UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JAN 3 1 1984

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Robert B. Minogue, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO. 138, "NUCLEAR POWER PLANT CONTROL ROOM CREW TASK ANALYSIS"

Reference (1) Memorandum, "Users Request for Initiation of a New Program: Task Analysis of Control Room Operating Crew" (NRR-80-7), December 8, 1980.

(2) Memorandum, "Request for Endorsement of Task Analysis Program" (NRR-81-7), March 17, 1981.

(3) Request for Proposed No. RS-RES-81-204, "Task Analysis of Nuclear Power Plant Control Room Crews," May 20, 1981.

(4) Memorandum, "Research to Satisfy NRR Research Needs for Human Factors Safety" (RR-NRR-81-2 and RR-NRR-81-5), January 4, 1982.

(5) "Task Analysis of Nuclear Power Plant Control Room Crews," Vol. 1, Project Approach and Methodology, Vol. 2, Data Results, NUREG/CR-3371, September 1983.

This memorandum transmits the results of a completed research task defining the proper human actions and responses by nuclear power plant control room crews during normal, off-normal, and accident conditions in the form of a task analysis. This research is fully responsive to your User Request of December 8, 1980 (Reference 1) to perform control room crew task analysis. A task analysis is a process of describing the units of human action necessary to accomplish system functions and the resources necessary for successful performance of each unit of action. A task analysis provides a quantitative description of the behavior patterns of operators when interfacing with procedures, training, control room hardware, management, etc., particularly under off-normal conditions.

This research was conducted as part of the Man-Machine Systems Program under the direction of the Human Factors and Safeguards Branch, Division of Facility Operations. The objective of the research program was to prepare a task analysis of the control room operating crews to provide data to NRR and other users of the data for subsequent evaluation of: (1) human engineering designs of control rooms, (2) the numbers and types of control room operators required with requisite skills and knowledge, (3) operator qualification and training requirements, (4) normal, off-normal, and emergency operating procedures, (5) job performance aids, and (6) communciations.

The proposed information is directly related to NRC Human Factors Program Plan (NUREG-0985).

The research was performed by General Physics Corporation (GPC) and their subcontractor, Bio Technology Inc. The task analysis project began with the issue of a Users Request (Reference 1) in December 1980 and was completed with the delivery of the final report (Reference 5) in September 1983.

The research requirements for the task analysis were described first in Reference 1 which was a Users Request to RES to obtain detailed task analysis information on control room operating crews during transient and accident conditions. The results of the task analysis research (data collection, storage and retrieval methods) were intended to provide NRR and other users with information to accurately and quantitatively define the role of the reactor operating crew and the various influences which tend to support or hinder their performance.

Reference (2) is the RES response to Reference (1) and was a request for endorsement of a task analysis research program. A pilot task analysis of selected sequences for a PWR was proposed by RES to establish a technical basis for proofing data collection methods, accessing accident sequences, and evaluating data reduction methods based on the research requirements contained in Reference 2. The principal data collection task would encompass both PWR and BWR NSSS vendor plants with significantly different control room vintages. The pilot program began in April 1981, was completed in October 1981, and was documented by "Nuclear Power Plant Control Room Task Analysis: Pilot Study for Pressurized Water Reactors," NUREG/CR-2598.

The principal task analysis research effort was procured through the competitive procurement process (Reference 3) and the contract was awarded to General Physics Corporation on December 5, 1981 with the final report due in 12 to 18 months. The task analysis program had the following special characteristics: (1) data collection will be done in a field environment, (2) the control room crew will be observed responding to plant events, (3) the focus of the project is the NPP control room, (4) control room crew members will be sampled across their range, and (5) a dynamic computerized data base will be developed.

Another characteristic of the task analysis research project was close information exchange and coordination with the Institute of Nuclear Power Operations (INPO) (Reference 4). First, the task analysis data base had to be compatible with the INPO job analysis data base; second, INPO would be furnished a copy of the final computerized data base for use on their PRIME computer; and third, NRC would have terminal access to the INPO job analysis data base.

The goals and requirements established in References 1-4 were accomplished by the task analysis research project and the significant results are documented in the Final Report, Reference 5, and can be summarized as follows:

1. A detailed program plan to collect data from eight cooperative nuclear power plants was developed by GPC as an initial step in the

program. The plan was reviewed by INPO, EPRI and within the NRC, and was approved before data collection began. The plan provided the detailed blueprint for all subsequent activities.

2. A methodology for the conduct of the task analysis data was developed in the form of a conceptual framework that related the control room crew's operational tasks and job functions to safe plant operations. A taxonomic (function based) structure was utilized to link operational functions (i.e., the human system) with plant functions (i.e., the machine system) for various events (i.e., the operating sequences) and is illustrated as:

Function	Sub-functions
· Supervise and Control Operations	- Generate power - Restore plant to a safe condition - Mitigate consequences of an accident
· Maintain Plant Systems & Equipment	- Test equipment - Implement maintenance - Improve maintenance
· Coordinate Plant Support Activities	- Fire protection - Plant Security - Administration

The taxonomy provided the basis for establishing system engineering functions, operating sequences which are a collection of system interactions required to implement a specific subfunction, and operator tasks which describe the units of operator and crew inputs, processing, and outputs necessary for successful performance for each element in the sequence.

3. A standard vocabulary of behavioral terms was developed which described all human processes, activities, and behaviors the operator engages in during the performance of a task. The standardized definitions of the many types of human perceptual, cognitive, motor, and communication processes provided a degree of consistency and reliability not available heretofore for describing and documenting operator actions in a control room.

4. Twenty-four operating sequences covering a broad range of normal, off-normal and accident situations were selected for the task analysis. These were based on the above taxonomy, recommendations contained in NUREG-0700, "Guidelines for Control Room Design Reviews," prior analyses performed under the Severe Accident Sequences Analysis Program, probabilistic risk assessments, Regulatory Guide 1.70, Chapter 15 (FSAR), the requirements in the RFPC (Reference 3), and expert opinion.

A description of each operating sequence is documented in Volume 2, Reference 5. The accuracy and completeness of each scenario are a consequence of the following factors: first, the adequacy of the simulator's software to emulate and present the range, rate of change, and special characteristics of the physical parameters and system variables which could be expected to occur in an individual sequence; second, the adequacy of the plant's procedures to be followed for an individual scenario; and third, the validity of the assumptions which underlay the above factors. For example, the scenario for a steam generator tube rupture may be a simplified replication of an actual event. However, the scenario is intended to elicit the crew responses typically occurring in a response to a tube rupture and to validly portray the system's initiating events and their subsequent states as a consequence of the crew's control selections. The accuracy and completeness of each scenario must be judged against these criteria. The sequences which were selected required significant participation by the control room crew in a variety of plant conditions. The plant conditions and operating sequences selected and investigated for each NSSS vendor are given in Figure 1.

5. Task analysis data was collected from eight nuclear power plants with licensed operators using seven NPP training simulators, one NPP control room, and one NPP control room mockup. The plants were sampled according to NSSS vendor, vintage, simulator availability, architect-engineer, and control room configuration. Two plants from each of the four NSSS vendors were selected. Summary statistics of the data collection effort reveal that 45 operational sequences were simulated, which required 1,062 tasks having 15,378 elements (a single action performed by a single control room crew member that contributes to the accomplishment of a task; see also the Glossary, Volume 1, Reference 5). This data is the basis for the computerized data base (cf P. XV, Volume 1)

6. Demonstration examples were provided to illustrate how the data base can be used to analyze problems and to answer questions of the type that could arise in the review of NPP control room operations. A specific example included: the hypothetical problem's definition; the NRC analytical information needs; the description of potential information sources in the NRC task data base, INPO job data base or by supplementary data; the identification of data manipulations; the formulation of data search strategy; the implementation of the search strategy; the display of desired data; and, the comparison of results with the original problem definition. A demonstration example for each of the six topical areas of control room emphasis (human engineering designs, staffing, crew qualifications and training, procedures, job performance aids, and communications) was documented in Volume 1 (Reference 5).

7. The research program's approach and methodology was documented in Volume 1, and a detailed description of 24 operational sequences was provided in Volume 2 (Reference 5).

	NSSS VENDOR			
Operating Sequences	GE	W	CE	B&W
Generate Power				
1. Increase/Decrease Generator Output	x	x		
2. Change Boron Concentration			x	
3. Change Steam Supply to SJAE	x			
4. Startup From Hot Standby				x
5. Shutdown From Minimum Power		x		
Restore Plant to a Safe Condtion				
6. Nuclear Instrument Malfunction		x		
7. Loss of Condenser Vacuum			x	
8. Reactor Vessel Level Control System Malfunction	x			
9. High Pressurizer Level				x
Mitigate Consequences of an Accident				
10. Station Blackout	x			x
11. Anticipated Transient Without Scram	x			
12. Chemical & Volume Control System Malfunction			x	
13. Tube Ruptures - Steam Generators		x		x
15. Loss-of-Coolant Accident		x	x	
Test Equipment				
16. Diesel Generator Start, Load, & Run		x		
17. MSIV Closure Exercise	x			
18. Auxiliary Feedwater Pump Operability				x
Implement Maintenance				
19. Maintain Auxiliary Feedwater Pump		x	x	
20. Maintain Emergency Bus Tie-Breaker	x			
26. Maintain Reactor Coolant Pump Bus Protection Supply Breaker				x
Improve Equipment				
21. Change SRM Chart Recorder Paper	x	x		
Plant Security				
23. Bomb Threat	x		x	
Administration - Radiological Emergency				
24. High Radiation Effluent	x		x	
25. Radwaste Discharge		x		x

Figure 1. Operating sequences selected for each power plant NSSS vendor.

8. The crew task analysis data base was organized and entered onto a magnetic tape for computer processing. A software management system, called SEEK, supports the data input, modification, and output of the data on a real-time basis as well as access to the data for searching and analysis. A hardware system to store and retrieve the data base (in order to perform software system operations) and several terminal portal accesses at NRC and NRC contractors (national laboratories) for data base analysis has been provided.

9. Documentation of the software system and training of NRC and national laboratory personnel to allow analysis of the data base to meet regulatory and research information needs was developed. Training for 15 NRC and DOE national laboratory personnel was given in September 1983 and a draft Users Manual was available for student use and comment/critique. A final users manual will be published in January 1984 after NRR and RES comments are integrated into the text.

10. A cross reference to the INPO job analysis was provided to give the user a capability to relate the NRC task analysis data base to the INPO job analysis data base. This is documented within the data base structure.

In summary, this research program developed and applied a method for obtaining and documenting individual and crew tasks that must be performed in the control room to properly accomplish NPP system functions required by a variety of operational sequences. The data base developed in this program is a major resource to the NRC, INPO and other users for human factors evaluation of a wide range of issues about nuclear power plant control room operations. The data base provides data and data manipulation capabilities heretofore unavailable that will allow NRC regulators and researchers and the nuclear industry to define and resolve control room issues more systematically and with a greater degree of standardization and validity.

We recommend that these results be used:

1. to assist in reviews of the man-machine interfaces in control rooms and local control stations and analysis of their man-machine functions;

2. to assist in establishing minimum operator qualification requirements;

3. to assist in analyses of personnel training issues and guidance;

4. to assist in evaluation of procedure utilization, effectiveness, and requirements for normal, off-normal and accident sequences;

5. to provide a qualitative and quantitative definition of existing roles and functions of control room operator crews; and

6. to identify potential sources of serious human error in important accident sequences.

It is recognized that the existing data base can be improved by additional control room crew data collection for other transient and accident sequences, such as core melt, or special comparisons such as function based procedures vs. symptom based procedures. There is a need also to develop additional methodologies and approaches for refining our understanding of the many factors that affect crew performance, including keener insight into the adequacy of control room information displays, operator aids, and controls for crew utilization. At the same time, this research product can be used immediately to assist regulators and others in analysis of human factors problems and man-machine interfaces.

Robert B Minogue

Robert B. Minogue, Director
Office of Nuclear Regulatory Research

Enclosure: NUREG/CR-3371,
Vol. 1 and 2

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RES Files	
Subject File No.	R-2611.01 ~~R-2611.04~~
Task No.	
Research Request No.	NRR-80-7
FIN No.	B-7491
NUREG No.	NUREG/CR-3371
Docket No.	
Rulemaking No.	
Other	NRC PDR
Return NRC-318 to RES, Yes X No	

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Original signed by:
ROBERT B. MINOGUE

Robert B. Minogue, Director
Office of Nuclear Regulatory Research

Enclosure: NUREG/CR-3371,
Vol. 1 and 2

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