critical input (a partial understanding of the operator's role in diagnosing and reacting to incidents) to the development of not only the DASS concept but to all decision aids for the control room operator.

No cost data are available.

This effort was well conceived and effectively executed by competent human factors professionals with input from NSSS vendors and other subject matter experts with operating experience.

3.3.2.1.8 Human Factors Review of Enhancement Approaches for Nuclear Control Rooms (RP 501-4)

Description

The objective of this program is to study and document approaches, based upon human factors principles and criteria, for enhancing power plant control rooms. The feasibility, methodology, and potential benefits will be documented and disseminated to the industry for its implementation and use.

Four plants were studied utilizing methodological tools found effective in earlier aerospace and EPRI-sponsored studies: checklists, physical and anthropology charts, structured interviews, review and analysis of plant records, and photodocumentation. Potential enhancement recommendations will be explored with plant managements for technical feasibility and practicability. Based upon findings, a practical "how-to" document will be prepared and disseminated. This report will constitute neither a standard nor a specification; rather, it will be a reference document.

The study was initiated in September 1980 and, to date, the project team has visited four plants and documented in detail human engineering problems observed there. Recommendations for correcting these problems were generated and discussed with the plant management. A workshop for the industry was held in August 1981. A final report is scheduled for release in June 1982.

Performing Organization

Honeywell, Inc. with Lockheed Missiles and Space Company as subcontractor.

Status

(1) Schedule/Priority: Start September 1980, end March 1982.

(2) Resources: Unknown

(3) Products/Publications: A practical "How To" enhancement guide will be published.

Evaluation

The objective is desirable and the effort is scheduled in a timely manner. The output of a reference document rather than a standard or specification is appropriate. As observed in the parent section on RP-501 (3.3.2.1.1), benefits of the continuation of this project are excellent and the plans of EPRI for that continuation are highly appropriate.

3.3.2.1.9 Survey and Analysis of Communications Problems in Nuclear Power Plants

Description

(1) Need

Prior EPRI reports dealing with control rooms (32) and maintainability (38) identified general communications problems that have the potential for degrading system effectiveness such as noise and inadequate communication channels. To determine the specific nature and magnitude of these problems, a human factors review of communication systems was conducted in four representative nuclear plants. Data collection tools include structured interviews, questionnaires, sampling techniques, and noise measurements.

(2) Objectives

The primary objectives of this technical planning study for were to define the nature and extent of communication problems at nuclear power plants and to make recommendations in areas where additional R&D might lead to better communications and more effective operations.

(3) Work Effort

Noise measurements were made in selected portions of the plants; speech intelligibility measures were taken; and data were obtained on message rates, duration, types, and points of origin and receipt. Specific problems that were identified include signal density, speech intelligibility, noise, procedural guidelines, equipment deficiencies, and lack of discipline in the utilization of existing facilities. The need to develop and test alternative approaches was established. Accordingly, a follow-on study designed to utilize the data base established in this study as a point of departure will be initiated in 1982.

One related project, RP501, resulted in the publication of EPRI NP-309 in 1977, "Human Factors Review of Nuclear Power Plant Control Room Design." A second related project, RP1126, resulted in the publication of EPRI NP-1567, "Human Factors Review of Power Plant Maintainability."

Even though the primary purpose of this study was to furnish a logical point of departure for the conduct of future research, the specificity and nature of the findings should be of interest to design organizations and plant managers.

Performing Organization

General Physics Corporation

Status

(1) Schedule/Priority: Completed in September 1981

(2) Resources: Unknown

(3) Products/Publications: EPRI NP-2035: Topmiller, D. *et al*., "Survey and Analysis of Communications Problems in Nuclear Power Plants," General Physics Corporation, September 1981.

Evaluation

The objective of this study was appropriate since degraded communications can lead to personnel errors with a subsequent impact on plant safety and availability. In particular, the conduct of emergency procedures or other activities during abnormal conditions requires a great deal of communication within the control room and between the control room and the plant.

This study was conducted on a timely basis and a follow-on effort (see 3.3.2.1.15) will get under way in 1982 to deal with communication enhancements.

No cost data are available but this appears to be a modest study which was conducted by competent investigators.

The project was well-conceived, and the data collection and analysis methods were well-planned. Interpretation of the data and recommendations made are appropriate.

3.3.2.1.10 Human Factors Review of Power Plant Maintainability

Description

This is a follow-on effort to an earlier project for Human Factors Review of Power Plant Maintainability (see 3.3.2.1.2). The earlier project was performed by career human factors professionals from LMSC. The current project is to develop a maintainability self-review methodology.

The rationale for this project is to furnish a tool, and guidance for its use, for plant managements of those that did not participate in the original study to accomplish an effective self-review program. LMSC will prepare a report which will provide a methodology, including an annotated checklist, for self-review purposes.

The methodology will be based upon empirical results from prior DOD and industry studies as well as the findings of this study. Checklists derived from military and space guidelines will be tailored to the specific applications of the power industry.

The general outline of the methodology documents will be coordinated with the EPRI Project Manager prior to detailed preparation. The rationale for both total coverage and order of presentation will be given.

As a minimum, basic topics to be covered would include workplace configuration, labeling and coding, spares and tools, safety, accessibility, handling and removal, maintenance procedures, and maintenance job aids.

The report will be extensively indexed and illustrated for ease of use and will include a list of source materials for future reference and use of plant personnel.

Performing Organization

Lockheed Missiles and Space Company

Status

(1) Schedule/Priority: Work completion date is March 1982.

(2) Resources: Unknown

(3) Products/Publications: Final Report scheduled for May 1982.

Evaluation

The objective of this effort is an important one. The approach being taken is good in the sense that it focuses on real design features instead of human reliability performance modeling. Consequently, the report to be generated can be expected to be useful to the industry. The contractor, Lockheed Missiles and Space Company, has experience in the problem area and has competent human factors professionals involved.

3.3.2.1.11 Test of Job Performance Aids (JPAs) for Power Plants

Description

Conventional procedures have been proven not to be optimally efficient in a variety of situations. The military has conducted an extensive evaluation of the techniques for presenting procedural information to operations and maintenance workers and has demonstrated the superiority of Job Performance Aids for selected applications. The candidate list of JPA procedures has been coordinated with industry representatives to select work areas that, for whatever reason, represent real significance to the industry. Unlike the military, which utilizes JPAs primarily in the area of maintenance, this project has included other potential areas of application, such as operations, administration, quality control, and health physics.

Eight JPAs have been completed and verified. A ninth JPA dealing with condenser tube leaks is in preparation. The final report will estimate costs and benefits of JPA use and will provide guidance for JPA implementation.

Performing Organization

Kinton, Inc.

Status

(1) Schedule/Priority: Completion date April 1982.

(2) Resources: Unknown

(3) Products/Publications: Workshop conducted for the industry in March 1981. A major report is scheduled for release in April 1982.

Evaluation

The objective is appropriate because it explores the feasibility of using detailed, step-by-step, illustrated JPAs in selected areas of operation, maintenance, and administration within the nuclear power industry. The effort appears to be concentrated into a format that is considered standard by the human factors/technical data communities. Thus, it is too early to determine if the wide range of users' capabilities covered by the functional areas addressed have been adequately considered.

The effort is timely because occurs when the industry is re-assessing the functional requirements by initiating a systems review and task analysis of the control room operations. This re-assessment carried to the other areas of the plant will identify the areas where and how JPAs should be incorporated into the operation, maintenance, and administration of the nuclear power plant.

No cost data are available.

The effort is being performed by a contractor with a long history of JPA development and human factors research. Validation within the cooperating utilities will enhance the quality of the product.

3.3.2.1.12 Human Engineering Guidelines for Operations

Description

(1) Need

The design of current power plants, and particularly control rooms, frequently deviates from several human engineering principles and practices. The deviations contribute to a degradation of the man-machine interface and are conducive to human and system error.

(2) Objectives

The purpose of this project is to develop a human engineering guideline (Guide) tailored to the needs of the power industry. The Guide will contain human engineering criteria and principles useful to design engineers in their design trade-off decisions. The Guide will be non-regulatory, neither a specification nor a standard. However, as a reference document, it will enable a design team to (1) weigh the advantages and disadvantages of alternative design approaches, and (2) apply scientific knowledge concerning human performance capabilities in the man-machine interface.

(3) Work Effort

A multidisciplinary team of human factors engineers (Essex Corporation) and engineers (Babcock & Wilcox, Bechtel, Combustion Engineering, and Ebasco) will derive the Table of Contents and write the Guide based upon design experience and military and commercial research. A design model will serve as the basis for topical coverage. The Guide will be extensively cross indexed for ease and effectiveness of use and will make extensive use of tables, graphs, and charts.

Performing Organization

Essex Corporation/Babcock & Wilcox, Bechtel, Combustion Engineering, and Ebasco

Status

(1) Schedule/Priority: 1 September 1980 - 30 June 1982

(2) Resources: Unknown

(3) Products/Publications: A three-volume guideline document is planned.

Evaluation

The objective is excellent and the effort is timely. The reference document to be produced should be useful to the industry because of its heavy use of illustrations and graphical material. The output should also be technically sound because of the desirable mix of human factors specialists and design engineers on the study effort.

3.3.2.1.13 Evaluation of Annunciator-Warning System Concept

Description

(1) Need

For some time annunciator-warning systems currently in use in nuclear power plant control rooms have been criticized for lack of compliance with human engineering standards and criteria. In particular, individual annunciators are difficult to read, are not well integrated with related displays and controls, and, most important of all, are not differentiated with respect to their criticality to plant safety or availability. Given these difficulties and the large number of annunciators present, operators may at times be overwhelmed by the volume of alarm information displayed. At present, many utilities have recognized the need to correct this problem, especially given the regulatory pressure to conduct control board reviews, but are hampered in their efforts by the lack of a proven alarm philosophy which could be implemented to solve most problems that have been identified with existing systems. Unless generic solutions are developed and tested, each utility will be faced with the task of developing its own solutions, many of which may be implemented without adequate evidence that they are effective.

(2) Objective

Utilities at present face regulatory requirements for review and enhancement of control boards including the annunciator-warning system. They also must respond to NUREG-0696. Moreover, given the enhancement to plant data systems which will be necessitated by NUREG-0696, utilities may also choose, in the longer term, to upgrade their control rooms through installation of a Disturbance Analysis and Surveillance System if such systems prove effective. Needed, then, is a proven alarm philosophy/approach which would aid utilities in satisfying near-term requirements, yet would also allow them to exploit the enhanced computer and CRT capability which may be available in control rooms over the longer term. A generic alarm philosophy adequately tested and which accommodates future growth could significantly enhance plant availability, safety, and operational effectiveness. Thus, the objective of this program is to identify and evaluate candidate approaches for upgrading existing annunciator warning systems. Candidates identified and tested will satisfy near-term requirements but will also be compatible with other longer term conrol board improvements.

(3) Work Effort

Candidate approaches will be identified via a detailed alarm requirements analysis, a survey of current industry plans for annunciator-warning system enhancement, and a survey of practices in the process control and aerospace industries. Criteria related to cost and technical ease of implementation will be used to select high-priority candidates (one or two) which will be field tested at a training simulator. Criteria related to operator performance and acceptance will be the basis of these simulator tests.

Performing Organization

To be selected

Status

(1) Schedule/Priority: Contract expected to begin in February 1982.

(2) Resources: Unknown

(3) Products/Publications: To be determined

Evaluation

The objective is excellent, the technical approach is sound, and the effort is needed as soon as possible. The end product should be very beneficial to industry when it is published. It is important that EPRI select a contractor with career human factors professionals and that the contract require coordination with experienced plant operators.

3.3.2.1.14 Work Performance Under Heat Stress

Description

(1) Need

Work performed under high temperature and humidity conditions poses a number of critical problems. Conditions constrain both the duration and intensity of work, impact on the worker's efficiency and morale, and, on occasion, may jeopardize personnel safety. Personnel protective garments currently being used in the industry do not provide the necessary cooling to negate the unfavorable environmental conditions and, in addition, are bulky and cumbersome. In fact, it is not uncommon for worker's exposure and meaningful work time to be limited to approximately 20 to 30 minutes.

(2) Objective

The objective of the study is to develop a cooling garment which will increase a worker's tolerance to exposure up to 2 or 2½ hours.

(3) Work Effort

Prototype garments will be designed, constructed, and tested under precisely controlled laboratory conditions. The efficiency of the garments will be measured by both objective and subjective criteria. After necessary modifications to the prototypes, and dependent on laboratory results, testing will be repeated under field conditions in conjuncton with the Duke Power Company. The final report will include specifications for production garments if the prototypes prove effective.

Performing Organization

Pennsylvania State University

Status

(1) Schedule/Priority: completion date, June 1982

(2) Resources: Unknown

(3) Products/Publications: Prototype garments, publications unknown.

Evaluation

Enhancing the effectiveness of maintenance personnel by reducing stress and thereby increasing the length of time during which they can perform effectively in the plant is a matter of unquestioned appropriateness to NRC objectives concerning safety of operations.

Work on the project is scheduled to end in June 1982. In view of the reported problems in this area it would appear that this should be a high priority program.

No information was provided on the EPRI investment in this program. The benefits clearly could be substantial.

The program plan very appropriately calls for assessment of the efficiency of the protective garments by both objective and subjective criteria. The proposed method of testing first under controlled laboratory conditions followed by validation testing under field conditions is most appropriate. The objective criteria are not specified, but it is clear that the operational relevance of the performance criteria should be of primary interest. The contractor has appropriate experience in this area.

3.3.2.1.15 Nuclear Power Plant Communications

Description

(1) Need

A recently completed EPRI Technology Planning Study (EPRI-NP-2035) documented several problems which degrade internal nuclear power plant communications. In particular, high ambient noise in some plant locations interferes with speech and masks alerting signals, messages are delayed because equipment cannot handle the communication demand, the communication burden placed on the control room operating crew is excessive at times, and communication practices lack discipline.

(2) Objective

The objective of this program is to identify and evaluate approaches to upgrading communication systems in existing nuclear power plants. The final product will be a set of guidelines a plant could use to improve communication system equipment and practices.

(3) Work Effort

Data from the Technology Planning Study which describes plant communications in terms of message rates, types, duration, and ambient noise levels will be used as a starting point to define candidate approaches to system improvements. These data will be supplemented by results of the extensive research and development work already completed in the communications field. Candidate improvements will be evaluated via testing either at a plant site, training simulator, or in an acoustics or human engineering laboratory.

Performing Organization

To be determined

Status

(1) Schedule/Priority: Work to begin in February 1982

(2) Resources: Unknown

(3) Products/Publications: Unknown

Evaluation

The objectives of this research are both appropriate and timely. No evaluation can be made of the benefits relative to cost as we do not have cost information.

3.3.2.1.16 Maintainability Studies

Description

(1) Need

Several EPRI studies (NP-309, NP-1567, and CS-1760) have substantiated the fact that many plant outages have either been caused or prolonged by human factors problems associated with maintenance actions or instrumentation and control activities. NP-1567, based upon an evaluation of five nuclear and four fossil plants, identified a number of problems which militated against the effectiveness of current maintenance programs in the industry. These problems include difficulty of access, crowded working conditions, environmental stresses and hazards, movement of men and equipment, deficient coding and labeling, supplies and tools, training, communications, procedures and manuals, design practices, productivity and organizational interfaces, and lack of preventive maintenance programs. CS-1760 concluded, based upon information from 14 utilities, that personnel error reduces fossil plant equivalent availability from 11% to 17% and that approximately 65% of these errors resulted from maintenance activities. Finally, as reported in a transcript of hearings between the NRC and the industry on NUREG-0700, an NRC official estimated that, based on his review of LERs attributable to human factors kinds of problems, more of these problems were related to maintenance than they were to control room design. While this estimate may be debated, it is an indication of the importance attached to maintenance by the NRC. However, despite its well substantiated importance, the maintenance problem has been practically ignored in formal human factors R&D efforts in the power plant industry.

Maintenance is of critical importance to the power plant industry on both a technical/economic and a regulatory basis. On a technical/economic basis, outages can be translated into incremental replacement power costs of $500,000 to $800,000 per day. Therefore, the economic leverage of improved maintenance is tremendous. The reduction of the outage time in one major plant by only a few days could amortize the projected cost of this program. Other variables which would be beneficially impacted by improved maintenance include plant and worker safety, improved worker morale, and reduction in worker attrition rates. On a regulatory basis, the industry has an enviable opportunity to resolve its problems on an active, self-initiated basis. Failure to do so, however, will undoubtedly result in solving them on a reactive basis as a result of a regulatory mandate.

2) Objective

Conduct a series of selected studies to address and resolve some of the more critical maintenance problems identified in earlier EPRI-sponsored studies. These problems were subsequently confirmed by a survey which was responded to by utility personnel directly responsible for the supervision of maintenance activities. In this survey, ten of fifteen potential R&D candidates were also confirmed as being of medium to high interest to the respondents. All studies will be directed toward the achievement of results which facilitate the rapidity, economy, ease, and accuracy with which maintenance operations can be performed which, in turn, will directly impact system effectiveness and plant safety.

(3) Work Effort

Accepted and proven R&D methodologies from the Department of Defense and the aerospace industry will be adapted and used as a function of the nature of the problem being addressed at any point in time. Among these methodologies are included such tools as task and function analyses, checklists, interviews, questionnaires, review and evaluation of plant records, noise and lighting surveys, econometric trade-offs, and development and test of protective garments, devices, tools, and equipment. Since a major focal point is the man-machine interface, human factors engineering expertise will in most instances lead the R&D team. However, as required, other technical skill will be added to the team to achieve a multidisciplinary capability. While other R&D candidates may emerge as the program moves forward, initial investigations will address such problems as:

* Develop tools and techniques to mitigate the effects of environmental stress on maintenance workers.
* Develop a maintainability standard that could serve as a commonly accepted mechanism for procuring and evaluating new plant or equipment design.
* Develop and test a preventive maintenance model.

Performing Organization

To be determined

Status

(1) Schedule/Priority: 1982-1985

(2) Resources: Unknown

(3) Products/Publications: Unknown

Evaluation

EPRI well understands the magnitude and importance of the problem and the objective here is highly appropriate. It is a natural extension to the work previously performed by EPRI contractors in this problem area. The funding level is understood to be appropriately high. EPRI also recognizes the criticality of requiring competent human factors professionals to head the R&D efforts.

3.3.2.1.17 Work Structure and Performance

Description

(1) Need

Work structure may be thought of as the integration of operational and maintenance personnel within the total power plant system. The efficiency of the integration process is directly related to productivity. Many factors are involved in the integration process. Some of them are relatively straightforward, such as plant and control room design, training, procedures, and communications. Other factors, while somewhat more evasive, are equally important and are inextricably interrelated. In fact, there is a wealth of research results which demonstrate that the way in which work is structured, organized, and perceived by employees has a significant bearing on the quantity and quality of organizational productivity and plant safety and effectivness. Several EPRI reports have concluded that the work structure in nuclear power plants is less than optimum. NP-81-3-LD, based upon 26 responses, perceived the following six factors as being critical: lack of materials (parts and tools), worker attitude, cooperation/coordination, inadequate supervision, red tape, and poor planning. Other problems or factors include shift work and overtime, fatigue, stress, boredom, attrition, organizational climate, worker recognition, economic rewards and job satisfaction. (This is not intended as a totally inclusive list.)

(2) Objective

EPRI plans to initiate a longitudinal program of R&D devoted to the generic area of Work Structure and Performance. The objective of this program is to conduct a series of studies relating to some of the most critical factors in the work structure matrix. The products of these studies will be conclusions and recommendations designed to improve performance through appropriate modifications in work structure.

Obviously, all factors cannot be addressed due to budgetary and time constraints. Therefore, follow-on studies, to be cost effective, must be carefully selected. The major purpose of this project is to provide a substantive and rational basis for EPRI and other organizations in the nuclear power plant industry, and to develop plans, policies, and programs to address the most critical factors in the work structure matrix. Specifically, this study project will identify and prioritize the work structure factors according to their importance, and verify the operational significance of these factors. Utilizing this information base as a point of departure, topics will be selected for follow-on studies appearing most amenable to high pay-off.

(3) Work Effort

The following task titles provide a suggested general approach for accomplishing the project objectives.

Task 1. Review of Literature

Task 2. The Identification of Work Structure Factors

Task 3. Prioritization of Work Structure Factors

Task 4. Verification of Work Structure Factors

Task 5. Conduct an Industry Workshop

Task 6. Prepare Final Report

Future Projects: The basic project plan will be developed in 1982 and specific studies will be recommended for the remaining three years. Candidate topics include overtime, stress, work-rest cycles, scheduling and manning, and attrition.

Performing Organization

BioTechnology, Inc.

Status

(1) Schedule/Priority: 1982 - 1985, beginning in March 1982.

(2) Resources: Unknown

(3) Products/Publications: Unknown

Evaluation

Work structure is defined by EPRI as the "integration of operational and maintenance personnel within the total power plant system". The objective is to improve performance through appropriate modifications in work structure. To do this, the project will develop information which will provide a substantive and rational basis for plans, policies, and programs to address the most critical factors in the work structure "matrix". Among the factors to be considered (based on earlier research) are: availability of required parts and tools, worker attitude, cooperation/coordination, adequacy of supervision, administrative red tape, and adequacy of planning. In addition, such variables as shift work and overtime, fatigue, stress, boredom, attrition, organizational climate, worker recognition, economic rewards, and job satisfaction are to be considered. The importance of many of these factors has been emphasized elsewhere in this report (see especially Volume 3, Section 4).

The first, definitional phase of this project is scheduled for one year commencing approximately March 1982. In view of the potential impact of many of the variables to be considered, the urgency of this first phase is clear. Detailed study will subsequently be directed at the more important variables as defined in the first phase, with completion of the work scheduled for 1985. Some of the factors to be investigated clearly require much longer term efforts than others.

This first phase of work is budgeted for not more than $120,000. The benefits of this initial project should be high in relation to the costs considering, the potential importance of the many variables to be considered.

This is a well-conceived project which reflects EPRI's plan for a longer term R&D effort that will be directed at those work structure variables that appear to have a strong operational impact. The success of the effort will depend to a great extent on the skill with which the contractor develops methods for properly establishing the priority and operational significance of the various factors to be addressed in the work structure. It is noteworthy that empirical evidence is called for that will substantiate the existence of critical factors which positively or negatively impact employee performance. This requirement constitutes the most significant technical challenge to a successful program effort.

3.3.2.1.18 Development of a Guideline for Use of CRT Displays in Conventional Control Rooms

Description

(1) Need

The method of communicating process information to the operator in a nuclear power plant control room is presently in a state of transition; the hardwired instruments currently in use are slowly being supplemented and may eventually be replaced by information displayed on CRTs. In the near term, this transition will be accelerated since many utilities plan to use one or more CRTs to satisfy this regulatory requirement for a safety parameter display system. In the longer term, vendors are already marketing advanced control room designs which rely on CRTs as the primary mode of display.

CRT displays offer tremendous potential as effective communicators between machines and operators. The flexibility they provide in terms of display format and information organization and coding cannot be approached with conventional hardwired instrumentation (i.e., meters, strip chart recorders, etc.). At the same time, the serial presentation of information which characterizes these systems places a greater burden on the display system designer. A system of poorly conceived or organized CRT display pages can delay operator access to and understanding of key information even more than can a poorly organized hardwired panel. Moreover, ranges and combinations of colors available for use offer as much potential for abuse as they do for exploitation. A review of the variety of display designs and hardware and software capabilities that are being offered in today's market indicates a need for guidance in performing a systematic and cost-effective approach to display system design and the selection of hardware and software.

Utilities at present face difficult decisions in the area of control room modifications, especially as regards the addition of computer graphic display devices. The difficulty is compounded by the general lack of industry experience with these display systems. In the near term, utility objectives are to install systems which provide adequate capability for the design of displays that achieve effective communication of critical safety information to the operator. In the longer term, utilities will want to take advantage of the programmable aspects of these systems and to evolve more effective safety-related displays based on operating experience and eventually to expand the system to include display of both safety and availability-oriented information. These objectives cannot be achieved without a systematic approach to display design which is cognizant of operator capabilities and limitations and which is linked to a cost-effective appraisal of CRT hardware and software capability.

(2) Objective

The objective of this study will be to develop a guide for use by individual utilities: (1) to design (or select) displays which ensure effective transfer of safety or availability-related information to the operator; (2) to determine CRT hardware and software capability required to meet both near-term needs as well as reasonable future growth in CRT usage; and (3) to install these systems in a manner which achieves effective human factors integration with other display devices.

(3) Work Effort

The guide will be developed based on state-of-the-art reviews in the areas of display design techniques (both nuclear and non-nuclear applications), CRT hardware and software capabilities (both current and future trends), and installation requirements. The focus will be on backfitting CRTs to conventional control rooms and will contain information on design techniques, speed of display call-up, vector/character graphics, display formats, and backfit features such as modularity and remote displays among other topics. Experience in CRT display system design, installation, and usage, both within and outside the nuclear industry, will be utilized in developing and reviewing the guide.

Performing Organization

To be determined

Status

(1) Schedule/Priority: Start in March 1982; finish in 1982.

(2) Resources: Unknown

(3) Products/Publications: Unknown

Evaluation

The needs analysis and statement of objectives are appropriate, perceptive, and accurate. The schedule may be a bit ambitious (ten months). Because no funding information is available, it is difficult to evaluate the cost-benefit relationship. However, the criteria for contractor selection, coupled with the well-defined objectives, indicate that this should be a worthwile effort.

3.3.2.1.19 Safety Functions Monitoring Concepts Evaluation Project

Description

(1) Need

The NRC task action plan (NUREG-0660) required specific improvements in the control room that related to monitoring critical safety functions (SPDS), a near-term goal, and assisting operators in the prevention, detection, correction, termination, and mitigation of plant disturbances which could compromise safety or impact availability (DASS), a long-term goal. NUREG-0696 augmented the near-term goal by requiring a system that can display plant information to assist operators in monitoring the safety status of the plant. These requirements and industry's involvement in trying to develop systems to satisfy these requirements prompted EPRI's Nuclear Power Division in conjunction with NSAC and DOE to initiate a series of projects to improve the process-operator interface at nuclear reactors. The safety functions monitoring study was to determine the differences among alternative approaches to safety status monitoring.

(2) Objective

Evaluate the impact of two candidate safety functions monitoring systems on operator performance during simulated severe upset conditions and:

(a) determine how the improvements relate to conventional control rooms;

(b) assess the effects on staffing, procedures, and training; and

(c) evaluate performance evaluation techniques, i.e., quantify changes in operator response associated with each alternative system.

(3) Work Effort

The effort used SNUPPS simulator at Westinghouse Nuclear Training Center to compare three approaches to safety status monitoring:

(a) SNUPPS main control board,

(b) safety panel, and

(c) safety console.

Eight crews were tested during each of sixteen transients. Data gathering included experimental logs, video tapes, computer records, and questionnaires.

Performing Organizations

Westinghouse Electric Corporation, Quadrex, and Bolt Beranek & Newman, Inc.

Status

(1) Schedule/Priority: Unknown

(2) Resources: Unknown

(3) Products/Publications: An EPRI report was scheduled for publication in February 1982.

Evaluation

The objective is appropriate because it provides basic information on whether an SPDS concept is an improvement over the existing control room configuration, at least for SNUPPS. The project may determine if the SPDS will be an effective aid for the operator. To provide a complete evaluation, however, the questions pertaining to the use of the SPDS only during upset conditions have to be resolved.

The effort is timely because NRC is requiring utilities to add SPDS to their control room without determining the system requirement for it.

No cost data are available.

The research team was well-balanced with professionals from several disciplines, including human factors specialists, behavioral scientists, psychometricians, and personnel with operating experience.

3.3.2.1.20 Physical Anthropometry Survey

Description

Knowledge of the body-size variability of the user population is a fundamental building block in the design of effective man-machine systems. Despite the importance of such physical anthropometric data, it was learned in prior EPRI studies that many power plant designs violate basic anthropometric criteria, that difficulty of access has been a universal complaint by maintenance personnel, and that many design engineers reported that they did not utilize any formal anthropometric criteria but would do so if the data were readily available.

The primary study objective was to develop anthropometric data based upon the men and women who operate and maintain nuclear power plants. Age, stature, and weight information were obtained by a questionnaire survey of current operator and maintenance personnel, and the data extracted from the questionnaires were analyzed to derive body-size information for a number of anthropometric variables of interest to designers. Body-size information was developed separately for both men and women. Results achieved for the male population can be utilized by designers with a high level of confidence for the design of general workplaces. While the number of women respondents in the sample proved to be too small to derive results to which a similarly high level of reliability could be attached, the data can nevertheless be used as reasonable indicators of the probable body-size variability to be found among female power plant employees. Designers can significantly increase both the operational and maintenance efficiency of future power plant workplaces by utilizing the data contained in this report.

Performing Organization

EPRI

Status

(1) Schedule/Priority: Completed in 1981.

(2) Resources: Unknown

(3) Products/Publications: NP-1918-SR Parris, H. L. and McConville, J. T., "Anthropometric Data Base for Power Plant Design, EPRI, July 1981.

Evaluation

The project's objective, to obtain anthropometric data for nuclear power plant personnel for comparison with existing data for other populations, was appropriate. However, we judge the requirement for the project to have a low priority compared to other needs.

The project was timely, considering some of the statements we have heard from nuclear industry personnel. Some utilities' resistance to consideration of modifying anthropometrically unacceptable designs has been couched in terms of the rationalization that adequate anthropometric data do not exist.

The cost/benefit ratio probably is reasonably good. We do not know the actual costs in terms of dollars or man-hours. However, because the data were obtained by mail survey, and the analysis requirements were modest, we estimate the cost to be quite low.

This project is subject to several criticisms in terms of scientific design and methodology. A critical evaluation certainly would question the appropriateness of a mail survey to obtain anthropometric data. The reliability and validity of the anthropometric data obtained in this manner are unknown. Furthermore, it is not known to what degree the sample who returned the questionnaire are representative of the total population of nuclear power plant personnel. The results of the project are interesting and agree with what might have been predicted for the variables of age and weight, in view of the conditions of recruitment of nuclear industry personnel and of military personnel.

3.3.2.2 Institute of Nuclear Power Operations (INPO)

The electric utility industry established the Institute of Nuclear Power Operations (INPO) in December 1979 to ensure the high quality of operation in nuclear power plants. The mission of the Institute is to:

* Promote a level of professionalism in nuclear power operations commensurate with the importance to the public of safe, reliable, and economically efficient operations.

* Involve plant operating staffs in development of benchmarks and training systems and in the conduct of the operational evaluation.

* Use the best available techniques and methods to develop operating and training practices and the human factors aspects of design and operation.

* Utilize independent professional advice and counsel toward accomplishing the Institute's objectives.

* Support and improve existing practices and training systems, wherever possible, rather than preempt their management responsibilities.

* Encourage excellence.

In carrying out this philosophy of operations, the Institute will:

* Establish industry wide benchmarks for excellence in the management and operation of nuclear power plants.

* Conduct independent evaluations to determine that the benchmarks are being met.

* Review nuclear power operating experiences for analysis and feedback to the utilities. Incorporate lessons learned into training programs. Coordinate information reporting and analysis with other organizations.

* Establish educational and training requirements for operations and maintenance personnel and develop screening and performance measurement systems.

* Accredit training programs and certify instructors.

* Conduct seminars and workshops for various utility employees, including instructors, utility

executives, and upper management, to ensure quality in the operation of nuclear power programs.

* Perform studies and analyses to support development of criteria for operation, for training, and for the human factors aspects of design and operation.

* Provide emergency preparedness coordination for the utility industry.

* Exchange information and experience with operators of nuclear power plants in other countries.

The organizational structure is shown in Figure 11. Most human factors projects are conducted within the Analysis and Engineering Division or the Training and Education Division. Principal human factors projects are described separately below.

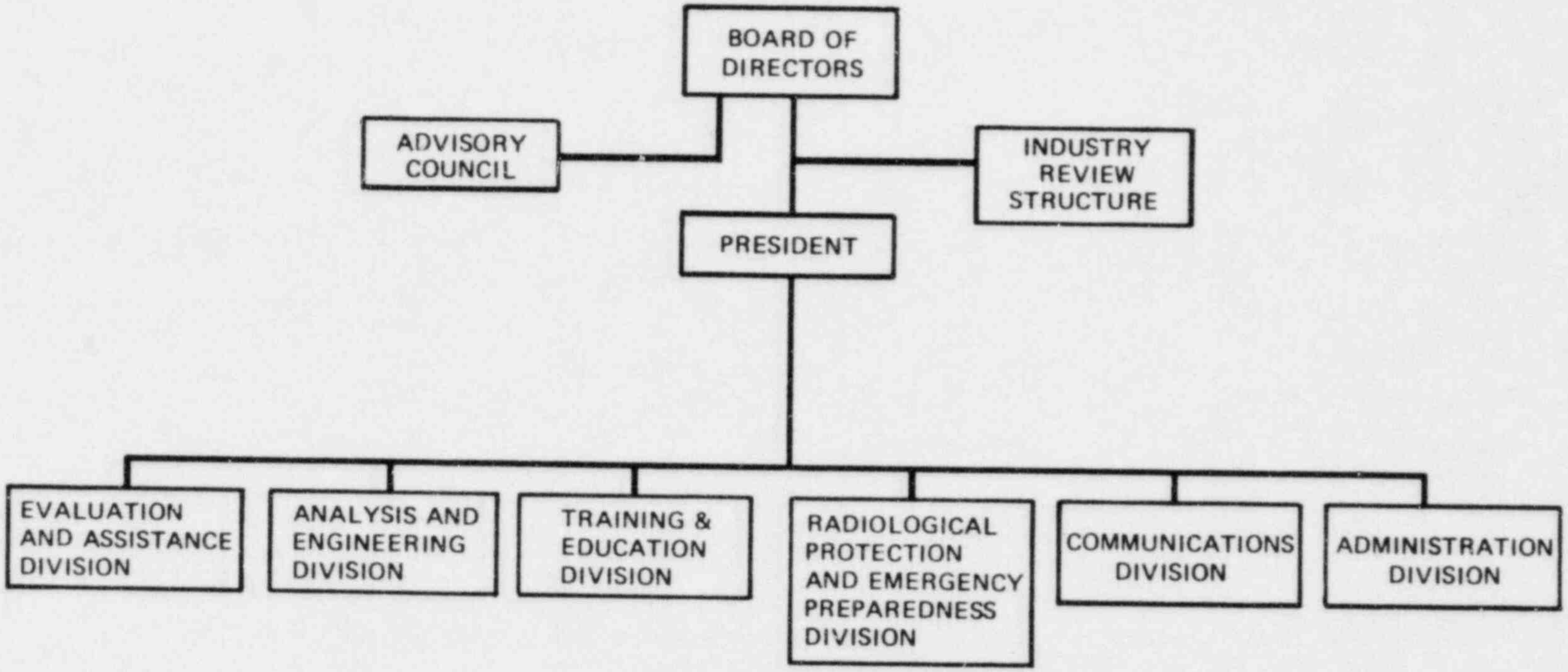

FIGURE 11. INSTITUTE OF NUCLEAR POWER OPERATIONS ORGANIZATION STRUCTURE.

3.3.2.2.1 Emergency Operating Procedures Development

Description

INPO is actively coordinating industry's efforts for emergency operating procedures. This coordination effort is taking the form of an emergency operating procedures Plan which will identify a logical, efficient, and cost effective approach to writing Emergency Operating Procedures given Emergency Operating Procedures Guidelines develcped by the NSSS Owners Groups. This approach coordinates with control room review, SPDS implementation, and training. Presumably this effort would be what INPO considers responsive to NUREG-0799.

The Coordinated Industry Emergency Operating Procedures Plan will cover the generation of four products to assist the individual utility in:

1. Developing an Emergency Operating Procedures Implementation Plan,

2. Preparing a Plant-Specific Writers Guide,

3. Conducting emergency operating procedures verification and validation, and

4. Developing an emergency operating procedures revision and review process.

Performing Organization

Information requested from INPO but not received; presumably by INPO staff.

Status

(1) Schedule/Priority: Information requested from INPO but not received.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: Information requested from INPO but not received.

Evaluation

The objective is appropriate because for emergency procedures, at least, it establishes a focal point for procedure development, from the generation of non-plant-specific specifications to the generation of plant-specific guidelines. After the specifications have been established by the NRC, this effort could provide, at the utility level, the coordination required to integrate procedures development with the re-assessment of the control room, i.e., the systems review needed to determine if all the emergency tasks are adequately covered by procedures and integrated with the training requirements for emergency procedures.

The effort is timely because the NRC is presently requiring improvement and upgrading of emergency procedures.

No cost data are available.

With the effort being performed in-house, the available resources at INPO may be strained. Career human factors professionals and technical data specialists, as well as personnel with operating experience, will be required.

3.3.2.2.2 Control Room Review

Description

INPO is applying human factors techniques in a joint effort with TVA to provide the industry an example of a model control room system review approach which is acceptable to both the NRC and the utilities. Presumably this effort would be what INPO considers responsive to NUREG-0700 and NUREG-0801. The results will be made available to the industry as an example of an acceptable approach. Another example approach development effort for operational experience review will be initiated to delineate the steps necessary to plan and complete such a review. Regarding control room enhancements, INPO is compiling NTOL experiences in meeting enhancements and methods.

Performing Organizations

INPO and TVA.

Status

(1) Schedule/Priority: The model Control Room System Review is complete and undergoing an approval review, and the result will be made available to industry in 1982.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: (a) Control Room Review Workshop in 1982

Evaluation

The objective of this effort is appropriate and represents a realistic approach for the industry's interest in applying

NUREG-0700 and -0801 in an orderly fashion. Cost data are not available here.

Since this effort is nearing completion, with an NTOL control room review workshop planned for early 1982, it has been conducted in an appropriate time frame.

3.3.2.2.3 Operator Aid Development

Description

The Safety Parameter Display System (SPDS) concept offers a potentially powerful aid to nuclear plant operators. SPDS development and implementation requires integration with parallel development initiatives such as function-based emergency operating procedures, operator task analysis and training, and control room system review and enhancement. Also, utility oriented human factors requirements and perspectives regarding SPDS need to be developed quickly. This will afford some "hands on" and pilot project empirical experience to facilitate an effective and efficient industry program. INPO is working in conjunction with NSAC to assist the industry in coordinating the application, procedures, and training aspects of SPDS in a manner which will lead to timely implementation and contribute to functional acceptability by both the NRC and the utilities. Presumably this effort will be what INPO considers responsive to NUREG-0696 and NUREG-0835.

Performing Organization

Information requested from INPO but not received.

Status

(1) Schedule/Priority. Information requested from INPO but not received.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: A pilot prototype project is scheduled for early 1982.

Evaluation

The objective is appropriate because the various control room improvement efforts need to be coordinated to insure that human factors concerns are being adequately addressed. The focus is on the SPDS, a requirement driven by the NRC. While the SPDS may indeed be an effective aid, the requirement for it has to be established by a systems review and task analysis of each facility. Improper integration of an SPDS will have a deleterious effect. The SPDS's potential evolvement into DASS must also be addressed.

The effort is timely because the NRC is presently issuing guidelines regarding the implementation of SPDS. Any efforts that reflect the requirement for an SPDS will be useful.

No cost data are available.

Effort will require career human factors professionals which are limited at INPO and unavailable at NSAC.

3.3.2.2.4 SEE-IN Program Support

Description

INPO has an ongoing effort in support of the industry SEE-IN program to determine the "root causes" of human related nuclear plant operational errors and to develop recommendations to reduce human related errors. A specific effort is a valve mispositioning study that was initiated as a result of the large number of LERs associated with valve mispositionings. Initial results from this effort have been obtained and will be available to the industry shortly. Another project is a method of identifying generic nuclear plant human factors related problems by monitoring frequent and/or recurring LERs and nonconformance reports that are human factors related. INPO will provide guidance to the industry on readily identifiable human factors-related problems.

Performing Organization

Information requested from INPO but not received.

Status

(1) Schedule/Priority: Information requested from INPO but not received.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: Interim report on valve mispositioning errors to be published in early 1982.

Evaluation

As stressed several places in this report, the availability of human performance data in nuclear power plants is scarce. The SEE-IN program objective of in-depth analysis of suspect human factors problems is laudable in this respect.

The program was apparently started as quickly as was feasible and is thus providing timely information which should be useful during detailed control room design reviews.

No cost data are available.

A brief review of the program process and some of the products suggests that the program was well conceived and managed. Specific human factors products were not available for examination and no comment can be made about their quality.

3.3.2.2.5 Risk Assessment Technique Development

Description

Application of probabilistic risk assessment (PRA) methodology to nuclear power plant operations surfaces the problem of identifying and dealing with human error in the analyses. On a specific basis, INPO is providing human factors support to the Oconee PRA Study being sponsored by NSAC and Duke Power. Input is in the form of estimates for human reliability and supporting documentation. In general, INPO is developing models and techniques for handling problem areas that have not been sufficiently considered in other PRAs. PRA, as a tool for problem identification, is being assessed by analyzing the results of completed PRAs and parallel sources of information to determine what types of problems current PRAs are revealing and the extent to which these indicated problems are independently verifiable as real problems to safe and reliable power plant operation.

Performing Organization

INPO

Status

(1) Schedule/Priority: Unknown

(2) Resources: Unknown

(3) Products/Publications: Unknown

Evaluation

This effort suffers from the same difficulty as do other programs in human reliability. There is a lack of validated data on human error rates; consequently, the INPO inputs to this PRA study will be largely unreliable. We see this effort as largely wasteful and potentially misleading if any significant conclusions are based substantially on human reliability data.

3.3.2.2.6 Occupational Analysis

Description

Emphasis on systematic approaches to nuclear power plant operator training has increased the utility's need for more and better job and task analysis data. INPO is conducting a pilot test of CODAP with a cooperating utility to demonstrate the capabilities and useability of CODAP for the nuclear power industry. CODAP is an acronym for Comprehensive Occupational Data Analysis Program. It is a computer assisted occupational analysis system, developed by the U. S. Air Force Human Resources Laboratory, which stresses the quantification and empirical testing of human performance factors for a given job or group of jobs. The pilot test is being conducted on the mechanical maintenance job positions.

The cooperating utiltity has conducted a job analysis of the mechanical maintenance positions. The resulting task inventory has been formatted as a CODAP occupational survey. Mechanical maintenance workers at each level will be asked to complete the survey indicating the relative amount of time they spend performing each task. The survey also includes a section on biographical background data and an equipment list. Mechanical maintenance job supervisors will complete a separate survey of the "consequences of incorrect task performance" and "current training emphasis" vs. "desired training emphasis." The surveys will be conducted on a schedule that will not interfere with the plant maintenance requirements. The usefulness of the additional information gathered using CODAP, in assessing job training program content, will be reported to the nuclear utility industry.

Performing Organization

Information requested from INPO but not received.

Status

(1) Schedule/Priority: Information requested from INPO but not received.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: Information requested from INPO but not received.

Evaluation

The objective of this program is to demonstrate the usefulness of CODAP as a database for designing training programs that are in maximum accord with the actual requirements of the job. Experience (Ontario Hydro) has shown that training programs may include instruction on tasks that are rarely if ever performed by plant personnel as well as some that may be better performed by outside services. The result has been an effective trimming of the "fat" from the training program by eliminating training on such tasks. It is assumed that the reverse can also happen -- that training requirements can be identified that are receiving less than appropriate emphasis in the training program. This is a pilot program whose objectives are clearly in accord with the objective of cost effective training.

The pilot test is nearing completion and is expected to be finished during the first quarter of 1982.

The investments in this program are modest compared to the potential benefits. CODAP was acquired at no cost. INPO staff involvement is modest. A utility that desires to participate in the program is required to invest considerable manpower in completing the survey instruments, but the recovery of these costs in terms of potential reductions in unnecessary components of training programs or needed improvements to the curriculum are likely to be highly beneficial compared to the cost.

If the pilot test proves successful, INPO will offer CODAP services to the nuclear power industry. The weakest link in its procedure is the dependence on job supervisors to properly assess the "consequences of incorrect task performance" and the appropriateness of the current training emphasis. Assuming that proper precautions are taken to insure the reliability of these estimates, as well as the incumbents' estimates of the relative amount of time spent performing each task, the data should be a valuable input to properly solving the curriculum design problem. Clearly the effort would benefit from other sources of data, particularly detailed task analyses of maintenance jobs. The centralized CODAP data bank should gradually prove to be a useful mechanism for evaluating differences and similarities in emphasis among the utilities, and whether or not those differences are appropriate to system and procedural differences.

3.3.2.2.7 INPO/DOE/ORAU Manpower Survey

Description

The purpose of this project is to identify and report to utilities the present and projected future manpower hiring and development needs. A survey was developed and mailed to the utilities requesting the following information: current staffing levels (employment, contractors used, vacancies), projecting staffing levels through 1991, and turnover rates for 1980. The survey data have been analyzed and resulted in the following conclusions:

* General

    - Increased manpower recruiting and development efforts are required.

    - Five key job categories are of most concern (senior licensed operators including shift supervisors, licensed operators, nonlicensed operators, health physics technicians, and electrical and electronic technicians).

* Manpower data (for nuclear-related managers, professionals, and technical personnel only):

    - 41,000 positions

    - 5,000 positions reported vacant (however, further analysis indicates that these responses include future hiring plans)

    - 5% left nuclear-related positions in 1980

    - 27,000 replacements will need to be hired if 5% turnover is maintained over the next 10 years

    - 13,000 new positions will be created by currently planned plant additions

Performing Organization

INPO and Oak Ridge Associated Universities (ORAU)

Status

(1) Schedule/Priority: The project was completed and the survey results mailed to member utilities in 1981.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: Information requested from INPO but not received.

Evaluation

The interests of operational safety are clearly served not only by adequate numbers of well-trained professional and technical personnel, but by stability in the staff as well, particularly among licensed operators and shift supervisors. There are anecdotal reports of substantial personnel turnover that need to be verified. Accurate projection of manpower and hiring development needs is clearly an objective appropriate to the interest of both industry and NRC responsibilities for safety.

This survey is complete and a report of the results was mailed to industry members late in 1981. It is planned that these surveys will be conducted on a periodic basis (see 3.3.2.2.8).

The high cost to the utilities of failing to develop and maintain sufficient numbers of technically trained personnel, particularly licensed ROs and SROs, is obvious. The cost of assessing projected needs and of collecting accurate data on turnover rates by well executed surveys is modest by comparison.

Professional costs at INPO for this program were less than one professional man year. ORAU costs for processing and analyzing the data are not known but likely to be modest in relation to the benefits. Industry has an unspecified investment in manpower required to properly complete the survey questionnaires, but the informational benefits should greatly outweigh the costs.

A 100 % sampling of the utilities was employed. It is reported that all utilities completed at least those portions of the questionnaire that applied to their current status. Telephone follow-up calls were employed to maximize the returns. It was reported that some of the critical data (for example, the estimated 5% turnover rate) may have a sizable error of estimate since some of the utilities have not kept records in a form appropriate to the survey objectives. This type of problem can be expected to be corrected as experience with the survey develops. The program appears to be well-managed; the survey instruments are being appropriately revised with desirable improvements and the estimates of manpower deficiencies in various positions can be expected to be refined as the utilities gain experience in what is required of them. Companion work has started on analyses directed at projected manpower resources with an early indication that the problems of meeting expected needs are much greater for some positions than for others. In all, the project appears to be a source of vital information to industry management. The need for keeping the information up to date, taking into account developments that might change either the projected need or potential supply, is recognized (see Section 3.3.2.2.8).

3.3.2.2.8 Monitoring and Reporting Results of Nuclear Utility Human Resources Development

<u>Description</u>

* Conduct manpower surveys (in conjunction with DOE/ORAU) annually to identify staffing status, trends, progress, and problems

* Report survey results to industry projecting overall manpower hiring and development needs

* Provide to each utility individual feedback on their survey response and individual recommendations where increased staffing appears to be necessary

* During plant evaluations, collect more detailed information on functional groups' responsibilities and staffing needs to develop a plant staffing "model"

* Use the staffing model to improve staffing recommendations provided in response to requests and as part of plant evaluations and annual survey feedback

* Maintain files with utility and plant information including

    * plant type and other staffing-related factors

    * annual survey results

    * survey feedback letters

    * staffing-related information gathered by evaluation teams

To accomplish this requires the following:

* Developing data-collection forms and providing indoctrination for evaluation team managers

* Revising the manpower survey forms and instructions

Performing Organization

INPO and Oak Ridge Associated Universities

Status

(1) Schedule/Priority: Information requested from INPO but not received.

(2) Resources: Information requested from INPO but not received.

(3) Products/Publications: Information requested from INPO but not received.

Evaluation

This project represents a continuing program on identification of staffing status, trends, and possible manpower problems as described in 3.3.2.2.7. The comments made there regarding the appropriateness of this objective apply equally to the continuing effort.

The next survey will cover the time frame from March 1982 to March 1983. The program is expected to be a continuing one, with periodic surveys to appropriately update the data and identify important trends. The project is urgent in the sense that any actions required to counteract projected deficiencies in critical manpower requirements (particularly licensed operators) may require long lead times.

The extensive benefits of this program in relation to costs were discussed in Section 3.2.2.2.7.

Some very preliminary work has been done on the development of the plant staffing "model". The staffing-related information gathered by INPO's evaluation teams, in addition to the survey results, should provide useful objective data relating to the NRC's interests in staffing guidelines (see Section 3.1.2.1.3(d)).

3.3.2.2.9 Accreditation of Nuclear Utility Training

Description

(1) Need

Through the accreditation process, INPO will approve nuclear utility training programs which meet the intent of established criteria, thereby promoting and ensuring training quality.

(2) Objective

The accreditaton process will consist of the following:

(a) self evaluation of training conducted by the utility,

(b) on-site evaluation by a visitation team, and

(c) accreditation decision by the Accreditation Committee based on the self-evaluation report, the visitation team findings, and the utility's response.

The INPO/NRC relationship with respect to accreditation requires the following:

(a) NRC acceptance of INPO accreditation in lieu of establishing their own program.

(b) NRC agreement to provide a member of the INPO Accreditation Committee.

(3) Work Effort

The present plans for implementing accreditation include the following:

(a) Complete the development of accreditation criteria which will be coordinated with plant evaluation performance objectives and interim training guidelines.

(b) Complete documents describing the accreditation process and procedures.

(c) Develop and implement an accreditation assistance program to ensure utility understanding of the accreditation process and requirements.

(d) Develop and implement a training program for visitation team members.

Criteria will be divided into the following areas:

(a) program content

(b) instructors

(c) training resources and facilities

(d) organization and administration.

<u>Performing Organization</u>

INPO staff

<u>Status</u>

(1) Schedule: continuous when fully implemented

(2) Resources: INPO Staff plus utility staff participants

(3) Products/Publications: "Description of the INPO Accreditation Process," SDR-01

"Applying for INPO Accreditation," SDR-02

"Organizational Self-Study Handbook," SDR-03

"Organizational Accreditation Criteria," SDR-04

"Program Accreditation Criteria," SDR-05

Evaluation

It is necesary to ensure the quality of training of operators, technicians, maintenance personnel, and others who may impact the safe operation of nuclear power plants. INPO's objectives form a sound solution to this need.

INPO's schedule of activities is progressing at a satisfactory rate; however, at some point, their future progress may depend upon a decision by the NRC regarding their acceptance of the INPO program.

Cost/benefit is difficult to assess, but these results are likely to be the most cost-effective solution to the need.

INPO is modeling their program after similar programs for the accreditation of institutions of higher education. The quality of the INPO effort is likely to be high.

3.3.2.2.10 Job and Task Analysis

Description

(1) Need

This effort will be used to develop model training programs for nuclear power plant personnel and other needs in support of INPO's objectives of assisting industry in achieving standards of excellence.

(2) Objectives

The job and task analysis project will focus on the following objectives:

a) to establish an INPO job and task analysis data base,

b) to centralize the quality control plan for the job and task analysis effort at INPO,

c) to use utility teams of subject matter experts,

d) to obtain industry support in the development of job and task analysis materials,

e) to develop training programs specifications, and

f) to develop valid model training programs based upon the results of the comprehensive job and task analysis.

(3) Work Effort

The current project for industry wide job/task analysis includes all operations job positions at light water reactors: non-licensed operators, control room operators, control room supervisors, shift supervisors, and shift technical advisors, for whom the job analysis portion is complete. A future project will analyze the tasks for the technician and maintenance positions. The job analysis for three maintenance positions is in progress.

The project includes the following steps:

1. Develop preliminary job descriptions and task lists from existing documents.

2. Collect additional job data through interviews.

3. Prepare and field test questionnaires for an industry-wide survey.

4. Administer surveys at all operating plants.

5. Select tasks for analysis.

6. Analyze tasks and validate analysis.

7. Develop training recommendations.

This seven step process is being followed with three exceptions. (1) For emergency tasks, the task lists are being developed from emergency procedures, safety analysis studies (such as WASH 1400) and other documents and will be validated by subject matter experts. (2) For supervisors, a special evaluation is being performed to identify team tasks, the degree of team involvement, and the degree of supervisor involvement, coordination, or direction. (3) For the STA position, an analysis methodology suitable for a new job position rather than an existing position is being used.

Performing Organization

Analysis and Technology, Inc.

Status

(1) Schedule: The present plans for completing the job and tasks analysis include the following:

(a) complete the job and task analyses for RO, SRO, and Shift Supervisor in August 1982.

(b) complete the job and task analyses for STA, PEOs in 1983.

(c) complete the job and task analyses for maintenance positions in 1983.

(2) Resources: FY82 funds are $800K. Industry job incumbents are needed to serve as subject matter experts. Up to 15 SMEs will be needed simultaneously.

(3) Products/Publications: None to date from the A&T effort; job analyses may be be available, but cannot be identified at this time.

Evaluation

This effort is necessary to support the overall need for quality control of utility training programs. The timeliness of this effort is appropriate as planned.

3.3.2.3 Nuclear Safety Analysis Center (NSAC)

The Nuclear Safety Analysis Cener (NSAC) was created at the request of the nation's electric utility industry in April 1979, several weeks after the Three Mile Island accident. The center functions as a part of the Nuclear Power Division of the Electric Power Research Institute (EPRI) in Palo Alto, CA.

Industry leaders perceived a need for an impartial and objective investigation of the TMI accident and its long-term implications. As an important response by the nuclear utility industry to that accident, NSAC was instructed to investigate and analyze the accident, to draw from the accident lessons that are generally applicable to the industry, to indicate areas needing improvement, and to set up a means for nuclear utilities to exchange safety information.

3.3.2.3.1 Human Factors Responsibility or Interest

NSAC is primarily concerned with programs for evaluation of, and defenses against, postulated low-probability but high consequence events that have potential for serious safety effects or extended plant outages. Programs of interest from a human factors point of view are those concerned with the Safety

Parameter Display System (SPDS) and the other control room instrumentation. These work efforts are described together as one program below.

3.3.2.3.2 Instrumentation and Control Projects

Description

Carrying out a detailed technical analysis of the events that occurred at Three Mile Island nuclear station's Unit 2 on March 28, 1979, and determining how to improve nuclear plant safety were NSAC's initial responsibilities. NSAC's present and continuing purpose is to supply the nuclear power utilities and INPO with technical advice and support on safety-related matters such as design, performance, and analysis of nuclear power plant behavior. Projects with human factors implications are:

1. Safety Parameter Display System

2. Core Damage Assessment

3. Diagnostc Instrumentation Evaluation

4. Fundamental Safety Parameters Validation

Performing Organization

Various contractors and consultants

Status

NSAC will continue to aid technical analysis of issues raised by TMI for the forseeable future.

Evaluation

NSAC is almost exclusively engineering oriented and thus focuses on hardware factors or engineering parameters. The results of their efforts do not impact human factors issues directly and for this reason no specific evaluation is offered by the Project Study Group.

The engineering analyses NSAC performs seems to be carried out by competent professionals in response to industry needs.

3.3.2.4 Edison Electric Institute (EEI)

The Edison Electric Institute, located in Washington, D.C., is an industry association representing approximatey 220 investor-owned utilities. No detailed information was received concerning the overall mission of the Institute, but its interests clearly include the development of methods for improving the selection of both operator and maintenance personnel throughout the power industry.

3.3.2.4.1 Plant Operator Selection

The Plant Operator Selection system is an outgrowth of a 30-month study performed under EEI sponsorship by Personnel Decisions Research Institute. The study addressed personnel selection techniques for a variety of plant operating personnel, including control room operators in hydroelectric plants, fossil plants, and nuclear plants. The "Selection System" is a battery of tests and questionnaires for administration to job candidates to assist employers in determining "how well a candidate compares with others on a number of important aptitudes or abilities, and whether or not a candidate possesses the kind of personal stability required in power plant operations positions" (28).

The research underlying this development was soundly based and performed by highly qualified professionals. A number of uncertainties remain concerning the generality of results, however: (1) a relatively small sample of nuclear power plant control room operators were included in the study and the modest predictive relationships obtained had not been cross-validated at the time of our inquiry; (2) only subjective criteria of performance (supervisory ratings) were available as a validation criteria; and (3) the criterion of emotional stability (also subjective) was not significantly related to any of the experimental predictor variables. It would seem that further research and development work on the prediction of control room operator performance (and stability) would be warranted if and when more objective criterion measurers become available. Work on more advanced predictor test methodology using dynamic computer generated displays could also be justified on the basis of the rather small percentage of the criterion variance that proved predictable from the more conventional pencil and paper test approach that was used.

3.3.2.4.2 Maintenance Personnel Selection

EEI has entered into another contract with Personnel Decisions Research Institute aimed at improved methods for selecting power plant maintenance personnel. It was indicated that the same general approach will be used as was employed for the operator selection study. This work will be concluded in March 1983. It was too early at the time of our inquiry to assess progress and likely success.

3.3.2.5 Atomic Industrial Forum, Inc. (AIF)

The following information, provided by the AIF, summarizes their human factors activities.

3.3.1.5.1 Human Factors Responsibility or Interest

The AIF Committee on Power Plant Design, Construction, and Operation is the principal AIF committee that addresses human factors issues. The charter of this committee is as follows. "The Committee shall identify and address power plant design, construction, and operational issues in which committee action can benefit Forum membership and the nuclear industry. It will maintain close liaision with appropriate government agencies including the Nuclear Regulatory Commission and the Department of Energy in order to facilitate the communication of industry positions and provide input to government policies which affect power plant design, construction and operation. Committee activities will include, but not be limited to the promotion of practices which will enhance cost effectiveness and plant productivity. Additionally, quality assurance will be a significant focus of Committee activity. The Committee will provide the Atomic Industrial Forum with a mechanism to address power plant issues that are outside the scope of the Committee on Environment and the Committee on Reactor Licensing and Safety. The Committee will work closely with other AIF Committees and will undertake joint projects when appropriate."

There are two subcommittees addressing these issues as indicated below:

(1) Subcommittee on Operations and Maintenance has been addressing such issues as reactor operator qualifications and training, utility management and organization, plant staffing, operator examinations, and plant maintenance.

(2) Subcommittee on Control Rooms and Emergency Response Facilities has been addressing human factors engineering considerations such as control room design and human factors engineering reviews, SPDS, nuclear data link, and data requirements for emergency response facilities.

3.3.2.5.2 Programs and Actions

Descriptions

Significant activities by the AIF within the last year are briefly annotated below:

(1) Subcommittee on Operations and Maintenance

Activity has focused on proposed rulemaking on qualification of reactor operators (SECY 81-84).

- Sent letter to NRC Chairman urging NRC not to issue rule because it was premature and poorly conceived. NRC then directed staff to form an advisory peer panel to make recommendations. The primary contention involves educational requirements for reactor operators.

- Developed alternate proposal (AIF/EEI/INPO) based on job-task-analysis to determine training and education requirements. Presented proposal to NRC Commissioners and later to Peer Panel.

- Presented proposal to NRC staff on operator examinations.

(2) Subcommittee on Control Room and Emergency Response Facilities

- Subcommittee has focused on control room review guidelines and evaluation criteria (NUREGs 0700 and 0801) and more recently SPDS evaluation criteria (NUREG-0835).

- Bill Coley took leadership role as chairman of the short term improvement task group at the NRC/IEEE Workshop on Human Factors and Safety (1981).

- Subcommittee acting to ensure that various new NRC requirements are adequately integrated; i.e., SPDS, nuclear data link, Reg. Guide 1.97 (accident monitoring instrumentation), electrical equipment qualification, symptom-based operating procedures, and control room reviews.

Performing Organizations

AIF work in human factors has been primarily through the efforts of committee members who are volunteers with some support from AIF staff.

Status

AIF efforts are ongoing and initiated as necessary to respond to potential issues raised by the NRC or by the industry.

Products of these efforts are letters, reports, and verbal exchange of ideas within the industry and government.

Evaluation

There is no appropriate means of evaluating the efforts of the AIF. Their activities are primarily responsive in nature and timely to issues that are raised relative to human factors. Their input seems to be valued by the NRC and the industry. The professional committee and staff members are well-qualified for their roles.

3.3.3 Architect-Engineer Firms

The commitment to a commercial nuclear power reactor usually involves the identification and selection of four major supplier organizations: the NSSS vendor, the generator supplier, the architect-engineer firm, and the constructor. In addition, there is of course the owning utility, making a total of five principal organizations involved in the design, construction, and licensing of a nuclear power plant. The architect-engineer (A/E) firm is usually brought in after the NSSS vendor has been selected by the utility and thus numerous constraints are already established which affect engineering flexibility.

There are perhaps a dozen A/E firms that have participated in the design and construction of nuclear power plants. However, the field is dominated by one major firm, followed by two or three firms who share most of the rest of the market, with the remaining eight or ten firms involved with one or two plants each. The A/E firms are typically quite large with thousands of employees and a large number of subcontractors in every conceivable area. Most of the large A/E firms are also constructors, but it does not necessarily follow that the A/E firm and the constructor will be the same organization even when they have both capabilities.

The A/E role in design, construction, and licensing of an NPP varies considerably. In the newer plants the A/E firms have seemed to emerge in a role of the organization responsible for the overall design and the "balance of plant" (BOP) which is essentially all the equipment with the exception of the nuclear steam supply system and the turbine-generator system. This role is in contrast to the first commercial power reactors, which were turn-key contracts to NSSS vendors. Another factor which affects the A/E role is the size of the utility. The very largest utilities have their own architects and design groups and frequently do their own construction. Smaller utilities rely more heavily on the A/E for design and construction. Finally, the A/E firms point out that the quality of design they can effect is often dictated by the operating philosophy of the utility (for example, with respect to the level of automation) and how much the utility is willing to spend.

While there may indeed be constraints that limit the degrees of freedom in design, it would be a rare exception to find any nuclear power plant that incorporated human factors considerations in the design of the control room or anywhere else. Also painfully missing in the final designs is the lack of systems integration, at least as it is practiced in the military/aerospace programs. The A/E firms are traditionally organized by discipline or trade (e.g., mechanical, electrical, etc.), and have not had strong systems integration or engineering perspectives. However, the A/E firms also say that the utilities don't require or won't pay for the systems integration function, or that the NRC is constantly changing the requirements without coordinating the changes within the NRC, and this makes it difficult if not impossible for those responsible for systems integration. It might be noted that those plants that have not yet received their operating license offer the opportunity for better systems integration by way of complete data management systems, which can be designed in from the start and which are flexible enough to absorb changes in operating philosophy or NRC requirements.

The A/E firms also point out that the lack of human factors considerations is due in part to the requirements for qualifications of instrumentation and controls. These requirements for environmental, reliability, fire separation, and seismic qualification result in the lack of alternatives available to the designer. In other words, a well-designed and human engineered display may not meet one or more of the qualification criteria, and therefore cannot be used. It does in fact take an investment of considerable time and money to qualify instrumentation and controls, and the tendency to use standard components is therefore predictable. However, the A/E firms tend to recognize that computer-based systems would provide the flexibility to accommodate new regulations and changes in technology if the utility would buy them and if the NRC would approve their use. Finally, the A/E firm responsible for design is quick to point out that the original design was considerably better and different, but that continual changes required by the NRC and to some extent the utilities over the years tend to exacerbate the lack of systems integration since many new instrumentation and control components are placed on the consoles wherever space is available.

In any event, there is no evidence that A/E firms were concerned about human factors prior to TMI. Since TMI, and particularly with the impending control room design reviews (NUREG-0700) which may require control room modifications, A/E firms have shown some interest in trying to understand the human factors issues. Several firms have sent some of their engineers to human factors consultants when necessary, and on rare occasions some A/E firms have hired a single human factors professional. However, it is the conclusion of this Study Group that without the NRC requirements for human factors, the A/E firms would probably return to "business as usual" without human factors except for what little may have rubbed off on their own engineers.

3.3.4 NSSS Vendors

In the parlance of the nuclear power community, a reactor and the associated equipment that provides steam to drive the turbines are referred to a nuclear steam supply system (NSSS). Companies that manufacture NSSSs are called NSSS vendors or sometimes simply vendors. Four NSSS vendors have manufactured all but one of the licensed nuclear power reactors in the United States. General Electric is the only NSSS vendor that manufactures boiling water reactors (BWR). Approximately one-third of the operating power reactors in the United States are BWRs. The remaining two-thirds are pressurized water reactors (PWR) manufactured by either Westinghouse, Combustion Engineering, or Babcock and Wilcox. The single reactor that was not manufactured by one of these four companies is a high-temperature gas-cooled reactor (HTGR) built by General Atomic Corporation. There are no orders for additional HTGRs to be built in the United States. Therefore, the remainder of this section will be concerned with the NSSS vendors of BWR's and PWR's.

NSSS vendors, since the very first contract for a power reactor to be built without government subsidy in 1963, have engaged in numerous activities that should have incorporated human factors considerations. These included design of displays and controls for the control room, development of both operational and maintenance procedures, operator training, and specification of training devices including control room simulators. There is no evidence that any of the NSSS vendors had human factors programs or made explicit use of human factors principles, procedures, techniques, or methods prior to TMI-2. Two of the NSSS vendors have had human factors organizations in other divisions of their companies for many years. These human factors groups have been extensively engaged in the design, development, and manufacture of military and space systems and, in at least one company, the design of consumer products.

It is true that, in most of the nuclear power plants that have been built, the NSSS vendor did not have complete responsibility for control room design. In some cases, the control room was the result of shared responsibility by the AE, the NSSS vendor, and the utility. In other cases, the AE was nominally responsible for overall design and layout but individual panels were designed and manufactured by the NSSS vendors and others. However, it is interesting to note that the contracts for the first nuclear power plants were with NSSS vendors for "turnkey" projects. This meant that the vendor was responsible for providing a complete nuclear power plant ready to operate at a fixed cost. In other words, the NSSS vendors were prime contractors, and thereby in a position to impose human factors requirements for integrated control room design. They did not. The two NSSS vendors who contracted for thirteen "turnkey" nuclearpower plants, beginning in 1963, were the two who at that time had human factors organizations in <u>other</u> divisions of their companies.

Since TMI-2, the NSSS vendors have responded to the criticisms of negligence regarding human factors. All four have instituted projects and activities under the human factors label. Among the vendors there are large differences in the scope of human factors activities and in the number of people assigned to human factors projects. There are also wide differences among the vendors in terms of the professional qualifications and experience of the people who have responsibility for human factors. In some cases, vendors have hired qualified human factors personnel and in others they have transferred or modified the areas of responsibility of qualified personnel already in the employ of the company. In some cases, it appears that vendors have hired unqualified or poorly qualified personnel for human factors positions. In some cases, employees qualified in other disciplines and with no human factors experience have been given responsibility for human factors activities. In general, with the exception of a very few individuals, the NSSS vendors have not assembled qualified human factors professionals to work on human factors projects.

The NSSS vendors as a group are addressing in some fashion a fairly wide range of human factors concerns. These include the human's role in advanced computer-based systems, advanced control room design, instructional system development, design of control room simulators and part-task trainers, etc. The degree of sophistication of the human factors work and its apparent quality vary widely among the vendors. In some cases, it is apparent that the human factors activities are window dressing or after-the-fact attempts to legitimize engineering design accomplished without human factors participation. In other cases, the human factors projects, both design and research, are significant and well-conducted.

In summary, the NSSS vendors' human factors programs vary widely in terms of qualified, experienced personnel, significance and quality of human factors work, and scope of human factors activities.

3.3.5 Human Factors Consulting Firms

Prior to TMI-2 there were many well-established organizations that conducted R&D and consulting efforts in human factors engineering. As a result of TMI-2, many of these firms became interested in applying human factors skills and knowledge to nuclear power generation. Some of the firms provided expertise in the TMI-2 investigations, others have assisted the utilities in control room and maintenance evaluations, and still others have conducted technical assistance or research programs for the NRC.

At the present time, approximately 20 firms have performed contracted studies or provided services to the nuclear industry and/or the NRC. The quality of these efforts has ranged from excellent to extremely poor. Many firms have provided competent, experienced personnel, while others have provided inexperienced, untrained nonprofessionals. As a result of several unfortunate experiences, the human factors discipline has received unfavorable evaluations from some sponsors of these activities. While it is beyond our scope to evaluate these firms and their activities individually, it must be said that the naive purchaser of human factors services needs to be cautious at this time, and to seek qualified advice prior to entering into such support arrangements.

3.4 Professional Organizations

3.4.1 The Human Factors Society

The Human Factors Society (HFS) was founded in 1957 at a meeting held in conjunction with the Fifth Annual Office of Naval Research Human Engineering Conference. The Society is an interdisciplinary organizaton of professional people involved in the human factors field. It promotes the discovery, exchange, and application of knowledge concerning the relationships of people to their tools, machines, and environment. HFS furthers the assignment of appropriate roles to humans and machines in systems and advocates the consideration of operators, maintainers, and users in the design of equipment and facilities. The Society supports the development of working and living environments which are comfortable and safe. It encourages the appropriate education and training of those who conceive, design, develop, manufacture, test, manage, and participate in manned systems.

The Society has a current membership of approximately 3000 individuals representing more than 1100 industrial and business corporations, universities, government laboratories, and consulting firms in the United States and 27 foreign countries. The most recent analysis of educational backgrounds of members showed that, based upon the highest academic degree held, the following academic specialties were represented: psychology, 55 %; engineering, 16 %; human factors/ergonomics, 7 %; industrial design, 4%; medicine/physiology/life sciences, 3%; education, 2%; and business administration, 2%. The remainder of the membership represents a variety of specialties such as physics, anthropology, sociology, architecture, industrial management, and operations research.

The Society is governed by officers and an executive council elected by the membership. It maintains a business office under the supervision of an executive administrator in Santa Monica, California. Several standing and special committees are concerned with the professional, educational, public service, and business affairs of the Society. The Society has representatives to Sections J, K, M, N, and T of the American Association for the Advancement of Science, and is a member organization of the International Ergonomics Association. The HFS has chapters throughout the United States which sponsor local meetings and publications. Nine technical groups of the Society serve to facilitate communication among individuals with interest in particular human factors domains.

Meetings and publications are sponsored by the Society to promote the exchange of knowledge and to advance human factors education and programs. An annual meeting is held in the fall. The Society publishes the bimonthly journal Human Factors which presents original papers of scientific merit that contribute to the understanding of human factors and which advance the consideration of human factors. The monthly Human Factors Society Bulletin features timely news of interest to human factors professionals.

3.4.1.1 General Activities Related to Nuclear Power

Because of the almost complete absence of concern for human factors in the nuclear power community prior to TMI-2, there was very little activity within the HFS related to nuclear power. Only one article with "nuclear power" in its title had been published in Human Factors prior to TMI-2 (McGinty, 1965). At the Annual Meetings of the Society held in 1978 and 1979, only three papers were presented that were concerned with human factors in nuclear power generation (114, 115, 124).

Following the publication of the reports on TMI-2 in late 1979 and early 1980, the level of Society activity related to nuclear power increased greatly. At the 1980 HFS Annual Meeting, three technical sessions were concerned with human factors in nuclear power generation. The number of nuclear power related sessions increased to five at the 1981 Annual Meeting.

During the past two years the numbers of applicants for membership in HFS has increased dramatically. This increase has been due, in large part, to applications from persons associated with the nuclear power industry.

The HFS does not certify a member's technical competence, and has relatively minimal requirements for full membership.

3.4.1.2 Development of Long Range Human Factors Plan for Nuclear Reactor Regulation

The HFS as an organization has made a serious committment to helping solve the human factors problems in nuclear power generation. At the 1980 Annual Meeting, the HFS Executive Council approved a comprehensive long range human factors plan for nuclear reactor regulation. A contract was awarded to HFS by the NRC. This report is the culmination of a project by the HFS Study Group to develop the plan.

3.4.2 The Institute for Electrical and Electronics Engineers (IEEE)

The IEEE is a worldwide professional organization of engineers which is well known and will not be discussed as an organization in this report. The IEEE does have two principal activities concerned with human factors in nuclear power plants. These activities are part of the Nuclear Power Engineering Committee (NPEC). This committee has subcommittees which are concerned with human factors Subcommittee 1, Power Generation, has a working group (WG) 1.2 for Nuclear Power Plant Control and Protection. This working group is responsible for two standards which affect human factors, and will be described below.

Subcommittee 5, Nuclear Reliability, has a working group 5.5, responsible for Human Factors. WG 5.5 was initiated in March 1980 as a result of a recommendation from the Workshop on Human Factors in Nuclear Safety, held in Myrtle Beach, South Carolina in December 1979, and sponsored by the IEEE and the NRC. An ad hoc meeting to explore interests of the human factors community in participating in WG 5.5 was held in May 1980, and the first formal meeting was held in June 1980. Meetings are held every two or three months, and the working group now has three principal task forces working toward the development of human factors related standards or guidelines. These are described further below.

WB 5.5 has been proposed to change from a Working Group to a Subcommittee in 1982. The proposed title and scope of the new subcommittee is as follows:

<u>Human Factors & Control Facilities Subcommittee (SC7)</u>

Scope: Treatment of all matters relating to the application and analyses of the human factors of systems and equipment, and the development of control facilities criteria, for nuclear power generating stations. Included is the development of the application of human factors to systems, equipment and facility design, operation, maintenance and testing; and the development of the methodologies of human factors data collection, modeling, model evaluation, and model validation.

Also included is the lead responsibility for coordination with other groups with respect to acquisition, evaluation, and application of human factors data, control facilities criteria, the coordination of nuclear standards, the sponsorship of technical sessions and education courses, the preparation and review of technical papers, the dissemination of information to the industry on new developments, and the advancement of nuclear engineering with students and educational organizations.

3.4.2.1 Working Group 1.2, Nuclear Power Plant and Control and Protection

WG 1.2 is part of the Power Generation Subcommittee of the Nuclear Power Engineering Committee. Two proposed standards have been developed and should be finalized in 1982 or 1983. These standards are:

(1) ANSI/IEEE Std. 567, "Criteria for the Design of the Control Room Complex for a Nuclear Power Generating Station"

(2) ANSI/IEEE Std. 566, "Recommended Practice for the Design of Display and Control Facilities for Central Control Rooms of Nuclear Power Generating Stations"

Description

IEEE Standard 567 addresses the central control room of a nuclear power generating station and the overall complex in which this room is housed. It is not intended to cover special or normally unattended control rooms, such as those provided for radioactive waste handling or for emergency shutdown operations.

The nuclear power generating station control room complex provides a protective envelope for plant operating personnel and for instrument and control equipment vital to the operation of the plant during normal and abnormal conditions. In this capacity, the control room complex must be designed and constructed to meet the following criteria contained in Appendix A of 10 CFR 50, General Design Criteria for Nuclear Power Plants:

(1) Criterion 2: Design Bases for Protection Against Natural Phenomena

(2) Criterion 3: Fire Protection

(3) Criterion 4: Environmental and Missile Design Bases

(4) Criterion 5: Sharing of Structures, Systems and Components (multiunit stations only)

(5) Criterion 19: Control Room.

The purpose of this standard is to provide guidance for the design of the nuclear power plant control room complex, which must meet the applicable criteria in Appendix A of 10 CFR 50. Requirements are established and recommendations are offered to aid the designer in meeting the applicable general design criteria.

IEEE Standard 566 established criteria to be used by power plant system, equipment, and main control room designers in the selection of the information and control features to be made available to plant operators in the main control room, and the methods to be used to provide such features. These criteria reflect the application of human engineering principles as they apply to power plant man-machine interfaces during normal and abnormal plant conditions. This includes the requirements of iterative systematic procedures to verify and validate the design process.

The purpose of this document is to provide criteria for the functional selection, design, coordination, and organization of controls and displays in the nuclear power plant control room so as to optimize operator performance and minimize the potential for operator error. The underlying requirement for the standard is Appendix A of the Code of Federal Regulations, General Design Criteria for Nuclear Power Plants:

- o Criterion 13, Instrumentation Controls
- o Criterion 19, Control Room.

Performing Organization

Working Group 1.2 of the Subcommittee on Power Generation of the Nuclear Power Engineering Committee.

Status

IEEE Standard 567 was issued October 1980 for trial use. IEEE Standard 566 was issued in revised form in 1980 for comment and will probably be published for trial use in 1982.

Evaluation

Both of these documents have a generally desirable objective. While they both include some human engineering concerns, they address criteria areas such as seismic, fire protection, etc. Consequently, from a human factors standpoint, they are virtually useless and are overshadowed by NUREG-0700 and 0801.

They probably have some value in that they include references to other ANSI/IEEE standards which bear on the overall design of a control room.

3.4.2.2 WG 5.5 Human Factors - Proposed Standards Development

WG 5.5 performs several activities such as preparing consensus positions and responses on IEEE standards, NRC requirements, and other human factors issues; and engaging in educational activities or information dissemination. However, the primary area of activity of interest to the Human Factors Society Study Group is the standards development areas of WG 5.5. As of September 1981, WG 5.5 had three task groups organized for the eventual development of standards. These proposed standards are concerned with:

(1) Guide to Evaluation of Man-Machine Performance in Nuclear Power Generating Station Control Rooms and Other Peripheries. SPAR approved by IEEE Standards Board, March 5, 1981, Project No. 845.

(2) Guide for Human Factors Engineering Requirements for Systems, Equipment and Facilities of Nuclear Power Generating Systems. SPAR submitted to NPEC Ad Com, June 23, 1982.

(3) Recommended Practice for the Use of Color Coding in Nuclear Power Plant Panels, Controls, and Displays. SPAR submitted to NPEC Ad Com, June 23, 1981.

Each of these projects is briefly descried below.

3.4.2.2.1 Development of a Guide for Human Factors Engineering Requirements for Systems, Equipment, and Facilities of Nuclear Power Generating Stations

<u>Description</u>

This project is concerned with the development of program plan guidelines for human interfaces throughout the nuclear plant. The guide will apply to all systems, equipment, and facilities, and provide requiements which must be met in conducting a human factors engineering (HFE) program on those significant human interfaces in all phases of their implementation: conceptual; validation; full-scale development;

production/installation; and utilization. The guide will be similar in concept to MIL-H-46855 and will describe the tasks to be performed in conducting human factors engineering efforts integrated with total system engineering.

Performing Organization

The guide is being developed by an ad hoc committee of engineering and human factors personnel.

Status

A Standards Project Authorization Request (SPAR) was submitted to the IEEE Nuclear Power Engineering Committee on June 23, 1981. A final draft is anticipated to be ready for formal review by the summer of 1982. The final product will probably be a guide and not a standard.

Evaluation

Though it is unclear in what final form this document will be published and adopted, it is an excellent description of how a human engineering program should be conducted in a systematic manner. It is based on MIL-H-46855, a similar document used successfully for many years by the military and aerospace community.

The product will be very valuable to the industry and, if followed closely, will help assure that the development of entire power plants will contain highly improved man-machine interfaces for both operation and maintenance. Its publication should move as rapidly as possible.

The working subgroup for the draft version of this document contains a mix of experienced human factors professionals and some people with limited or negligible experience. The continued involvement of experienced human factors professionals is essential.

3.4.2.2.2 Development of a Guide for Human Performance Evaluation in Nuclear Power Plants

Description

The need for this effort is to help the engineer evaluate human performance in a nuclear power plant environment. The ultimate goal is to identify the tools with which to review and compare existing man/machine interfaces with proposed changes. It is presumed that this comparison can help to optimize a decision-making process by identifying needed changes in the control room and other areas of nuclear power plants. It also proposed that the guide will help prevent non-effective or even potentially degrading changes from being implemented. The present purpose of the guide is:

(1) Evaluation of a given man/machine design to indicate the degree of possible deficiency,

(2) Determination of changes that make a man/machine design acceptable, and

(3) Determination of the equivalency of alternative designs.

A survey of models and data bases related to human performance in nuclear power generating stations has been conducted, and a working draft report prepared. Current effort is focused on assembling and evaluating existing information on models, methodologies, and data bases related to human performance.

Performing Organization

An ad hoc task force of engineers and human factors professionals is developing the guide.

Status

A standards project authorization request was approved by the IEEE Standards Board on March 5, 1981, for this project. A white paper on human performance data bases and methodology is being prepared and should be complete in the summer of 1982. Eventually, guidelines for the use of models and data should be available.

Evaluation

The emphasis in this development is on helping the engineer evaluate human performance in a nuclear power plant environment. This goal, though certainly appropriate, is considerably more difficult to achieve than if the tools were to be used by experienced human factors professionals or behavioral scientists. The objectives are ambitious. Their appropriateness in terms of NRC requirements outlined in NUREG-0700 and 0801, and ongoing risk assessment work, is clear. Their appropriateness in terms of the presumed availability of appropriate human performance data bases and behavioral models with demonstrated validity is more questionable.

The timeliness of this project is a function of how one assesses the current state of development of human performance models and the appropriateness of existing human performance data banks to applications in nuclear power plant operations. Assuming that appropriate data and models exist, the project is urgent. If not, it is premature. It is expected that there will be a thorough assessment of these issues by the summer of 1982.

The assessment of models, methods and data bases is being done with volunteered professional effort. Successful development of the Guide would likely involve a substantial investment of both money and time.

The July 1981 report on the Task Group's survey of models and data bases relating to human performance reflects some of the technical difficulties faced in reaching the objectives of this program. That report identified 15 models and 14 data bases that were considered by participants in the survey to be related to the objective of evaluating human performance in nuclear power plants. Although the Task Group believed that much of the required empirical data would be revealed by this survey, and that there were appropriate predictive or heuristic models already available, the results cast doubt on both of these assumptions. It is noted, for example, that the data bases often reflected developments in other industries or in the military on task that were far different from those performed in the nuclear power industry. Where the data sources were nuclear based, they were often the result of performance in simulators and raised questions about transferability of the data. One data base reflecting information from LERs and one from "in-plant" data were reportedly "limited in statistical content." Thus, it was concluded that the availability of human performance data sources is not as promising as had been hoped but it was expected that increases in the human performance informational data base will occur during the course of this program. It is recognized that proper structuring of data acquisition programs to support the objectives of this program is essential as is the development of the interface between the data base user and the data base.

With respect to the models, a casual glance at those identified through the survey raises serious doubts about the applicability of most of them to nuclear power plant operations. Questions also remain concerning the "validation" of many of these models although the authors invariably espouse their usefulness.

During the next phase of effort, the task group will be engaging in detailed technical reviews and evaluations of the information collected thus far. It seems clear from the conclusions reached by the Task Group on Human Performance Theories and Models (Myrtle Beach 2, September 1981) that extensive work remains to be performed, particularly in the area of modeling the cognitive behavior of nuclear power plant operations which is likely to be the largest source of human-related risk. Yet this group recommended the "early application" of cognitive models in nuclear power plant applications, as well as application of cognitive models to delineate and qualify performance shaping factors. The potential uses of the models were seen to include:

(1) aid in procedure writing for plant operations,

(2) aid in system evaluation and design,

(3) provide tools to enhance training,

(4) aid in the process of selecting operators and other personnel

(5) be combined with the use of reliability and risk models to establish priorities for human factors analysis, and

(6) aid in organizing work for plant operation.

These are undoubtedly significant, worthwhile objectives. It seems doubtful, however, that either the human performance data banks or presently available behavioral models are as yet ready for such broad application, especially by engineers using a Guide. The amount of research and development work necessary to reach this objective is viewed as a large scale undertaking, requiring substantial budgets and several years of development. The Task Group will have performed a service if they pinpoint what needs to be done to properly develop such a Guide. There is considerable risk associated with premature application of what may be known about human performance in other contexts.

3.4.2.2.3 Recommended Practice for the Use of Color Coding in Nuclear Power Plant Panels, Controls, and Displays

<u>Description</u>

The use of color coding in nuclear power plants is not standardized, frequently not consistent within the plant, and frequently violates good human factors practice. The need for a better, more standard guidance in color coding is not currently to be found in any document or reference accepted by the nuclear power utilities. This project will recommend practices for the use of color codes in nuclear power plant panels, controls, and displays. The intent is to provide specific guidance for the use of color to aid the operator in performance of required tasks and increase the reliability of the electrical and control equipment by improving the equipment/operator interface. Guidance will be provided concerning:

(1) The criteria for the use of color as a coding means to aid operator performance,

(2) Identification and categorization of plant information types suitable for color coding,

(3) The acceptability of the use of the same color for different meanings, and

(4) Appropriate application of this Recommended Practice to plants in operation, under construction, and in design.

The intent of the eventual document is to provide a coordinated, effective, and consistent approach to intra-plant color codes, including the application of color to backfits as well as to new designs.

Performing Organization

This project is being conducted by an ad hoc task group of engineers and human factors professionals.

Status

A standards project authorization request for development of a recommended practice for the use of color coding in nuclear power plant panels, controls, and displays was submitted to the Nuclear Power Engineering Committee on June 23, 1981. A draft proposed practice has been developed in a final white paper, and is expected to be available in the summer of 1982.

Evaluation

The objectives of this task are meaningful and appropriate. However, the task has many subtle complexities, due largely to (1) differences among plants and systems, and (2) transfer of training issues. While categorization of color codes by subsystem appears logical, it may be quite difficult to implement meaningfully in control rooms with vastly different configurations. Then there is the argument about negative transfer versus better coding.

It appears to us that an ad hoc group, however qualified, may not have the necessary quantitative data to write a useful standard for this problem at this time. It may well be the case that thorough, specific control room analyses and simulations are required to provide such data. In addition, while this task group has an adequate contingent of nuclear engineers and instrumentation personnel, their original draft (presented at Myrtle Beach 2, 1981) showed considerable human factors naivete. Thus, we have little hope that this effort will be very beneficial.

3.4.2.2.4 Development of a Human Factors Bibliography

Description

A special project conducted within the WG 5.5 auspices is preparation of a human factors bibliography relevant to nuclear power plants. A bibliography dedicated to human factors in nuclear power plants is being compiled. The existing IEEE bibliography from the Myrtle Beach 1 Conference Record will form the beginning, but the primary input will include an author and title index, and will be divided into 10 to 20 subject areas with cross indexing within the areas. The use of key words is also being considered, and where possible, abstracts will be included.

Performing Organization

A special project group of WG 5.5

Status

The preliminary bibliography was completed in September 1981. It will be published by the IEEE as a companion document to the proceedings of the Myrtle Beach 2 Conference on Human Factors and Nuclear Power, which has not yet been distrubuted.

Evaluation

The objective of this activity is of course commensurate with many other human factors activities and projects that are in progress or are being planned. Similarly, the timing (if the document is available in early 1982) is basically suitable to support many of the major human factors activities sponsored by the NRC and industry.

Not enough is known about the content and form of the final product to make any meaningful evaluation at this time. Further, plans for disseminating the bibliography or making it available are also important and not known at this time. Thus, while the objective and timeliness of this effort are noteworthy, its ultimate value remains to be determined.

3.4.3 The American Nuclear Society (ANS)

The American Nuclear Society, an international organization of engineers and scientists, was founded at the National Academy of Sciences in Washington, D.C. on December 11, 1954, as a non-profit scientific and educational organization. The Society was founded by a group of individuals who perceived the need for an organization to unify the activities within the diverse fields of the nuclear power industry and related groups. The Society currently has a membership of 13,000 individuals representing over 1,600 corporations, educational institutions, and government agencies. Approximately 1,200 members live overseas in 40 countries. The Society is governed by a Board of Supervisors elected by the membership.

The main objectives of the Society are for the advancement of engneering and science relating to the nuclear power industry and other nuclear activities, and the integration of the scientific and management disciplines constituting nuclear science and technology. Other purposes are to encourage research, establish scholarships, disseminate information, hold meetings devoted to scientific and technical papers, and cooperate with government agencies, educational institutions, and other organizations having similar purposes.

The ANS interest in human factors derives from its general concern for advancement of engineering and science related to the nuclear power industry. Of particular relevance to the present project is the activities of the Technical Group for Human Factors Systems (TGHFS) and the promulgation of selected standards related to human factors.

Evaluation

The TGHFS is a relatively new organization and its ultimate contribution to human factors in nuclear power is yet to be determined. Certainly, the American Nuclear Society needs (and has needed for many years) a technical group concerned with human factors. The objectives of the group, both recent and planned, are commensurate with the Charter of the American Nuclear Society. There are no specific mission-oriented activities which can be commented on at this time.

The principal concern of the project study team is that there appear to be few career human factors professionals who are members of the TGHFS. Most of the technical group members are engineers who have recently become interested in human factors. Of course, it should be recognized that there are not many human factors career professionals who are also members of the American Nuclear Society and therefore the TGHFS has a small population to draw upon these members. The TGHFS also seems amenable to cooperating with other professional groups, e.g., the Human Factors Society, and this would appear to be an excellent idea to bring more balance to both groups.

In summary, the TGHFS does not represent the scope and depth of experience in human factors by the members of the group that are representative of the profession as a whole. This is unfortunate since the group members are probably perceived by the nuclear utilities services as being representative of the human factors profession.

3.4.3.1 American Nuclear Society Standards

The American Nuclear Society has promulgated several standards in the personnel selection and training area. Two of these standards which are related to human factors concerns are described and evaluated below.

3.4.3.1.1 ANS 3.1

This standard provides criteria for the qualification and training of personnel for stationary nuclear power plants. It addresses itself to the qualifications, responsibilities, and training of personnel in operating and support organizations appropriate for the safe and efficient operation of nuclear power plants.

Individual job titles and organizational structures vary among organizations operating power reactors; therefore, the standard is predicated on levels of responsibility rather than on a particular organizational concept. This standard is further limited to personnel within the owner organization.

The NRC and other regulatory agencies promulgate regulations applying to many aspects of the design, construction, and operation of nuclear power reactors. This standard shall not take precedence over any such regulation, but it is believed to be compatible with Title 10, Code of Federal Regulations, Part 55, "Operators' Licenses".

Performing Organization

Subcommittee ANS-3, Reactor Operations, of the American Nuclear Standards Committee.

Products/Publications

ANS 3.1 (Draft Revision 12/6/79), "Standard for Qualification and Training of Personnel for Nuclear Power Plans."

Evaluation

This standard provides considerable guidance towards the development of a training curriculum. However, it is not based on criteria with reference to training but in most cases specifies duration of training or experience levels. Thus, while it identifies, for all personnel, the essential kinds of training and experience required, no specific criteria are provided nor is there guidance provided for the general approach to instructional system development. In general, it lacks inclusion of instructional approaches currently recommended by training professionals.

3.4.3.1.2 ANS 3.2

Description

This standard provides requirements and recommendations for an administrative controls and quality assurance program to help ensure that activities associated with nuclear power plant operation are carried out without undue risk to the health and safety of the public. It applies to all activities affecting those functions important to the safety of nuclear power plant structures, systems, and components. It contains criteria for administrative controls and quality assurance during the operational phase of plant life. It is consistent with applicable criteria or quality assurance, including those given in Title 10, Code of Federal Regulations, Part 50, "Licensing of Production and Utilization Facilities", Appendix B.

Performing Organization

Subcommittee ANS-3, Reactor Operations, of the American Nuclear Society Stnadards Committee.

Products/Publications

ANSI/ANS-3.2, "Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants," Draft 8, April 1981.

Evaluation

Although it provides some general guidance, the document is vague and almost devoid of human factors input. The complete lack of understanding of human factors is exemplified by the section "Human Factors Considerations" that covers scheduled work time. There are no data to support the guidance given. In fact, results exist for which very different guidelines can be suggested. There is a lot of "what" information in the standard, but very little "how" information.

4.0 Recommended Comprehensive Long-Range Human Factors Plan

4.1 Introduction

The recommended comprehensive long-range human factors plan is the result of a planned sequence of identification, review, and evaluation activities by the HFS Study Group. The members of the group became familiar with the human factors issues in nuclear power generation through meetings and visits with all sectors of the nuclear power community over a period of some nine months. In addition to identifying purely technical aspects of the man-machine relationships in nuclear power generating systems, the group studied these in the context of the regulatory environment both from the viewpoint of the NRC and from the viewpoints of representative segments of the nuclear power industry.

Study Group members became familiar with nuclear power operations through a special course in reactor fundamentals taught at the I&E Training Center, a week of operator training provided by I&E instructors in the Brown's Ferry control room simulator at the TVA Training Center, and study of numerous documents and reports provided by NRC, companies, and industry sponsored organizations.

The first phase of the study was concerned with identification of human factors issues and concerns from the viewpoint of the regulatory agency. The NRC provided extensive briefings on its organization and operations. At the beginning, most of these were formal briefings. Later, as specific human factors issues were identified, one or more Study Group members, as appropriate, met with the cognizant person(s) in the NRC organization. Familiarization with NRC operations also included a visit to Region I Headquarters in Valley Forge, Pennsylvania. Later some Resident Inspectors were interviewed. The process of identifying and defining human factors areas of concern was guided by a system approach, as described in Section 2.0 of this Volume. The areas of concern were organized into six categories. Four of these correspond to four major areas of specialization within the field of human factors: human engineering, procedures and job performance aids, personnel and staffing, and training and training equipment. The fifth category includes general human factors concerns that either encompass several of the specialized areas or do not fit neatly into one of the specialized areas. The sixth category is concerned with the NRC incident response plan and facilities. This category was included as a special area at the request of NRC.

During the second phase of the study the human factors issues and concerns that had been identified were checked extensively for validity, completeness, and importance with representative elements of the nuclear industry. These included utilities, NSSS vendors, AEs, industry-sponsored organizations, professional societies, and others. The areas of concern were refined, expanded, narrowed in focus, or otherwise modified as appropriate in the light of additional information and new insights.

During the third phase of the study the areas of human factors concern were analyzed, evaluated in terms of their relationships to other system elements, and discussed by the Study Group to reach concensus. Specifically, each area of concern was treated in terms of (1) the requirements and its significance, (2) constraints (technical, management, and other), (3) present status, (4) planned activities, (5) missing elements, (6) technical feasibility, (7) interaction with other system requirements, and (8) recommendations. A report of these evaluations of the human factors areas of concern constitutes Volume 3 of this report. The comprehensive long-range plan presented here integrates the final recommendations for all of the areas. Readers who are interested in the details of the identification and evaluation of specific problem areas should consult the appropriate sections of Volume 3.

The recommendations for action under each of the areas of concern were organized in terms of the technical requirement, importance, schedule, resources, implementation, and dependencies.

One or more technical requirements are associated with each human factors area of concern. Priority, schedule, and resource information are provided as appropriate for each technical requirement. The technical requirements are in the form of statements that either constitute recommended management and staff actions or provide the basis for development of specific statements of work.

Each technical requirement has been evaluated in terms of its importance. These evaluations were based upon several kinds of considerations. These included the requirement for a specific action to meet a system safety need, the comparison of the action with other actions that are needed, consideration of programs already in progress or planned by the NRC, industry, industry sponsored organizations, and professional societies, and the composite experience of the Study Group members with the same and similar type problems and requirements in the design and operation of other kinds of complex man-machine systems.

The ratings of importance that are presented are the concensus of the Study Group. Each technical requirement was assigned one of three levels of relative importance. These are high, medium, low. Medium and low should not be interpreted as meaning unimportant. Each technical requirement is considered important by the Study Group or it would not be included. However, the different levels of importance have been assigned as an aid to planning.

Suggested scheduling information is provided in terms of the urgency of the requirement and the estimated duration of the recommended action. Evaluation of the urgency of a requirement was made separately from the evaluation of its importance. This procedure stemmed from the recognition that in a long-range plan some actions that are of the highest importance in terms of human factors in system safety may not be appropriately performed until the nuclear power programs are initiated or, more frequently, until some prerequisite actions have been undertaken and completed. Four categories of urgency were used. The schedule for recommended actions is based upon those that should be started (1) immediately, (2) within one to two years, (3) within three to five years, and (4) within six to ten years.

The estimated resources required are stated in terms of person-years for each recommended action. Implementation requirements are described in terms of special scientific/technical skills and in terms of unique facilities and equipment. Finally, if the recommended action is contingent upon results from some other action or interacts with other requirements or other system developments, the dependencies are described.

A word of explanation is in order regarding the use of the urgency category "immediately". The Study Group members are aware of all the time-consuming but necessary requirements for evaluation, coordination, review, and approval that characterize the normal operations of government agencies in general, and the NRC in particular. Therefore, many of our recommendations that carry a fairly high degree of urgency have been assigned to the "1-2 year" start category. However, a few technical requirements have been assigned to the "immediate" category. These, for the most part, consist of NRC policy decisions. In the judgement of the Study Group, they are of such high importance and urgency as to warrant extraordinary management actions to expedite their implementation.

Recommendations include requirements for research, technical assistance, regulatory actions, and administrative, organizational, and personnel changes. In many cases the requirements apply specifically to the NRC. These are clear from the nature of the requirement and the specific wording used. In the case of requirements for research the activities may be accomplished by the NRC, contractors, the DOE national laboratories, industry, or industry-sponsored organizations. However, regardless of the organization performing the research, it is considered the responsibility of NRC to ensure that it is accomplished.

4.2 General Human Factors Problem Areas

The first group of human factors problem areas differs from the other groups in several ways. The problem areas are not related directly to each other in terms of concepts or operations such as is the case with problem areas that are grouped under training or human engineering. These general problem areas typically transcend the boundaries of the other categories. In some cases, the problems simply do not fit into any of the other categories. And finally, in a few cases, the recommended actions, for a variety of reasons, may be more difficult to implement.

4.2.1 Professional Human Factors Qualifications in Nuclear Power

Prior to the accident at TMI-2, the nuclear power community was, for all practical purposes, unaware of the human factors discipline and its relevance to power plant safety and operations. As a result of the several TMI-2 inquiries and reports, the NRC, utilities, vendors, and others attempted to fill the human factors void in fact or in appearance. This void still exists in many organizations and has been filled only partially in most of the others. There are no valid constraints on meeting the requirement for competent career human factors professionals. This issue is a fundamental one which is related to all other human factors issues in nuclear power. It must be considered in the context of meeting all technical requirements included in this plan.

Technical Requirement

The NRC, utilities, vendors, and AEs must realistically assess their human factors staff needs, make a much better effort to understand the meaning of and role of human factors in their organizations, and take the necessary steps to meet that need. This action is of the highest priority in the human factors area. It is no longer acceptable to annoint a control engineer with the title of "human factors specialist", and to assume the necessary skills can be acquired immediately. Competent career human factors professional staffs must be acquired, placed into suitable organizational positions, and assigned to projects involving man-machine systems. This process should be implemented immediately.

Importance: High

Schedule: Urgency - immediately

Duration - continuing indefinitely

4.2.2 The NRC Organization

Human factors issues are central to both safety and economy in nuclear power plant design and operation. Plant designers must be knowledgable in applicable human factors design technology, and the utilities must be knowledgable in human factors principles relevant to operations, maintenance, training, personnel selection and staffing, and management. The NRC, to discharge its responsibility for safety regulation, must have adequate human factors skills to monitor plant design and operations, and to evaluate and support research in critical human factors areas. Further, the NRC must be organized in a manner that the required human factors skills can be applied in regulatory, design, operations, and research processes.

The NRC has had some notable successes in obtaining a small number of qualified career human factors professionals. In other cases, key human factors positions have been filled with persons without human factors experience. The NRC plans to hire additional human factors engineers and still needs to fill the position of Director of the Division of Human Factors Safety.

The issue of building effective human factors groups staffed with competent human factors professionals is a fundamental issue related to all other human factors problem areas in an obvious manner.

Technical Requirement

In the Division of Human Factors Safety, the chiefs of the branches of Human Factors Engineering, Procedures and Test Review, and Licensee Qualifications should be replaced with career human factors professionals. These changes are needed to provide detailed branch-level technical guidance to the staffs, based upon the perspective of the human factors literature, experience with other (non-nuclear) systems, and information achieved from career human factors professionals in other organizations.

Importance: High

Schedule: Urgency - immediately

Duration - indefinitely

Technical Requirement

Either the DHFS Director or the Deputy Director must be a senior career human factors professional, and recognized as such by his peers. This career human factors professional should be authorized to take a direct hand in establishing technical policy for the Division and in providing technical direction to the branch chiefs. (The Deputy Director currently meets this requirement.)

Importance: High

Schedule: Urgency - immediately

Duration - indefinitely

Technical Requirement

The organizational visibility of human factors in the Office of Nuclear Regulatory Research should be increased to reflect the importance and magnitude of the human factors research activities. Alternative possibilites are (a) elevation of Human Factors to Division status, (b) creation of a separate "pure" Human Factors Branch, independent of quality assurance, and (c) creation of two parallel Human Factors Branches, one concerned with hardware and software (control/display) research and the other with personnel, training, and procedural areas. Regardless of which of these alternatives is followed, the career human factors professional staff should be greatly enlarged to provide the specialized, experienced talent needed to plan, monitor, and understand the diverse human factors research programs.

Importance: High

Schedule: Urgency - immediately

Duration - indefinitely

Resources: Additional NRC staff

4.2.3 System Integration

Significant system integration during design and development is necessary for the most effective performance of humans in the operation of a large scale, complex man-machine system. A major underlying cause of many different kinds of human factors problems in the field of nuclear power generation is the inadequacy of system integration during the design and construction of nuclear plants.

The level of safe, effective operation of a nuclear power plant is determined by the adequacy of the man-machine interface. This adequacy is limited by the effects of system integration upon the various elements of the interface. To some degree, enhancement of some of the elements can compensate for deficiencies in others. Tradeoffs occur routinely during system design and development of most man-machine systems. However, when there is little or no system integration the results affect both the physical and behavioral elements of the man-machine interface. This places severe limits on the amount of improvement in the overall man-machine interface that can be achieved after the system has been built.

System integration as it is practiced in the aerospace industry has been almost completely unknown or ignored in the nuclear power industry. Unfortunately, system integration cannot be accomplished after a system has been designed and built. Certain steps can be taken to improve the man-machine interface for safety and efficiency of operations. The guidelines in NUREG-0700 and NUREG-0801 are steps in the right directon and should be implemented.

The NRC needs to develop a policy and a mechanism for insuring effective system integration during the design and development of new nuclear power plants in the event that the construction of any more should ever be proposed. There are no technical feasibility problems to be overcome. Organizational constraints will have to be faced and overcome. A single organization - either within the utility, the AE, or the NSSS vendor company - should have the responsibility for performing system integration during design of a nuclear power plant. Human factors, as well as other major functional subsystems, should be included in the system integration process. The NRC should ensure that system integration is accomplished.

Technical Requirement

Establish within the NRC a system integration organization. This organization will determine policy and procedures for NRC to use in ensuring effective system integration during the design and development of nuclear power plants.

Importance: High

Schedule: Urgency - 6-10 years, unless new licensee demand requires faster response.

Duration: 1 year for policy formulation, organization to continue.

Resources: NRC staff

Implementation: Members of this NRC organization should include legal personnel as well as technical representatives of major subsystems, including human factors. Head of the organization should be a career system engineering professional.

Dependencies: The initiation of this recommendation is not dependent upon accomplishment of any other task. The execution of the recommendation will require interactions with all major functions and organizations involved in the design and development of a nuclear power plant.

4.2.4 Safety Related Equipment Classification

Equipment and subsystems in nuclear power plants are classified as safety-grade class (safety-related) or non-safety-grade class (non-safety-related) for purposes of NRC licensing design review. Design requirements are applied to the safety-related equipment, but generally are not applied to the non-safety related equipment. The items that are not classified as safety-grade do not have to be reviewed. Furthermore, the non-safety-related equipments ordinarily are not inspected or tested.

The TMI-2 Lessons Learned Task Force (LLTF) pointed out that "The interactions between non-safety grade and safety-grade equipment are numerous, varied, and complex and have not been systematically evaluated." (73, p. 3-3). The emphasis of LLTF was upon physical interactions between non-safety-grade and safety-grade equipment. We do not minimize the importance of the types of interactions described in NUREG-0585. However, we believe that the interaction between safety-grade and non-safety-grade equipments and subsystems is equally, if not more, critical in the man-machine interface. The reactor operator is an integral part of each of the subsystems for which there are displays and controls in the control room.

The reactor operator is an important functional part of both safety grade and non-safety-grade subsystems. When there is a requirement for time sharing of responses by the operator among subsystems, the distinction between "safety-related" and "non-safety-related" is not useful. Such a distinction may be detrimental if it results in inferior human engineering design of displays and controls for the non-safety-grade subsystems or if it results in the development and provision of procedures for non-safety-grade subsystems that are incomplete, confusing, or hard to use. Instances of both kinds of results are common. This happened because, traditionally, the non-safety-grade equipments (and by extension, some of the elements of the man-machine interface associated with them) have not been subject to NRC inspection and have not had to meet NRC design criteria.

Because of the nature of the reactor operator's participation in the functioning of multiple subsystems and because of the human behavioral characteristics of sequential dependency and of limited time sharing capability, it is necessary to give careful atttention to human engineering design of displays and controls and to develop and provide good operator procedures regardless of the safety classification of related equipment or subsystems.

It is technically feasible to adopt a policy that requires all design and development of the man-machine interface be done on the basis of system requirements and accepted human factors principles and practice. The NRC should either (1) adopt a new approach to the issue of safety qualification of equipment as previously recommended (NUREG/CR-1250, page 148), or (2) classify all elements of the man-machine interface as safety-related. In the event the latter alternative is selected, then the following requirement exists.

Technical Requirement

Determine the system interactions and effects of classifying all elements of the man-machine interface as safety-related and implement any necessary guidelines and regulations.

Importance: High

Schedule: Urgency - immediate

Duration - 1 year

Resources: 4 person-years and NRC staff

Implementation: Career human factors professional, I&C engineer, nuclear systems engineer

Dependencies: None

4.2.5 Analysis and Evaluation of Operational Data

Within the nuclear power generation industry, methods for systematically collecting data on reactor operation are necessary to detect design and operating difficulties with safety implications. Specifically, data concerning human performance and unusual or abnormal events in operating power plants would be valuable to the mission of all NRC offices concerned with human factors and safety. Such data would be useful in revealing the cause of human errors and could be used to evaluate the effects of changes.

Although NRC has had event reporting systems for many years, they have not been designed and used in a manner that would provide usable and useful data concerning human factors in design and operation. There are no technical problems that would preclude changes necessary to provide human factors data.

Technical Requirement

Initiate a project to accomplish the following:

(1) Establish a program/mechanism to define the existing and long-term human performance data requirements from the various perspectives within the NRC and utilities: safety, regulation, enforcement, operation, research.

(2) Match data needs with existing data systems.

(3) Determine unmet data needs and develop candidate methods for filling data requirements.

(4) Establish a program to complete the development and implementation.

Importance: High

Schedule: Urgency - 1-2 years

Duration - 1 year

Resources: 2 person-years

Implementation: Personnel skills required - Behavioral Scientist and Computer Data Management Specialist

Dependencies: None

4.2.6 The Human's Role in Increasingly Automated Systems

There are two general but opposite positions which authoritative and knowledgable technical specialists have taken with respect to increased automation. Both of those positions also exist within the NRC regarding the ideal level of automation for nuclear power process control and, thereby, the design and facilities of the control room.

Even after many years of NASA, DOD, and aerospace experience with manual, semi-automatic, and highly automatic systems, there is no solid evidence to suggest an ideal level of automation in the control of complex systems. Obviously, the human element cannot be eliminated entirely. The proper mix of human and computerized control is not apparent, and is highly system, cost, and mission dependent.

The basic requirement then is not whether to increase (or decrease) automation but rather to determine an optimal role for the human early in the design of new systems or modifications to existing systems. This is referred to as the allocation-of-functions process in the discussion of The Systems Approach to Human Factors, Section 2.2 of this volume.

Answering the question concerning an ideal level of automation seems to be quite impossible. No builder of a complex aircraft, spacecraft, or power plant has intentionally built two side-by-side systems (one manual, one highly automated) in order to compare directly the error rates, manning requirements, training needs, or life-cycle costs. It would be unreasonable to do so. One might argue that the problem could be studied at least partially by means of simulators. This would be an enormouus task requiring resources that do not completely exist, and would require enormous amounts of software programming, extremely meticulous experiment construction to control relevant variables, and a large pool of carefully selected test subjects, to name only a few obstacles. Nevertheless, enough is presently known about human capabilities and limitations to develop a method and criteria for the allocation of functions early in system design to determine an optimal role for the human in a specific system design. This is consistent with the systems approach (Section 2.2).

Recommendations

The Study Group does not believe it to be appropriate to suggest a research effort to define the ideal level of automation. However, a modest research program to develop design criteria for function allocation should be continued. Additionally, there are indications that some European work may eventually provide some data about human performance and automation, and we suggest that the NRC continue to monitor that work as it progresses.

4.2.7 Risk Analysis and Human Reliability

The authors of WASH-1400 concluded that human reliability is a major contributor to overall system reliability. While this may have been an important insight for some persons in the nuclear power generating community in 1975, it would have been considerably less than an earthshaking revelation to human factors professionals who had been working with the design and operation of man-machine systems for the preceding thirty years. The authors of WASH-1400 also concluded that better estimates of human reliability were required to obtain more precise estimates of event probabilities and system error rates.

Subsequently, the authors of NUREG/CR-1278 elaborated on the concepts, data, and calculations that may be used in obtaining human error probabilities. The approach taken in NUREG/CR-1278 appears reasonable, and the authors are most careful to point out, repeatedly, that the HEPs are often estimates based upon non-empirical data, quite frequently their own experiences. They make it abundantly clear that empirically obtained HEPs simply do not exist for most of the tasks described in the handbook. Indeed, their purpose is to present a methodology, with examples, that can incorporate HEP data, when such are obtained and validated.

Unfortunately, the constraints to obtaining valid HEP data are substantial, and the application of such data, under current conditions at least, is impossible. The feasibility of this overall effort, to an acceptably valid level, is questionable.

If proven system design techniques associated with human engineering of workstations, personnel selection, operator procedures and aids, and training systems are applied to NPP operations and maintenance, then HEPs will be minimized and human operator performance will be maximized. Under these conditions, no further improvements are likely and predictions resulting from HEPs become superfluous, even if generated from an improved, valid HEP data base. (The potential argument that PRA might distinguish between the relative merits of two different designs, each based upon the same, proven human factors design techniques, is fallacious, for the PRA/HEP data base will always be less valid, or more "noisy", than will be tried and proven design concepts based upon empirical human performance data.)

Accordingly, it is recommended that the current high level of research in HEPs be reduced to only an informed awareness of performance measurement activities.

Technical Requirement

Maintain awareness of other tasks that might provide useful, empirical data on HEPs. Attempt to shape those tasks, where feasible, such that valid HEP data can be obtained at little or no additional cost or effort.

This effort can be an NRC staff (RES) function, and requires no substantial resources.

4.2.8 Evaluation Criteria

Possibly the most general requirement related to attempts by NRC and the nuclear power industry to improve safety and efficiency of power plant operations is the need to develop objective evaluative criteria for use in validating proposed or mandated changes. This is equally true whether the need is to evaluate control room "enhancements", operator examination standards, purported improvements in training programs, specification of simulator features, assessment of operating and maintenance procedures, improvements in personnel selection, or recommended work/rest cycles. What is lacking in all instances are objective measures of effectiveness (criteria) against which to validate the presumed system improvements.

The principal constraint in the development of evaluative criteria is associated with the difficulty of objectively assessing all important facets of operator and maintainer performance. There are two constraints: (1) collecting performance data should not interfere with normal operation or change the way in which the personnel typically perform; and (2) collecting a representative sample of behaviors reflecting the full scope of critical skills, knowledge, and cognitive processes can be an enormous data collection/reduction task.

Several projects that are related to the problem of performance evaluation have been completed, are in progress, or are planned. Various segments of the nuclear power community are involved (NRC, EPRI, ORNL, Sandia, Battelle Pacific Northwest Laboratories, INEL, and others). While most of these are concerned with significant aspects of performance measurement and evaluation, objective criteria against which to validate regulatory decisions concerning such things as operator examinations, control room design, and operator procedures simply do not exist.

Technical Requirements

1. Research should be conducted to identify objective performance criteria by which to evaluate proposed changes to design, procedures, training, personnel selection, qualification standards, work schedules, management practices, and so forth.

2. To the extent possible, the criterion measures should reflect performance on a representative subset of the universe of actual operational (or maintenance) tasks. This subset should be identified. The feasibility of defining a common set of performance criteria based on this subset of tasks that will serve a diversity of evaluation needs should be determined. Prior work at various laboratories should be evaluated with respect to scope and measurement properties.

3. The practicality, cost, and technical feasibility of employing unobtrusive data collection methods relating to the evaluative criteria should be determined for (a) actual operating plants, (b) full-scale simulators, and (c) part-task simulators.

4. Research should also be conducted to define useful secondary criteria such as progress through training, licensing examination scores, supervisory ratings on various dimensions of performance, frequency of involvement in "events" or critical incidents, and turnover rate.

5. Research should be directed toward the development of a comprehensive criterion of performance effectiveness for operator and maintenance personnel. This criterion should reflect not only technical competence but other job relevant considerations such as performance under stress.

Importance: High

Schedule: Immediate start on evaluative criteria that will be required for evaluating near-term changes or developments. More general effort starting in one to two years. Completion in three to five years.

Resources: Five professional person-years per year. Access to control rooms; unrestricted use of simulators.

Implementation: Expertise in human performance measurement, statistical methodology, plant operations, plant maintenance, application of computers to performance masurement.

Dependencies: Completion of NRC task analysis desirable but not essential.

4.2.9 System Engineering of the Regulatory Requirements

The NRC has issued many new requirements since TMI-2 that impact human factors. Many existing requirements have been updated and reissued to reflect new policy. Essentially all the items in Chapter 1 of NUREG-0660 (and clarifications in NUREG-0737) are items which will effect changes in some human factors areas including personnel and staffing, training, procedures, and control room design. Therefore all changes should be carefully planned and integrated in order to obtain the optimum benefit from such changes and to maintain overall human factors integrity.

Technical Requirement

The NRC should issue a clarification as soon as possible which will integrate the individual activities of the major human factors efforts and will take into account dependencies, conflicts, and compliance dates. Such a clarification will not only strengthen the end results but also tend to reduce the variance in methods of approach and levels of effort contemplated by the utilities. SECY-82-111 partially addresses this issue.

Importance: High

Schedule: Urgency - immediate.

Duration - no more than three months, including publication.

Resources: NRC staff time.

Implementation: NRC staff.

Dependencies: None.

Figure 12 summarizes the recommended schedule and manpower estimates by year for meeting the technical requirements identified for each of the general problem areas. The recommended importance of each item (H - high; M - medium; L - low) is given in the last column.

PROBLEM AREA AND TECHNICAL REQUIREMENT	START TIME, DURATION, AND PERSONNEL REQUIREMENT										
	1	2	3	4	5	6	7	8	9	10	
4.2.1 PROFESSIONAL HUMAN FACTORS QUALIFICATIONS IN NUCLEAR POWER											
• NRC AND INDUSTRY REALISTICALLY ASSESS AND MEET HUMAN FACTORS NEEDS	IMMEDIATELY										H
4.2.2 NRC ORGANIZATION											
• APPOINT CAREER HUMAN FACTORS PROFESSIONALS DHFS BRANCH CHIEFS	IMMEDIATELY										H
• APPOINT SENIOR HUMAN FACTORS PROFESSIONAL DHFS DIRECTOR OR DEPUTY	IMMEDIATELY										H
• ELEVATE RES HF ORGANIZATION TO DIVISION OR BRANCH STATUS	IMMEDIATELY										H
4.2.3 SYSTEM INTEGRATION											
• ESTABLISH NRC SYSTEM INTEGRATION ORGANIZATION								STAFF			H
4.2.4 SAFETY-RELATED SYSTEM CLASSIFICATION											
• DETERMINE EFFECTS OF CLASSIFYING MAN-MACHINE INTERFACE SAFETY-RELATED	4										H
4.2.5 ANALYSIS AND EVALUATION OF OPERATIONAL DATA											
• ESTABLISH HUMAN PERFORMANCE DATA ACQUISITION REQUIREMENTS		2									
4.2.6 HUMAN'S ROLE IN INCREASINGLY AUTOMATED SYSTEMS											
• MONITOR HALDEN AND OTHER RELATED WORK					STAFF						L
• CONTINUE FUNCTION ALLOCATION CRITERIA RESEARCH	2	2	2								L
4.2.7 RISK ANALYSIS AND HUMAN RELIABILITY											
• REDUCE LEVEL OF RESEARCH. OBTAIN EMPIRICAL DATA FROM OTHER TASKS.					STAFF						L
4.2.8 EVALUATION CRITERIA											
• RESEARCH ON OBJECTIVE PERFORMANCE CRITERIA	2	5	5	5	5	5					H
4.2.9 SYSTEM ENGINEERING OF REGULATORY REQUIREMENTS											
• INTEGRATE AND CLARIFY H.F. REQUIREMENTS AND GUIDELINES	IMMEDIATELY – PUBLISH WITHIN 3 MONTHS										H

Note: Numerical entries are person-years per year.

FIGURE 12. SCHEDULE FOR MEETING TECHNICAL REQUIREMENTS IN GENERAL PROBLEM AREAS

4.3 Human Engineering Problem Areas

Proper human engineering practice has not existed within the nuclear industry nor has it been required by the NRC. Even after the lessons of TMI-2, it is not obvious that consistently valid and effective human engineering practices will occur, in spite of good intentions by some people within key elements of the nuclear industry and the NRC.

There is no excuse for the nearly total avoidance of human engineering application in the nuclear industry. The human factors discipline existed since World War II; design standards have been in aerospace circulation for decades; studies have been conducted within the nuclear industry which identified serious problems as well as recommendating actions for resolving them; and some knowledgable people have urged attention to this area affecting nuclear safety. The Kemeny Report as well as the Rogovin Report brought the results of disregard for human factors well into focus.

A well documentated history of poor human engineering design of nuclear power plants exists. On the basis of our study of these documents and our intensive contacts with the NRC, utilities, NSSS vendors, AEs, and others, the specific issues which require attention have been identified and are presented in the following sections.

4.3.1 Design Induced Error

The most important concern about safe operations in nuclear powerplants is that of human error. From a human factors point of view, human error can result from many causes. Detrimental environmental factors such as excessive noise, temperature extremes, inadequate lighting or illumination glare, poor ventilation, etc., are all known to affect human performance negatively -- and all exist in nuclear powerplants. Inadequate training results in human error, and training programs in the nuclear industry have been found wanting. Poorly prepared or inaccurate procedural manuals is another source of operator error. Manuals used in nuclear power plant control rooms have been found to be inaccurate and/or difficult to use. Fatigue, boredom, and stress are personal factors producing human error, and all exist in a nuclear powerplant. Although all of these factors are found in nuclear plants, they are differentially operant in the control room versus other plant areas. For example, ambient illumination may be too low for good maintenance in an auxilliary building. It may be bright enough in a control room, but glare may be reflected on the surface of indicators from the light sources. Fatigue may plague maintenance personnel from excessive work hours, while fatigue may be boredom-related in a control room due to long periods of monitoring.

In a sense, all of the factors mentioned above are design-induced error sources: poor environmental design, poor training program design, poor design of procedural manuals, poor control of working shifts/durations/rotations, and so on. However, from strictly a human engineering standpoint, design-induced error usually refers to errors caused by improper design and arrangement of displays and controls. Specific control room deficiencies in which design-induced error can be expected are well documented.

For nuclear plants being designed currently, there is no unusual constraint that would prevent control rooms and plants from evolving systematically, thereby reducing/eliminating design-induced error. The importance of using human engineering design criteria in the trade-off analyses is essential to achieve that goal.

For plants in operation, there are real constraints which will not permit complete conformance to established human engineering criteria. Much, however, can be done to reduce design-induced error by "enhancement" -- the paint-label-tape process as illustrated by the Summary Volume and Volume 1 of EPRI NP-1118.

If all the current activities related to design induced error are completed successfully and if the planned activities are initiated, the goal to reduce design-induced error to an acceptable minimum could be realized. There are no technical constraints that would prevent the issues included under design-induced error from being solved.

Technical Requirement

The intent of all major provisions of NUREG-0700 should be implemented as requirements rather than as guidelines. The NRC should review license applicants not only in accord with NUREG-0700 and NUREG-0801 but also in accord with the recommendations of EPRI-NP-1118. A guideline document for human engineering maintainability features that is similar to NUREG-0700 should be published.

Importance: High

Schedule: Urgency - Immediate.

Duration - two years.

Resources: NRC staff.

Implementation: N/A

Dependencies: Maintainability data for NUREG maintainability document.

Technical Requirement

The NRC should produce a guideline document which requires license applicants to achieve designs of emergency shutdown panels with controls, displays, and layouts as similar as possible to those in the control room used for the same required functions.

Importance: Medium

Schedule: Urgency - 3 to 5 years

Duration - 1 year to produce Guidelines, 1 year for utility implementation

Resources: NRC Staff

Implementation: N/A

Dependencies: N/A

Technical Requirement

The local control stations, such as those located in the radiation waste control rooms, should be equipped with controls and displays that meet the human engineering design criteria of NUREG-0700 and the NRC should provide a guideline document for that purpose.

Importance: Medium

Schedule: Urgency - 3 to 5 years

Duration - 2 years; 1 year for guidelines, 1 year for utilities to implement.

Resources: NRC Staff

Implementaton: N/A

Dependencies: N/A

Technical Requirement

A serious study of the use of color coding, especially the use of red and green, and a serious study of the "green board" concept should be conducted both empirically and analytically.

Importance: Medium

Schedule: Urgency: 6 - 10 years

Duration: 3 - 4 years

Resources: 30 - 40 person-years

Implementation: Software, laboratory, reconfigurable simulator, test subjects, career HF professionals, behavioral/statistical analysts.

Dependencies: None

Technical Requirement

The NRC should continue research and development on advanced display technologies such as that currently being performed by LLNL (see 3.1.2.1.1 f) and INEL (see 3.1.2.2.1 e).

Importance: Medium

Schedule: Urgency - 1 - 3 years

Duration - 2 years

Resources: Contractor or National Laboratory

1982: 2 person-years

1983: 3 person-years

Implementation: N/A

Dependencies: N/A

4.3.2 Inconsistent Control Room and Plant Design

The designs of nuclear power plants in the United States can be likened in one respect to the handicraft designs of Navajo Indian blankets or the designs of woolen, knitted sweaters from what is left of the cottage industry of the islands of Scotland - no two are alike. If it were not so readily apparent, this condition would seem to be incredible. It is not at all surprising when one considers that the designs are not the result of a system approach but rather an almost haphazard process in which no single organization has authority and must be accountable for the overall design of the system.

The desirability for similarity (at least in a developmental sense) among nuclear power plant control room designs is beginning to be addressed by the NRC. There are no plans concerned with this issue. No documents have been released yet, however.

Recommendations

In the event that there are indications of a reversal of the current trend regarding planning and construction of nuclear power plants, the NRC should initiate a program to ensure that standards and specifications relating to good human engineering practice are followed.

4.3.3 Annunciators and Alarms

The seriousness of the control room annunciator (visual or auditory alarm) problem is well-documented. Often 1000 to 2000 of these may exist in a control room to alert the operator to abnormal or emergency situations. Most of the visual indicators are placed into matrix panels above the control boards. Each matrix might consist of 50-80 indicator "tiles," each about 2" x 3" with a legend on the tile face.

Many specific problems exist in typical annunciator complexes because no standards have existed for their design features. Consequently, color coding is inconsistent, legend terminology varies, flash rates vary, faults are not presented in a hierarchical manner, various schemes are used for alarm acknowledgement, and auditory alarms have different characteristics of pitch, intensity, on-off cycles, etc.

The key point underlying the technical inadequacies is, as is so often the case in nuclear power plant design, the lack of a system engineering approach and a distinct system integration function. Fortunately, the annunciator problem is receiving a lot of attention. In support of the research and application studies that are in progress and planned for the near future we recommend the actions that follow.

Technical Requirement

The NRC should initiate appropriate rulemaking activity to require adherence to Section 6.3 of NUREG-0700 for existing annunciator systems. Utilities should analyze the systems and identify changes which can be made toward compliance in order to enhance their effectiveness.

Importance: High

Schedule: Urgency - immediate

Duration - 2 years; 1 year for rulemaking, 1 year for utility analysis and report

Resources: NRC Staff

Implementation: N/A

Dependencies: None

Technical Requirement

Studies should be conducted to extend that reported in NUREG/CR-2147. The end product should be a standard or specification for annunciators of the traditional type dealing with flash rates, acknowledgement/silencing procedures, location, color coding, etc.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 1 year

Resources: 1 person-year plus NRC Staff

Implementation: Career HF professional

Dependencies: None

Technical Requirement

NRC should encourage industry studies to determine the requirements for development of logic systems aimed at filtering or restricting alarms. These studies are to be structured with a systems approach to include consideration of operator information requirements, operator tasks, mode-dependent signaling, functional hierarchies, prioritization, and other similar factors.

The NRC should sponsor studies and then issue an alarm requirements document for advanced control rooms using CRTs and computer-generated displays.

Importance: High

Schedule: Urgency - 3 - 5 years

Duration - 3 years

Resources: 12 - 15 person-years plus NRC Staff for NUREG

Implementation: Laboratory and computer facilities, flexible programming, systems modeling, test subjects, career HF professionals, experienced nuclear engineer.

Dependencies: None

Technical Requirements

The NRC should continue and expand research in the area of system status verification guidelines. This is the kind of study approach that should be done to provide data that could replace the executive decision-based-upon-non-scientific-assumption basis for adoption of the SPDS.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 2 years

Resources: 4 person-years in 1982; 4 - 6 person-years in 1983.

Implementation: N/A

Dependencies: None

4.3.4 Design for Maintainability

If a maintenance person cannot easily find the desired piece of equipmnt, if that person has difficulty in gaining adequate access to it, if he or she must search through a poorly prepared manual, and if that person does not have the proper tools to use on the piece of equipment, then the maintenance person is potentially exposed to radiation for a longer period of time than would be otherwise necessary. This factor impacts, therefore, the number of personnel required, thereby resulting in additional costs to the utility (and the public). Further, the likelihood of serious maintenance errors is increased, especially when such activity occurs in the presence of temperature extremes, noise, and inadequate lighting. Those errors may result in significant control room problems and errors.

The major human engineering needs are for better accessibility, better identification of equipments, and better control of environmental factors.

Technical Requirement

Emphasis of the NRC research in the human factors maintenance area should be shifted from error models and risk assessment to that of design analysis. We believe more reduction in error is possible by the kind of maintenance planning study being done by NRR (see 3.1.2.1.1 h) than in that represented by the Maintenance Error Model being done by the Office of Research (see 3.1.2.2.4 c).

Technical Requirement

Publish a Guideline document, similar to NUREG-0700, that defines human engineering design criteria for maintenance. As part of that document, require utilities and AEs to demonstrate through models, mockups, and task analysis that critical maintenance tasks can be performed in an acceptable human factors manner.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 1 year

Resources: NRC Staff

Implementation: N/A

Dependencies: This should be done immediately upon completion of the NRR maintenance planning study (see 3.1.2.1.1 h) scheduled for completion in October 1982.

Technical Requirement

The NRC should sponsor empirical and analytical studies on development of (a) better protective garments and (b) better tools and instruments used for maintenance in a radioactive environment.

Importance: Medium

Schedule: Urgency - 3 - 5 years

Duration - 3 years

Resources: 9 person-years

Implementation: Requires personnel experienced in biomechanics, environmental physiology, biochemistry, and human factors.

Dependencies: This should be coordinated with EPRI work.

4.3.5 Design Freeze

"Racheting" is a term that is commonly used throughout the nuclear industry. It refers to the process wherein the NRC may require the addition of instrumentation or control display devices to planned or existing control rooms based upon operational experience. This process is a significant one because of (a) redesign costs (wherein large numbers of drawings, wiring diagrams, and specifications may be affected) and (b) the distinct possibility that a basically "good" design from a human engineering standpoint may become less than good because of clutter, intrusion on functional grouping, interference with controls, etc. Further, the change or addition may have questionable validity if measured against objective effectiveness criteria.

Currently, the utilities have little recourse when racheting occurs. They must comply with the specific requirements or else be prepared to defend a position that other design features already exist to serve the newly required function or that alternatives to the specific requirement are equivalent to or better than that being mandated.

Technical Requirement

The NRC should perform an analysis to determine the relative merits of using a "design freeze" process vs. the currently used racheting process for design of power plants. The design review process of the DOD should be used for the design freeze model. Comparison factors should include a cost/safety tradeoff.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 1 - 2 years

Resources: NRC staff

Dependencies: None

The recommended schedule and manpower estimates for meeting the technical requirements in human engineering are summarized in Figure 13. Importance levels are indicated in the last column.

4.4 Problems in Procedures and Operator Aids

The nuclear power plant, like any complex man-machine system requires procedures for operations, maintenance, and administrative control. The procedures serve as a blueprint for the human actions in the system. When defined as a result of the system analysis, the procedures provide the human with all the information he needs to operate and maintain the nuclear power production process.

Problems in the procedures and JPA areas can be solved by establishing standards that will help ensure consistency and adequacy across types of procedures and across plants.

PROBLEM AREA AND TECHNICAL REQUIREMENT	START TIME, DURATION, AND PERSONNEL REQUIREMENT										
	1	2	3	4	5	6	7	8	9	10	
4.3.1 DESIGN INDUCED ERROR											
● IMPLEMENT 0700 AS REQUIREMENT	IMMEDIATELY										H
● DEVELOP HE MAINTAINABILITY GUIDELINES		STAFF	STAFF								H
● DEVELOP HE GUIDELINES FOR EMERGENCY SHUTDOWN PANELS											M
NRC DEVELOP				STAFF							
UTILITIES IMPLEMENT					STAFF						
● DEVELOP HE GUIDELINES FOR LOCAL CONTROL PANELS											M
NRC DEVELOP				STAFF							
UTILITIES IMPLEMENT					STAFF						
● RESEARCH ON COLOR CODING AND GREENBOARD CONCEPT						10	10	10	10		M
● CONTINUE RESEARCH ON ADVANCED DISPLAY TECH.		2	3								M
4.3.2 INCONSISTENT CONTROL ROOM & PLANT DESIGN											
● ENCOURAGE ADVANCED DESIGN MODULARITY AND SOFTWARE FLEXIBILITY		CONTINUING									L
4.3.3 ANNUNCIATORS AND ALARMS											
● INITIATE RULEMAKING TO REQUIRE SECTION 6.3 OF NUREG-0700											H
RULEMAKING	STAFF										
INDUSTRY COMPLIANCE		STAFF									
● EXTEND TYPE OF RESEARCH REPORTED IN NUREG/CR-2147		1									H
● DESIGN LOGIC SYSTEM FOR FILTERING/RESTRICTION OF ALARMS				5	5	5					H
● CONTINUE & EXPAND RESEARCH ON SYSTEM STATUS VERIFICATION		4	6								H
4.3.4 DESIGN FOR MAINTAINABILITY											H
● SHIFT EMPHASIS FROM ERROR MODEL/RISK ASSESSMENT TO DESIGN ANALYSIS											
● DEVELOP HE DESIGN CRITERIA FOR MAINTENANCE GUIDELINES		STAFF									M
● RESEARCH ON PROTECTIVE GARMENTS AND TOOLS FOR MAINTENANCE				3	3	3					M
4.3.5 DESIGN FREEZE											H
● STUDY AND EVALUATE MERIT OF DESIGN FREEZE PROCESS		STAFF	STAFF								

FIGURE 13. SCHEDULE FOR MEETING TECHNICAL REQUIREMENTS IN HUMAN ENGINEERING

4.4.1 Standards and Specifications Governing Procedure Development

In a nuclear power plant literally thousands of procedures have to be generated. Specifications for development of procedures are essential.

Technical Requirement

NRC should assume the responsibility for developing non-plant-specific specifications for procedure development that define the criteria for meeting the requirements of 10 CFR 50. Specifications are needed for plant operation, plant maintenance, and plant administration. Each specification should address development, format, validation and verification, implementation, quality assurance, and revision. The NRC should elicit the support of the professional societies (IEEE, ANS, and Human Factors Society) and coordinate the specification development effort.

Importance: High

Schedule: Begin in 1-2 years; complete in 3 years.

Resources: In addition to the effort expended by the professional societies, NRC should be able to complete the effort as a staff function.

Implementation: NRC staff participants will include career human factors professionals who have a background in technical data development and presentation techniques.

Dependencies: Coordinate activity with requirements of NUREG-0799, ANS 3.2 - Draft 8, and Regulatory Guide 1.33 - Revision 3.

4.4.2 Procedure Development Process

Problems in procedure development have been well documented. Problems occur with written procedures because they are difficult to read, difficult to locate, and inconvenient to use. In an analysis of the incomplete control rod insertion incident at Brown's Ferry (55) it was found that the procedures were not detailed enough to provide the information the operator needed to recover from the equipment failure.

In maintenance operations, the problem is worse. Seminara and Parsons (38) found that approximately half of the maintenance technicians interviewed in five nuclear power plants described their procedures as being inadequate.

Technical Requirement

Each utility should develop plant specific guidelines for emergency operating, normal operating, maintenance, and administrative procedures. Each guideline document should identify covered procedures and provide information on technical content, development process, format, validation and verification, implementation, quality assurance, and revision. The deveopment process should recognize the importance of a technical writing group consistng of a career human factors professional, technical writers, and staff subject matter experts from operations and maintenance. These guidelines should be reviewed by the NRC against the non-plant-specific specifications for compliance.

Importance: High

Schedule: Begin in 3-5 years; complete in 1 year.

Resources: The utilities will require a 2 person-year effort and the NRC will require an additional person-year to review the guidelines for compliance.

Implementation: Both the utilities and the NRC will require career human factors professionals with technical data development experience for the compilation and review of the guidelines, and nuclear engineers for the input and review of the technical content.

Dependencies: Effort cannot begin until the non-plant-specific specifications have been generated. The systems analysis/review of NUREG-0700 has to be completed prior to procedure development to ensure complete coverage of required procedures.

4.4.3 Job Performance Aids

Technical Requirement

In conjunction with NRC's and INPO's job/task analysis efforts and implementation of NUREG-0700, and based upon user needs, establish the requirements for hard copy, electronic, and computer-based JPAs. These efforts should include the determination of fundamental user requirements for the more sophisticated multiple JPAs, e.g., SPDS and DASS. Specifically, all system requirements have to be identified and functions have to be allocated to ensure that the JPAs are designed and developed to satisfy those requirements and functions. Both operator and maintenance JPAs should be considered.

Importance: High

Schedule: Begin in 3-5 years; complete in 2 years.

Resources: Level of effort cannot be determined until the requirements have been established for the various JPA types.

Implementation: Personnel will include career human factors professionals, system analysts, and subject matter experts.

Dependencies: Completion of NRC and INPO job/task analyses, implementation of NUREG-0700, and coordination with ongoing EPRI research will be needed. Input from the ISD for the training-JPA tradeoff will also be needed. This effort should interact with the ISD process for the training requirements and the personnel selection process.

4.4.4 Formats for Procedures and Job Performance Aids

Technical Requirement

Review and evaluate existing formats for applicability. Determine (1) alternative choices of information presentation techniques, (2) format limitations of CRT and other computer-based displays, and (3) feasibility of using CRTs for the presentation of procedures. Develop guidelines describing acceptable JPA formats and delineating validation/verification and implementation procedures.

Importance: High

Schedule: Begin in 1-2 years; complete in 3 years.

Resources: Research will require 10-12 person-years with access to computer driven CRTs, part and whole-task simulators, and mathematical models of reactor system. Guidelines can be developed as an NRC staff function.

Implementation: Personnel will include career human factors professionals, system analysts, programmers, technical criteria, graphics illustrators, and subject matter experts.

Dependencies: Coordinate with ongoing efforts by NRC, INPO, and EPRI.

4.4.5 Procedure Implementation and Revision

Technical Requirement

Conduct a study to determine an effective process for implementing and revising plant operational and maintenance procedures. Develop requirements for an information management system that will (1) index and cross-index all plant procedures to ensure that all changes are incorporated into the affected procedures and (2) track procedures (a) to ensure that all procedures are distributed and recalled, if necessary, in a timely manner, and (b) to ensure that operational feedback data from within and outside the plant are incorporated into procedure revision, when necessary.

Importance: Low, but desirable

Schedule: Begin in 6-10 years; complete in 1 year.

Resources: Research should require 1 - 2 person-years.

Implementation: Personnel skills will include a management information specialist and a career human factors professional.

Dependencies: None

4.4.6 Performance Verification

Performance verification is necessary to ensure that critical tasks and safety procedures are performed correctly. There are three major safety aspects of performance verification. Firstly, because of the large size of a nuclear power plant and the large number of components and equipments that are highly similar in appearance, it is necessary to verify positively the location of the component involved in the tasks. Secondly, it is necessary to verify that equipment is properly tagged-out before starting a maintenance task or other procedure that requires equipment to be taken off-line. Thirdly, the correctness of the performance of the task or procedure itself must be verified.

There are some obvious constraints to complete independent performance verifications for some tasks. For example, to verify the correctness of valve reseating would require another strip-down of the valve and another reseating. Nevertheless, a vast improvement is needed and is possible in the areas of development of performance verification procedures and the use of the verification procedures.

Philadelphia Electric has started to use the Critical Equipment Monitoring System (CEMS), a system that uses handheld terminals with optical bar code scanners radio-linked to a central computer. This kind of system shows some promise for improvement in all aspects of performance verification.

Technical Requirement

Study the development of a reliable automatic system status monitoring device that will provide information on (1) valve and switch positioning upon completion of surveillance, test, calibration, and standard maintenance tasks, (2) completeness of tag-out procedures including removal upon task completion, and (3) inadvertent violations of the technical specifications.

Importance: Medium

Schedule: Urgency - 6 - 10 years

Duration - 1 year to develop the basic system. Effort should continue as long as reliability can be continued to be improved significantly.

Resources: 5 person-years. Access to state-of-the-art computerized monitoring devices.

Implementation: Career human factors professionals, system analysts, programmers, nuclear engineers, and knowledgable plant personnel.

Dependencies: None

4.4.7 Change-of-Shift Procedures

At each shift change, before the new crew takes responsibility from the old crew, it is imperative that the new crew be fully aware of the status of the plant. It is necessary to have a shift turnover procedure that ensures systematic, complete, and precise transfer of information to the new crew. This implies some overlap of shifts. Both management and union policies have generally opposed overlap in the nuclear power industry. These are not insurmountable constraints. Overlap of shifts is practiced in other organizations where thorough briefing of the incoming crew is important.

Although change of shift procedures have always been required, it was not until after the accident at TMI-2 that serious consideration was given to the content and structure of those procedures. Change of shift procedures have been improved. The lack of a standard or specification detailing what is required and the format and content of checklists have resulted in inconsistencies in level of detail.

The NRC considers that the recommendations of Task Action Plan Item I.C.2 have been completed. There are no known planned actions in this area. Revisions to ANS 3.2 and Regulatory Guide 1.33 are scheduled to be published. All the necessary ingredients for ensuring adequate change of shift procedures are available. However, compilation, integration and application of them are lacking.

Technical Requirement

Establish criteria for effective change of shift procedures. Develop requirements for checklists and procedures such as walk-throughs and log reviews by both operational and maintenance personnel.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 1 year

Resources: NRC Staff function

Implementation: Competent career human factors professional and nuclear engineer.

Dependencies: None

Figure 14 summarizes the recommended schedule and estimates of manpower required for each of the technical requirements in the area of procedures and job performance aids. The importance of each requirement is given in the last column.

4.5 Personnel and Staffing Problems

The fundamental requirement of the personnel system is to ensure initial and continuing quality control of the performance of all categories of plant personnel. Personnel and staffing demands are driven by the requirements for operational quality assurance, maintenance effectiveness, safety standards, and effective management for normal, off-normal, and emergency conditions. In addition to extensive interaction with plant design and training, the personnel and staffing area is impacted by selection criteria, operator qualification and requalification standards, examining procedures, shift duration and rotation practices, performance assessment and feedback practices, and a variety of factors that constitute the reward system.

PROBLEM AREA AND TECHNICAL REQUIREMENT	START TIME, DURATION, AND PERSONNEL REQUIREMENT										
	1	2	3	4	5	6	7	8	9	10	
4.4.1 STANDARDS & SPECIFICATIONS GOVERNING PROCEDURE DEVELOPMENT											
• DEVELOP SPECIFICATIONS FOR PROCEDURE DEVELOPMENT			STAFF								H
4.4.2 PROCEDURE DEVELOPMENT PROCESS											
• REVIEW UTILITY-DEVELOPED GUIDELINES FOR PROCEDURES				STAFF							H
4.4.3 JOB PERFORMANCE AIDS											
• ESTABLISH REQUIREMENTS FOR HARD COPY, ELECTRONIC, AND COMPUTER JPAs				TBD	TBD						M
4.4.4 FORMATS FOR PROCEDURES AND JOB PERFORMANCE AIDS											
• DEVELOP GUIDELINES FOR JPA FORMATS, VALIDATION AND IMPLEMENTATION		4	4	4							H
4.4.5 PROCEDURE IMPLEMENTATION AND REVISION											
• DEVELOP EFFECTIVE PROCESS FOR IMPLEMENTING AND REVISING PROCEDURES						2					L
4.4.6 PERFORMANCE VERIFICATION											
• DEVELOP AUTOMATIC SYSTEM STATUS MONITORING						5					M
4.4.7 CHANGE OF SHIFT PROCEDURES											
• ESTABLISH CRITERIA FOR CHANGE OF SHIFT PROCEDURES		1									H

FIGURE 14. SCHEDULE FOR MEETING REQUIREMENTS FOR PROCEDURES AND OPERATOR AIDS

4.5.1 Personnel Selection - Practices and Standards

Personnel selection procedures for a nuclear power plant should ensure that all staffing requirements can be met with personnel who have (1) appropriate aptitudes for efficiently learning and properly performing the job and (2) appropriate temperamental characteristics, including emotional stability, for coping with both the tedium of routine nuclear power plant operations and the stress associated with occasional accident events. A corollary of these requirements is that the selection procedures should identify personnel who will develop a career interest in nuclear power plant operations, in the interest of minimizing personnel turnover.

A large number of activities by NRC and by industry have been directed at improving personnel selection. Others are planned. The most fundamental missing element in the work to date has been the absence of objective criteria whose relevance and scope with respect to operator or maintainer performance is assured. There have been few industry attempts to validate selection procedures against training criteria, including assessments of performance in a simulator. Although these are not the ultimate criteria of interest, they are certainly of considerable practical and economic interest as intermediate criteria. Curiously, we know of no attempt to validate selection criteria against probability of successfully becoming licensed. Suitable criteria of psychological fitness and emotional stability on the job are also missing. The definitions in NUREG/CR-2076, being based on actual incidents involving power plant personnel, may represent a starting point for development in this area.

Technical Requirement

Research should be conducted leading to the validation of current and newly proposed selection procedures against comprehensive criteria of the job effectiveness of operator and maintenance personnel. The validation should reflect both technical performance and secondary criteria such as trainability and probability of meeting NRC qualifications for licensing.

Importance: High

Schedule: Immediate start using currently available criterion measures. Completion indefinite - continuing effort is called for as criterion measures are refined and new selection technology becomes available.

Resources: 1 person-year per year.

Implementation: Professional psychologist with experience in industrial or military personnel selection. Access to data reflecting various criterion measures.

Dependencies: None, but coordinate with results of INPO and NRC task analyses, and EEI work in the selection process.

Technical Requirement

Conduct research on individual abilities to cope with the stress generated by accident conditions. Develop methods of screening individuals for high emotional stability. Consider using a simulator and physiological indicators of stress for this research.

Importance: High

Schedule: Urgency - 1 - 2 years

Resources: 3 -4 person-years/year

Implementation: Research psychologist; stress psychologist; dedicated simulator time.

Dependencies: None

Technical Requirement

Monitor and critically evaluate behavioral reliability programs initiated by industry, including benefits, evidence of validity/payoff, and potental deficiencies/abuses.

Importance: Medium

Schedule: Upon initiation of behavioral reliability programs. A continuing effort until benefits of the program are clearly established.

Resources: NRC Staff plus consultants - ½ person-year per year.

Implementation: Qualified industrial psychologist

Dependencies: Implementation of behavioral reliability programs

Technical Requirement

Research should be conducted on new technology testing procedures in an attempt to predict variance in personnel effectiveness criteria that is not well predicted by presently available aptitude and temperament tests.

Importance: Low

Schedule: Urgency - 6 - 10 years

Duration - continuing

Resources: 2 person-years per year

Implementation: Qualified cognitive/measurement psychologists; technology specialist in computerized testing.

Dependencies: Completion of technical requirement for research leading to the validation of selection procedures against comprehensive criteria of the job effectiveness of operator and maintenance personnel.

4.5.2 Operator Certification and Licensing

The objectives of certification and licensing are to ensure that control room and other plant personnel, as appropriate, have the necessary technical knowledge and skill to ensure safe, competent plant operation and maintenance. (Maintenance and management personnel are not presently licensed or certified, although it has been argued that they should be.) The focus of attention since Three Mile Island has been on enhancing the qualifications of ROs, SROs, and Shift Supervisors. NUREG-0737, which is viewed as the most definitive NRC statement on operator qualifications (116), calls for the immediate upgrading of RO and SRO qualifications. It details experience and training requirements and specifies certain control manipulations required of operators to assure their capability for controlling plant parameters. In general, the NRC emphasis has been on upgrading of formal education, more stringent examination cut-off scores, and increased involvement of management in certifying the technical competence of their personnel.

All efforts to evaluate and validate current or proposed qualification procedures objectively depend upon the availability of criterion measures that reflect all important dimensions of job performance. As noted elsewhere, objective performance measures have not been developed on a broad scope for either operator or maintainer personnel in nuclear power plants. There does exist, however, NRCs planned activities on this problem for FY83. The EPRI-sponsored research by General Physics to develop automatic measures of operator performance in simulators is clearly relevant and promising, as is ORNL's work on the collection and assessment of performance data associated with safety related operator actions and performance shaping factors. A significant attack on the maintenance problem has been initiated but, once again, a criterion of maintenance personnel performance will need to be developed if clear associations are to be made with selection, training, and qualification variables.

In the short term, it is evident that performance assessments of RO, SRO, and Shift Supervisor personnel will continue to depend on subjective evaluations (i.e., supervisory ratings). The scope and reliability of these procedures is generally undocumented despite their importance to many decisions.

The meaning of operating "experience" is in need of definition since this is a critical variable in all RO, SRO, and Shift Supervisor qualification criteria. Clearly, it cannot be adequately defined in terms of length of service alone.

Technical Requirement

Conduct research aimed at the development of objective performance standards for operator and maintenance personnel. Develop methods for routinely evaluating all major dimensions of the job performance of ROs, SROs and Shift Supervisors. Perform studies necessary to identify and define those dimensions.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 3 years

Resources: 3 person-years per year

Implementation: Career human factors professional; unrestricted use of simulators; access to operating plants.

Dependencies: NRC task analysis; refinement of performance monitoring system.

Technical Requirement

Conduct research with the objective of developing more specific qualification requirements for non-licensed personnel who are in a position to directly or indirectly impact plant safety.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 2 years

Resources: 5 person-years per year; access to operating plants and personnel.

Implementation: Career human factors professionals; engineers familiar with plant design and maintenance requirements.

Dependencies: Advantage should be taken of any related work by EPRI and INPO.

Technical Requirement

Research should be conducted leading to the development of methods for assessing and tracking progress through in-plant training programs, with the objective of improving the certification process for license candidates.

Importance: Low

Schedule: Urgency - 6 - 10 years

Duration - 1 year

Resources: 1 person-year

Implementation: Training specialist; computer programmer

Dependencies: None

Technical Requirement

Research should be conducted to define objectively the scope and length of "experience" required prior to qualification of ROs, SROs, and Shift Supervisors, and to provide a defensible basis for trading of formal education against "experience".

Importance: Medium

Schedule: Urgency - 1 - 2 years

Duration - 2 years

Resources: 2½ person-years per year

Implementation: Career human factors professional; power plant subject matter experts.

Dependencies: Task analysis of control room and auxiliary operator jobs. Objective evaluation criteria (see Section 4.2.8).

4.5.3 Staffing and Organizational Characteristics

It is necessary to provide the personnel staffing levels and technical expertise necessary for the utility to conduct safe nuclear power plant operations and all required plant maintenance. In addition, both management and technical resources must be provided for accident mitigation, including long term efforts required to return the plant to normal conditions in the event of accident.

NUREG-0731, issued for interim use and comment in September 1980, provides guidelines for nuclear plant staffing in accordance with various recommendations of the studies following Three Mile Island. It describes an acceptable organizational structure and specifies competence levels for nuclear power plant operations. "Competence" is defined in terms of level of formal education and years of relevant experience in the power industry. The guidelines address both on-site and off-site resources and the minimum shift staffing considered essential for short-term and long-term response.

Thus far, there do not appear to be pressing research issues or major differences in viewpoint between industry and NRC with regard to these organizational and staffing guidelines. A notable exception, however, is NRC's requirement for a Shift Technical Advisor (STA).

RR-NRR-81-2 (H. R. Denton) notes that present methods of assessing the capability of a utility organization to manage a nuclear power plant effectively and safely are quite subjective. It is recognized that there is a need for guidelines and methods for making such assessments in a valid manner. There are few data dealing with the attitudes of nuclear power plant management toward safety, and a need is felt for systematic study of those elements of management and those indicators of effectiveness which are important for assessing utlity management qualifications from the standpoint of assuring safe operations.

Planned activities include the development of measures reflecting safety attitude and behaviors of the plant staff and a standard information collection system for management reviews, including interview guides, observation and information-recording forms. The review system would be pilot tested on selected utilities to obtain indications of its feasibility and effectiveness. The methodology would include individual and group interviews at utilities, NRC ratings of management elements, and a retrospective look at construction safety in new plants and operational safety in older plants managed by the utility. In the longer term, it is hoped that it will be possible to relate effective and ineffective management behaviors to safety criteria through an appropriate model.

NUREG-0660 (I.A.3.4) calls for a determination of which plant personnel, other than ROs and SROs, may need to be licensed by NRC. The personnel to be considered include managers, engineers, auxiliary operators, maintenance personnel, technicians and STAs.

Section 307(B) of Public Law 96-295 directed the NRC to study the feasibility and value of licensing plant managers and other senior licensee officers. A technical assistance contract has been placed with ORNL to study this issue.

A part of the license application process involves an assessment of management and organizational resources based on NUREG-0731 by the Licensee Qualifications Branch of NRR. A contract has been let to Battelle Pacific Northwest Laboratory to develop and recommend guidelines for NRC licensing actions relating to utility management and organization for nuclear power plant construction and operation.

The major missing element in current planned programs in the area of staffing and organizational characteristics is a set of suitable intermediate criteria by which to judge management attitudes toward safety on the impact of organizational variables upon safety.

Technical Requirement

Conduct research aimed at the development of criteria whereby the effects of staffing and organizational variables can be objectively assessed. Consider not only performance measures (see Section 4.2.8) but secondary criteria that may reflect safety-related management attitudes, (e.g., procedures for maintenance quality control, various forms of operating relief from boredom, methods used for feedback of industry operating experiences, level of understanding of human-related safety issues, and so forth). Once suitable behavioral indices of safety-related attitudes have been agreed upon, conduct research to identify the extent to which plant management practices differ on these indices and determine methods for generating desirable changes.

Importance: Medium

Schedule: Urgency - 3 - 5 years

Duration - 1 year

Resources: 2 person-years

Implementation: Career human factors professional and/or industrial/organizational psychologist

Dependencies: Progress on development of evaluative criteria (see Section 4.2.8)

4.5.4 Shift Duration and Rotation

The power industry is one of but a few industries with a requirement for full operational manning 24 hours a day, 7 days a week with operational personnel who are not only competent technically but who are fully alert to indications of changing conditions that may be symptomatic of preaccident states.

The shortage of qualified operator personnel in some geographic areas makes it difficult, if not impossible, for the utility to meet the requirements for continuous operations without longer than normal industry work shifts. It is reported that the more stringent examination cut-off scores, which have produced a higher failure rate among operators up for requalification, have contributed to this problem. The requirement for round-the-clock operations makes it unavoidable, as long as rotating shifts are used, that operational personnel will periodically be exposed to circadian depressions in level of central nervous system arousal.

There are three fundamental safety related questions to be answered:

1. How long can plant operators continuously perform without suffering some degradation in performance? Is the degradation serious?

2. What is the optimal work/rest pattern for a given shift?

3. What is the optimal shift rotation pattern to avoid cumulative fatigue and minimize probable circadian effects on performance?

Each of these issues is complex and relates not only to safety of operations but to the morale of the working force.

The NRC has provided guidelines with respect to permissible overtime in NUREG-0731 but has not as yet officially addressed performance problems that might arise during routine work days of accepted length. To date, no confirmatory research has been done to indicate whether these recommendations are good, bad, or indifferent with respect to operational safety. However, one study of the scientific literature was performed (NUREG/CR-1764). The problem of shift duration is compounded by shift rotation practices that require personnel to work on irregular schedules with respect to the 24-hour clock. Virtually all utilities follow this practice. The influence of natural cicadian rhythms on the performance of personnel in a variety of industrial and military setups is well established.

Certain nuclear industry practices would appear to compound the possible adverse effects of long shift durations and adverse circadian influences. For example, in one plant visited by the Study Group, a four day 12-on, 12-off watch cycle was employed with phase advance and shift rotation occurring after either one and a half or two and a half days off. Using this scheme, the personnel are exposed to quite lengthy watches and the night shift, which begins at 7 PM and ends at 7 AM, combines lengthy watches with the worst period of circadian influence. Whether or not consequential performance degradation occurs under these circumstances is, as noted, unknown and we know of no suitable research that has been performed in nuclear power plants to address the issue.

It is recognized within NRC that there is a need to establish a "more rigorous scientific basis" for deciding what is acceptable from the standpoint of shift length, shift rotational schemes, and the use of overtime in nuclear power plants (Denton memorandum, March 27, 1981). The NRR priority list shows this item as No. 7 in a list of 15. Current work includes in-house analysis of LERs to determine their relationship to shift work variables. An earlier review of overtime data proved "inconclusive." LERs are being examined for potential correlations between error frequency and time of day.

The Department of Energy is sponsoring work at Argonne National Laboratory on how to adapt most rapidly to a new shift with minimum disturbance. In particular, these investigators are studying dietary practices which are designed to accelerate circadian phase shifts. This work, which is being done on animals, investigates the influence of consuming meals, on "days off", of a type and at times which anticipate the next shift schedule.

The key element in these planned activities is the need to identify or develop a performance criterion measure that is sufficiently sensitive to detect changing levels of operator alertness or quality of performance as a function of time on the job and time of day. While it is certainly worthwhile to try to relate LERs to shift duration, overtime, and possible circadian effects, failure to detect these influences in the LERs may simply mean that the LER reporting system is not properly designed to detect them. Or, as in the case of accident research in other industries, it may be that only a very carefully defined subset of operator behaviors is related to shift duration and rotation practices.

Technical Requirement

Research should be conducted aimed at determining whether and under what conditions operator performance in the control room measurably deteriorates. Particular attention should be directed at identifying cognitive variables (information processing), performance measures, and physiological indices that are likely to be sensitive to loss of alertness and cumulative fatigue (see Section 4.2.8).

Work should be performed on the (necessary) redesign of LER reporting methods so that an appropriate data bank of events can be related to various independent variables logically associated with shift length, work/rest cycles, and shift rotation.

Assuming that performance deterioration is documented, conduct research to identify variables that influence its severity. These variables should include, but not be limited to, shift duration, shift rotation schemes, procedures for alleviating boredom, and so forth.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 3 years

Resources: 10 person-years; access to control room and control room personnel

Implementation: Career human factors professional or experimental psychologist; work physiologist

Dependencies: Development of unobtrusive sensitive measures of performance deterioration or long alertness. Cooperation of management, union, and personnel.

4.5.5 Factors Affecting Job Satisfaction

The complexity and critical nature of nuclear power plant operations and maintenance requires not only a highly skilled work force but a highly motivated one as well. Staff stability is also important because the loss of skill and plant knowledge associated with high turnover rates may adversely impact safety of operations. The requirement is for a stable, motivated staff that is willing to live with long hours, shift work, usually tedious (but sometimes highly stressful) conditions, and a certain degree of non-acceptance by the general public. Some plants are in locations that restrict the social or cultural activites of the family. There are limits on economic reward. Requirements for frequent requalification are viewed by some as placing their livelihood in jeopardy. Career development may depend on educational credentials that are viewed as difficult to achieve.

While it is technically feasible to develop measures of personnel attitudes and job satisfaction, the validity of such measures is a function of how skillfully the investigators deal with emotionally tinged issues, the reprentativeness of the respondents, and their willingness to be completely candid. Success of the methodology is obviously dependent upon sound procedures for sampling the appropriate populations of utility personnel in various job categories and methods of inquiry that ensure the anonymity of the respondents.

With respect to the validation of job satisfaction data, the most relevant criterion, of course, is turnover rate. Obviously it would be desirable to develop intermediate measures that are predictive of this undesirable outcome so that appropriate and timely corrective actions can be initiated by management.

Technical Requirement

If industry does not take the lead in research leading to the minimization of turnover and maximization of job satisfaction (particularly among ROs and SROs), it is recommended that:

1. Research be conducted to establish recent turnover rates and rates that are predicted for the next 2 - 3 years throughout the nuclear power industry. (Attention should be directed to the distinction between personnel who actually leave the industry versus those that simply move to a new position within it.); and

2. If those rates are judged to be excessive in relation to safety considerations, perform research to identify causes and changes in industry or NRC practices that would be necessary to significantly reduce them. Identify the reward/feedback/professional growth structure necessary to minimize job dissatisfaction and to maximize stability.

Importance: High

Schedule: Urgency - Immediate

Duration - Continuing periodic assessment of trends is necessary

Resources: 2 person-years per year

Implementation: Career human factors professional and/or industrial/organizational psychologist

Dependencies: None

The recommended schedule and estimates of manpower necessary for meeting the technical requirements identified in the area of manpower and staffing are summarized in Figure 15.

PROBLEM AREA AND TECHNICAL REQUIREMENT	START TIME, DURATION, AND PERSONNEL REQUIREMENT										
	1	2	3	4	5	6	7	8	9	10	
4.5.1 PERSONNEL SELECTION – PRACTICES & STANDARDS											
• RESEARCH ON VALIDATION OF SELECTION PROCEDURES	1	1	1	1	1	1	1	1	1	1	H
• RESEARCH ON EFFECTS OF ACCIDENT–GENERATED STRESS ON PERSONNEL		4	4	RE-EVALUATE							H
• MONITOR & EVALUATE INDUSTRY BEHAVIORAL RELIABILITY PROGRAMS			0.5	0.5	0.5	INDEFINITE					M
• RESEARCH ON NEW TECHNOLOGY TESTING PROCEDURES						2	2	2	2	2	L
4.5.2 OPERATOR CERTIFICATION & LICENSING											
• RESEARCH TO DEVELOP OBJECTIVE PERFORMANCE STANDARDS FOR RO, SRO, & SS		3	3	3							H
• RESEARCH TO DEVELOP QUALIFICATIONS FOR NON-LICENSED PERSONNEL		5	5								H
• RESEARCH TO ASSESS PROGRESS THROUGH TRAINING PROGRAMS						1					L
• RESEARCH ON TRADEOFF OF FORMAL EDUCATION VERSUS EXPERIENCE		2.5	2.5								M
4.5.3 STAFFING & ORGANIZATIONAL CHARACTERISTICS											
• RESEARCH TO DEVELOP CRITERIA FOR ASSESSING ORGANIZATIONAL VARIABLES			2								M
4.5.4 SHIFT DURATION AND ROTATION											
• MODIFY LER SYSTEM: DATA FOR SHIFT LENGTH, ROTATION, ETC.		STAFF									H
• RESEARCH ON OPERATOR PERFORMANCE DETERIORATION		3	3	3							H
• RESEARCH ON VARIABLES INFLUENCING OPERATOR PERFORMANCE DETERIORATION					3	3	3				H
4.5.5 FACTORS AFFECTING JOB SATISFACTION											
• RESEARCH ON JOB TURNOVER RATES	2	2	2	2	2	2					H

FIGURE 15. SCHEDULE FOR MEETING TECHNICAL REQUIREMENTS IN PERSONNEL & STAFFING

4.6 Problem Areas in Training

Training of nuclear power plant personnel is affected by two sets of requirements. On the one hand are the required skills and knowledges for each job as determined by plant design and operating parameters and procedures. On the other hand are the licensing and other quality control systems that are employed to assure that the required skills and knowledges are met and maintained. The focus of the NRC needs to be on these two aspects of training. We believe it desirable, if possible, to leave the choice of particular training methods and training equipment to industry. However, since the NRC cannot predict the adequacy of behavior, but can only assess it after its occurrence on the job or during examinations, the NRC should take some role in ensuring that training programs are comprehensive so that there will be a high likelihood of adequate job performance by plant personnel at all times.

4.6.1 Instructional System Development

In much the same way that the man-machine interface should be developed using systematic analysis, so should the training components of the nuclear power system be developed. By definition (131), the process of Instructional System Development (ISD) is "a deliberate and orderly process for planning and developing instructional programs which ensures that personnel are taught the knowledges, skills, and attitudes essential for successful job performance." For small systems requiring relatively few trainees per year, the formal ISD process is usually too expensive and time consuming to employ. Such is not the case, however, in the nuclear power industry, which is characterized not only by high training and refresher throughput rates, but also by the high costs incurred by damage or disruption of the nuclear power plant.

Effort put into training development and implementation has payoff in maximal public safety, reduced operating costs, and potentially high levels of job satisfaction of the employees. ISD initiated at the time of plant design accrues the benefit of economies in utilization of the same data bases needed for other human factors efforts, access to subject matter experts knowledgeable in the intricacies of plant system interactions, and the acquisition of well-trained personnel as they are required.

There are no significant technical constraints to the implementation of ISD in the nuclear industry. However, there may be organizational constraints. The adequacy of an ISD program depends heavily upon the team experience, team composition, and management support provided. The best experience for this type of effort comes from the major military ISD programs since these programs typically follow the process more closely than the "factory training" approach typical of most commercial training departments. The latter approach, which usually meets the established training requirements due to the generally high level of technical expertise and teaching experience of the staff, does not provide the comprehensiveness of the ISD approach, nor does it provide the opportunity to integrate all of the related areas of the nuclear power system. There are, in fact, very few individuals available who have had the exposure to a major ISD effort. Instructional technologists and educational psychologists are available, but in high demand, who are well versed in the ISD technology and who have had practical experience on similar systems.

NRC regulations covering training and licensing drive the construction of training programs, but since those regulations are not derived from an ISD process, or from any body of instructional technology literature, they typically cause training programs to fall short of professional standards. It is apparent that the training content of syllabi is selected not on the basis of the criticality/frequency/difficulty estimates associated with the task analyses and training objectives, but rather from the content of the licensing exams and requalification requirements.

Current training requirements, as set forth in NRC regulations, directives, and so forth, do not call for the application of ISD to any personnel positions. What requirements exist are not related to objectively derived job criteria, but rather to expert judgments as to what learning experiences would make better qualified operators.

INPO has taken the lead (and, in fact, may be the only entrant) in ISD applications. The NRC is acting to upgrade its role in training, but to date has had a role which was little more than conducting SRO examinations for instructors of certain courses at utilities and auditing utility training programs to ensure that they are being conducted in accordance with the utilities' applications for licensing.

It is our understanding that the NRC is favorable toward self-regulation with NRC verification, but the verification process will require well-experienced NRC personnel who are charged with and able to bring about the coordination of what are now separate activites both within and outside the NRC. Confirming the compatibility (i.e., cross-validation) of the separate data bases (from INPO, EPRI, NRC, utilities) being generated is alone a formidable job. Such an NRC group does not now exist.

To support the possible role of NRC as a verifier of industry's self-regulation, a standard for the ISD process is needed but is not currently set forth in any NRC regulations or guidelines. Several standards exist, including the Florida State University model used by INPO.

Although the INPO effort has been discussed in very favorable terms in this section, one area to which INPO has not seemed to have given sufficient emphasis is the application of modern training technology (e.g., computer-based instruction) and the functional specification of hands-on training equipment and their efficient incorporation into a syllabus. That is not to discount that the INPO Guidelines for Qualification Programs do call for mixing of academics and hands-on during training, but the manner by which their efficient integration should be brought about is not specified.

Technical Requirement

A point of contact should be established within the NRC to coordinate the training-related research and development efforts among the NRC groups with those of the utilities, INPO, and EPRI. This activity will also include ensuring the dissemination of training-related plant operating experience data from LERs and SALP (or 766 File), and from other observations of training-related deficiencies in plant personnel performance that should be routinely elicited from IE Resident Inspectors. This activity should also include the monitoring of the adequacy of training programs used for NRC personnel.

Importance: High

Urgency: Immediate

Implementation: Staff Educational Technologist

Technical Requirement

The NRC should publish a Regulatory Guide for Instructional System Development procedures which are suitable for use by industry for the development of training for all plant personnel. For each plant personnel training program, the NRC should use that Regulatory Guide to evaluate the adequacy of the behavioral objectives and antecedent data. The NRC should monitor the procedures used by industry for the development of training to ensure that they are suitable for the development of comprehensive training programs and quality control.

Importance: High

Schedule: Urgency - 1 - 2 years for issuance of Regulatory Guide

Duration - 1 year for Regulatory Guide; continuous monitoring and evaluation

Resources: Issuance of Regulatory Guide, 1 person-year; evaluation and monitoring, 0.1 to 0.5 person-year per plant per position.

Implementation: Educational technologist; support from subject matter experts. Schedule of availability of data from the utilities will constrain the evaluation and monitoring.

Dependencies: Utilities will use as inputs the task analysis activities of the NRC and INPO and the Model Training Programs under development by INPO. Coordination with the accreditation program of INPO will assist NRC efforts.

Technical Requirement

The NRC should sponsor research in retention of critical skills and knowledges for each plant job category. The results of this research should be used to develop a guide for determining refresher training requirements which will be implemented in the ISD Regulatory Guide.

Importance: High

Schedule: Urgency - 3 - 5 years

Duration - 3 years

Resources: 4 person-years per year; simulators or part-task trainers

Implementation: Career human factors professional; support from training equipment programmers. Educational Technologist for Regulatory Guide update.

Dependencies: Research designs will need inputs from ISD-based training programs and from the results of evaluation criteria research (Section 4.2.8). Results of this program will impact on the requalification requirements for licensed personnel (Section 4.5.2).

4.6.2 Licensed Personnel Training

When the activities of a job holder have an unusual potential for affecting the health and welfare of other individuals, government licensing of those job holders is common. Licensing requirements may include initial training and experience; a written, oral, and performance examination to qualify for the license; periodic in-service training; and peer or licensing board review in the event of malpractice.

To date, the only nuclear power plant personnel required to be licensed are ROs and SROs. Licensing requirements include many of the elements listed above. In practice, the licensing examinations are poorly related to the job requirements since they are developed independently of a job/task analysis or any other systematic process, and are not subjected to validation against job performance. As a consequence, training programs have been directed toward ensuring that trainees pass their licensing examination, rather than ensuring that all of the job-related skills, knowledges, and attitudes are learned.

A particularly thorny problem concerns the amount and type of training licensed personnel should receive subsequent to licensing. The ISD process can tell us which tasks are not performed very often, and of those, which are critical of difficult to perform. Our state of knowledge, however, has not advanced to the point where a training technologist can predict how often and how much those tasks must be practiced in order that they can be adequately performed if ever required. Unfortunately, those tasks are the most likely to be related to emergency situations. Requalification requirements were established on the basis of expert opinion. To do any better requires lengthy research and much data to establish on a statistical basis the "forgetting curve" for each type of task.

Current attempts by the NRC to upgrade training are primarily to raise the passing grades on examinations or to require that certain courses or topics be added to the curriculum. Although adequate for a short-term solution to obvious deficiencies, neither solution can be justified from objective job-referenced criteria.

The NRC has achieved a major step with the analyses reported in NUREG/CR-1750 ("Analysis, Conclusions, and Recommendations Concerning Operator Licensing") and NUREG/CR-1482 ("Nuclear Power Plant Simulators, Their Use in Operator Training and Requalification"). Industry is also making major strides toward putting operator training on a sound basis. Both INPO and EPRI have projects concerned with improving licensed operator training.

It is evident from the NRC research plans that the NRC is sensitive to major issues concerning licensed operator training. However, it is not clear from documentation whether some specific issues will be addressed. For example, will the unusual training requirements for the SPDS (which is not used on a day-to-day basis, but may be critically important when needed) be recognized by the ISD personnel from data supplied by those responsible for the development of the SPDS requirements? Will management training for senior control room personnel and shift supervisors include training in the techniques for subjectively evaluating their subordinates? Will the concept of a "passing score" on an examination be scrutinized for validity considering that "need to know" skills and knowledges require a perfect score (except when it is established that the trainee will have sufficient opportunity to "master" the remaining material when on the job)?

Technical Recommendation

The NRC should adopt the recommendations of NUREG/CR-1750, Section 2.10, License Training Instructors, which are summarized (NUREG/CR-1750 pp. 6-16, 6-17) as:

1. Before receiving any instructional assignments, all training personnel (including Training Managers) should attend a certified course or program specifically aimed at the familiarization with and applicaton of instructional methods and techniques.

2. During periodic audits, ensure that instructional staffs have received training or possess the equivalent education necessary to demonstrate effective training practices.

3. Utilities should implement periodic workshops or retraining programs for assessing and improving instructional skills.

4. In evaluating instructors, utilities should consider several measures, including: a) meeting of well-stated, valid objectives; b) periodic observation by an instructional specialist; c) trainee feedback; d) trainee performance on the job (supervisor feedback); and e) Training Coordinator or senior instructor observation using a detailed, structured observation list.

Importance: High

Schedule: Urgency - Immediate

Resources: NRC Staff

Implementation: Immediate staff action

4.6.3 Non-Licensed Personnel Training

Data from job task analyses presented in NUREG/CR-1750 indicate that each of the following plant personnel positions has some job requirements that are safety related:

a) Radiation Protection Technician
b) Engineers and Technical Support Personnel
c) Maintenance Personnel
d) Chemistry Technicians
e) Instrumentation and Control Technicians
f) Quality Assurance and Quality Control Inspectors
g) Auxiliary Operators
h) Shift Technical Advisor

i) Managers
j) Independent Review Personnel

Requirements are in place for utilities to provide suitable training programs for all such personnel. For the purposes of this report, we would add utility/vendor instructors.

Currently, training practices run the gamut from the most formalized training programs for auxiliary operators and many other curricula run by utilities and training vendors, to nothing more than on-the-job training (OJT). Unlike the licensed positions, the only NRC responsibility for the unlicensed plant position training is to audit to ensure that the programs are being run in accordance with the utility's approved plan. In most cases, instructors are not themselves instructed in the techniques of teaching; however, the better training programs audit the quality of instruction and attempt to employ "good" teachers. Training centers run by utilities and vendors tend to be well-supplied with training aids, classrooms, laboratories, and other work areas (not to mention simulators for the operator training programs) which can provide the proper learning situations.

It appears that most of the mechanisms are in place through the efforts of INPO to guide the development of training programs and quality control for non-licensed utility personnel.

Technical Recommendation

The NRC should adopt the recommendations of NUREG/CR-1750, Section 2.10, as summarized on pp. 6-16, 6-17 for specified non-licensed personnel training instructors, as well as for licensed personnel training instructors. These recommendations are:

1. Before any instructional assignments, all training personnel (including Training Managers) should attend a certified course or program specifically aimed at the familiarization with and application of instructional methods and techniques.

2. During periodic audits, ensure that instructional staffs have received training or possess the equivalent education necessary to demonstrate effective training practices.

3. Utilities should implement periodic workshops or retraining programs for assuring and improving instructional skills.

4. In evaluating instructors, utilities should consider several measures, including (a) meeting of well-stated, valid objectives; (b) periodic observation by an instructional specialist; (c) trainee

feedback; (d) trainee performance on the job (supervisor feedback); and (e) training coordinator or senior instructor observation using a detailed structured observation list.

Importance: High

Schedule: Urgency - immediate

Resources: NRC staff

Implementation: Immediate staff action

4.6.4 Training Equipment

Full-scale control-room simulators are used for training and for examinations in current and proposed licensing requirements for control room operators. This use has been accompanied by a growing acceptance of training equipment of various kinds (other than simulators) into training programs. The acquisition and use of full-scale simulators in the nuclear industry has followed a course which parallels the introduction of full-mission simulators into military aircrew training. Namely, such devices have been designed and promoted as replicating all aspects of the operational system. This is not surprising since the major manufacturer of nuclear power plant control room simulators is also the major manufacturer of military aircraft simulators.

Fortunately for our national defense in terms of effective aircrew training, and for the taxpayers' pocketbooks in terms of the cost of extremely high fidelity full mission military aircraft simulators, the training philosophy in the military has been changing. For the last several years, there has been a growing trend for training equipment to be specified (at least functionally) on the basis of behavioral data. The best known early research was initiated by the Air Force Human Resources Laboratory (at Wright-Patterson AFB) in which the criticality, difficulty, and frequency of each task to be taught with hands-on equipment were examined. Priorities were then established for inclusion of the necessary system representation in the trainer and were traded off with the cost of their inclusion. The result would be a trainer that had a high training utility at the lowest cost. No unnecessary functions were included.

Full-scale simulators are not the only training equipment to be considered for nuclear power plant personnel training, however. The following provides a spectrum of the possibilities:

a) pictorials -- two-dimensional photos or diagrams -- can be used for familiarization and mental rehearsal,

b) scale models and "cold" mock-ups -- scale or full-sized replicas of equipment; may have movable parts, but no response to actions -- can be used for familiarization and mental rehearsal,

c) computer-aided instruction -- computer controlled graphics representation of equipment supported by mathematical models; graphics change in response to trainee inputs -- can be used for concept development, systems knowledge, and procedures training,

d) "hot" mock-ups -- full-sized replicas of equipment; partially interactive (low fidelity) with trainee's actions -- can be used for procedures training,

e) systems trainers -- two or three dimensional replicas that also present status information for system components not included in operational equipment displays -- can be used for concept development and systems knowledge,

f) part-task trainers -- fully-interactive, high fidelity replicas of a subset of systems -- can be used for procedures training and decision-making training, and

g) full-scale simulators -- fully interactive, high fidelity replicas of all systems -- can be used for procedures training, decision-making training, and team training.

It is important to note that these generic devices are as applicable to maintenance and technician training as they are to operator training. The manner in which one decides which to use is a special topic within the Instructional System Development (ISD) process.

Subsequent to the TMI-2 accident, it became apparent that, if simulators were to meet their requirement in operator training and licensing, the models that drive them must be made capable of reproducing the full sequence of events in multiple failures and emergencies.

For the long term, the ISD process can provide the best process for determining the best combinations of simulator experiences for training and testing, the required fidelity of the systems to be represented (and, hence, the particular training equipment required), and the instructional/PMS features needed. The more comprehensive ISD approach can then provide a basis for establishing instructor and examiner training requirements.

There is one other process which has gained attention recently in the acquisition and use of training equipment.

Simulator certification (SIMCERT) or training effectiveness analysis (TEA) is now being required by military communities, following the FAA lead for commercial aircrew programs, for new equipment added to their inventory. The SIMCERT/TEA process of validating that the training equipment provides adequate training to meet specific training objectives is equally applicable to operator, maintenance, or technician training devices. It goes beyond determining that the device was built to specifications, and requires proof in the form of transfer-of-training tests that the training device can be substituted for actual equipment to meet some particular learning objective. The objective may be any subset of skills required for the terminal objective (i.e., the job requirements). This process has been used by the FAA to allow them to certify commercial airline simulators for use as substitutes for particular airborne training phases. The outcome of the SIMCERT/TEA process, then, is a specification for what tasks a device can be used to train, and by implication, how it is to be used. The obvious corollary is that it also determines those tasks that can be adequately tested on the equipment.

The RES response to the NRR research needs lists one program that impacts on training equipment, and another which has a secondary impact. The first is "Capability of Training Simulators" (Tasks A1 and A2 of RR-NRR-81-5). Work is proposed to continue the effort in NUREG/CR-1482 to define the emergency tasks that need to be simulated in order to provide adequate training. These decisions will be based on accident sequences from documented risk analyses. In another part of that program, data will be gathered on simulators from other technologies for comparison of their capabilities, uses, fidelity, design, and procurement practices. Both of these efforts should prove useful, if included in a broader range program to integrate trainers and simulators into training programs. The second RES program is "Research Dependent on Advanced Simulators" (Task B of RR-NRR-81-5). Its importance lies in the potential of using an advanced engineering simulator to validate the design of full-scale training simulators and part-task trainers. The availability of such a device for that use is unprecedented in the simulator community. It would be nice to have, but it cannot be justified as being necessary.

The design and incorporation of training equipment into the training programs for nuclear power personnel has made little use of modern technology except in the simulators designed for control room operators. There is no program for the validation of training (or testing) carried out on training equipment, i.e., SIMCERT or TEA studies.

Technical Requirement

The NRC should publish a Regulatory Guide for the certification of the training effectiveness of training simulators and other devices upon which terminal training objectives will be met.

Importance: High

Schedule: Urgency: 1-2 years

Duration: 1 year

Resources: 2 person-years

Implementation: Career human factors professional; support from educational technologist and subject matter expert.

Dependency: None

Figure 16 summarizes the recommended schedule and manpower estimates for meeting technical requirements in training. Importance ratings are given in the last column.

4.7 Incident Response Plan and NRC Facilities

One of the specific results from investigations of the accident at Three Mile Island Unit 2 was a recommendation that the NRC improve its capability for response to nuclear emergencies. Several related efforts are presently underway to address this recommendation. For the sake of simplicity and clarity, these have been divided into four areas for discussing human factors concerns. The areas are:

1. The incident response plan

2. The NRC operations center

3. Utility emergency response facilities

4. The safety parameter display system

4.7.1 Incident Response Plan

Human factors issues within the broad area of emergency preparedness are beyond the scope of the present contract and thus no specific concerns were identified. Obviously, however, the planning for and implementation of major emergency response actions have a great deal to do with human factors and other people-related issues.

The most significant planned activities by the NRC with respect to emergency response plans and preparedness will be to run incident response exercises. These exercises will simulate

PROBLEM AREA AND TECHNICAL REQUIREMENT	START TIME, DURATION, AND PERSONNEL REQUIREMENT										
	1	2	3	4	5	6	7	8	9	10	
4.6.1 INSTRUCTIONAL SYSTEM DEVELOPMENT											
• ESTABLISH NRC COORDINATOR OF TRAINING ACTIVITIES	IMMEDIATE & CONTINUING – staff career prof. and educational technologist										H
• DEVELOP AND PUBLISH REG GUIDE FOR ISD; MONITOR TRAINING PROGRAMS		STAFF									H
			15	12	12	10	10	10	10	10	H
• RESEARCH ON RETENTION OF SKILLS & KNOWLEDGES				4	4	4					H
4.6.2 LICENSED PERSONNEL TRAINING											
• ADOPT RECOMMENDATIONS OF SECTION 2.10, NUREG/CR-1750	IMMEDIATELY										H
4.6.3 NON-LICENSED PERSONNEL TRAINING											
• ADOPT SECTION 2.10, NUREG/CR-1750 FOR SPECIFIED NON-LICENSED PERSONNEL	IMMEDIATELY										H
4.6.4 TRAINING EQUIPMENT											
• ISSUE REG GUIDE FOR CERTIFICATION OF TRAINING SIMULATORS		2									H

FIGURE 16. SCHEDULE FOR MEETING TECHNICAL REQUIREMENTS IN TRAINING

various events of national concern and presumably will be used to provide feedback for subsequent modification to plans and facilities as necessary. Similarly, utilities are conducting exercises simulating emergency response activities as a result of incidents in the vicinity of the nuclear station.

The focus for human factors concerns during this project was the control room. The Incident Response Plan review goes well beyond the control room, but was briefly reviewed because of its unique significance. The primary human factors concerns that were identified relate to the utility emergency response facilities and the safety parameter display system which are discussed in sections to follow.

Technical Requirement

A systems analysis should be done to identify more precisely the behavioral and human factor issues related to planning for response to emergencies. Many people will be involved if an emergency response plan is implemented, and the preparedness of these people is a significant human factors concern.

Importance: Medium

Schedule: Urgency - 1-2 years

Duration - 3 years

Resources: 3 person-years

Implementation: Requires a career human factors professional and a social scientist experienced in emergency planning and behavior.

Dependencies: None

4.7.2 NRC Headquarters Operations Center and Regional Facilities

The NRC Operations Center for incident response and support was visited on two occasions and discussions were held with personnel responsible for the Center design and operations. In addition, some documentation on the Center design and operations has been reviewed. Based on this preliminary information, the following human factors issues have been identified, although it must be recognized that the list is neither complete nor necessarily totally valid:

1. The mission of the Headquarters Operations Center and, consequently, the responsibilities of its members do not appear to be firmly established.

2. The decision-making functions have not been thoroughly identified and therefore the information and communication requirements of the various organizations and individuals cannot be readily assessed.

3. The present facility seems to be highly dependent upon telephone communications, which raises concerns over the timeliness and accuracy of information transmitted.

4. Storage and display of information does not seem to be based on any systems or task analysis. Consequently, techniques such as common or shared displays, or the ability for individuals to obtain scientific information rapidly and accurately may not be effectively employed.

It should be strongly emphasized that the present facilities and equipment of the NRC Headquarters Operations Center does not reflect the current state of planning or thinking that has been accomplished by the personnel responsible for the design and operations of the Center. A complete conceptual design has been prepared; however, there have been no long-range commitments for implementation of this design. Consequently, it is recognized that the types of human factors issues identified above may well be improved upon or eliminated if resources are committed to implement the longer-range system concept.

Technical Requirement

A complete systems analysis of the NRC incident response need and the facilities to meet that need should be done to derive human performance requirements. These requirements, which relate primarily to decision making tasks, can then be further task analyzed to determine specific information and communication requirements, job designs, and the necessary staffing and organization. The proper human factors evaluation of the NRC Operations Center can then be performed and design specifications prepared based on these analyses.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 1 year

Resources: 3 person-years

Implementation: Skills required are a career human factors professional, and the NRC Operations Center staff.

Dependencies: None

4.7.3 Utility Emergency Response Facilities

These utility emergency response facilities are part of the overall incident response plan and facilities as discussed in the previous section. This section is limited to those utility emergency facilities found onsite (or nearby) which are part of the nuclear power plant facility. The safety parameter display system (SPDS) may be considered part of the onsite facilities, but it is discussed separately in the section to follow because of its unique importance and human factors considerations. The emergency response facilities (ERF) considered in this section are the technical support center (TSC), onsite operational support center (OSC), nearsite emergency operations facility (EOF), and the nuclear data link (NDL).

The TSC requirement in general seems responsive to human factors issues derived from the experience at TMI-2. Relieving the control room personnel of tasks for communications not directly related to reactor control is certain to increase the effectiveness of personnel in the control room. Similarly, simply removing some personnel from the control room and providing more technical support when requested appears to be a positive feature.

Some general human factors concerns that must be considered in the final design and operation of the TSC are:

1. The actual number of personnel, their responsibilities, and specific information and communication needs to carry out those responsibilities. This suggests some form of job analysis although some of this information may be the licensee's emergency response plan.

2. Layout and arrangement of equipment and work space to optimize movement and coordination.

3. Training for TSC staff personnel.

The OSC also appears to be responsive to some manpower and personnel needs and coordination tasks as derived from the TMI-2 accident. In general, the OSC should reduce unnecessary personnel and traffic in the control room and serve as a central point for logistics support. The number of personnel and their responsibilities should be defined and presumably will be contained in the licensees' emergency response plans.

The EOF will be the basis for overall management of the emergency response by the licensee, including coordination with federal, state, and local officials. The responsibility of the

EOF to adequately and reliably implement emergency response actions involving the general public will require displays, communications, personnel, staffing, and procedures, all of which have implications for human factors issues.

Two specific human factors issues have been raised concerning the EOF to date. First, there is a question as to what data are required in the EOF to support the functions of that facility. NUREG-0696 (Section 4.8) requires the entire Reg. Guide 1.97 Data Set in addition to the Reg. Guide 1.23 and NUREG-0654 Revision 1 Appendix 2 Data to be provided in the EOF. These data requirements do not appear to be derived from any kind of functions analysis or job analysis and should be reexamined in this context.

Second is the question of whether the SPDS displays should also be provided to the EOF as required by Section 4.2 of NUREG-0696. The EOF primary purpose is to provide a near site facility for the management of overall licensee emergency response (including coordination with federal, state, and local officials), coordination of radiological and environmental assessments, and determination of recommended public protective action. The human factors issue is what data are required to support the above responsibilities. If the EOF does not involve the diagnosis of plant conditions, which presumably is the responsibility of the TSC, the question of providing too much data including the SPDS is a legitimate concern of human factors because the EOF personnel can be distracted from their primary responsibility.

The NDL is proposed as a data transmission system for providing reactor performance data for the NRC Headquarters Operations Center. The display at Headquarters could be equivalent to an SPDS. Aside from the human factors issues of the SPDS identified in Section 4.7.4, the critical human factors issue here seems to be the use of such information. The intent would be that the NDL and its display system provide plant system data to be used by the NRC for analysis and technical support -- not for management. The concept would appear to unburden some of the other communications between the site and the NRC Headquarters but needs to be more thoroughly considered in light of the mission and responsibilities of the NRC Headquarters Operations Center, as discussed earlier.

Human factors concerns in the onsite emergency response facilities were an incidental task in this project and were not the main thrust of the effort which was oriented towards the control room. However, the human factors concerns discussed above could be significant in the event of an alert or emergency simply because large numbers of people will be involved and a great deal of coordination will be required between individuals and organizations.

It is beyond the scope of this project to present a description of what the industry is doing with respect to site emergency response facilities. In general, because of the individual differences required at each site, there seem to be plans under way for the design and construction of the major facilities, with the exception of the nuclear data link. Thus, the TSC, OSC, and EOF are in various stages of construction. However, the emphasis seems to be on the construction of the facility, and much less emphasis on the instrumentation and controls, communications, and other features important from the human factors point of view which could be derived from use considerations. In short, operational use requirements seem to be minimal with little or no job or task analysis which would define the requirements for data, communications, and staffing in a systematic manner.

One exception might be noted, which is the emergency response information system (ERIS) that has been conceptually described by the BWR owners' group. This system is less concerned with the facilities and more concerned with the information in those facilities. It will be considered under the section to follow dealing with the safety parameter display system.

Technical Requirement

A system analysis should be conducted to determine the human factors requirements for the emergency response facilities. This should be a straightforward analysis starting with the identification of major functions of each of the facilities and then some form of job or task analysis to identify the responsibilities expected of the user personnel. Design of specific procedures, displays, and the facility layout would evolve from this analysis. The NRC should provide guidance on conduct of this type of system analysis and they should further provide evaluation criteria for the review of designs submitted in accordance with that guidance.

Importance: High

Schedule: Urgency - 1 - 2 years

Duration - 2 years

Resources: 8 person-years

Implementation: Skills required are a career human factors professional, a nuclear engineer, and an I&C engineer.

Dependencies: None

4.7.4 Safety Parameter Display System

The Safety Parameter Display System (SPDS) is part of the emergency response facilities, but is being treated separately in this report because of its significance in terms of human factors.

The purpose of the safety parameter display system is to assist control room personnel in evaluating the safety status of the plant. The SPDS will be located in the control room with additional SPDS displays provided in the TSC and EOF. An SPDS is apparently also being considered for installation at the NRC Headquarters Operation Center.

The SPDS will directly affect the operator's role in the control room. It is the most significant human factors issue in the area of emergency response facilities. It is thus imperative that all facets of human factors, including human factors engineering, procedures, personnel training, and operator acceptance be considered in this design. NUREG-0696 does acknowledge the importance of human factors, and specific evaluation criteria for human factors are provided in NUREG-0835.

Further it appears that a backup SPDS will be required if the primary SPDS display will not function during an earthquake. This implies that the backup system would be made up from other required control room instrumentation needed to comply with Reg. Guide 1.97. It also implies that the backup instrumentation should be concentrated in one area on the control board. Because of the significance of the SPDS for control room personnel to assess the overall safety status of the plant, several human factors issues must be addressed:

1. The requirement for a backup SPDS with a different design and different instrumentation should be reconsidered (although the seismic qualification requirements are, of course, beyond the scope of any human factors issue). If the backup instrumentation is different from the primary SPDS, some question exists about the utilization and acceptance of two different systems.

2. If a backup is required, the need to install separate seismic instrumentation in a concentrated area is also questionable from a human factors viewpoint. Further, this may also conflict with the design criteria of Reg. Guide 1.97, which states "it is prudent to select the required accident-monitoring instrumentation from the normal power plant instrumentation to enable operators to use, during accident situations, instruments with which they are the most familiar." This suggests that the instrumentation will be associated with the various systems and not concentrated in one area.

3. A considerable amount of research and development is being carried out by industry to develop safety parameter display system concepts. However, in most cases, the R&D efforts are focusing on new technology display systems with minimum regard to human factors. New technology does not equate to good human factors and this final concern may well affect both initial acceptance and long-term utilization by operating personnel.

The SPDS is a potentially costly modification to the control room, in addition to being required for the TSC and EOC. The underlying need for an SPDS has not been clearly established and it represents a significant human factors concern with respect to safe and effective use and user acceptance.

Several industry activities are directed at development and promotion of SPDS concepts. The Nuclear Safety Analysis Center (NSAC) has contracted for several studies of SPDS concepts and hardware and software alternatives.

In brief, SPDS activities to date do not appear to have been well integrated, and many alternative approaches are being pursued. From a human factors point of view, it would appear prudent to define the user needs more explicitly before detailed design alternatives are pursued. This suggests some test and evaluation plan which incorporates not only engineering design considerations but human factors ones as well.

The NRC finalized NUREG-0835, "Human Factors Engineering Design Review Acceptance Criteria for the Safety Parameter Display System," in early 1982. The draft report has been reviewed and the following opinions are offered. In general the content and format appear to be quite well done. A few specific comments follow. First, there does not seem to be much if any input from professional human factors personnel; second, the document relies heavily on guidelines developed in NUREG-0700; and third, the document does not address the user needs of tasks but rather addresses the more specific considerations of the man-machine interface.

From the industry side, the most significant activity planned is by the Electric Power Research Institute (EPRI), which has a study scoped to address some of the designs of the owners groups (and perhaps others) and has obtained the services of a recognized professional human factors contractor to support this effort. The specifics of this planned activity are not known at this time, and cannot be futher reported.

One further significant industry activity mentioned in the section on utility emergency response facilities is the BWR Owners Group Emergency Response Information Systems (ERIS). ERIS is described as an "integrated system that gathers the required plant data, stores and processes the data, generates visual displays for the operator and other personnel who need plant status information, provides printed records of transient events, and has the capability to transmit essential information to the NRC should this become a requirement. The basic components of ERIS are the Data Acquisition System, the Central Processor Units, and the Graphic Display Consoles. Specifics of the ERIS are proprietary information and cannot be discussed in this report. The information received about ERIS is not sufficient to judge its adequacy from a human factors point of view. It does appear, however, to be primarily hardware and computer system oriented, with some consideration given to the man-machine interface, but no apparent user needs or task analysis has been performed.

From a human factors point of view, the missing element with respect to the safety parameter display system seems to be any form of functional analysis, user needs analysis, or task analysis to support the need for the SPDS and to form the basis for deriving the specific information requirements.

Technical feasibility does not represent a problem for SPDS. Rather, the reverse might be true in that the state of the art in display systems and computer systems might be driving the design of many SPDS alternatives rather than the functional and user requirements.

Technical Requirement

The need for an SPDS has not been established from any system or task analysis. A well designed control room may be satisfactory. Therefore, a thorough systems analysis should be done. The job/task analysis being done by INPO and the Reactor Operator task analysis being done by NRC must be coordinated with any similar analysis for SPDS. The general approach and recommendations for any type of operator aid are discussed in Volume 3, Section 3.3, Operator and Maintenance Aids.

If any SPDS is to be developed then the following tasks must also be a part of the human factors considerations:

(a) Evaluate the need for a backup SPDS as specified in NUREG-0696.

(b) If a backup SPDS is required, evaluate the need for installing separate seismic instrumentation in a concentrated area.

(c) Review the potential conflict with Reg. Guide 1.97.

(d) Develop evaluation criteria for user acceptance.

Finally the work effort described above should be integrated with that recommended in Section 4.4.3, Job Performance Aids.

Importance: High

Schedule: Urgency - Immediate

Duration - 1 - 2 years

Resources: NRC staff, plus an undetermined level of effort in conjunction with Section 3.3.

Implementation: Personnel required are a career human factors professional, computer systems analysts, and subject matter experts on reactor safety parameters.

Dependencies: Should be contingent upon the INPO and NRC job/task analysis efforts. However, a unique special systems analysis could be performed which would not delay SPDS if this analysis justifies the need.

The recommended schedule and estimates of staffing for the technical requirements for the incident response plan and NRC facilities are summarized in Figure 17. Importance values are given in the right column.

PROBLEM AREA AND TECHNICAL REQUIREMENT	START TIME, DURATION, AND PERSONNEL REQUIREMENT										
	1	2	3	4	5	6	7	8	9	10	
4.7.1 INCIDENT RESPONSE PLAN											
● PERFORM SYSTEMS ANALYSIS TO IDENTIFY HUMAN FACTORS ISSUES		1	1	1							M
4.7.2 NRC HEADQUARTERS OPS CENTER AND REGIONAL FACILITIES											
● PERFORM HUMAN FACTORS EVALUATION OF NRC OPERATIONS CENTER		3									H
4.7.3 UTILITY EMERGENCY RESPONSE FACILITIES (ERF)											
● PROVIDE GUIDANCE AND REVIEW FOR HF ANALYSIS OF ERF		4	4								H
4.7.4 SAFETY PARAMETER DISPLAY SYSTEM											
● EVALUATE NEED, EFFECTS, AND POSSIBLE INTEGRATION OF SPDS	IMMED.– STAFF										H

FIGURE 17. SCHEDULE FOR MEETING TECHNICAL REQUIREMENTS FOR INCIDENT RESPONSE PLAN AND NRC FACILITIES

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LIST OF ACRONYMS AND INITIALISMS

The following acronyms and initialisms have been used in this report. They are listed in alphabetical order for the convenience of the reader.

ACRS	Advisory Committee for Reactor Safeguards
AE or A/E	Architect-Engineer
AEC	Atomic Energy Commission
AEOD	(Office of) Analysis and Evaluation of Operational Data
AFSCDH	Air Force Systems Command Design Handbook
AFSCR	Air Force Systems Command Regulations
AIF	Atomic Industrial Forum
ANS	American Nuclear Society
ANSI	American National Standards Institute
BNL	Brookhaven National Laboratory
BOP	Balance of Plant
BPNL	Battelle Pacific Northwest Laboratory
BTP	Branch Technical Position
BWR	Boiling Water Reactor
CAI	Computer-Aided Instruction
CEMS	Critical Equipment Monitoring System
CFMS	Critical Function Monitoring System
CODAP	Comprehensive Occupational Data Analysis Program
CP	Construction Permit
CR	Control Room
CRDR	Control Room Design Review
CRGR	Committee to Review Generic Requirements

CRT	Cathode-ray Tube
DASS	Disturbance Analysis and Surveillance System
DCRDR	Detailed Control Room Design Review
DEDROGR	Deputy Executive Director for Regional Operations and Generic Requirements
DHFS	Division of Human Factors Safety
DOD	Department of Defense
DOE	Department of Energy
EDO	Executive Director for Operations
EEI	Edison Electric Institute
EOF	Emergency Operations Facility
EPRI	Electric Power Research Institute
ERF	Emergency Response Facilities
ESF	Engineered Safety Feature
FAA	Federal Aviation Administration
FSAR	Final Safety Analysis Report
HE	Human Engineering
HEP	Human Error Probability
HER	Human Error Rate
HFEB	Human Factors Engineering Branch
HF	Human Factors
HFE	Human Factors Engineering
HFS	Human Factors Society, Inc.
HIAPSD	Handbook of Instructions for Aerospace Personnel Subsystem Designers
HTGR	High-Temperature Gas-Cooled Reactor
IE	(Office of) Inspection and Enforcement
IEEE	Institute for Electrical and Electronics Engineers

IEORS	Integrated Operational Experience Reporting System
INEL	Idaho National Engineering Laboratory
INPO	Institute of Nuclear Power Operations
IREP	Interim Reliability Evaluation Program
ISD	Instructional System Design
ISEG	Independent Safety Engineering Group
ISFSI	Independent Spent Fuel Storage Installation
JPA	Job Performance Aid
LER	Licensee Event Report
LLNL	Lawrence Livermore National Laboratory
LLTF	Lessons Learned Task Force
LMFBR	Liquid Metal Fast Breeder Reactor
LOCA	Loss-of-Coolant Accident
LOFT	Loss-of-Fluid Test
LQB	Licensee Qualifications Branch
M-M	Man-Machine ("Man" is used in the generic sense.)
NDL	Nuclear Data Link
NPP	Nuclear Power Plant
NPRDS	Nuclear Plant Reliability Data System
NRC	U. S. Nuclear Regulatory Commission
NREP	National Reliability Evaluation Program
NRR	(Office of) Nuclear Reactor Regulation
NSAC	Nuclear Safety Analysis Center
NSSS	Nuclear Steam Supply System
NTOL	Near-Term Operating License
ODPS	Operator Diagnostic and Display System
OJT	On-the-job Training

OL	Operating License
ORAU	Oak Ridge Associated Universities
ORNL	Oak Ridge National Laboratory
OSC	Operational Support Center
PDRI	Personnel Decisions Research Institute
PMS	Performance Measurement System
PORC	Plant Operations Review Committee
PRA	Probabilistic Risk Analysis
PSF	Performance Shaping Factor
PTRB	Procedures and Test Review Branch
PWR	Pressurized Water Reactor
RES	(Office of) Nuclear Regulatory Research
RO	Reactor Operator
SAT	Systems Approach to Training
SER	Safety Evaluation Report
SIG	Special Inquiry Group
SIMCERT	Simulator Certification
SME	Subject Matter Expert
SNL	Sandia National Laboratory
SPAR	Standards Project Authorization Request
SPDS	Safety Parameter Display System
SRG	Special Review Group (of the Office of Inspection and Enforcement)
SRP	Standard Review Plan
SRO	Senior Reactor Operator
SS	Shift Supervisor
STA	Shift Technical Advisor
TAG	Technical Advisory Group

TEA	Training Effectiveness Analysis
TIM	Task Identification Matrix
TSC	Technical Support Center
TMI-2	Three Mile Island, Unit Two
TVA	Tennessee Valley Authority
USAF	United States Air Force

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16. ABSTRACT (200 words or less)

This comprehensive long range human factors plan for nuclear reactor regulations was developed by a Study Group of the Human Factors Society, Inc. This Study Group was selected by the Society to provide a balanced, experienced human factors perspective to the application of human factors scientific and engineering knowledge to nuclear power generation.

The report is presented in three volumes. Volume 1 contains an Executive Summary of the 18-month effort and its conclusions. Volume 2 summarizes all known nuclear human factors activity, evaluating this activity, wherever adequate information is available, and describes the recommended long-range (10-year) plan for human factors in regulation. Volume 3 elaborates upon each of the human factors issues and areas of concern that have lead to recommendations in the long range plan.

17. KEY WORDS AND DOCUMENT ANALYSIS — 17a. DESCRIPTORS

Human factors engineering	Training device
Human engineering	Human feasibility
Procedures	System integration
Job performance aids	System engineering
Personnel selection	Annunciators/alarms
Staffing	Maintainability
Training	Operator licensing

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