TECHNICAL PROPOSAL FOR DEVELOPMENT OF A COMPREHENSIVE HUMAN FACTORS PLAN FOR NUCLEAR REACTOR REGULATION (REVISED)

Response to Request for Proposal No. RS-RES-80-227

Submitted by

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FOREWORD

RESOLUTION:

As a public service of the human factors profession, and consistent with stated purposes of the Human Factors Society "to promote and advance . . . understanding of the human factors involved in the design, manufacture 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).

Passed by the Executive Council
12 October 1980

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1. FOREWORD

The Human Factors Society, Incorporated (HFS), a non-profit, interdisciplinary organization of professional people involved in the human factors field, proposes to develop, for the Nuclear Regulatory Commission (NRC), a comprehensive human factors plan for nuclear reactor regulation. The plan should become an essential part of the basis for determining the human factors efforts that need to be addressed over the next five to ten years.

This technical proposal sets forth our approach for the development of the comprehensive human factors plan, the organization of the human factors Study Group, the qualifications of the key personnel in the Study Group, the personnel budget, and the proposed schedule.

2. BACKGROUND

The neglect of human factors principles, procedures, and standards has been widespread in the design and operation of nuclear power plants. In 1975, the Reactor Safety Study, WASH 1400 (7) reported,

> 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.

Later, a 16-month human factors review of five representative nuclear power plant control rooms was performed for the Electric Power Research Institute by the Lockheed Missiles and Space Company. The results of this review (1), published in 1976,

> 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.

The experience with the Three Mile Island Two accident in March, 1979, and the results of the investigations and reviews subsequent to the accident--notably the reports of the President's Commission (4) and the Report to the Commissioners and to the public by the NRC Special Inquiry Group (5)--have emphasized that inadequate attention has been devoted to human factors in the broad areas of man-machine interface design, personnel qualifications and training, and operational procedures. Of the 13 final recommendations of the TMI-2 Lessons Learned Task Force (2), the first 7, and 9 of the 13, are directed at human factors problems.

The Nuclear Regulatory Commission has initiated a variety of actions to rectify some of the more significant deficiencies that have been identified in human factors areas. In addition to these current activities, a comprehensive long-range human factors plan is required to insure the most efficient and cost-effective incorporation of human factors considerations in all the necessary aspects of nuclear reactor regulation.

3. OBJECTIVE

The objective of the proposed study is to develop a comprehensive human factors plan for the next 10 years that will meet the diverse requirements for human factors considerations imposed by the different regulatory functions and responsibilities of the various NRC Program Offices. The plan will identify needed programs throughout NRC, but will focus on those areas concerned with commercial nuclear power plant safety. Nuclear fuel cycle activities, such as mining, transportation, and waste disposal, will not be considered. The plan will provide estimates of priorities and schedules for accomplishment and the resources required. The plan will also include recommendations for the collection of specific types of human factors operational data and for their analyses and dissemination to the appropriate activities within NRC.

4. APPROACH

A key element in our approach to the development of a comprehensive human factors plan for nuclear reactor regulation is the organization and composition of our Study Group. The nucleus of the Study Group consists of seven persons: a Project Manager, a Technical Director, an Agency Liaison Technical Officer (ALTO), and four others to head four subgroups representing major human factors areas that are significant for nuclear reactor regulation. These are headed by human factors professionals who are widely recognized for their competence in these special areas. The areas represented by the subgroups are human engineering, training and training devices, manpower and personnel, and procedures and operator aids. Some representative specific human factors concerns within these areas are shown in Table 1. A concern for human performance standards is common to all four areas.

It should be evident that evaluation of the specific concerns identified in Table 1 imply also consideration of the underlying behavioral aspects of operator performance. Rather than break them out separately, we have left them implicit. As examples, the patterns and modes of human operator decision-making behavior have design, training, and procedures implications, and the characteristics of limited human memory capacity also impinge upon system and equipment design, training, and procedures development.

TABLE 1

Representative Human Factors Concerns for Each Study Subgroup

Human Factors Study Subgroup	Representative Specific Human Factors Concerns
HUMAN ENGINEERING	Human factors systems analyses and evaluation Assignment of functions Design of displays and controls Design for maintainability Workplace design Man-machine system test and evaluation Human performance standards
TRAINING AND TRAINING DEVICES	Training and proficiency assessment requirements Training system development Training equipment requirements Simulation requirements Design characteristics Use in training programs Human performance standards
MANPOWER AND PERSONNEL	Operator teaming and coordination Personnel qualifications Operator selection Human reliability Control room staffing Work scheduling Human performance standards
PROCEDURES AND OPERATOR AIDS	Procedures development and analyses Operator and maintenance performance aids Computer-based aids to human performance Trouble shooting logic and system diagnostics Human performance standards

The nucleus of that Study Group will therefore consist of the seven people just identified. It is anticipated that these seven will be responsible for performance of Task A, Survey of NRC Program Offices, and other professionals will be brought in to supplement the four major technical subgroup areas as required in Tasks B and C. Over 80 qualified human factors professionals have expressed an interest in participating in this function, and they will be selectively used, depending on the topical area and the expertise of each individual.

The four technical subgroup areas should not, however, be considered as independent or isolated, but rather as key elements in an overall systems engineering context. Each of these areas contributes substantially to system planning and design, having direct impact on such system characteristics as architectural design, overall control room design, communication subsystems, and security and sabotage control.

We recognize that certain elements within the four major human factors areas impact the functions and responsibilities of several--and, in some cases, all--of the NRC Program Offices. Therefore, we believe that the usefulness and value of the comprehensive human factors plan we develop, as well as the efficiency with which we develop it, is enhanced by planning, organizing, and executing the Study Group's work in the context of a conceptual matrix in which the rows are defined by the five Program Offices of NRC and the col-

umns defined by the four major areas represented in the Study Group (Table 2).

This approach insures that each of our subgroups responsible for a major human factors technical area is cognizant of and responsive to the peculiar requirements for specialized human factors applications of each of the NRC Program Offices. The development of the human factors plan consists of the following three major tasks.

4.1 TASK A, SURVEY OF NRC PROGRAM OFFICES

During the first phase (Task A), we will determine the aspects of nuclear power plant safety that are impacted by or have an impact upon human factors issues and describe the nature of these impacts. This is 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 will also include the organization and staffing of the Offices.

Immediately after receipt of approval from NRC to start work on the project, key personnel will meet with the NRC Project Officer to plan and coordinate activities necessary for Task A. These activities include meetings with appropriate personnel in each of the Program Offices and arrangements to facilitate access to reports and documents relevant to the Study Group's survey requirements.

TABLE 2

Likely Minimum Intersection Points between Program Office Functions and Responsibilities and Broad Human Factors Area

	Human Factors Study Subgroups			
NRC Program Offices	Human Engineering	Training and Training Devices	Manpower and Personnel	Procedures and Operator Aids
Nuclear Reactor Regulation	HF Systems Analyses Design of Displays & Controls Design for Maintainability		Human Reliability Control Room Staffing Work Scheduling	Procedures Development Operator Performance Aids Computer-Based Aids Trouble-Shooting Logic
Nuclear Material Safety and Safeguards	HF Systems Analyses	Training & Proficiency Assessment	Human Reliability	Operator and Maintenance Performance Aids
Nuclear Regulatory Research	Man-machine Interface	Simulation Requirements Training Requirements		Computer-Based Aids Trouble-Shooting Logic System Diagnostics
Standards Development	Human Performance Standards	Human Performance Standards	Human Performance Standards Human Reliability Control Room Staffing	Human Performance Standards

Inspection and Enforcement	Man-machine System Test & Evaluation	Training & Proficiency Assessment Training System Development Training Equipment Requirements Simulation Requirements	Personnel Qualifications Operator Selection Control Room Staffing Work Scheduling	Operator Performance Aids Computer-Based Aids

The formally defined functions and responsibilities of the NRC and the various Program Offices in the licensing and regulatory processes are a starting point. But we shall develop an effective comprehensive plan for human factors only by learning, understanding, and taking into consideration the detailed requirements and problems of the various Program Offices in the execution of their functions and responsibilities, and by determining how they impact specific human factors areas (Table 3).

Although some members of our Study Group are knowledgeable in the general area of nuclear power generation, we make no claims as a group, at the outset, to expertise in the details of the process of licensing and regulation of nuclear reactors. What we do provide at the outset is a Study Group of highly qualified human factors personnel representing major areas of specialization who have successfully used human factors analyses, principles, and proce-

TABLE 3. Potential Impacts Between NRC Activities and Specific Human Factors Areas

KEY: L = Likely P = Possible blank = to be determined	Representative NRC Activities Involving Human Factors Considerations								
Specific Human Factors Areas:	Design	Standards Development	License Qualifications	Research	Construction	Operation	Inspection	Safety Review	Training
HF Systems Analyses & Evaluation	L	L	P		P	L	L	L	L
Assignment of Man-Machine Functions	L		P	L		P			L
Display and Control Design	L	L		P				P	L
Workplace Design	L	L				L		L	L
Man-Machine System Test and Evaluation	L				L				
Human Performance Standards	L	L	L			L	L	L	L
Training and Proficiency Assessment Requirements		L	L			L	L	L	L
Training System Development	L			P		P			L
Training Equipment Requirements	L			L			L		L
Simulation Requirements a) Design Characteristics	L	P		L		L			L
b) Use in Training Prgms.				P			L	L	L
Personnel Qualifications		P	L			L	L		
Operator Selection			L			L			
Human Reliability	L	L				L		L	L
Control Room Staffing						L			L
Work Scheduling						L		P	
Procedures Devel. & Anal.		L				L	L	L	L
Oper. & Maint. Perf. Aids	L	L		L		L		P	L
Computer-Based Aids to Human Performance				L		L		P	L
Trouble Shooting, Logic & System Diagnostics	P	P		P					

dures in a wide variety of man-machine systems to improve safety and efficiency of operation. We strongly believe this expertise can be applied to the nuclear power generation area to result in the development of plans to insure greater safety and performance.

As a part of a general orientation and familiarization process, very early in the survey phase, key personnel of the Study Group will take an NRC nuclear power training course, such as the boiling water reactor fundamentals course presented by the Office of Inspection and Enforcement. In addition, other training or indoctrination materials, training courses, and information available from the industry will be reviewed by key personnel of the study group. For example, informal contacts with General Electric, Westinghouse, and Babcock and Wilcox have assured us that they will provide us with materials describing the Nuclear Steam Supply Systems which they manufacture. Study Group personnel will also take a simulator training course for control room operators. All key personnel of the Study Group will need to spend some time in nuclear power plant control rooms to become familiar with and to assess current operational environments, activities, and procedures.

During the survey phase, the Study Group key members will spend considerable time on-site at the facilities of the Nuclear Regulatory Commission in the Washington, D. C. area, to interact with representatives from the five Program

offices. The group will document, collate, and evaluate its findings from these surveys. These will be integrated to form a preliminary account of problem areas, specific problems, requirements, and priorities--really a working document--to be checked against the realities of the nuclear power generating industry during the next phase.

At the completion of Task A, a briefing will be made to the NRC by the Study Group nucleus and an informal report will be submitted summarizing the findings and recommendations.

4.2 TASK B, SELECTIVE CHECK WITH NUCLEAR INDUSTRY

The findings of Task A will be expanded as necessary and refined to insure completeness and accuracy as we check selectively with representative elements of the nuclear industry. Sectors of the industry involved in this task include at least utilities, architect-engineers, nuclear steam system suppliers, the Electric Power Research Institute, and the Institute of Nuclear Power Operations.

Finally, as a part of this task we will interact with representatives of other professional organizations, such as the American Nuclear Society and the IEEE, who have functional working groups concerned with human factors and the nuclear industry.

Task B will culminate in the preparation of a Tasks A and B report reflecting modifications and refinements resulting

from the checking of the findings of Task A against relevant factors determined by our interaction with the various elements of the nuclear industry. We will also present a briefing to NRC at the completion of this task.

4.3 TASK C, EVALUATE CURRENT ACTIVITIES AND RECOMMEND COURSES OF ACTION

We will evaluate current activities and programs for each of the regulatory functions identified as having human factors involvement. We anticipate that at least some of the regulatory responsibilities of each of the NRC Program Offices will include requirements for attention to human factors. In light of our evaluation of what is being done and our previous determination of what needs to be done, we will recommend courses of action that need to be taken to insure nuclear power plant safety. If additional study or research is needed, we will make recommendations regarding the problems to be addressed and suggested approaches.

Our recommendations for courses of action will take the form of a plan to cover the next ten years. The plan will provide estimates of priorities, schedules, and resources required. In addition to the final report, which is a comprehensive plan for human factors, we will present a briefing to the NRC staff at the conclusion of our work.

5. PROJECT ORGANIZATION

5.1 HUMAN FACTORS STUDY GROUP

The nucleus of the Study Group consists of a Project Manager, a Technical Director, an Agency Liaison Technical Officer (ALTO), and four heads of major human factors study areas. Resumes for the seven persons to serve in these roles are in Appendix A of this proposal.

Dr. Harry L. Snyder will be the Project Manager. He will be the point of contact between the HFS Study Group and the NRC for contractual and business management matters. Dr. Snyder is the immediate Past President of the Human Factors Society and is one of a small group of people who provided liaison between the HFS and the NRC during the past year. He is Professor of Industrial Engineering and Operations Research, Virginia Polytechnic Institute and State University.

Mr. Harold E. (Smoke) Price will be the Agency Liaison Technical Officer for the Study Group. Mr. Price is a Fellow and member of the Executive Council of the HFS and, along with Dr. Snyder, is a member of the ad hoc committee which has maintained liaison between the HFS and the NRC previously. By virtue of his work with the Nuclear Regulatory Commission and his location in the Washington, D. C. area, Mr. Price is a direct and convenient point of contact for technical and administrative matters between the NRC and the HFS Study Group. He is Executive Vice President of Bio-Technology, Inc.

Dr. Charles O. Hopkins will be the Technical Director of the Study Group. He will be responsible for all scientific and technical activities, technical reporting, and planning and coordinating the work of the subgroups of specialists in major human factors technical areas leading to the development of the human factors plan for nuclear reactor regulation. Dr. Hopkins is a Past President of the HFS. He is Professor of Psychology and of Aeronautics and Astronautical Engineering, University of Illinois.

The heads of the subgroups will be Dr. Richard J. Hornick, Human Engineering; Dr. Robert C. Sugarman, Training and Training Equipment; Dr. Robert R. Mackie, Manpower and Personnel; and Dr. Robert J. Smillie, Procedures and Operator Aids.

Dr. Hornick has served as Secretary-Treasurer, member of the Executive Council, member of the Publications Board, and Editor of the Bulletin of the Human Factors Society. He is Human Factors Head, Ground Systems Division, Hughes Aircraft Company.

Dr. Sugarman is Chairman of the Technical Training Group of the Human Factors Society. He is also Chairman of the Training Operations Subcommittee of the National Security Industrial Association, and a member of the Education and Training Committee of the Society of Engineering Psychologists. A registered professional engineer, Dr. Sugarman is Director, Human Factors and Training Center, Calspan Corporation.

Dr. Robert R. Mackie is a Fellow of the Human Factors Society, and is President of Human Factors Research, Inc. For two decades, he has been a leader in many areas of human factors applications to systems design.

Dr. Robert J. Smillie is a member of HFS. He is a Research Psychologist, Performance Enhancement, U.S. Navy Personnel Research and Development Center. He is recognized widely as an expert in procedural problems of complex systems, and in the generation of job aids to improve system performance and safety.

It is important to note that all of the key members of the Study Group just identified, by virtue of their education and experience, have extensive experience in working with engineering personnel and major complex systems in military, aerospace, and commercial industry.

The seven persons who constitute the nucleus of the Study Group, in addition to being among the most highly qualified and experienced persons in the various speciality areas of the human factors profession in the United States, represent a desirable and valuable combination of university, government/military, industry, and consulting firm backgrounds, as well as a balanced geographical distribution.

The organizational relationship between the HFS and this Study Group is illustrated in Figure 1. The management plan for this work is discussed in our separate Cost Proposal.

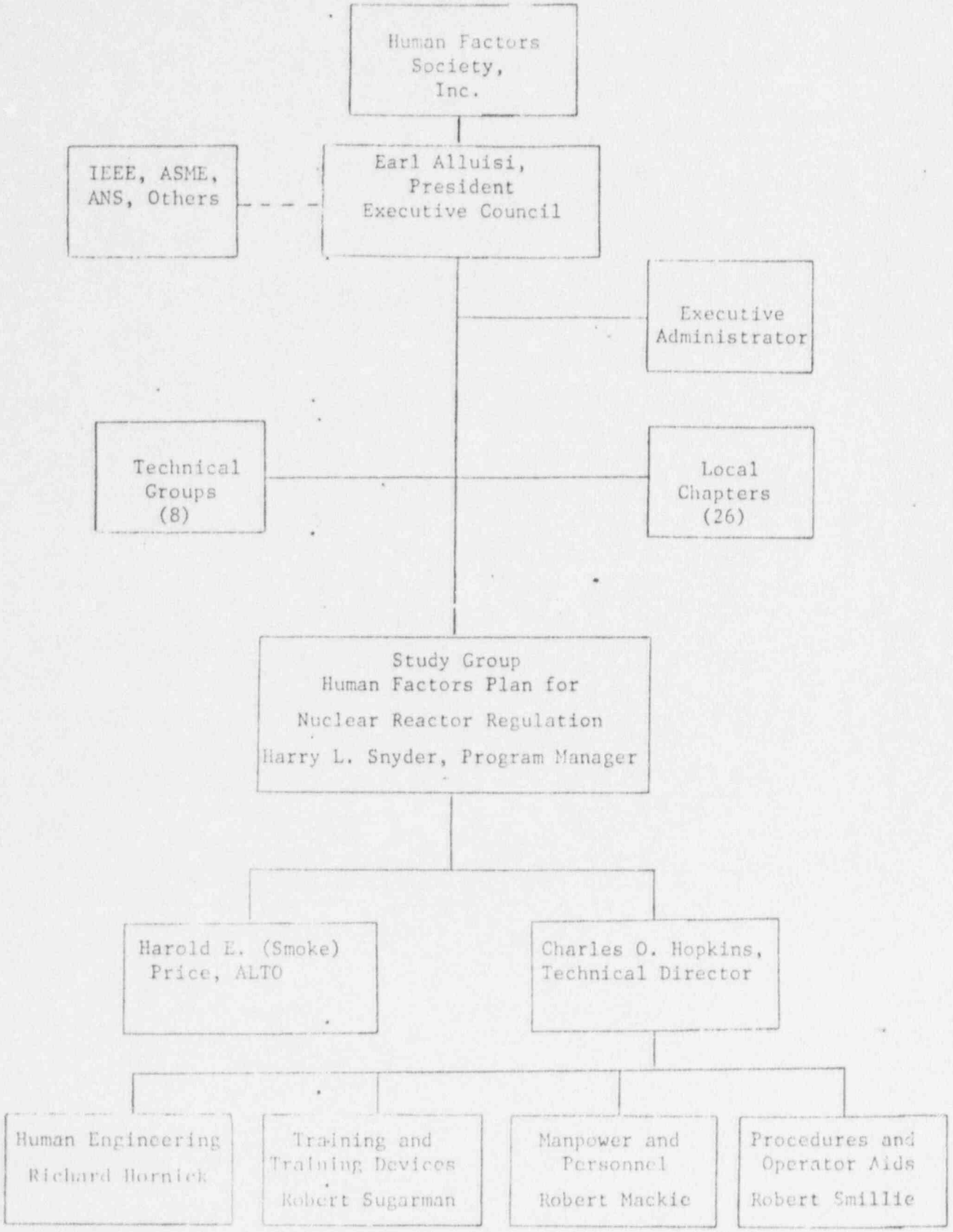

Figure 1. Project Organizational Structure

5.2 ADDITIONS TO STUDY GROUP

The above named individuals have been selected by the HFS to perform the work in Tasks A and B. While the HFS and this initial team recognize that additional personnel, having perhaps other areas of expertise, will be required for this effort, it is presumptuous at this time to identify those areas and qualified individuals. Rather, the following approach has been selected to complete the professional staffing requirements.

Our earlier announcement of this possible effort led to receipt of over 90 letters of interest and related resumes, from which the above named individuals were selected. Many of the respondents have acknowledged expertise in areas likely to be required for this intensive study. However, the final selection of other professionals to serve on this Study Group will be delayed until specific needs are identified by Dr. Hopkins and the subgroup team leaders. At that time, the best individuals with the most suitable credentials and knowledge will be added to the Study Group.

In this manner, we hope to provide the NRC with persons best suited for the task of the Study Group, yet with maximum efficiency and minimum cost through flexible staffing.

Complete resumes of the seven key individuals described above are attached as Appendix A.

5.3 PROPOSAL REVIEW COMMITTEE

This proposal for development of a comprehensive human factors plan for nuclear reactor regulation has been reviewed by the President of the Human Factors Society and by a Review Committee appointed by the President and approved by the Executive Council of the Human Factors Society. Members of the Review Committee are Dr. Alphonse Chapanis, Professor, The Johns Hopkins University; Dr. John J. O'Hare, Assistant Director, Engineering Psychology Programs, Office of Naval Research; and Dr. Richard W. Pew, Principal Scientist, Information Sciences Division, Bolt Beranek and Newman, Inc. Drs. Chapanis and O'Hare currently are serving as Members of the Executive Council of the HFS and Drs. Pew and Chapanis are Past Presidents of the HFS.

6. LABOR BUDGET

The following man-hours of effort are planned for this work. The hours are considered to be accurate for the named Study Group personnel, and estimated for unnamed Study Group personnel and supporting personnel.

TABLE 4

Labor Budget (Man-hours) for Each Task

	Task A	Task B	Task C
Program Manager (H. L. Snyder)	392	312	360
Technical Director (C. O. Hopkins)	480	416	568
ALTO (H. B. Price)	120	136	112
Subgroup Leaders:			
Human Engineering (R. J. Hornick)	384	240	312
Training (F. C. Sugarman)	368	224	312
Personnel (R. R. Mackie)	384	224	312
Procedures (R. J. Smillie)	384	240	312
Others, to be determined	0	0	864
Business, Accounting	131	96	112
Secretarial/Clerical	624	624	780
Subtotals	3,267	2,512	4,044

GRAND TOTAL: 9,823 man-hours

7. PROPOSED PROJECT SCHEDULE AND PROGRAM PLAN

7.1 PROGRAM PLAN AND SCHEDULE

Previous parts of this Technical Proposal have described the plans and rationale for activities during Tasks A, B, and C. The Program Plan elements are as follows. Each task will last four (4) months, with the final report due at the end of the thirteenth (13th) month.

7.1.1 Task A, Survey of NRC Program Offices

1. Meet with NRC Program Office directors or their designated representatives to discuss the overall program and to obtain information on Office responsibilities.

2. Review all available reports and documents having current or potential human factors related content.

3. Attend one or more courses to become familiar with nuclear reactor designs and operations.

4. Visit a nuclear plant to become familiar with problems, operations, and variations.

5. Prepare letter report briefing describing the aspects of nuclear power plant safety that are impacted by or have an impact upon human factors.

7.1.2 Task B, Selective Check with Nuclear Industry

1. Schedule and hold meetings (1) to determine ongoing or planned technological developments and human factors activities, and (2) to check on the accuracy and completeness of the findings of Task A. These meetings shall be held with utility representatives, nuclear steam suppliers, and various professional/research/safety organizations.

2. Modify Task A findings, as necessary, based upon information received in this selective check.

3. Prepare report and briefing summarizing results of Task B.

7.1.3 Task C, Evaluate Current Activities and Recommend Courses of Action

1. Review all current and planned human factors related activities of NRC, its contractors, and related organizations.

2. Define additional human factors activities needed to improve nuclear power plant safety, and logical actions required to implement and support those activities. Define priority, scope, urgency, and estimated resources required for each activity.

3. Based upon the results of this Task and other data generated in previous Tasks, prepare a 10-year human factors plan for reactor regulation. This plan will include time-phased recommendations, other rejected recommendations, and supporting data.

4. Prepare final report and briefing covering all Tasks and containing recommendations and results in (3) above.

7.2 TRAVEL REQUIREMENTS

A critical part of this effort is the collection of information regarding (1) the design and operation of nuclear power facilities, and (2) the activities, responsibilities, and plans of the NRC and related industries and organizations. For this reason, travel is anticipated to gather this variety of information, and to facilitate the need for the Study Group to evaluate and analyze the information.

Anticipated travel requirements are summarized, by Task, in the Cost Proposal. The rationale for these trips is discussed below.

7.2.1 Task A

Required travel during the performance of Task A consists primarily of trips to the Washington, D. C. area. The purposes of these trips are for project management; technical direction coordination; familiarization and survey of human factors impacts on the licensing and regulatory processes of the various NRC program offices; and Study Group members attendance at reactor fundamentals training courses.

Additional trips have been planned for Study Group members to attend a training course in the Chattanooga, TN area.

We will schedule one of our trips to the NRC in the Washington, D. C. area to coincide with the Midyear Meeting of the Human Factors Society Executive Council for the purpose of reporting to that body our status on this project.

7.2.2 Task B

During the performance of Task B, there will be fewer trips to the Washington, D. C. area, although some trips have been planned for project management, technical direction coordination, and special consultation between Study Group members and the staffs of the NRC Project Offices.

For purposes of estimating travel costs, we have selected certain representatives of utilities, architect-engineers, and nuclear steam systems suppliers for visits. The actual representatives of the nuclear industry with whom we will

check on our Task A results will be determined later after consultation with the NRC Project Officer.

We have planned to visit Bechtel in San Francisco, most likely in conjunction with a trip to visit the Electric Power Research Institute (EPRI) and General Electric in Palo Alto, and Lockheed Missile and Space Company in Sunnyvale.

Nuclear steam power suppliers we expect to check with include Westinghouse in Pittsburgh, Babcock and Wilcox in Lynchburg, VA, and Combustion Engineering in Windsor, CT.

7.2.3 Task C

As during Task A, the preponderance of travel during Task C will be to the Washington, D. C. area for project management, technical direction for coordination, and evaluation of current NRC programs. Interspersed with the Washington, D. C. trips will be one trip to Champaign for the purpose of coordinating, preparing, reviewing, and editing the final report.

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