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Nuclear

3901 Castle
Hayne Rd

Wilmington, NC 28401

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LICENSING TOPICAL REPORT

ESBWR
TASK ANALYSIS

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1 Introduction

Human factor improvements are being made in plant hardware (e.g. in ergonomic layout), plant procedures, training and other areas to help prevent or mitigate human error. The objective for reducing human error is to simplify the information reaching the operating personnel and to enable control room personnel to have a clear understanding and control of the status of the plant. Task analysis has been employed as a technique to review operation and maintenance activities and to determine whether they can be improved by changing the information flow, the work, the instructions or the procedures. The input of experienced plant operators is sought to identify enhancements in information flow, operations and maintenance tasks.

In the ESBWR opportunities for human factor improvements in the MMIS layout and information flow structure can be enhanced through the use of digital computer systems. Digital systems have advanced capabilities for both monitoring and controlling plant functions. For example, they permit substitution of automated self-testing for manual testing. Such computer systems need to be carefully designed and installed to ensure that residual faults and design errors do not mask or prevent any required safety action..

The key issue for task analysis is to show how tasks allocated for human and shared can be performed. The initial task allocations are made in the allocation of functions (AOF). The subtasks that support the allocated functions are identified during the task analysis. For example, a function involving monitoring or control of the plant may require communication between the control room and operators out in the plant. Such communication can be by messengers, intercom, plant telephones or computers. These choices may have both safety and availability implications.

Task analysis can be applied during many phases of the design. All system designs tend to pass through similar phases: from the initial concept of the system, through its preliminary and then detailed design phases, to the system's construction, commissioning, and operation, and ultimately its decommissioning. This process is known as the "System Life Cycle," and any task analysis studies must occur within one or more of these stages.

1.1 Purpose

The purpose of this plan is to recommend methods and criteria for the performance of task analyses that are consistent with accepted HFE practices and principles for the ESBWR.

The purpose of the task analysis is to identify the specific tasks that are needed for function accomplishment, including related information, control and task-support requirements. Results are captured in the results summary reports and provided to the engineering disciplines to iterate the design as well as perform the HFE V&V activities.

The inputs to the Task Analysis include the results of the Allocation of Functions and the HFE developed risk-important human actions (HA). The functions allocated to plant personnel define their roles and responsibilities. Human actions (HAs) are defined to accomplish these functions. HAs can be further divided into tasks and subtasks. A task is a group of related activities that have a common objective or goal. Task analysis is the identification of requirements for accomplishing these tasks, i.e., for specifying the requirements for the displays, data processing, controls, and job support aids needed to accomplish tasks. As such, the results of task analysis are identified as inputs in many HFE activities; e.g., it forms the basis for:

- Staffing, qualifications, job design, and training
- HSIs, procedures, and training program design
- Task support verification criteria definition.

Figure 1 shows where this plan fits into the overall HSI Design Implementation Process.

1.2 Scope

In summary the scope of this task analysis includes operations and maintenance performed at the operator interface in the Main Control Room (MCR),the Remote Shutdown System (RSS), and other applicable MMISs. The analysis shall be directed to the full range of plant operating modes, including startup, normal operations, abnormal operations, transient conditions, low power, and shutdown conditions. The analysis shall also address personnel tasks during periods of maintenance of plant systems and equipment including the Human-System Interface (HSI) equipment. The initial task analysis (e.g., tabletop) does not address system maintenance. System maintenance requirements and procedures are prepared in later phases of the project. As the maintenance and surveillance procedures become available, they will be walked through with the applicable MCR operator interfaces. The details of the scope are described as follows includes:

(1) Task characterization for the important human tasks include:

- selection of representative and important tasks from the areas of operations, maintenance, test, inspection, and surveillance;
- addressing a full range of plant operating modes, including startup, normal operations, abnormal; emergency operations, transient conditions, and low-power and shutdown conditions;

- including HAs that have been found to affect plant risk by means of PRA importance.

- ESBWR employs extensive use of automated safety (passive) functions. EESBWR task analyses will consider all human tasks including monitoring amd maintenance of the automated system and execution of backup actions if the system fails.

(2) Tasks are linked using operational sequence diagrams.

(3) The task analysis is iterative and becomes progressively more detailed over the design cycle. It identifies information and control requirements to enable specification of detailed requirements for alarms, displays, data processing, and controls for human task accomplishment.

(4) The task analysis addresses issues such as:

- the number of crew members
- crew member skills
- allocation of monitoring and control tasks to the (a) formation of a meaningful job and
- management of crew member's physical and cognitive workload.

The task analysis results will be used to define a minimum inventory of alarms, displays, and controls necessary to perform crew tasks based on both task and instrumentation and control requirements.

The task analysis results will provide input to the design of HSIs, procedures, and personnel training programs.

The Task Analysis activity will result in the explicit identification of the individual tasks, mental and physical, necessary to support the functions allocated to the plant operator. Human tasks will be subjected to interactive analysis and validation through techniques such as walk-throughs in control room mockups, dynamic modeling and simulation, and use of a full-scope plant simulator (post DCD).

The communications requirements for operators will be included in the task analyses and the needed communications equipment will be integrated into applicable facilities
.

Local control stations will be considered in the task analyses and will be consistent with the integrated design of the MMIS. The design of local control stations will include interaction with suppliers as necessary to ensure that specific HFE requirements are passed to suppliers via engineering specifications and use of standards. Likewise, the HFE team will verify that the local station design meets the HFE requirements established in the HFE documentation for MMISs.

This task analysis will be performed in accordance with the Plan and those tasks that will be performed at Local Control stations as identified in the analysis. The availability and arrangement of indicators, displays and controls; and lighting, access, communications, and special equipment needs of the operator will be considered during the design by analysis of the functions and tasks of the station.

1.3 Methodology Background

This Task Analysis Implementation Plan recommends methodology for performing task analysis during the design stage for human actions associated with the MCR, RSD, and other applicable MMISs. It is important to note that task analysis methods can be undertaken at any stage in the life cycle of a system or plant. Task analysis techniques can be applied effectively during the design stages (before the plant becomes operational). However, the level of detail of the task analysis is dependent on the availability of design information and its accuracy (i.e., trial design).

1. Task analyses will consider all functions allocated to the plant operator in the Allocation of Functions through use of a Function/Task Analysis cross-reference matrix or similar means;

2. The methods and criteria recommended for conducting task analyses are in accordance with accepted human factors practices and principles;

3. The scope of the task analyses will include operations performed at the operator interface at the MCR and at the Remote Shutdown Display (RSD). The task analyses will be directed to the full range of plant operating modes, including startup, normal operations, abnormal and emergency operations, transient conditions, low power and shutdown conditions. The task analysis will identify the need for information, controls and alarms. The task analyses will also address operator interface operations during periods of maintenance and test of plant systems and equipment, including MMIS equipment;

4. The task analysis will support identification and evaluation of tasks that are important to safety through interactions with the HRA/PRA task;

5. The task analysis will develop narrative descriptions of the personnel activities required for successful completion of the task;

6. The task analysis will identify requirements for alarms, displays, data processing, and controls to enhance reliability of the function, and

7. That task analysis results will be made available as input to the procedures and personnel training development personnel training programs.

Preliminary, interim and results summary reports from the task analysis will be design input to the HRA analysis and changes from the Reference ABWR identified to the systems engineering process. Task Analysis results requiring HSI design changes from the Reference ABWR will be iterated on as described in the HFE V&V Plan.

In the case of the ESBWR design, which builds directly upon the ABWR, a considerable number of interactions between design features and human tasks have already been accomplished. As the design matures, changes identified as desirable during the later stages of task analysis may become more expensive to implement. Consequently, the earlier task analysis is applied in the system design cycle, the more cost-effective the process is likely to be. If task analysis is performed early in the design process, it is also possible to establish a two-way flow of information, with knowledge about human requirements and limitations feeding into the design process, and the design preferences and constraints feeding into the task analysis. This can avoid the situation in which equipment design dictates personnel requirements, which may lead to sub-optimal systems and even make necessary retrofit design solutions later on in the system life cycle.

The timing of task analysis is thus a critical determinant of the usefulness of its results, especially if it is being used to assist optimization and enhancement of the HSI design. If task analysis is undertaken at the initial conceptual phase of a system, there is an opportunity to address human factors issues in a cost-effective manner. However, task analysis is not a "one-step" process; instead it usually requires one or more iterations as more detailed information about the system becomes established and the roles of various personnel within it become clearer. The task analysis will contain more detail as the design progresses.

Task analysis and system design (interface design included) initially considers the types of information that personnel need to understand the current system status and requirements for information and displays. In parallel, the types of controls necessary to respond to existing information must also be identified.

When the outputs (e.g., displays, controls, procedures, etc.) have been identified it is then necessary to specify ways that these will be provided.

In other words, there are two elements to the task analysis process:

1. Assessing WHAT will be needed to do the job
2. Determining HOW this will be provided

The prime aim of each task analysis is to examine specific human actions required for a task, in order to determine whether the facility design features, which are to be provided (such as procedures, hardware, software, or training), would match the user's requirements and thereby enable the user to perform this task effectively. Where a specific design has been developed, the possibility of undertaking the task is assessed against the design specification, and recommendations are made for overcoming any features that are considered likely to make the task particularly difficult or prone to human error.

Where the design has not been specified in detail, recommendations are given for the basic features that are considered necessary to ensure that the task can be accomplished. Typical examples of such features are information requirements based on the task analysis that may be based on a preliminary system design.

The design of a complex system involving equipment and human performance is founded upon Systems/Operations Analysis, which has been defined as the methodological examination of a complex organization (system and its components to define their relationships and the means by which their action and interactions are regulated to achieve systems goals). The tasks required to perform each function are defined and analyzed to establish detailed design requirements.

In the engineering design process, a task is defined as the collection of activities performed by a person or by a machine directed toward achieving a single sub-function. The product resulting from the task analysis applied to those functions allocated to humans is basic for determining:

- Information requirements
- Decision making requirements
- Response requirements
- Feedback requirements
- Staffing and communications requirements
- Workplace factors
- Personnel workload
- Associated task support requirements

- Task associated hazards
- Estimation of automation options

To clearly understand the recommended methods described in this document, the hierarchical structure of the job in terms of its principal components must be defined.

Job: Comprises all the duty areas and tasks performed by a single worker. It is a group of positions that are identical with respect to their major or significant tasks and sufficiently alike to justify their being covered by a single analysis.

Task: Is the lowest level of behavior in a job that describes the performance of a meaningful function in the job under consideration. Examination of the job at the task level allows the job to be described in sufficient detail to serve as the basis for a complete instructional system. Each task is independent of other tasks.

A task should be characterized as follows:

- Be a highly specific series of actions
- Have a definitive beginning and end
- Be performed in a relatively short period of time
- Be observable so that a determination can be made that the task has been performed
- Be measurable in terms of performance
- Be independent of other tasks
- **Element:** The task elements provide the step-by-step direction and guidance concerning task performance. An element is the smallest division of behavior that has practical meaning to instructional engineers. The elements of a task describe how the task is accomplished. Each element is dependent upon other elements. An element is relatively meaningless outside of the group of elements that make up a task.

Elements within a task may be:

- Fixed sequence (the elements always are done in the same order)

- Alternate path (the specific situation encountered determines the appropriate sequence)
- A combination of both

2 References

2.1 Supporting Documents

1. ESBWR Composite Specification.
2. ESBWR Man-Machine Interface System Human Factors Engineering (MMIS) Implementation Plan.
3. ESBWR Allocation of Functions Implementation Plan.
4. ESBWR Human-System Interface Design Implementation Plan.
5. ESBWR Human Factors Verification and Validation Implementation Plan.
6. ESBWR System Functional Requirements Analysis Implementation Plan.

2.2 Codes and Standards

1. IEEE Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations, 1989, The Institute of Electrical and Electronics Engineering.

2.3 Regulatory Requirements and Guidelines

1. NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control Functions to Human or Automatic Control, 1983 (U.S. Nuclear Regulatory Commission).
2. NUREG/CR-3371, Task Analysis of Nuclear Power Plant Control Room Crews, 1983 (U.S. Nuclear Regulatory Commission).
3. Nuclear Power Plant Control Room Task Analysis, 1982 (U.S. Nuclear Regulatory Commission).
4. NUREG/CR-3557 "CRT Displays Evaluation: The checklist evaluation of CRT-generated displays" Appendix A (1983).
5. NUREG-0700, Guidelines for Control Room Design Reviews, 1981, (US Nuclear Regulatory Commission)
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1. EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984.

2. Advanced Light Water Reactor Utility Requirements Document, Vol. II ALWR Evolutionary Plant, Chapter 10, Man-Machine Interface Systems.

3. EPRI-NP-3701 Computer-generated Display System Guidelines (Vol. II and I).

4. EPRI-NP-2360, Human Factors Methods for Assessing and Enhancing Power Plant Maintainability, (Seminara, 1982).

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1. AD/A233 168, System Engineering Management Guide (Dept. of Defense, Defense System Management College, Kockler, F. et. al.).

2. MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities (Dept. of Defense) May 1999.

3. DOD-HDBK-763, Human Engineering Procedures Guide, Chapters 5–7 and Appendixes A and B.

4. Guidelines for Job and Task Analysis for DOE Nuclear Facilities, 1983 (U.S. Department of Energy).

5. Military Standard Task Performance Analysis, 1991 (U.S. Department of Defense).

6. MIL-STD 1472C, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, Dept of Defense.

7. AD-A226 480, U.S. Army Test and Evaluation Command, Human Factors Engineering, Test Operation Procedure 1-2-610 (Part 1), May 1990.

2.6 Industry and Other Documents

1. IEC 964, Design for Control Rooms of Nuclear Power Plants, 1989 (Bureau Central de la Commission Electrotechnique Internacionale).

2. Handbook of Human Factors by Gavriel Salvendy, John Wiley and Sons, 1987.

3. Task Analysis Methods Applicable to Control Room Design Review (CDR), 1985, Atomic Energy Control Board.

4. Control Room Design Review Task Analysis Guidelines, 1983, INPO.

5. Guidebook on training to establish and maintain the qualification and competence of Nuclear Power Plant Operations Personnel, 1989, International Atomic Energy Agency.

6. Proceedings of the Human Factors Society 35th Annual Meeting, 1991.

7. CRT Display checklist (Blackman et. al., 1983).

8. Human Factors Design Handbook, (Woodson, 1981).

9. Visual Displays Terminals, (Cakir et. al., 1980).

10. Human Factors in Industrial Safety" (HSE Checklist, 1989).

11. "A study of Control Room Evaluation Techniques in a Nuclear Power Plant" (Ainsworth, L.K., 1985).

12. Rasmussen, J. "Information Processing and Human-Machine Interaction, An Approach To Cognitive Engineering," Elsevier Science publishing company, New York 1986.

13. IAEA-TECDOC-668, The Role of Automation and Humans in Nuclear Power Plants, IAEA, Vienna, 1992.

14. NUREG/CR-2598, Nuclear Power Plant Control Room Task Analysis: Pilot Study for PWRs, 1982.

15. IAEA-TECDOC-525, Guidebook on Training to Establish and Maintain the Qualification and Competence of Nuclear Power Plant Operations Personnel, Vienna, 1989.

3 Task Analysis

Task analysis is the name given to any process that identifies and examines the tasks that must be performed by users when they interact with systems. It is the evaluation of the performance requirements that places demands on plant personnel (operating crew, maintenance, etc.) to identify the task requirements for accomplishing the functions allocated to them. Indirectly, the task analysis also defines in a task element fashion, how the system operates. The response to system indicators and alarms with postulated controls is the task performed by operator, hence, an analysis of tasks. Task analysis is a fundamental approach essential to achieving higher safety and availability standards. This technique aims to establish task requirements or to carry out task assessments.

Task analysis is applied to:

- Analysis of the efficacy of allocated safety functions (the extent to which they are "safe");
- Investigation of functions pertinent to non-safety systems; and
- Assessments of operator interactions with new technologies, (i.e., Automation, electronic displays or new formats for operating procedures.

Task analysis covers a range of the techniques used by designers, operators, and Human Factors Engineering to describe and—in some cases—evaluate the human-machine and human-human interactions in systems. Task analysis can be defined as the study of what operators and maintainers are required to do in terms of actions and/or cognitive processes, to fulfill system functions. It can also be used to document the information and control facilities necessary to carry out the task.

Task analysis is a method, supported by specific techniques, to collect and organize information. The data is used to make various judgments or design decisions. The application of task analysis provides the designer with a "blueprint" of human integration with a system. Therefore, the system is viewed from a human perspective. This structured information is used to ensure compatibility among system hardware and software functions and human capabilities and limitations. Consequently, system goals are achieved.

As applied to the initial tabletop task analysis (TA) for ESBWR, the TA addresses those tasks performed by the MCR operator crew in responding to monitoring, control and alarm actions. These initial TAs address the tasks in response to a full range of operation of the plant systems including safety and non-safety systems. .

3.1 Why Use Task Analysis?

Use of explicit task analysis provides one of the bases for making decisions between the use of automation or manual actions in the design. This is expected to support a more efficient and effective integration of the human element into the system design and operations. The support impacts both safety and availability.

1. Safety

   a. It provides a basis for reducing human error, and resolving errors that occur, by systematically integrating various design decisions on human tasks at different stages of the design and implementation process. An enhanced level of system safety can be achieved through design for human use.

b. It can be used to verify that human-performance requirements do not exceed human capabilities for the operator/maintainer tasks during all modes of operation.

c. It can be used as basic input for developing emergency operating procedures which form the basis for self identification of human errors.

2. Availability

a. It can be used as basic information for developing the staffing, training, and communication requirements of the plant to address the complexity of some human operations within the systems and the coordination that will be required during operations.

b. It forms the basis for specifying the design requirements for the displays, data processing, and controls needed to carry out tasks.

c. Task analysis can be used to identify testing and maintenance demands and to define the need for maintenance support tools and systems of work. Optimal work design should also reduce errors that lead to unscheduled downtime. Systems must be adequately maintained and run to keep downtime within acceptable limits.

3.2 How Must Task Analysis Be Accomplished?

The major phases of the overall task analysis process are listed below. Specific phases for this plan are defined in the flowchart shown in Figure 2.

1. Input data collection for task analysis

2. Initial high level Task description and analysis

3. Detailed Task Analysis (desk top, walk/talk through, or simulation)

4. Reporting and documentation

5. Task requirements V&V

3.3 Data Sources to Be Used in Conducting the Task Analysis

The first stage of the initial Task Analysis (on paper) consists of a process of recording and organizing the data to be used later. This stage is basic, because all the task analysis will be based on this data.

The data sources for carrying out the task analysis will be as follows:

1. Data coming from implementation of the System Functional Requirements Analysis Implementation Plan

2. Data coming from implementation of the Allocation of Functions Implementation Plan

3. System design documentation

4. Important actions for beyond design basis events from the PRA/HRA

5. ESBWR PRA

6. HFE and Industry guidelines (Section 2)

The recording of data will be carried out in such a way that their selection and documentation are adapted to the analysis that will take place in the following stage. The actual human factor techniques and forms for data collection will be selected by the analysts. They will document results using typical methods recommended for the technique. .

3.4 Performers of Task Analyses

The principle performers of task analyses are the members of the ESBWR Project Control Room Design Team [2.1(3), Section 3.2]. Other organizations, including human factors subcontractors also use this Plan to ensure consistent methodology. Task Analysis is performed at different phases of the design and these are addressed in Section 3.5.

3.4.1 Task Analysis Methods

For the functions and tasks, which have not already been analyzed in previous designs, a task analysis should be performed based on the information available. A process for screening out duplication of effort should consider the degree of change in the ESBWR processes, changes to the HSI, changes to cognitive skills required for the task, and applicability of generic task analysis for normal operations, maintenance, testing and emergency responses. For new or significantly changed functions the specific Human Factor techniques selected to conduct the initial (high level Task Analysis) are:

- Mission scenarios (MS). In this document (plan), a modification of this technique called Operating Sequence Scenarios is used [derived from document NUREG/CR-3371 "Task Analysis of Nuclear Power Plant Control Crews." (2.3(2))]

- Functional flow diagrams (FFDs) (derived from the system functional requirements analysis)
- Task descriptions (TDs)
- Operating Sequence Diagrams (OSDs)

A detailed description of each one of these techniques can be found in the Army document DOD-HDBK-763, "Human Engineering procedures guide" [2.5(3)]. Table 1 shows the main characteristics of these techniques. These characteristics were the basis for their selection.

As can be derived from Table 1, all these techniques have the following characteristics in common:

- The conceptual phase is the program phase that is best suited to its use;
- They are relatively simple to perform (except the OSD, which can be very complex);
- They should be used for gross analysis (except the OSD, which can be used to perform detailed analysis);
- Only single tasks can be handled by these techniques (except the OSD, which may handle multiple tasks simultaneously);
- The time to perform them for a given task is medium (except for the OSD, which can be high); and
- Its relative cost and relative cost effectiveness is medium (except for the OSD, which its relative cost can be high).

Due to these characteristics, these techniques have been considered as the best suited to perform the initial task analysis. In addition, the OSD can be used during further stages.

The use of OSDs and Narrative Task Descriptions is explained below. The use of functional flow diagrams can be found in the System Functional Requirements Analysis Implementation Plan [2.1(7)], and methods to develop Operating Sequence Scenarios are shown in the Subsection "Converting Functions to Tasks," Section 3.5.1 of this Plan.

3.4.2 Use of Operational Sequence Diagrams

The OSD is probably the most powerful single manual analysis technique that can be used, because so many outputs and applications derive from its use. It is particularly useful for the analysis of highly complex systems that require a lot of time-critical information-decision-action coordination between several operators and equipment items.

The OSD is a graphic presentation of operator tasks as they are related sequentially to both equipment and other operators. The OSD symbology is shown in Figure 3. The symbology is consistent with the ASME (American Society of Mechanical Engineers) flowchart standards.

By using symbology to indicate actions, inspections, data transmitted or received, data storage, and decisions, the OSD shows the flow of information through a system. The information flow is shown in relation to both time and space. The OSD may be used to develop and present the system reaction to specified inputs. In the OSD, the interrelationships between operators and equipment (man-machine interfaces) are easily displayed. Whenever information transferred is mismatched with the format to be received, interface problems are clearly indicated. Operator activities are sequentially categorized. Decision and action functions are clearly identified, and task frequency and load become obvious.

The OSD is useful in terms of outputs, because so much must go into it. Integrating all the data that goes into a typical OSD is generally a tedious and time-consuming process. Experience has shown that the construction of OSDs requires a trained individual with analytic skill. The information needed to construct an OSD might come from scenarios, functional flow diagrams, narrative descriptions, or other sources.

A procedure for constructing OSD with an example is shown in "Development of Operational Sequence Diagrams (OSD)", Section 3.5.8.

3.4.3 Use of Narrative Descriptions of Personnel Activities Required for the Completion of the Task

A task description is a statement of basic task requirements. It proceeds from general task statements to specific display, control, and decision activity details. Generally, the level of detail for specifying task activities used is about the same as in an instruction manual for a novice. A good task description could easily become a procedural manual for the job.

Task descriptions should proceed from general task statements to specific display, control, and decision activity details. In a task description under the heading "elements" the task's activities are listed. These are tasks that may be classified as actions, perceptual motor activities, straight monitoring, communicating and decision making, or problem solving. The specific details of this method for task analysis are developed in "Decomposition of Task to Individual Activities," Section 3.5.6.

3.4.4 Definition of the Input, Process, and Output Required by and of Personnel

The use of techniques described and especially the development of the operational sequence diagrams, allow for the identification of:

- Function performance cues (stimuli/input signals);
- Processes resulting from input signals;
- Required and/or expected operator actions (operator responses);
- Operator inputs; and
- Resultant predicted system output.

3.5 Methods for Conducting the Initial (High Level) Task Analysis

The aim of the initial stage of task analysis is to collect and organize the information (data) in a meaningful way, such that subsequent to analysis, the information is easily and efficiently used for a variety of purposes (e.g., training requirements, training content, design and design review, etc.). Specifically, the goal of this task analysis is design; therefore, information management is structured toward that end. .

Because the aim of this task analysis is design, one must compile the information keeping this in mind. The type of analysis conducted must therefore be predictive, because an attempt will be made to determine requirements that allow for a later definition of an optimum man-machine interface, on the basis of the information derived from the system design bases and the experience of the industry. Nevertheless, one must also seek to obtain information concerning the training of operation and maintenance personnel and power plant procedures.

In order to optimize the task analysis results, the steps for compiling and organizing information are structured thusly:

- Converting functions to tasks;
- Developing narrative task description;
- Developing the basic statement of task performance requirements;
- Decomposition of task to individual activities; and
- Developing operational sequence diagrams.

The information compiled at this stage will be used as input in the following "development of detailed task description" in which it will be analyzed, and HSI design recommendations will be made as the final result..

3.5.1 Converting Functions to Tasks

The aim of this step is to develop a high-level sequential description of the operations that must be carried out to fulfill the functions of a particular system (operational sequence). The narrative description, as well as the functional diagrams created during the functional analysis stage, establishes the foundation for the sequential descriptions.

The performance requirements that must be met to fulfill the functions of the system are presented in this description. However, there is no attempt to account for the temporal causality relationships that exist among the requirements. The conversion of functions into tasks consists of developing a sequential description of the operations identified in the functional diagrams.

These sequential descriptions of operations for a specific function use Processing Elements from the functional diagrams. The sequences of human and system actions needed for each Processing Element are called Operating Sequences; these, in turn, can be broken down into tasks, sub-tasks, and task elements. Such a breakdown has the following advantages:

- Since the Processing Elements are defined at a high functional level, they are often repeated in other operating sequences, thereby reducing the number of analyses.

- Each Operating Sequence can independently focus on detail of its' tasks and subtasks by keeping the description of the other processing elements at a high level. The identification of human dependencies in risk important accident sequences is addressed in the PRA/HRA.

Given that the operation of a system forms part of the overall operation of the plant, it is necessary to define the conditions in which the operating sequence under study is carried out. In order to develop the descriptions of the operating sequences, it is necessary to define scenarios that include all the operations that can be performed with the system. And, this must be done in such a way that all the possible alignments and modes of change in normal, abnormal, and emergency conditions appear. These scenarios minimally contain the following:

- Initial Conditions

- Sequence Initiator

- Final Condition

- Operation Classification

- Normal Operation
- Abnormal Operation

- Progression of Action

  Operating sequence descriptions developed from each scenario minimally contain:

  - Phases and maneuvers
  - An indication of the relationships among actions within a sequence.
  - How those actions are coordinated and how pertinent information is transferred.

The criteria for the selection of scenarios and operating sequences are based on the following:

- Function of the system that is being studied (as defined in the systems design description);
- Operating modes and change modes of the system;
- Plant operating modes;
- Operating procedures of existing BWR and ABWR plants;
- Events studied in Chapter 15 of the ESBWR DCD;
- Maintenance operations necessary for system functioning;
- Likelihood of system/component failure; and
- Operational experience

As a result, a series of operating sequences will be developed for each function of the systems being studied, and these will include all the procedural steps necessary for its operation. The functions and modes of operations for each system are defined in the system's SDD.

The operating sequences and the scenarios chosen will be documented in two formats: one for the definition of the operating sequence entitled Operating Sequence Scenario (Figure 4); and the other, entitled Task Sequence Chart (Figure 5). They define and sequentially list the tasks required of the operating sequence.

This data-compiling format consists of a heading identifying the system under study and the function of the study, together with the title and the identification of the operating sequence concerned. The identification of the operating sequence will use a code that specifies the Master Parts List (MPL) codes for the system being studied, the function to be studied, and the operating sequence . To illustrate the process, the Reactor Water Cleanup (RWCU) System was selected as an example. Thus, for the first operating sequence defined from the first RWCU function, the code will be G33-F01-S01. Figure 8 provides an example of a completed form. The contents of the rest of the fields will be as follows:

1. Initial Condition Field

   The condition of the system indicated will be specified in this field:

   a. Operating mode (alignment)

   b. Operability condition of equipment and components

   c. Values of the system characteristic parameters identified at the functional analysis stage and the condition of the plant, as indicated by its operating mode. Examples of system parameters include the following:

      i) Reactor coolant temperature

      ii) Reactor vessel water level

      iii) Reactor vessel pressure

      iv) Reactor vessel quality

      v) Reactor coolant forced circulation flow rate

      vi) Reactor power level (thermal and neutron flux)

      vii) Core neutron flux distribution

      viii) Feedwater temperature

      ix) Containment temperature and pressure

      x) Suppression pool water temperature and level

      xi) Spent fuel pool water temperature and level

2. Sequence Initiator Field

   The information to be included in this field will be the reason or situation that has made it necessary to carry out the sequence being studied.

3. Final Condition Field

   The expected state of the system components (alignments) of the parameters of the plant, etc., after carrying out the sequence being studied will be included in this field.

4. Operation Classification Field

   This field will include the classification of the sequence as Normal or Abnormal Operation. The classification used, is shown in the ESBWR DCD Chapter 15 Appendix 15A "Plant Nuclear Safety Operational Analysis (NSOA)." Into the Abnormal Operations are included those defined as Moderate Frequency Incidents (Anticipated (Expected) Operational Transients), Infrequent Incidents (Abnormal (Unexpected) Operational Transients, Limiting Faults (Design Basis (Postulated) Accidents), and Special (Hypothetical) Events in the ESBWR DCD.

5. Special Safety Considerations Field

   This field will include the identification of those specific situations or circumstances related with personnel safety (hazards) (i.e., task performed in a high radiation zone, etc.).

6. Consequence of Inadequate Performance Field

   Consequences of error in performing some task in the operating sequence under study will be included in this field.

7. System Interface Field

   All relationships between actions of one single operating sequence, coordination, and transfer of information will be included in this field. Relationships with other plant systems will be also included.

8. Human Interface Field

   In this field, the relationships between MCR operators and the rest of plant personnel required for the progression of the operating sequence are recorded.

The task sequence necessary to perform the tasks of the defined operating sequence is then analyzed. The sequence will be determined with the aid of the format shown in Figure 5.

In addition to the data concerning the identification of the system, function, and operating sequence studied, the data needed for each one of the sections of the Task Sequence Chart is as follows:

1. Task Identification Field

   Task identification number within the sequence being studied.

2. Task and Purpose Field

   Identification (title) of the task and its aim, including its scope and the objective to be achieved.

3. Cue Field

   Initial condition of the task. It may be the value of a significant parameter within the system, or a specific condition thereof.

4. End of Task Field

   Information that will indicate the correct accomplishment of the task. It may be the value of a significant parameter within the system, or a specific condition thereof.

5. Comments Field

   All the relevant comments and observations concerning the task, which might be conducive to a better understanding of the description of the task, or specific indications for carrying it out.

To prevent ambiguity when filling in the data collecting formats (given that different people may carry out the task), Table 2 shows a series of recommendations for the development of the narrative description. These recommendations are valid for the whole Task Analysis process.

3.5.2 Example of Converting Functions Into Tasks

For example, the Reactor Water Cleanup System (RWCU G33) of a BWR-6 will be used as an example. The information to be used will be that obtained in the example developed in the System Functional Requirements Analysis Implementation Plan [2.1(7)]. The function to be studied will be Purify RPV Water (code as F01).

Figure 6 shows a block diagram of this RWCU for a typical BWR-6. The possible alternatives for carrying out each one of the processes can be seen.

The scenario to be developed will be the starting of the system with the reactor at high temperature, in accordance with an operating mode referred to as "mode A," in which the alternative (known as A), will be chosen from all the possible alternatives for each process.

According to the results of the functional analysis, it will be determined that the above-mentioned "Mode A" uses the alignment described in Figure 7.

When the operating mode to be studied has been determined, it will be necessary to define a scenario that delimits it, i.e., specify the "environment" in which the operating sequence to be studied will be developed.

The form shown in Figure 8 must be filled in using tasks as specified by the scenario. The form in Figure 8 has been filled in for the operating sequence for starting the RWCU in high-reactor coolant temperature conditions.

This form lists the tasks that must be carried out to get the system to fulfill its function. Each task is identified with a code that contains the MPL of the system, the code for the function to be studied, the sequence code and the ID of the task (e.g., G33-F01-S01/T01 for the first task identified).

To carry out the placing the system in service in these conditions, it will be necessary to perform the operating sequence shown in Figure 9, whose Task Sequence Chart can be seen in Figure 10.

3.5.3 Developing Narrative Task Descriptions

Each one of the tasks defined in the Task Sequence Chart will be carried out with a narrative description that will consist of an explanation of the maneuver that defines each one of the tasks and which will include the points listed below.

1. Cue

   This will define exactly the alarm, signal limit, schedule reminder, transition from another task, or an external requirement that triggers the need for a human task, specifying the exact moment of the operation when the task must begin, or the parameter values, where appropriate.

   In the particular case when it is a specific parameter, the cue in question must specify the component that is to generate the signal.

2. Task and Purpose

   These are actions that include the task in question. They refer to the blocks of activities that, as a whole, constitute the task that considers the operating team collectively. That is to say, without specifying the operator, yet identifying those actions that must be carried out locally; in as much as these actions must be given special treatment in later analysis.

   This is the set of actions that is expected as a response from the system to the maneuvers performed by the operating team. Both the changes in the state of operability of the system components and the variations in the system parameters must be included, and special mention must be made of those parameters that are cues for other tasks or maneuvers within the same task.

   The behavior of the main components of the system must also be mentioned, if these are defined as cues for other tasks or maneuvers within the same task.

   The main parameters of the system must be given the most detailed treatment possible, indicating the team in charge of their measurement and their placing within the system.

3. End of task

   This is a signal that indicates that the task has been completed in its entirety. It provides a way of letting one know that the task carried out has been satisfactorily completed.

4. Final condition

   Alignment and operating mode of the system once the task is completed, indicating:

   a. Alignment of components

   b. State of the equipment

   c. Value of the main parameters

   d. Alarms and special indications

3.5.4 Example of Developing Narrative Task Description

The narrative task description for the example of the RWCU of a typical BWR-6 and specifically for task T03 (put in service vessel drain for heating pipes and components) is shown below.

1. Narrative Task Description

2. Task ID: G33-F01-S01/T03

3. Task Title: Put in service vessel drain for heating pipes and components

4. Cue

   This task will be initiated as soon as a flow path is available for the suction of the system from the reactor containment vessel. Regardless of the suction loop used, it is even possible to initiate the heating of the system with only the suction from the drain at the bottom of the vessel.

   The heating can start to take place as long as the RWCU system is at a temperature lower than that of the reactor coolant and the latter is at > 60°C when it is necessary to start heating.

5. Actions

   To prepare the RWCU system for heating, by carrying out the following maneuvers it will be configured:

   a. Isolation of the system exchangers

      Given that the aim is to heat the equipment of the system, those items that might let heat escape must be isolated in order to prevent flow through the system exchangers.

   b. Alignment of the drain

   The alignment for the operating mode for drainage of the vessel of the main condenser will be used, because the flow required for the heating of the system is low enough. Attention must be paid to the pressure of the main condenser, because any lowering thereof could cause changes in its performance (possible loss of vacuum).

   c. Venting and filling of the pump to be started

      This maneuver is carried out locally, and there is a degree of radiation risk; therefore, it requires special attention. Close collaboration is required between the plant personnel and the control room personnel.

   d. Control of the heating rate

When the pump to be started is full and vented, as well as being in the correct sealing and cooling conditions, communication will be made for the flow system, controlling the heating flow with the bypass valve of the pump discharge.

The heating rate will be set to 5.6°C/min., because that is what the manufacturer has recommended for the equipment.

The temperature must be measured locally with a digital thermometer connected to a thermocouple installed in the pump shell. In the control room, the reading of the TI-R607 will be made at the point for the input temperature for the regenerative heat exchangers.

6. System Reactions

   The temperature of the tubing and the rest of the system equipment will increase at a steady rate.

   It will be necessary to observe the layout of the system locally, in search of any possible leaks in the flanges of any of the components as the temperature increases.

7. Final Conditions

   Once this task has been carried out, the system will be aligned for the operating mode for the main condenser drainage vessel and with the bypass valves for pump discharge open.

   The temperature for the system coolant, as well as the equipment thereof, is increasing in temperature and approaching that of the reactor coolant.

8. End of Task

   The task is complete when the temperature of the pump shell of the system that is to be started up, is close to the temperature of the reactor coolant at that time.

3.5.5 Developing the Basic Statement of the Task Functions

Once the sequence of operations of all the functions of a system has been conducted and all the tasks have been identified, they must be classified. The classification is done in such a way that a complete set can be obtained of all the different tasks that can be performed for the system being studied.

There is a clear advantage in developing this basic statement of task before developing each task in individual activities, given that, by identifying which tasks are repeated in one or various sequences, it is unnecessary to carry out the same analysis several times.

If two tasks are to be regarded as the same, all the actions necessary to carry them out must be the same, they must all be developed in the same sequence, and they must all have the same aim.

If, for example, the Start Pump A to obtain pumping capability (G33-F01-S01/T08) appears in two different sequences, it will only be necessary to carry out the analysis of this task once, and this analysis will be valid for both sequences.

Tasks in parallel will be identified and documented by performing the Operational Sequence Diagrams [see "Development of Operational Sequence Diagrams (OSD)", Section 3.5.8].

3.5.6 Decomposition of Task to Individual Activities

Once all the tasks have been obtained that must be carried out so that a system fulfills its functions, it will be necessary to decompose these tasks into individual activities. An individual activity is defined as a single action that contributes to the completion of a task.

The Berliner taxonomy of action verbs shown in Table 3 has been used to define these individual activities. The Berliner task-descriptive taxonomy has been used in numerous tasks in the nuclear industry (e.g., Ref. 2.3(2)) involving conventional control room designs and technologies. The taxonomy may not be fully applicable to a particular advanced nuclear power plant control room design emphasizing human information processing and human-computer interaction. It is presented here because the taxonomy can be tailored for the application and the four basic processes (i.e., perceptual, cognitive, communication, and motor) are still characteristic of operator tasks in advanced control rooms."It is important to note that due to prevailing regulatory requirements, the application of some conventional displays and controls, especially on the remote shutdown system, are still necessary[GWH68].

The determining of the individual activities will be based on:

- Operational experience
- Data from the manufacturers of the equipment and components
- Technical design characteristics of the equipment and components
- System design information (System Design Descriptions (SDD), P&ID, Process diagram, Logic Diagrams, etc.)

- Technical Specifications (Chapter 16 ESBWR DCD)
- Procedures used in earlier BWR plants

The technique known as Task Description, presented in "Use of Narrative Descriptions of Personnel Activities Required for the Completion of the Task" (See Section 3.4.3), will be used to carry out the breakdown of functions into detailed tasks. This technique has been chosen because it is the one that adapts best to the analysis that is to be carried out. (Design basis: HE analysis techniques, DOD-HDBK-763) [2.5 (3)].

To carry out the task description, the form in Figure 11 must be filled in.

The form consists of a heading in which the task to be studied and the operating sequence to which it belongs are identified by means of a title and code, together with five columns that will contain the following information:

- **Act. No:** Number of order of the activity within the task
- **Component:** Component or item of equipment that is the subject of the activity.
- **Element:** Activity to be carried out (in accordance with the verbs of action contained in or tailored from the Berliner Taxonomy).
- **Feedback (e.g., indication):** Information generated by the system, which makes it possible to monitor the activity being developed and check that it is being properly accomplished. The feedback provided to the operator allows the operator to perform the next sequence of tasks(s).
- **Remarks:** Comments, precautions, dangers, etc. that help to improve the definition of the activity.

A field "time" could be included if that information is available.

3.5.7 Example of Breakdown of Task to Individual Activities

By way of example, the breakdown of task G33-F01-S01/T03, *Put in service vessel drain for heating pipes and components*, is presented below. The results format is shown in Figure 12.

3.5.8 Development of Operational Sequence Diagrams (OSD)

In order to provide a general view of each task, a diagram will be developed at the end of each task, in which the operations to be carried out will be presented. The type of diagram chosen is the one known as the Operational Sequence Diagram (OSD) (Reference DOD-HDBK-763). This method is presented in "Use of

Operational Sequence Diagrams" (See Section 3.1.1). The criteria to be followed in the construction of an OSD are indicated below.

The flow of events and tasks is always from the top of the sheet to the bottom. The operator and machine names are entered in the column heading of the OSD. It generally is a good idea to place in adjacent columns the names of the operators and the machines with which they interface. If the people and equipment have not been specified, the analyst will have to specify them. In the process of doing the OSD, it may be found that too many or too few operators or machines have been selected. The reason for doing the analysis is to "drive out" crew size and interface requirements.

The OSD is initiated by the first event designated by scenario. The event and event times are written in the two left-hand columns. Using the appropriate letter code shows all of the machines or people who will receive the input. The subsequent actions taken by the crew/equipment (operations, transmissions, etc.) as they react to the input are shown. External outputs are plotted in the far right-hand column. As the reactions are plotted, the analyst should be cognizant of the time required to perform the actions. The process of plotting the inputs and subsequent reactions is continued as dictated by events given in the scenario or narrative. No attempt is made to keep the actual space between scenario time events proportional to the time itself.

A brief notation describing the process or actions should explain all of the steps shown on the OSD. The OSD analyst should be sure that all logical possibilities are included, all loops are completed or terminated in a valid exit, and all tasks are capable of being performed by the operators.

An example of OSD for the task G33-F01-S01/T03, *Put in service vessel drain for heating pipes and components*, is shown in Figure 13. The symbology used in these diagrams is shown in Figure 3.

Due to the nature of the initial system TAs, the system OSD for most systems, do not have links with other system OSDs. Only when a TA of the integrated systems and plant operator would an OSD define interaction across OSDs.

3.6 Methods for Developing Detailed Task Descriptions

In the engineering design process, a task is defined as the collection of activities performed by a person or by a machine directed toward achieving a single sub-function. The product resulting from the task analysis is an electronic database (e.g., access). The information in the database fields is obtained for the functions allocated to humans. Information developed for the database is described in the sub sections of 3.6.2 to3.6.10 and Attachment A In general detailed task descriptions address:

1. Information requirements
2. Decision-making requirements
3. Response requirements
4. Feedback requirements
5. Associated task support requirements
6. Workplace factors
7. Staffing and communications requirements
8. Hazard identification
9. Personnel workload

To effectively support each of these applications, this next part of the task analysis should identify and describe for each task the related requirements listed.

- Information required (parameters, units, precision, accuracy)
- Information source (alarms, displays, verbal communication, etc.)
- Description of the decision to be made (relative, absolute, probabilistic)
- Evaluation to be performed
- Decisions that are probable based on the evaluation
- Action to be taken
- Overlap of task requirements (serial vs. parallel task elements)
- Frequency
- Time available for operator response based on the plant response characteristics
- Temporal constraints (task ordering)
- Tolerance and accuracy
- Operational limits of personnel performance
- Operational limits of machine and software
- Body movements required by action taken

- Feedback required to indicate adequacy of the actions taken
- Cognitive and physical workload
- Estimation of the difficulty level
- Special and protective clothing
- Job aids or reference materials required
- Tools and equipment required
- Computer processing support aids
- Workspace envelope required by action taken
- Work environment (lighting, heat, noise, and radiation)
- Workspace location
- Number of personnel, their technical specialty, and their specific skills
- Communication required, including type
- Personnel interaction when more than one person is involved
- Identification of hazards involved

This information will be used in such a manner that the Design Team will be capable of identifying information and control requirements to enable specification of detailed requirements for alarms, displays, procedures, personnel, qualifications, training, data processing, and controls for human task accomplishment.

The outputs will be the definition of a minimum inventory of alarms, displays and controls necessary to perform crew tasks based on both task and instrumentation and control requirements.

The detailed task descriptions will provide the principal results for direct use in identifying human engineering discrepancies. The task data should be organized into requirements for the design of the workstation's panels in the control room.

The results of the system function analysis, the allocation of functions task and the high-level task analysis, listed above, are the inputs used to perform this next part of the task analysis:

- Functional block diagrams that identify the functions

- System level function narrative descriptions
- The human-machine allocation of functions, and the identification where control of the function occurs
- Task sequence charts
- Narrative task descriptions
- Operating sequence diagrams (OSDs)

After identifying and documenting of operator functions, the operator tasks associated with each function should be identified, and the instrumentation and equipment required for task performance should be analyzed. In many cases, the set of operator tasks associated with the operator function/system interface will be identical for more than one sequence. In those cases, the analysis of task requirements need not be repeated for each sequence. Care must be taken; however, to assure those sets of operator tasks for a function are truly identical for more than one sequence.

Task analysis is a continuation of the function analysis in which detail is provided about the inputs, actions/decisions (throughputs), and outputs by which the operator implements a function or sub-function. Particular attention should be given to describing decision-making tasks. It is important to define all data needed for these kinds of tasks. Like the functional analysis, the task analysis should specify the subsystems with which the operator interacts. This will also help define the dynamic response needed from instruments, displays, and indicators for the operator to perform assigned tasks successfully.

Because this task analysis is to support a human engineering design and evaluation of operator HSI equipment, the focus should be on establishing operator action/decision relationships, and the instrumentation, control, and equipment requirements for action and decision making. Ultimately, the perceptive information is shown in the Table Data Form in Appendix A. These tables have a format considered adequate in order to collect all the information related to the tasks. Any format may be used as long as it presents the required information, maintains the association of the tasks with systems function, and indicates the general order in which tasks are performed. This material will provide benchmarks for design, verification, and validation of control room adequacy at the task and function levels.

3.6.1 Operator Decision-Making Model

One of the primary goals of the nuclear power plant Man-Machine Interface System Designer is to build a man-machine interface in which the human and the machine truly complement each other to produce an integrated system. Attainment of this goal requires a well-defined, rigorous design process that provides a mechanism to define the specific operational tasks to be supported, and a complete set of requirements for the design of a man-machine interface.

Currently, industry is searching for methods, techniques, and products that will reduce human error in the operation and maintenance of these power stations.

Assuming the operator's role in process control, there are three commonly applied approaches to reducing human error in a control room, all of which can apply modern digital computer technology.

1. The use of procedures and training (this is a very familiar and traditional response to human error).

2. Replacing the operator with automation (reducing human error by removing the human).

3. Making the computer system a part of the operating team. The objective is to build a human-computer team in which team members back up each other by observing, checking, and confirming each person's decisions and actions.

The key to designing such a computer system lies in creating within the computer system a map of the decision and action problem space of the process being controlled. The problem is to design a computer system that is to be the interface between operators (taking into account a decision-making model) and some process that obeys forces outside of the computer.

Assuming the preceding, the first consideration to make is to establish a model of the human operator decision-making process. This model provides the types and relationships of questions that operators need to ask (and to answer) in the course of properly controlling the process.

Figure 14 shows the schematic representation of the operator decision-making model that was originally developed by J. Rasmussen .

In this model, the activity is started by an indication of some abnormality that generates an alarm or an alert signal to the operator. From there, the following are steps of stereotypical "shortcuts" that are taken when the "symptoms" of the abnormality are very familiar to the operator or the response to the symptoms is dictated by the procedures:

1. Observe plant state

2. Identify plant state
3. Recognize implications of the state
4. Select goal
5. Plan success path
6. Select/formulate actions
7. Execute actions
8. Receive feedback on effects of actions. These are activities that the operator needs to complete his/her own understanding of the plant's abnormality

However, most human process control error has its root causes in frequency or in familiarity. Shortcuts are prone to these "mistakes." A vast majority of the time, these shortcuts are the correct thing to do because the identified response is the proper one, they save time, and, in doing so, they tend to reduce operator stress.

On the other hand, these shortcuts do not necessarily guarantee that the operator really understands either the plant state, which is the basis of the shortcut, or whether the assumed plant state actually justifies the subsequent "reflex" action. Further, an operator can follow and execute a procedure without understanding its limits of applicability. The purpose of the task analysis is to identify the functionality necessary in the man-machine interface design. The operator finds the additional support needed to reason, to evaluate, and to make judgments about the validity of process data, about hypotheses concerning the plant state, and about the consequences of planned actions.

In order to facilitate the understanding of this model, it can be simplified to three major activities:

1. Monitoring (and feedback)
2. Planning
3. Control

The man-machine interface designer's attention can focus upon what data needs to be collected and displayed together in order to support the decision making model activities.

There are generic questions that should be answered related to the three major activities:

- Monitoring
  - Goal satisfaction
  - Process performance
  - Alternative process availability
- Planning
  - Choices among alternatives
- Control
  - Process initiation
  - Tuning
  - Termination

These questions appear simple enough. The complexity is in determining their applicability for all plant operating situations.

The answers to the questions above are in the complete set of data that represents the plant physical structure, represented by the usual piping and instrumentation drawings (P&IDs). All of design data, such as control setpoints, system design limits, operating limitations, system descriptions, etc., are available; but the data does not indicate where the questions need to be asked.

The plant-specific operational-task analysis is accomplished by superimposing the generic questions from the operator behavior model work onto the functional structure.

Although advanced technology is generally considered to enhance system performance, computer-based operator interfaces also have the potential to negatively impact human performance, to spawn new types of human errors, and to reduce human reliability. It is therefore important to understand how operators perform their tasks from an information-processing and decision-making point of view and how human information processing relates to HSI design and human error. Cognitive issues and human information processing are emerging more significantly than the physical and ergonomic considerations that dominated the design of conventional HSIs. Taking into account these considerations, the general model represented in Figure 16 is the basis for establishing a brief overview of the operator's decision-making model. The model is needed for understanding the development of the actions included in the detailed task description.

3.6.2 Table Data Form: General Requirements

In this phase of task analysis, the accuracy and reliability with which the task can be analyzed and described will clearly depend on the choice of labels for the columns in the table data form, and on the words chosen to fill in entries in columns. The tables in the following sections can be maintained in an database (e.g., Microsoft® Access)to support transfer between reports. During preparations for the Task Analysis, decisions must be made in order to make the analysis valid, reliable, and cost effective.

The quality of task analysis data is strongly dependent on decisions made about the use of language and methods to describe data. The degree of detail, the reliability of the data, and the validity of the use are all affected.

On this point the distinction between Prescriptive Task Analysis (PTA) and Descriptive Task Analysis (DTA) is crucial. In a DTA, identifying the action depends on observing the behavior; in a PTA, such is not the case. In PTA the task analysis begins from a definition of the task and proceeds to a description of how it must (of logical or empirical necessity) be done. The difference can be summarized in this way: In a DTA, the occurrence of an action is a matter of observation; in a PTA, it is a matter of prescriptive necessity [Table 4: Criteria for description in task analysis (from DOE/EP-0095)].

It follows that validating DTA taxonomy or method may be difficult. It depends upon the analyst's ability to design measurement, recording, and observational techniques. Validating a PTA is a matter of ensuring that the analyst has correctly deduced from engineering documents what the operator logically must do to carry out the tasks.

The choice of a Task Data Form is more complicated. The level of detail required determines the number of columns. But considerations of analysis, and the way in which data are going to be transcribed for use in a database also determine the choice. Furthermore, in a PTA there is no need to be able to transcribe real time data, and the amount of detail that can be included is not reduced.

In order to clarify the process in the detailed task descriptions, the tasks are listed in a summary format, identified with a step number. The sub-tasks are listed as components of each task, and secondarily as a sub-task heading in which elements are listed as components of the sub-task. This summary list is the first output of the general plan.

The coding taxonomy at the lower level allows the data to be entered into the Table Data Form. At the sub-task level, the verbal description is a narrative version and at a level at which the taxonomy category, skill, and knowledge required is listed. This information, which does not appear in the DTA, is important in relating operator training and qualifications to control room design, probability of error, and personnel performance.

The proposed PTA Table Data Form, shown in Table 4, provides the necessary detail and is easy to use. The form should be printed in such a way that it can be folded along the indicated dot line, and bound in such a way that it can be kept open either with the sheets fully open or with the right side of the sheet folded back.

Assuming that the complete list of tasks is available at the end of this first part of the task analysis, there are three main steps in the performance of the task analysis:

- Table Top Analysis (TT)
- Walk Through/Talk Through (WTTT)
- Simulator Analysis (SA)

Of these, the first two should be regarded as mandatory in all Task Analysis, and when a simulator is available, the third should also be regarded as mandatory.

In conclusion, there are three stages at which data will be entered on the table data form during performance of the TT, the WTTT, and the simulator. It is desirable to indicate the source of each entry by using different colors or other coding techniques. After all three stages have been carried out; all cells in the table data form should be fully evaluated. The form as provided can accommodate all stages.

In addition, there are supporting activities, namely quality control and reliability checks of codification. The quality control stages are mandatory.

During the above phases of Task Analysis, a complete list of tasks is obtained, and all the information related to them should be placed in a simple format. This format is called the Table Data Form and is described in the next subsections.

The products from this step of Table Data Form-General Requirements are completed at the three phases mentioned above (TT, WTTT, and simulator). The relationship of the outputs from this step and the Human-System Interface Design Implementation Plan [2.1 (5)] is defined in the scope of that plan. The HSI design will implement the requirements (identified in Section 3.3 as data sources 1 through 8) that have been developed in the task analysis process, including those tasks identified as critical tasks.

3.6.3 Task Analysis Data Form: Data Identification

The preparation of the TA is defined in this plan. In addition to preparing the TA, information related to system and TA preparers must be captured for the TA traceability. As a minimum, the following information should be captured in a Table similar to Table 4.

1. Plant Identification
2. Design Engineers: a, b, and c
3. Control Room Designers: a, b, and c
4. Data base
5. Data base personnel: a, b, and c
6. Task analysis personnel: a, b, and c
7. Operators (Depending on the phase when data are collected, it may be necessary to record the name or code name for personnel performing functions of operator or licensed operator.).
8. Task sequence number
9. Task definition
10. INPO task code
11. Type of task analysis:
    a. Tabletop
    b. Walk-through/talk-through
    c. Simulator
    d. All
12. Quality control completed (quality program related information such as quality level)
13. Quality check performed
14. Taxonomic coding performed
15. Taxonomic coding checked

3.6.4 Task Analysis Data Form: Information and Decision-Making Requirements

The level of detail desired is an important issue in this analysis. It is a major determinant of the time and materials required performing the analysis. The level in this plan is defined as the element level that can be identified, as the smallest integrated action required in completing a task. For example, if an operator wishes to start a pump (2-position switch), the element would be "activate pump to start." Taking into account the level of detail defined above, the detailed descriptions at the element level described on the Table Data Form are needed in order for one to know in a specific manner all the characteristics related to the task identified in the first part of this plan.

The outputs will be obtained by the combination of the information available on the columns. By sorting the field descriptors, one can obtain the requirements listed in Section 3.3.

The second part is the Table Data Form (Table 5) which is used to record data during the three stages of the task analysis: TT, WTTT, and SA. Fields in this Table Data Form are described below. The entire blank form is provided in Appendix A (Tables A-1 and A-2).

- **Task ID Field:** Task identification code. If applied, it could also be the activity number.
- **Who Takes Action Field:** Whose job is it to perform the task?
- **Element Field:** What the operator does. Enter the generic verb that can be used with any appropriate specific noun. Action verbs at the level of task elements based on the Berliner Taxonomy. Reference Table 3: Berliner Taxonomy.
- **Component Field:** Specific identification code of the component (MPL included) that it is affected by the verb (e.g., E11-F101 manual valve mode ACIWA ESBWR RHRS).
- **Parameter Field:** A specific noun indicating what aspect of the component is affected by the verb that is performed by the job performer (i.e., pressure regulation by the operator).
- **State Field:** An adjective, noun, or adverb that identifies the value of the parameter.

- **Other Obj Field:** A task specific noun that is also (incidentally) affected by the verb performed by the job performer. In most of the cases, the value is "null" if no other noun (i.e., pressure, temperature, etc.) is applicable. .

- **Plant System Field:** A label for the system involved in the task. This label is NPP-specific, depending on the engineering and control room design. This is not needed for a system level, but rather, is needed when more than one system is reviewed.

- **INPO Code Field:** A cross- reference to a table for the system above used in the taxonomy by the Institute of Nuclear Power Operation (if applied).

- **Means of Action Field:** How does the operator bring the parameter of the component in the plant system to its required state by the action described by the element?

- **Information and Control Capability Required Field:** This field describes the minimum information required by the operator to perform the element. This column includes cues for task initiation, controls, displays, and any other sources of information.

Any required information not available from the display system must come from some other source such as training, experience, and/or procedures.

The analyst team must partition a task into elements and then recombine them, as the operator will perform them, because the presentation of the information must support not only each individual element but also each task and function as a whole. Consequently, the operator can be effective without being inundated with extraneous information.

The purpose of this step is to identify the information needs of the user in terms of the attributes of the data to be presented (these attributes are defined in Table 6), the intended use of the information, and the control capability required. The process begins with the definition of the objectives of the computer-generated display system. These objectives should be clearly and accurately stated (functional analysis). To meet these objectives, the information to be transferred to the operator via the new system should be defined (task analysis). From this required information, pictures composed of elements such as mimics, bar charts, and trend graphs will be designed. These pictures (paper drawings) will later be transformed into displays that comply with the system constraints, defined by the design team. The analysis of tasks must yield sufficient detail about the attributes of the information requirements in order to determine what information must be presented and how it must be presented to be useful.

The product is a list of the information required by the intended user, grouped by task, and a description of the data characteristics and intended uses of the information. This list serves as the primary input to the design phase, wherein the design team specifies a display system for supplying the user with the required information.

The information may be solicited or unsolicited by the user, but in either case the information requirements must be well defined. Failure to do so will result in displays that have insufficient, inappropriate, or extraneous information, all of which are undesirable.

A proper design will integrate the presentation of user-solicited and unsolicited information. The unsolicited information should not be forced on the operator to the exclusion of solicited information.

The following set of questions provides a structure for defining key properties of information requirements. The answers to these questions, through the three phases of the task analysis, with emphasis on the Table Top phase and revision on WTTT and simulator phases, provide the basis for design decisions*.

1. How many dimensions of plant state does this task depend on?

   Dimensions are temperature, pressure, flow, speed, height, time, and switch position (taking into account the number of dimensions, the task should be unidimensional, duodimensional, or multidimensional).

2. How many variables does this task depend on?

   Single variable might be a single temperature value or a particular combination of temperature and pressure. If several variables were involved, it would be classified as limited multivariate.

3. How many samples of each variable are needed for this task?

   The number of samples to be displayed may depend on how rapidly the particular stream of information changes or how frequently the sensors sample the source.

4. Does this information come directly from measured data, or is it derived using a formula or model?

5. What is the primary function of the information?

* Questions 7 to 10 will be not applicable to qualitative information.
Questions 9 to 12 should be answered by "expert judgments."

Category 1: To alert, alarm, call attention, or otherwise make known to the operator that some noteworthy event has occurred. Such displays allow the operator to answer the question: Has something happened?

Category 2: To inform or supply detailed information about specific state variables and configuration of the plant. Such displays allow the operator to obtain quantitative or qualitative values for a variable or variables.

6. Does this task require quantitative or qualitative information?

   If numeric values or percentages are required, the information is quantitative, but status indicators and warning signals are examples of qualitative information.

   In answering this question, the analyst should specify whether needed quantitative information should be exact, approximate, or relative and whether qualitative information will be used for status or warning, prediction or pattern recognition.

7. What is the range of this variable?

   The normal operating range of the variable and the highest and lowest meaningful values of the variable.

8. What is the required level of accuracy for using this information?

   The required level of accuracy may depend on the current range of the variable.

9. How quickly will this information respond to control actions?

10. Is this information to be used in an absolute or a relative manner?

11. How important is this information relative to other information?

12. What are the temporal relationships between this information requirement and other information requirements?

13. Recommended picture and alternative recommendation: Criteria for selecting pictures according to data characteristics and intended uses are described in EPRI-NP-3701 [2.4(3)].

    A table form as presented in Table 6 can be used to record the answers to these example questions. The contents of Table 6 establish the characteristics and the use of the information requirements already identified on the suitable column of the Table Data Form (Table 5).

Related to the control capability required, the criteria should be considered from the following sources:

a. Control requirements are documented in the appropriate ESBWR DCD chapter, from the PRA (i.e., summarized in DCD Chapter 19), and in the EPGs;)

b. Designer's recommendations; and

c. Expert judgments obtained from task analyst's team

- **Information Available Field:** This column records additional information available to the operator in the control room during the performance of the element. Additional means the most suitable information besides that required above.

- **Evaluation Process Field:** This field describes the decision the operator needed for performance of the element. Evaluation process is filled out only when an action occurs as a result of a decision made by the operator.

3.6.5 Task Analysis Data Form: Response Requirements

- **Time Field:** Recorded from the beginning of the task, if possible, in hours, minutes, and seconds to the end.

- **Skill and Knowledge Requirements Field:** This column describes the relationship among objectives, functions, tasks, and information requirements that are not built into displays and therefore must be known by the operator.

This information supports identifying potential users. Although potential users are defined during system definition and objectives, the Skill and Knowledge Requirements field provides additional information needed to identify any special training requirements as well. Many design decisions depend on the identification of these special requirements. As part of the display design process, as necessary, displays of information are designed to accommodate the intended user with the special requirements identified in this column. This fit involves both cognitive and physical components.

Knowledge requirements: Cognitive fit supplies needed information at the proper level of detail or abstraction. This requires an understanding of the user's perspective of the plant. Therefore, identifying the user helps to determine the level of information needed. Also, it is important to know, if the user will be actively involved in controlling the plant or more involved with managing or supervising the active plant directly controlled by others. Additionally, knowing the user role(s) in plant control is essential. For example, knowledge requirements expected from operators are quite different, albeit non-exclusionary from management.

Skill requirements: The physical fit as well as the cognitive fit is highly dependent upon the intended user. This can be further broken down into the number of persons actually manipulating the controls. In this category, the number of simultaneous users and the types of skills required must be specified.

- Manual skills involve the coordination of hand movements in response to information received through the eyes or other senses.

- Communications skills include the ability to transfer information to and from others, orally and in writing.

In discussing the competence requirements of nuclear power plant personnel, it is useful to distinguish four levels of intellectual ability:

- Recall: the ability to recall factual information.

- Comprehension: the ability to use knowledge by translating it into a different form, by interpreting it (summarizing, generalizing, inferring), and by extrapolating it (estimating and predicting on the basis of trends).

- Application: the ability to apply and generalize knowledge to new situations.

- Evaluation: the ability to analyze, synthesize, and interpret information and to derive new relationships and concepts.

The levels of intellectual ability required for task performance are indicated in Table 8:

The three main types of nuclear power plant technical personnel (craftsmen, technicians, and engineers) require an appropriate combination of knowledge, intellectual ability, and manual skills as shown in Table 9. Specific training is also provided by the utility.

Taking into account Tables 8 and 9 (criteria from IAEA-TECDOC-525 [2.6(15)]), it may also be possible to identify additional specific knowledge and skilled requirements. Like the MCR operators, plant maintenance crews are made up of different skill levels. Requisite skills and knowledge may impact design decisions. This may cause the system designers to modify their definition of the user skill set.

- **Frequency of Action Field:** This descriptor identifies the number of times a specific action is performed. This column is not used, as each action is considered a separate element in the analysis.

  The rating scales are:

  - Rarely (less than once a year)
  - Seldom (one to three or four times a year)
  - Occasionally (about once a month)
  - Often (about once a week)
  - Very often (daily)

- **Difficulty of Task Performance Field:** Now it may be determined if the task performance requires a high, medium, or low degree of mental activity and the amount of motor combination required; once the two scales are established, the difficulty is the difference between the two scales.

- **Learning Difficulty Field:** This column describes the difficulty of learning to perform the task.

  The rating scales are:

  - When and how to perform this task properly without any direct training or practice is learned easily.
  - When and how to perform this task properly without direct training, but some practice would make it easier to learn.
  - Learned when and how to perform this task properly given sufficient time. However, training and practice would make the learning much easier.
  - The task would be difficult to learn to perform properly without some training and practice.
  - The task would be very difficult to learn to perform properly without significant training and practice.

- Potential for Error Field: The process of human error identification and assessment of the associated probability of successful performance of the human activities necessary for successful system performance is termed human reliability analysis.

There are these different steps:

- Identify the error and the potential for error (subjective determination made by the subject matter expert).

  High (greater than 10%)
  Medium (1% to 10%)
  Low (less than 1%) (referenced from NUREG-CR-2598 [2.6(14)])

- Estimate the likelihood that each error will be undetected or uncorrected.

- Estimate the consequences of each undetected or uncorrected error.

- Suggest system changes.

The purpose of human error analysis is to investigate the probability of operator error and to evaluate the consequences resulting from such errors. Modifications to the control room design to lower the operator's workload must be made for conditions where a great potential of human error exits in conjunction with unacceptable safety consequences due to human error.

By sorting the "potential for error" column and the "element," the actions that are likely to be made in error can be identified. This is very helpful when procedure writing. It indicates when cautions need to be stated in the procedure. It also aids the panel designer to design out operator error by special labeling or by procedural cautions.

The potential for error column is filled out last, using subject matter expert input.

3.6.6 Task Analysis Data Form: Feedback and Task Support Requirements

- **Connected with Other Tasks Field:** In some cases, it is adequate to mention the relation between other tasks.

- **Feedback Requirements Field:** This descriptor identifies feedback informing the subject of adequacy or inadequacy of means of action, i.e., the type and source of indications available to the operator which indicate that system response has occurred. This descriptor is filled in only if an action has been taken. Feedback requirements are addressed in the HSI Design Implementation Plan [2.1(5)]

  The actions that the operator performs to accomplish the elements of a task are identified in the data form of Table 5. The analysts then document in the feedback column the need for and characteristics of first and/or second level feedback to verify actions identified in the table. Feedback Time Field:

Response time is effectively the time the user spends waiting for a response to a request. The response may range from a simple acknowledgment of the command to the completion of the operator's request. The acceptable response time depends on the nature of the request and the nature of the response; it can be an important factor in reducing operator errors and in achieving operator acceptance of computer systems[GWH85].

In the previously described feedback column of Table 5, the analyst team members document the need for a first or second level of feedback according to the characteristics of the actions identified above. In this case, the analysts suggest the time at which the feedback should be provided. Job Performance Aids Field: This column describes job aids, references, or procedures (if applied) used by the operator in element performance. It depends on the choices of the design team. The task can be accomplished with or without these kinds of aids.

- **Tools/Equipment Field:** Any tool(s) or equipment required for use during the performance of a particular element.

For example, the kinds of tools and equipment are:

- Computers
- Electrical test equipment
- Portable radiation detection equipment
- Measurement test equipment
- Mechanical tools
- Lifting and transfer equipment
- Protective equipment
- Communications equipment
- Miscellaneous tools and equipment

The resource documents and references are:

- Operational procedures
- Technical references

- Operating shift documents
- Miscellaneous references

3.6.7 Task Analysis Data Form: Staffing, Communications, and Workplace Requirements

- **Location Field:** This field identifies the position in the control room the operator physically occupies when element is performed.
- **From Field:** This field identifies the person who starts the communication and his/her location.
- **To Field:** This field identifies the person who receives the communication and his/her location.
- **How Field:** This field identifies the way in which the communication takes place.
- **Content Field:** This field describes the text of the communication.

3.6.8 Task Analysis Data Form: Hazards Involved

- **Any Hazards Involved Field:** This column records any special or hazardous situation related to the task's performance.
- **Comments Field:** This column includes any particular recommendation or consideration about the adequate performance of the task.

By using the descriptors of columns described above, a preliminary definition of the outputs of this part of task analysis will be obtained. These outputs will allow the analyst team to identify the information and control requirements that form the basis for specifying the requirements for the displays, data processing, and control needs to carry out the tasks. It can also be used to maintain human performance requirements within human capabilities, as input for developing personnel skills, personnel training, procedures, and communications requirements. It can also be used as an input to the evaluation of the control room staffing levels of established plant operations.

- The control and information requirements compiled in the appropriate columns in the Table Data Form will assist in determining the type of equipment necessary in the HSIs (hardware and software). The task analysis shows which of the many plant parameters must be monitored or manipulated to accomplish the task.

- Having the table sorted by the "information available" and the "information required" descriptors, allows comparison of the information explicitly presented with that information needed to perform the task. This kind of comparison establishes the training requirements or changes, which must be made to the information available.

- By listing the "element," "means of action," and the "feedback requirements" descriptors, one can analyze whether sufficient indication is given when a control is manipulated. One can also analyze the availability of sufficient information and sufficient feedback of action (that it can be cited as critical items).

- By analyzing the sequential accumulation of task times, one can evaluate the capability of the control operators to perform all assigned tasks in the time required to maintain plant safety and availability.

- By having a sort of the elements and the location descriptors, one can derive the information to a link analysis and thus help achieve a near-optimal design for the workplace and avoid congestion of personnel activities.

- This part of the task analysis process can also provide the basis for a human error analysis, in order to investigate the probability of operator error and to evaluate the consequences resulting from such errors. By sorting the "potential for error," and the "element" descriptor, which actions are likely to be made in error can be identified. This is an output for the written procedures (this formal task analysis helps assure that nothing will be overlooked and that the step-by-step format translates easily into a procedure).

- By sorting the "elements," "time," and "evaluation process" columns, one can define a total spent time for each evaluation process.

- By fulfilling the communications descriptor effort one could categorize and document communications in a more detailed way. This reveals the nature and frequency of the communications that are an integral part of the task.

All the requirements derived from this process will be documented in the Task Analysis Report defined in Section 3.9.

3.6.9 Database Recommendations

The full usefulness of a task analysis depends on the flexibility and ease with which the data can be examined. It should be possible for the analyst team to ask a wide variety of questions, to compare different tasks and elements, and to examine the data for establishing the types of cognitive information processing and decision making required. A multi-disciplinary technical staff is needed to conduct the task analysis. The disciplines and experience of the staff should include nuclear engineering, instrumentation and control engineering, and human factors engineering.

Given the enormous quantity and complexity of the data, the recommended way in which it can be used is by a well-organized computerized database management program. The characteristics of the INPO database are the more interesting because it is derived from a PTA.

3.6.10 Workload Assessment

An important indication of the acceptability of the design of a man-machine system is that of the physical and mental workload of the operators. Physical workload in this context refers to the time for which an operator is physically busy, as opposed to psychological capacity or endurance.

Operator workload is widely recognized as having a potentially major effect on human reliability. High levels of workload may lead to stress and hence to an inability to perform the operations required to meet the necessary standards in the time available. If the workload is too low, reliability can be affected through boredom or reduced operator vigilance.

The workload is a function of the time available to carry out the tasks, the amount of tasks to complete, and the duration and difficulties of the tasks.

Techniques for addressing workload issues have involved timeline analysis. In this way, it can be demonstrated how workload may be predicted at a relatively early stage in the system development.

The human operator has a limited capacity to process and respond to information. If the processing and response demands of a task exceed available capacity, the resulting overload can lead to reduction in operator performance. Under most conditions, increases in task difficulty lead to increases in resources or capacity expenditure.

The term "workload" refers to the portion of the operator-limited capacity actually required to perform a particular task. The objective of workload measurements is to specify the amount of expended capacity. This quantification can be used to avoid existing or potential overloads, to ensure adequate operator performance. Demand may or may not correspond with performance.

The importance of mental workload may be viewed in two different contexts:

- Workload estimation

- Assessment of workload imposed by the system or experienced by the human operator

There are a number of techniques proposed as workload estimation and assessment procedures, and their use depends on the task analysis phase at which this workload estimation and/or assessment has to be obtained.

At an early stage of the design process in which there is available data from the criteria for staffing in the DCD, tabletop analysis, it should be convenient to utilize a technique for the workload estimation. In the next phases, in which other support and a part-task simulator are available, other techniques to assess the workload should be more adequate. The next paragraph describes the kind of techniques appropriated for each situation.

1. Workload estimation

   At an early stage of the design process in which there is available data from Tabletop analysis and personal minimum requirements, it should be convenient to utilize a technique for the workload estimation based on task assessment.

   a. Task assessment:

      Each individual task is assessed by the analyst team and rated in terms of difficulty, complexity, accuracy, special skills/knowledge requirements, time constraints, and critical cues (e.g., when to start and/or finish the task) and criticality (for safety, and/or for plant availability). To assist in the task assessment and rating, the Table Data Form (Section 3.6.2) may be used.

      Task assessment combines the virtues of being resource-efficient and capable of identifying potential man-machine interface shortcomings, while containing a rating scheme that could allow a rapid indication of the task workload to be obtained.

      To graphically describe the overall estimation of the potential workload, a workload indicator is produced based on time-weighted task ratings. The summated task ratings are plotted in the form of a histogram to give a comparative indication of the potential operator workload throughout the performance of the task.

   When the time is identified as a critical factor in the overall estimation of the potential workload described above, it is necessary to develop a timeline analysis (e.g., OSD diagrams described in Section 3.5.8).

Timeline analysis is a method of identifying the density of tasks to be performed. It graphically represents the relative timing of different tasks and the duration of individual tasks, and hence identifies where parallel tasks, are required to be performed.

Timeline analysis maps the tasks of operators along the time dimension, taking into account: task frequency, task duration, and interactions with other tasks and other personnel. It is useful for estimating workload; it can also be used in human reliability analysis to estimate the likelihood that an operator or operating team will complete a task within a particular time.

Workload analysis can be done effectively by using a temporal operational sequence diagram. (The process of task identification used in the first part of this plan includes a temporal operational sequence diagram (OSDs). It is really a specific type of vertical timeline analysis.)

The time is associated with the timeline for each task element (first column of the Figures 13 through 15) can be derived either from direct observation, from observation of similar tasks, or by estimation. Specific time allowances should be estimated for decision-making. The systems engineers may provide system response times as system requirements, communications, etc., and such allowances must be clearly defined and consistently applied.

The timelines are to be based upon a single time estimate for each task element through one of two ways:

b. Objective single time measures for task element

c. Subjective single time measures for each task element

In the first method, one could analyze more precisely by estimating the average times and by doing some statistical measures of variability, (such as the standard deviation), on the same timeline diagram.

The method for doing this depends upon how the task elements are associated with each other. If the analyst has any reason to suspect that the time taken on one-task element influences the time taken on the subsequent task element, standard deviations cannot properly be estimated for the individual task elements.

This situation is likely to occur when operators have to make decisions while undertaking other tasks (time-sharing). In such situations, it is preferable to base the timeline upon the standard average times for each task element; however, leaving gaps between each timeline section to account for planning , observation, communications, etc. should lengthen the time from the start of the task sequence to its conclusion. These gaps aggregate to one standard deviation of the entire task duration.

The size of each of these gaps should be carefully estimated by first calculating the proportion of the total average task time taken by the preceding task element. The following gap should then represent the same proportion of the standard deviation time. Thus if the average time for a particular time task element is twice as long as the time for another task element, this should be followed by a gap that is twice as long.

This approach is appropriate when the task-sharing time is competing for the same resources because it is based in the single-resource theory.

This timeline analysis has to take into account the cognitive processing resources required to carry out the tasks. (The multiple resources model recognizes that two tasks overlapping on the time line could provide either very efficient or very disruptive performance, depending on their degree of resource conflict: Wickens et al., 1989.)

In many situations, the system imposes certain constrains upon when particular tasks can be undertaken. For instance, certain task elements may have to be completed within a limited time window. Such external time constrains can be shown clearly on a timeline diagram, by drawing a distinctive line or lines at the appropriate point.

A way to graphically describe a workload analysis is to convert the timeline diagram into histograms in order to illustrate it. This technique requires that an "expert" make a subjective assessment of an operator's workload while this operator is undertaking particular tasks. These assessments are usually made on a five- or six-point scale, with ranges from a workload of 0% to one of 100%.

However, care must be taken in interpreting workload profiles, because long periods of low workload can be detrimental.

It is usually acceptable to have very short periods of high workload. As a rule of thumb, for sustained tasks, workloads of between 50% and 75% can be considered acceptable.

The final estimation of the workload derived from time analysis can be estimated taking into account the time available ($T_{available}$) to perform the task and the time at which the operator is occupied ($T_{occupied}$). Workload is calculated as:

$$\text{WORKLOAD} = \{ T_{occupied} / T_{available} \} * 100 \qquad (1)$$

The workload is considered satisfactory if the following applies:

$50\% \leq x \leq 75\%$, where x = calculated workload for an individual operator.

2. Assessment of workload imposed by the system or experienced by the human operator.

   In the next phases of the design process in which there are other supports (such as part-task simulator) available, traditional techniques to assess the workload should be considered adequate.

   a. Primary task measures

   b. Secondary task measures

   c. Subjective measures

   d. Physiological measures

Because of the variety of workload assessment techniques available, care must be exercised in selecting appropriate techniques for each specific application.

Any technique to assess workload in this phase should ideally meet a number of criteria: sensitivity, diagnosticity, selectivity, obtrusiveness, implementation requirements, and operator acceptance.

- Sensitivity: The technique should be sensitive to changes in task difficulty or resource demand.

- Diagnosticity: The technique should indicate not only when workload varies but also the cause of such variation. It should indicate which of the capacities or resources are varied by demand changes in the system.

- Selectivity: The technique should be selectively sensitive only to differences in capacity demand and not changes in such factors as physical load or emotional stress, which may be unrelated to mental workload or information processing ability.

- Obtrusiveness: The technique should not interfere or disrupt performance of the primary task whose workload is being assessed.

- Implementation requirements: Factors related to the ease of implementing a particular technique, which include instrumentation requirements and any operator training that might be required.

- Operator acceptance: Degree of willingness on the part of operators to follow instructions and actually utilize a particular technique.

Some of these criteria may trade off with one another, so rarely—if ever—will one technique be found that satisfies all criteria.

- Primary-task measures:

    The operator's ability to perform a task ought to serve as a validating measure for any other measure of workload. The level of performance an operator achieves on any task is a direct measure of the difficulty, and by implication, of the workload associated with the task. In this consideration, one can assume that neither motivation nor the basic ability changes. One can also take into account changes in performance due to limitations on the information processing system. In this case, it would be appear natural to use the performance on the primary task as a measure of the workload.

    Work area location is defined on the Table Data Form (Table 5) as workspace descriptor.

    The kinds of measures that can be obtained are direct measures of performance, time of the adequate performance of the task, errors, and their types, etc.

    If the measures obtained are satisfactorily related to the adequate performance, primary task measures do not indicate the amount of reserve or spare information processing afforded by the performance of the task.

    However, under conditions of adequate performance, it may still be critical to determine, for instance, which of two display options (e.g., alphanumerical versus pictorial) imposes the lower workload and affords the greatest capacity. This would be the case when it was anticipated that other information processing and response requirements in the operational environment might be sufficient to overload the operator and lead to degraded performance.

    In this case, secondary-task, subjective, and physiological measures can be more sensitive than primary task measures and should be more appropriate to meet the objective of identifying potential workload.

- Secondary task measures:

The workload task associated with a given task (the "primary task") is measured by assigning the operator another task to perform concurrently with the primary task.

Fluctuations in performance on the secondary task or primary task, depending on the instructions allocated to the operators, are therefore assumed to reflect the fluctuations in the associated workload and the pool of resources.

When selecting the secondary task, an important decision to make is whether to maximize the interference between the concurrently performed tasks (competing for the same resources) or to search for a paired task that can be performed in parallel uninterrupted.

The secondary-task technique has distinct benefits: It has a degree of face validity, and it predicts the amount of residual attention an operator will have available. Also, the same secondary task can be applied to two very different primary tasks, and it will give workload measures in the same units.

The problems of obtrusiveness (this is the disadvantage generally cited in the cost-benefits analysis of this technique) could be avoided by the use of embedded secondary tasks. In this case, the secondary task is actually a legitimate component of the operator's total task responsibilities.

This validity places the technique in contrast with the subjective and physiological measures described below.

- Subjective measures:

A variety of subjective techniques have been proposed to assess the effort required to perform a task.

A common multidimensional assessment technique is the NASA TLX scale (Figure 15), which assesses workload on each of five 7-point scales. This technique has formal descriptions for how the multiple scales may be combined to obtain a single measure.

The TLX technique has a greater number of scales and a greater resolution per scale, potentially allowing it to convey more information than others techniques, such as the SWAT (Subjective Workload Assessment Tool) technique. {Both of these techniques are from AD/A226480 [2.5(7)]}.

In regard to the benefits of these subjective techniques, note that they do not disrupt primary task performance, and are relatively easy to derive. However, these measures are subject to biases such as uncertainty with which an operator's verbal statement truly reflects the availability of or demands for processing resources.

- Physiological measures:

  This kind of measure is based on recording, unobtrusively, the manifestations of workload or increased resource mobilization through appropriately chosen physiological measures such as: heart-rate variability, pupil diameter, and evoked brain potential.

  However, these techniques measure the reaction to the load, not the load itself; they are indirect indicators.

  Workload differences measured by physiological means must be used to infer that performance breakdown would result or to infer how the operator would feel about the task.

  The results of these measures indicate the lack of generalization, sensitivity, and reliability across some mentally demanding tasks. Another difficulty could be that these measures could indicate increase in mental activity when task difficulty increases from low to medium, but it may show decrease after the workload continues to increase.

3.7 Methods for Identification of Critical Tasks

Critical tasks shall be identified to have a specific treatment during the design stage. The task descriptions and operational sequence diagrams shall be used to identify a task as critical task.

The MMIS and HFE plan [2.1 (3)] and appropriate section of ESBWR Chapter 18 of the GE ABWRESBWR Standard Safety Analysis Report (SSAR) documents that critical task shall include as a minimum: :

- Those operator actions that have significant impact on the Probabilistic Risk Analysis (PRA) results, are described in the insights section of the ESBWR DCD Section 19.4.

- The operator actions to isolate the reactor and to inject water for the postulated event scenarios of a common mode failure of the safety System Logic and Control System and/or essential Multiplexing System concurrent with a design basis main steamline, feedwater line, or shutdown cooling line break LOCA.

In addition to those tasks imposed by the ESBWR DCD, the tasks that meet the following requirements should be considered as critical:

- A task involved in the achievement of a critical function to safety.
- A task with a great potential for human error.
- Task failure will make impossible the achievement of the associated safety critical function.

Where critical functions are automated, the analysis shall address the associated human task including the monitoring of the automated function, and the backup manual actions that may be required if the automated function fails.

The process to follow in order to classify a task as critical is shown in Figure 18.

Once all critical tasks are identified, these tasks should be carefully analyzed and documented to take into account during the design stages. The identified set of critical tasks shall be used as:

- Inputs for the training programs

  Critical tasks should be carefully treated in the training programs. This reduces an operator's error by ensuring that the operator has a better understanding of the task's importance and its adequate performance.

- Inputs for review the task analysis process

  Task analysis of critical tasks should be reviewed to obtain detailed assessment of personnel workload and requirements about information, controls, feedback, support, etc.

- Inputs for procedures development

  During the procedure development process, all documented critical tasks should be taken into account in order to provide special guidance for critical task performance.

3.8 Identification of Requirements for Alarms, Displays, Controls, and Data Processing

Requirements for alarms, displays, controls, and data processing are obtained from the Table Data Form described in Section 3.6.2. This table should be detailed enough to identify all these requirements. A complete set of requirements will be those defined in the ESBWR standard design features complemented with those derived from other matching areas identified in the Table Data Form.

At that early design stage (Table Top task analysis), using the recommendations derived from the Table Data Form, the design team supported by the task analyst team could define a preliminary HSI design. This preliminary design is to be refined by the feedback process performed during the subsequent Task Analysis phases. For ESBWR, these requirements are captured and documented in the human-system interface (HSI) report.

3.9 Task Analysis Report

The task analysis report will be produced by the analyst team and available to the ESBWR design team members for review. This report will address the following:

1. Objectives of the task analysis
2. Description of the methods employed in the conduct of the task analyses
3. Identification of the deviations from this Task Analysis Implementation Plan
4. Presentation and discussion of the results of the task analysis, including discussion of design change recommendations derived from these analyses and/or negative implications that the current design may have on safe plant operations
5. Conclusions regarding the conduct of the analyses and the analyses results

The TA report summarizes the system functions, modes of operation system and human operator tasks. The TA report also identifies the OSDs that are useful in viewing pieces of the overall system tasks.

The Design Team's evaluation of the task analyses shall be reviewed in accordance with the applicable GE Engineering Operation Procedures for document revision control. The review of the Task Analyses Report should consider the following criteria as part of their review:

1. The methods and procedures used for review of the completed task analyses
2. An evaluation of the compliance with the Task Analysis Implementation Plan and theMMIS Implementation Plan andMMIS Implementation Review Plan [2.1(8)]
3. Document human engineering discrepancies into the HFE Issues Tracking database [2.1(3)]

4 Methods for the Evaluation of the Task Analysis Results

4.1 Objectives

The objective of evaluating the results of task analysis is to ensure that the task analysis defines the system design goals. Consistent with these goals, the evaluation should identify tasks being performed by the task performer or system that are not consistent with the system's design requirements. The information obtained with the implementation of this plan must fulfill criteria such as specificity, completeness, consistency, good documentation, understandability, and usefulness from conceptual design through evaluation phase.

The evaluation process presented here was developed with two objectives in mind: First, evaluation should be an integral part of design. This requires that the evaluation process be iterative in the sense of including multiple phases of evaluation, with the results of each phase being used to modify the design of the system as necessary.

The second objective was that the evaluation process be efficient in terms of both time and cost. The importance of time and cost dictates the use of fast and inexpensive evaluation methods to the greater extent reasonable.

Therefore, the combined objectives of efficiency and design-oriented successive refinement dictate that the overall evaluation processes include multiple evaluation methods. These alternative methods range from the checklist or paper-simulation (utilized in the first phase of task analysis to part-task evaluation) or full-scope simulator evaluation (applied in the related phase of task analysis). The main criteria to be taking into account in general process of design evaluation will be the following:

- Compatibility: The nature of physical presentations to the operator and responses expected from the operator must be compatible with human input-output abilities and limitations.
- Understandability: In the sense that the structure, format, and content of operator-system dialogue must result in meaningful communication.
- Effectiveness: A system is effective only to the extent that it supports an operator or a crew in a manner that leads to improved performance, results in a difficult task being less difficult, or enables accomplishing a task that could not otherwise be accomplished. Regardless of the measures chosen, however, it is of no use to attempt an assessment of effectiveness unless compatibility and understandability are first assured.

Based on the above line of reasoning, a general evaluative sequence emerges: Compatibility must be assured before assessing understandability, and understandability must be assured before assessing effectiveness.

4.2 Techniques

These techniques are used to assess the adequacy of the facilities that the operator(s) have available to support the execution of the task. They directly describe and assess the interface (displays, controls, tools, etc.).

These techniques are usually in the form of:

- Paper-and-pencil evaluations
- System Operating Procedures (SOP)
- Ergonomics checklists
- Special interface survey

The categorization above requires qualification. First, some of the techniques are difficult to classify, and they appear to be able to fit into more than one category in a global evaluation of task analysis (static mockup, part-task simulator, or full-scope simulator as described in the Human-System Interface Design Implementation Plan [2.1(3)]). Next, these techniques offer one part of a complete human factors process.

The task analysis results identify the requirements needed to design the interface. The evaluations of these results are an integral part of the general design evaluation.

For ESBWR, the system responsible engineer (RE), responsible for the mechanical and controls, will contribute a valuable review. The RE shall be responsible for reviewing the TA recommendations for system changes. The RE will also check for technical accuracy.

4.2.1 Paper and Pencil Evaluations

The paper and pencil evaluation is so named because the evaluator uses written guidelines or questions as evaluation criteria. One purpose of paper and pencil evaluation is to catch obvious or glaring human engineering deficiencies that might compromise system understandability or effectiveness.

To determine that the information required by the task in the column related to information requirements in the Table Data Form can be extracted, each "picture design" should be evaluated along the following dimensions:

1. Content density

   The design team may be able to evaluate content density by considering the following questions for each picture:

a. Does the picture appear congested?

b. Is it difficult to locate needed information due to the large number of picture elements?

c. Are there likely to be many elements competing for the user's attention?

d. Does this picture require lines of demarcation or other symbols to separate elements from one another?

e. Does scanning this picture for important information, require focusing on each individual element separately?

2. Content integration

   Content integration pertains to how well the elements of the picture fit together to form an integrated presentation of the information.

3. Format orientation

   Format orientation pertains to the ability of the picture format to organize and highlight meaningful information. Proper format orientation requires a consideration of what information is needed and how it will be used.

   The following questions may help:

   a. Is there a meaningful relationship between how the information is displayed and the operational use of the information?

   b. Does the format present the information with the necessary level of precision?

   c. Does the format highlight important elements to attract attention?

4. Cognitive fidelity

   Cognitive fidelity pertains to how well the display of the information matches the user's internal model of the plant. It is important to convey information at a level of abstraction consistent with the need of the user.

4.2.2 System Operating Procedures (SOPs)

The system operating procedures (SOPs) are used by the evaluators to check against the TA and HSI reports. The tasks in the SOPs should be consistent with the TA report. The reviewers should be careful because the tabletop TA defines the task required to support system safety and non-safety functions. The SOP will provide additional tasks to perform prerequisites and other tasks that may be beyond the TA report. The RE and HFE need to review and interact to ensure that the goal of the TA compliments the goals of the SOP.

4.2.3 Checklist

The development of checklist items can be very resources-intensive. Because they are so different from applications that only require a few checklist items, it will be preferable to use, or adapt, an existing checklist than to design a new one. There are several ergonomics checklists that can be used in part, or in whole, for analysis tasks and their associated interfaces (reference documents).

- The first stage in checklist design is to select the criteria against which checklist assessments are to be made.
- The criteria should be worded as clear positive statements, which demand either agreement or disagreement.
- All the items should be written in a consistent manner.
- To the right of each item, at least two columns should be provided.
- In many situations it will also helpful to use a "not applicable" column.
- It will be necessary to provide some background information to assist the analyst in making his/her checklist judgments. Such information should be provided as close as possible to the checklist items and should remain part of the checklist (with explanatory diagrams where possible).
- If it is necessary to have a large number of items on a checklist, it will be helpful to group these under a limited number of subheadings.
- An analyst should fill in checklists in a systematic manner, either by checking through each checklist item in turn, or else by checking the same item on all instruments, or parts of the system, before moving on to the next item.
- As a measure of the inadequacy of the system there are:
  - Items that have failed to meet the prescribed criteria. These numbers of items are a measure. However, because checklist items are not generally scaled in terms of their importance, it is not possible to compare the responses to different items without further information. Therefore, for every checklist item that fails to meet the prescribed criterion, the analyst should gather further information so that the significance of that non-compliance can be judged.

- One relatively simple method of making such an assessment is to use two numerical rating scales for each noncompliance on a 3-point scale, with noncompliance rated as 1 and large numbers of noncompliance rated as 3. The other scale should assess the likely consequences of a failure due to a noncompliance, with a rating of 3 being given to the most serious errors. Then the significance of each noncompliance can be calculated by multiplying the two ratings.

- A less informal method is to use the TA, SOP, and HSI reports and to annotate comments directly on them. This ensures that comments are captured and the marked up documents can be used to prepare document changes and also used as input into the design record file (DRF). This method is preferred over the lengthy preparation of a "checklist". Any open issues or human engineering discrepancies (HEDs) can be document in the HFE ITS.

4.2.4 Interface Surveys

Interface surveys are groups of information collection methods that can be used to gather information about specific physical aspects of the person-machine interface at which tasks are carried out. For these purposes, the person-machine interface is defined very broadly, so that it encompasses the ambient environment, as well as the controls and displays for the system. Each survey method is limited to considering specific aspects of the interfaces, and so it will usually be necessary to select a set of these methods that can address the particular issues of interest to an analyst.

Some of the survey methods can be used throughout the life cycle of a system, but others (such as environmental surveys and operator modification surveys) cannot be used until there is an actual system in existence.

The information from interface surveys can be used to produce detailed system control and display lists, which define the facilities that the system provides for the user. These control and display lists can be then compared to the task requirements to check whether there will be any mismatches between the information and control facilities that are supplied by the system to the operator, and those required to conduct particular tasks effectively.

4.2.4.1 Control/Displays Analysis

A control/displays analysis is a detailed survey of the control and display facilities provided in a system. This can then be used to ensure that all necessary instrumentation has been provided for a particular task.

In order to develop a control list, the analyst should systematically examine each control in turn, identifying the control, recording the parameter, recording the type of control (push-button, rotary switch) and listing other details that might be useful during any subsequent analysis (its safety classification).

The same could be applied in the case of a display list; however, for some displays (dials, indicator lights, computer screens) it may be also appropriate to note any particular important values (such as normal and abnormal operating limits).

The manner in which the list is ordered should be system, subsystem, and parameter, with alphabetical and numerical ordering within each level of the hierarchy.

Using a format like the following might be helpful.

Control				Display		
Ref.	**Type**	**Range**	**Parameter**	**Ref.**	**Type**	**Range**

The lists can also be used as a source of information for checklist studies.

4.2.4.2 Coding Consistency Surveys

A fundamental ergonomics principle for the design of complex systems is that the human perception and organization of information can be significantly aided by providing additional cues to the users, in the form of various types of perceptual coding.

A coding survey is intended to systematically investigate the coding systems; this should enable the analyst to determine what meanings have been associated with various codes, so that ambiguous or misleading coding can be identified. It should also show where additional coding is required.

In its simplest form, the output from a coding consistency survey consists of:

- An item reference
- A full description of the coding that has been observed for a particular item
- Any other supplementary coding that is present
- A full description of the feature/function being coded

Using a format like the following might also help.

Reference	Coding	Supplementary Coding	Meaning

Conducting a coding consistency survey can be done in two ways:

1. Examine a single type of coding systematically throughout the entire system
2. Work to the display pages for all coding methods at once

The coding systems that could be surveyed could include:

- Color of illuminated indicators
- Color of controls
- Background color
- Size of controls
- Shape of controls
- Relative position of instrument
- Relative position of specific markings on multiple position switches
- Relative position, or orientation, of scale markings (such as zero points) on scales
- Instrument identification codes
- Auditory coding
- Highlighting methods

After all the information has been collected, it can be analyzed to identify how well particular coding conventions have been established, and also to show where the coding needs to be modified.

Finally, the preceding information should be used to determine whether groups of controls and their related displays are related to each other in a compatible and ergonomically acceptable manner.

4.3 Advantages

4.3.1 Ergonomics Checklists

Checklists provide an easy way to evaluate whether a system meets specific criteria, which are either mandatory or are particularly important to an organization.

The completed checklist can be used as evidence that the system meets a particular set of criteria.

4.3.2 Interface Surveys

Examining system drawings, thus requiring only a limited amount of the analyst's time can generally collect the information for each of these interface surveys. Each survey method is relatively easy to administer.

4.4 Disadvantages

4.4.1 Ergonomics Checklists

- It is often necessary to have a good understanding of the underlying ergonomics and psychological principles before certain checklist items can be effectively answered.

- Checklists do not generally make any attempt to assess the relative importance of different items, or to indicate the degree to which items may fail to meet the criteria. Thus, there is a need to undertake some prioritization of checklist failures, in order to avoid misinterpretation of the information.

- Checklist items are usually unidimensional, and take no account of the important interacting variables (e.g., one item may concern the avoidance of a "cluttered" display structure on a VDU system, and another checklist item may recommend that all relevant information should be placed together on the same page). In cases such as this, the analyst must use judgment to decide where the trade-off between these potentially opposing principles should lie.

- In large systems, equipment-based checklists can soon become unwieldy, and use up a considerable amount of an analyst's time.

4.4.2 Interface Surveys

- Although the surveys are relatively simple, in some situations the volume of items that have to be related could make this a somewhat enormous task.

- Some of the survey methods can only be used when a system is already in existence.

4.5 ESBWR Evaluation Techniques

The techniques in Section 4 have been provided for the use of the ESBWR design team. They provide alternate methods to be used for the evaluation of the appropriate TA. Due to the necessary schedule for preparation and review of the user interfaces, it is anticipated that the TA reviews and comments will be captured directly onto the TA and HSI reports. Preparation of the checklists and surveys are good but they are time consuming in preparation and their cost-benefit is questionable.

The TA may provide suggestions for operator training and qualifications but the utility is still responsible for meeting regulatory requirements for training and personnel selection. Because the ESBWR is an evolutionary design, the training and personnel requirements are based upon existing requirements. Selected changes may be made, as necessary, to accommodate the new computer-generated plant information and control displays for both non-safety and safety systems.

5 Training

One application of task analysis is in the area of personnel training and establishment of qualifications for position. Qualifications and training are overlapping areas. The needs addressed in both may include job skills and knowledge, basic education/academic skills and knowledge, adaptive skills and attitudes, and physical abilities.

Job training may be analyzed in terms of content (the learning to be acquired) and also in terms of delivery, including such matters as instructional methods and materials, settings, providers, length of training, and measurement. The major role of task analysis is in establishing the training contents requirements. This includes identification of skills and knowledge required meeting task responsibilities, as well as the development of learning objectives that provide the structure for performance-based training.

Qualifications may be evaluated at two levels: the ones necessary for probable success in the training program and the ones necessary for successful performance as a job incumbent. Basic education, adaptive skills, attitudes, and physical abilities are primarily concerned with selecting candidates for admission to training. Job (or licensing) qualifications are primarily concerned with job-specific skills and knowledge.

This section shows how task analysis results can be used as input for training program development.

5.1 Methods to Document and Assemble the Task Analysis Results to Provide Input for Development of Personnel Training Programs

One of the first steps to establish performance-based training is to conduct a job analysis. Job is defined as the duties and tasks performed by a single operator, and job analysis is a process to produce a list of tasks to be included in the training program for a specific job. This list clearly and accurately defines the activities performed on the job.

Job analysis is used to identify all of the tasks that are involved in performing the job and in determining the importance and difficulty of each task. This information is used to determine which tasks require training and which may require continuing training. The process of task identification (OSDs, narrative task descriptions) and detailed task analysis (Table Data Form) performed shall be used to conduct this job analysis (all tasks performed by each member of the operating team shall be grouped).

The selection of which tasks should be included in initial and continuing training programs can be based on the application of criteria such as:

- Frequency of carrying out the task
- Degree of difficulty/complexity
- Implication of incorrect execution on plant safety
- Implication of incorrect execution on plant availability

All this information can be derived from the Table Data Form presented in Section 3.3 of this document. A flowchart showing the process of training requirements identification is shown in Figure 17.

After a function's tasks have been identified and the appropriate tasks selected for the training program, those tasks shall be analyzed from the viewpoint of training. Experts experienced in the performance of the applicable job (subject matters experts) shall perform the analysis. The output of this analysis is a list of the skills and knowledge required for the proper performance of the tasks of that job/position.

The following three task attributes should be considered as input for training programs:

- The action to be taken or accomplished
- The conditions under which that action is taken (plant conditions, etc.)
- The standard of acceptance performance

Task analysis is a powerful tool for defining the knowledge and skill requirements for a specific job. Task analysis is also useful of quantifying the expected performance of job performers. In general, it is difficult to achieve this goal completely. The difficulty lies in performing job and task analysis for complex, non-repetitive tasks and particularly in determining performance standards for such tasks. Determining the competence requirements for jobs that involve intellectual tasks must rely on expert judgment as well as the results of task analysis.

In order to associate all the tasks selected for training with the skills, knowledge, and abilities required to perform them, NUREG-1123 "Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Boiling Water Reactors" can be used. This document is based on an industry survey of nuclear-power plant control-room personnel conducted for INPO (Analysis and Technology, Inc., 1981). This survey of operator tasks provides ratings of task difficulty and importance. From these two documents, inputs for training program development are obtained using the list of skills, knowledge, and abilities that they provide.

6 Maintainability

The general process for task analysis includes considerations about operations during periods of maintenance, test, and inspections of plant system and equipment.

Operating modes during periods of maintenance, test, and inspections are identified as a result of system functional requirements analysis, using the ESBWR DCD as the starting point. These operating modes will be analyzed (equal to the rest of operating modes) during the allocation of function and task analysis phases. This will ensure that the plant maintenance tasks can be monitored and controlled through the HSI.

Requirements about information, controls, displays, alarms, communications, etc., will be obtained as an output of the task analysis process. This will include the maintainability of the HSI that supplies information, alarms, controls, etc. during the operational periods. Once these requirements are established, they will be used to provide specific man-machine interface design recommendations for both maintenance of plant systems and maintainability of HSI during operational situations.

The maintenance of safety systems is regulated by technical specifications for both frequency and components. The TA may provide or identify information and controls that are not consistent with expected new staffing. As an example, a task may require the operator to perform a maintenance task at one location in the MCR, when the surveillance procedure may assume that the same operator is at different panel in MCR or at a local panel. .

A TA that is performed to evaluate the performance of maintenance tasks would be performed n the same manner except that more steps could be performed to account for a larger amount of usual prerequisite tasks. The number of tasks, of course, would be dependent on the level of detail of both the TA and/or the maintenance procedures.

Table 1 Studies Techniques Selection Chart

(Design Basis: 7.1.2 HE Analysis Techniques, DOD-HDBK-763)

Selection Evaluation Characteristics		Mission Scenarios	Function Flow Diag.	Task Description	Op. Seq. Diagrams
Most Applicable Program Phase	Conceptual	✓	✓	✓	✓
	Validation		✓	✓	✓
	Full Scale Develop.			✓	
	Production				
Relative Complexity	Simple	✓	✓	✓	
	Average				
	Complex				✓
Used For	Gross Analysis	✓	✓	✓	
	Detailed Analysis			✓	✓
Breadth	Single Task	✓	✓	✓	
	Multi Task				✓
Relative Time to Perform	Short		✓		
	Medium	✓	✓	✓	
	Long	✓			✓
Relative Cost	Low		✓		
	Medium	✓	✓	✓	
	High				✓
Relative Cost Effectiveness	Low			✓	
	Medium	✓	✓	✓	✓
	High		✓		

Table 2 Criteria for Descriptions in Task Analysis (From DOE/EP-0095)

Requirement	Task Statement	Example
Clarity	Use wording that is easily understood.	Use words like "Compare written description to actual performance" Don't use, "Relate results to needs of fields."
	Be precise so it means the same thing to all personnel.	Don't use words such as "check, coordinate, assist" — they are vague.
	Write separate specific statements for each. Avoid combining vague items of skill, knowledge, or responsibility.	Use clear statements such as "Supervise files" "Maintain files." Avoid general statements such as "Have responsibility for maintaining files."
Completeness	Use abbreviations only after spelling out the term.	"Human-System Interface (HSI)" "Complete Task Description Worksheet (Form No. XXX)."
	Include both form and title number when the task is to complete a form, unless all that is needed is the general type of form.	
Conciseness	Be brief.	"Write production and control reports." Avoid statements such as "Accomplish necessary reports involved in the process of maintaining production and control procedures."
	Begin with a present-tense action word (subject "I" or "you" is understood).	"Clean" or "Write."
	Indicate an object of the action to be performed.	"Clean engine." "Write report."
	Use terminology that is currently used on the job.	Use most recent industry documentation.
Relevance	Do not state a person's qualifications.	Do not use "Has one year computer training." Instead use "Load computer tapes."
	Do not include items on receiving instructions, unless actual work is performed.	Do not use "Attend lecture." Instead use "Prepare lab report."

Table 3 Berliner Taxonomy

Processes	Activities	Specific Behaviors	Definitions
1. Perceptual	1.1 Searching for and receiving information	1.1.1 Inspects	To examine carefully, or to view closely with critical appraisal
		1.1.2 Observes	To attend visually to the presence or current status of an object, indication, or event
		1.1.3 Reads	To examine visually information that is presented symbolically
		1.1.4 Monitors	To keep track of plant performance over time
		1.1.5 Scans	To quickly examine displays or other information sources to obtain a general impression
		1.1.6 Detects	To become aware of the presence or absence of a physical influence
	1.2 Identifying objects, actions, events	1.2.1 Identifies	To recognize the nature of an object or indication according to implicit or predetermined characteristics
		1.2.2 Locates	To seek out and determine the site or place of an object
2. Cognitive	2.1 Information Processing	2.1.1 Interpolates	To determine or estimate intermediate values from two given values
		2.1.2 Verifies	To confirm
		2.1.3 Remembers	To retain information (short-term memory) or to recall information (long-term memory) for consideration

Table 3 Berliner Taxonomy (Continued)

Processes	Activities	Specific Behaviors	Definitions
	2.2 Problem Solving and Decision Making	2.2.1 Calculates	To determine by mathematical processes
		2.2.2 Chooses	To select after consideration of alternatives
		2.2.3 Compares	To examine the characteristics or qualities of two or more objects or concepts for the purpose of discovering similarities or differences
		2.2.4 Plans	To devise or formulate a program of future or contingent activity
		2.2.5 Decides	To come to a conclusion based on available information
		2.2.6 Diagnoses	To recognize or determine the nature or cause of a condition by consideration of signs or symptoms or by execution of appropriate texts
3. Motor	3.1 Simple/Discrete	3.1.1 Moves	To change the location of an object
		3.1.2 Holds	To apply continuous pressure to a control
		3.1.3 Pushes/Pulls	To exert force away from/toward the actor's body
		3.1.4 Attaches	To affix an object to a larger object tying or gluing
		3.1.5 Gives	To put an object into the possession of another for his use
		3.1.6 Removes	To detach and move out of position
		3.1.7 Discards	To get rid of an unnecessary or useless object
	3.2 Complex/Continuous	3.2.1 Positions	To operate a control that has discrete states
		3.2.2 Adjusts	To operate a continuous control
		3.2.3 Types	To operate a keyboard
		3.2.4 Installs	To put into an appointed place or position

Table 3 Berliner Taxonomy (Continued)

Processes	Activities	Specific Behaviors	Definitions
4. Communication		4.0.1 Answers	To respond to a request for information
		4.0.2 Informs	To impart information
		4.0.3 Requests	To ask for information
		4.0.4 Records	To document something, as in writing
		4.0.5 Directs	To ask for action
		4.0.6 Receives	To be given written or verbal information
		4.0.7 Returns	To give an object back to its owner

Table 4 Task Analysis Data Form: Data Identification

Plant Identification	Task Identification	Data Collected At
1. 2. 3. 4. 5. 6. 7.	8. 9. 10.	11. A) B) C) D)
	Quality Control	
12.	13.	
	Taxonomy Coding	
14.	15.	

Table 5 Table Data Form Information (Part 1)*

Task ID:	Behavior	Object of Action					
Who takes action	Element	Component	Parameter	State	Other Object	Plant System	INPO Code

* See Appendix A Table A-1 for Complete Table Data Form

Table 6 Table for Determining Information Requirements

Function				
Task ID:		Control Requirements	Designer's Recommendations	Expert Judgments
Characteristics of the Information	1. Number of dimensions			
	2. Number of variables			
	3. Number of samples			
	4. Measured or derived			
Uses of Information	5. Alert or inform			
	6. Qualitative or quantitative			
	7. Range and units			
	8. Required accuracy			
	9. Acceptable delay time			
	10. Relative or absolute			
	11. Relative importance			
	12. Temporal relationship			
Picture Element	13. Recommended picture element and alternative recommendation			

Table 7 Table Data Form Information (Part 2)*

Time		Skill and Knowledge Requirements	Frequency of Action	Difficulty of Task Performance	Learning Difficulty	Potential for Error	Connected with Other Tasks
Start	Stop						

* See Appendix A, Table A-1 for Complete Table Data Form

Table 8 Levels of Intellectual Ability Required for Task Performance

Type of Action	Level of Required Intellectual Ability
Carry out specific action directed by supervisor or procedure	Recall
Take specific action when required by a condition or indication	Comprehension
Carry out multiple or complex actions when required by conditions (rule-based decisions)	Application
Independently decide on action to be taken based on diagnosis of a situation not previously encountered	Evaluation

Table 9 Knowledge, Intellectual Ability, and Skill Requirements for Nuclear Power Plant Personnel

Craftsmen	
Scope of Knowledge	Limited
Level of Knowledge	Descriptive
Intellectual Ability	Predominantly recall
Manual Skills	Highly developed
Technicians	
Scope of Knowledge	Usually a limited scope of applied technology
Level of Knowledge	In-depth, especially for higher-level of technicians
Intellectual Ability	Lower-level technicians: the comprehensive level and to a limited extent the application level Higher level technicians: the application level and to a limited extent the evaluation level
Manual Skills	To understand the capability and limitations of craftsman techniques, but not to acquire craftsman skills; in some disciplines, technicians develop manual skills to a higher level than craftsmen do.
Engineers/Physicists	
Scope of Knowledge	A broad base of general science and technology
Level of Knowledge	In-depth, especially in subjects of their specialization
Intellectual Ability	All levels up to evaluation
Manual Skills	Not usually developed

Table 10 Table Data Form Information (Part 3)*

Feedback Requirements	Feedback Time	Job Performance Aids	Tools and Equipment

* See Appendix A, Table A-1 for Complete Table Data Form

Table 11 Table Data Form Information (Part 4)*

Location	Communications					
Workspace	From		To		How	Content
	Person	Location	Person	Location		

* See Appendix A, Table A-1 for Complete Table Data Form

Table 12 Table Data Form Information (Part 5)*

Any Hazards Involved	Comments

* See Appendix A, Table A-1 for Complete Table Data Form

Implementation Plan Process Flow Chart

PROCESS FOR PERFORMANCE AND PREPARATION OF HFE

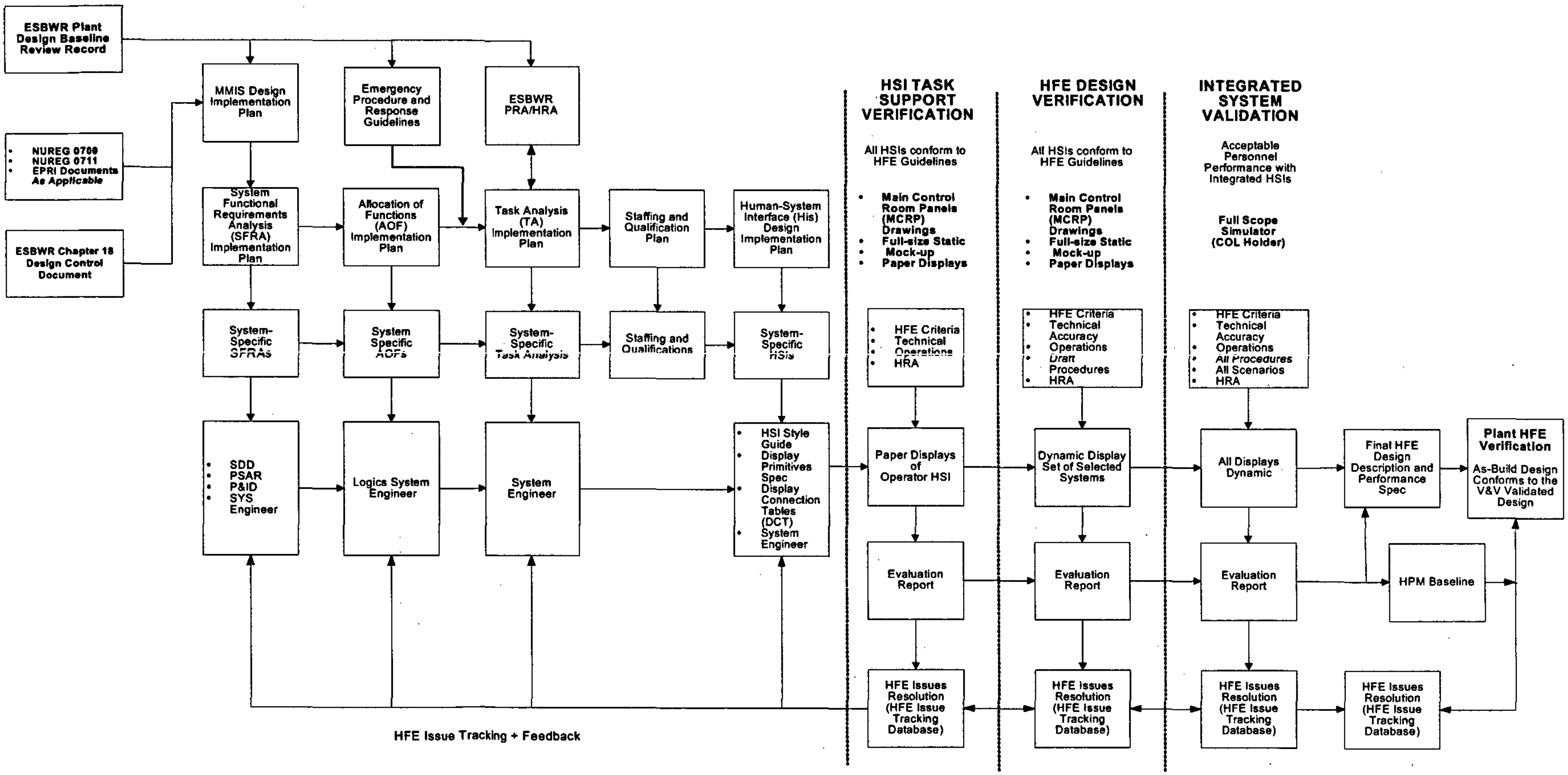


Figure 1 Human-System Interface Design Implementation Process

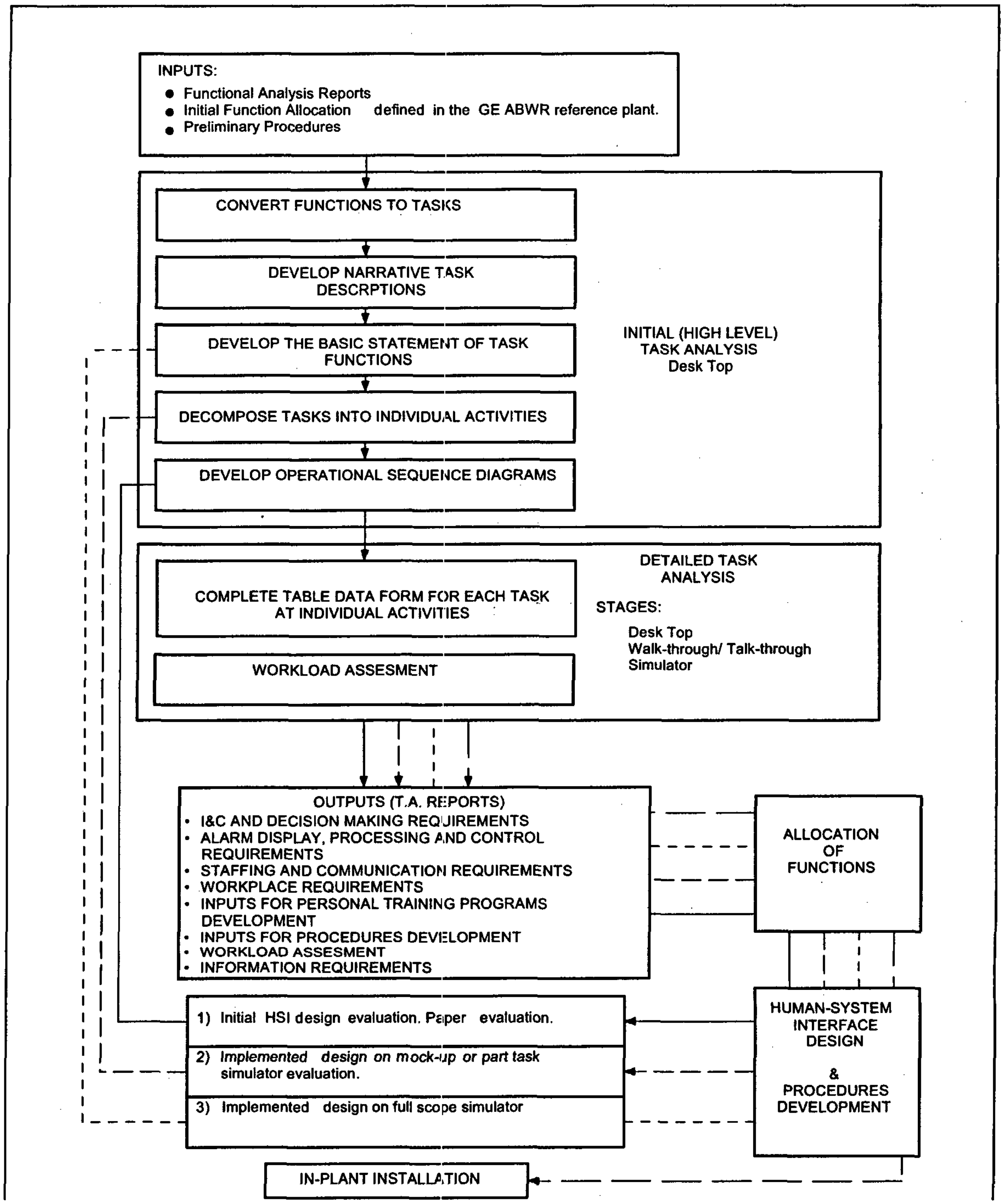
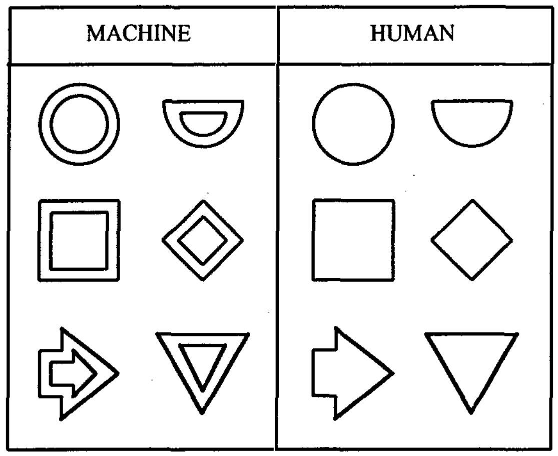
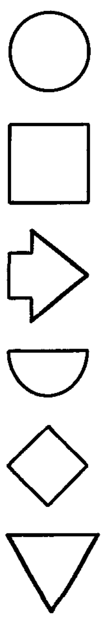


Figure 2 Task Analysis Implementation Process





Operate - an action function to accomplish or continue a process. (Sometimes used for received information).

Inspect - to monitor or verify quantity or quality. An inspection occurs when an object is examined (Sometimes used for action).

Transmit - to pass information without changing its form.

Receipt - to receive information in the transmitted form. (Sometimes used for stored information).

Decision - to evaluate and select a course of action or inaction based on receipt of information.

Storage - to retain. (Sometimes used for transmitted information).

Figure 3 OSD Symbology

(Design Basis: 7.1.2 HE analysis techniques, DOD-HDBK-73)

* A code letter may indicate Mode of transmission and receipt.

V	Visual	E	Electric/Electronic
S	Sound (verbal)	IC	Internal communication
EX	External Communication	T	Touch
M	Mechanically	W	Walking
H	Hand Deliver		

Operating Sequence Scenario	
System: **Function/Subfunction:**	**Operating Sequence Title:** **Operating Sequence ID:**
a) Initial Conditions:	
b) Sequence Initiator:	
c) Final Conditions:	
d) Operation Classification and Standards:	
e) Special Safety Considerations:	
f) Consequences of Inadequate Performance:	
g) System Interfaces:	
h) Human Interfaces:	
Revision:	

Figure 4 Format for Operating Sequence Scenario

Task Sequence Chart				
System: Function/Sub-function:		Operating Sequence Title: Operating Sequence ID:		
Task ID	Task and Purpose	Cue	End of Task	Comments

Figure 5 Task Sequence Chart

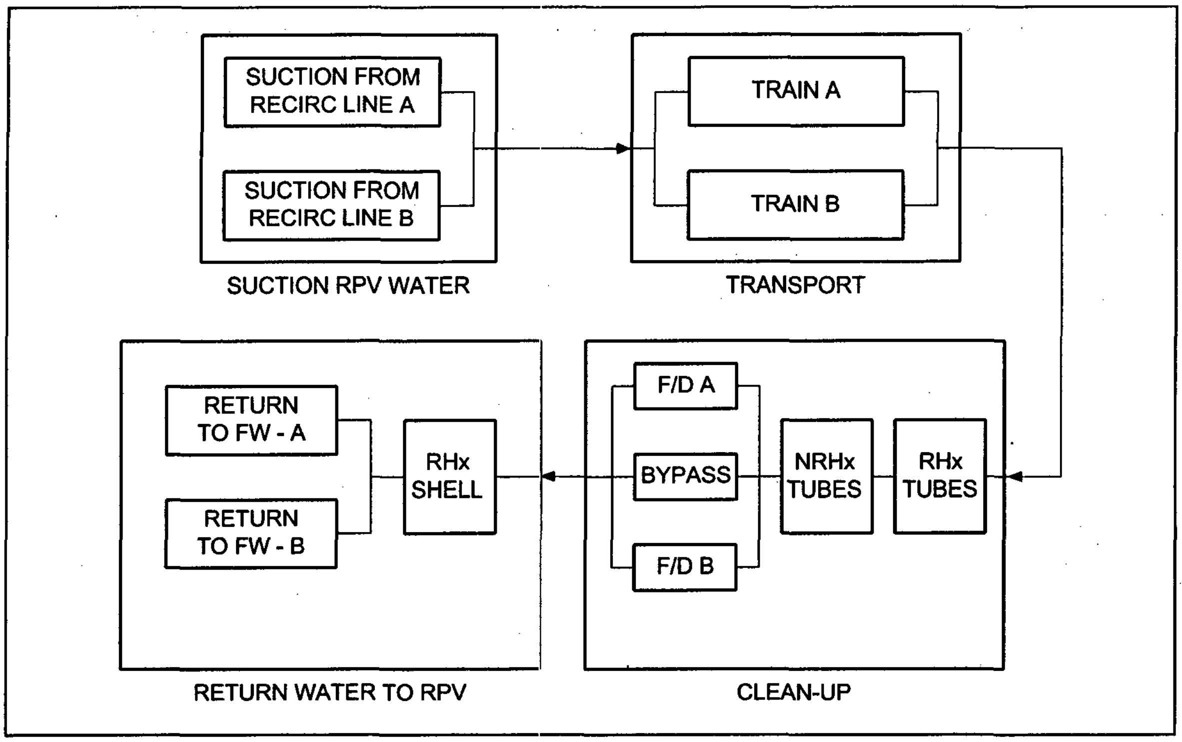


Figure 6 Block Process Diagram for RWCU BWR-6 System

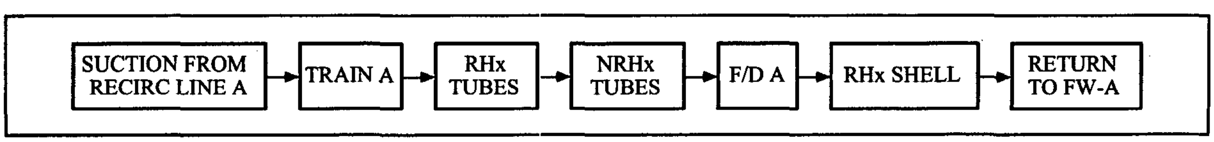


Figure 7 RWCU Operation Mode A

Operating Sequence Scenario	
System: Reactor Water Cleanup (G33) **Function/Sub-function:** Purify RPV Water	**Operating Sequence Title:** Starting RWCU at high coolant temperature **Operating Sequence ID:** G33-F01-S01
a) Initial Conditions • Reactor in nominal operating conditions • Plant in normal power operation • RWCU system isolated and cold	
b) Sequence Initiator: Administrative conditions determine the starting of the RWCU (ETFs determine the conductivity limit of the coolant), after a system of maintenance in the system generated by a defect in one of the pieces of equipment.	
c) Final Conditions: • Reactor in nominal operating conditions • Plant in normal operation • RWCU system in nominal operating conditions	
d) Operation Classification and Standards: The operation to be studied is a normal recovery operation after an irregular situation, such as a possible isolation of its maintenance system, etc. Heating rate (Manufacturer Specifications) will be in the range from 5°C/min. to 15°C/min.	
e) Special Safety Considerations: • The local maneuvers will be performed in a high radiation zone.	
f) Consequences of Inadequate Performance • Possible vessel drain in case of alignment error • Possible loss of main condenser vacuum when the system is venting	
g) System Interfaces • Recirc. Syst. (B33) • FW&CS (N21) • CCW (P42) • RHR (E21) • RW (G17) • AC Distribution • SLC (C41) • LDS (E31) • NSSS (B21) • Cond. (N61)	
h) Human Interfaces • Shift Supervisor • Non-Licensed Auxiliary Operator	
Revision:	

Figure 8 Completed Form of Operating Sequence Scenario for a RWCU Function

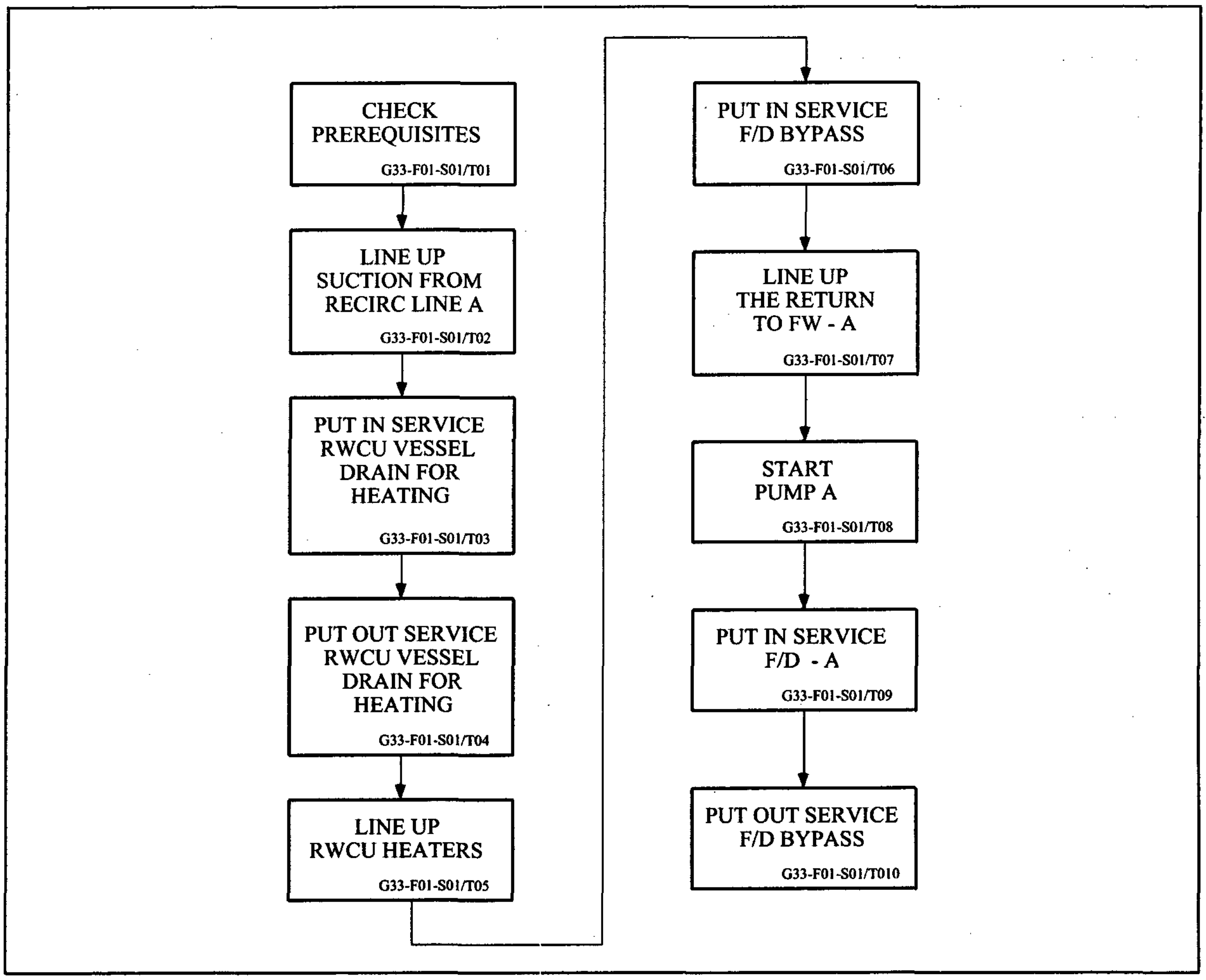


Figure 9 Operating Sequence Overview (G33-F01-S01)

Task Sequence Chart				
System: Reactor Water Cleanup **Function/Sub-function:** Purify RPV Water		**Operating Sequence Title:** Starting RWCU at high coolant temperature **Operating Sequence ID:** G33-F01-S01		
Task ID	**Task and Purpose**	**Cue**	**End of Task**	**Comments**
T01	Check prerequisites to check availability of components	Procedure	Prerequisite table checked	Requires local activity
T02	Line up suction from recirc. line to obtain a flow path	Operating practice	Suction flow path available	
T03	Put in service vessel drain for heating system pipes and components	Coolant Temperature >60°C	System temp. similar to coolant temp.	Rate of heating depending on manufacturer's specifications controlled by valve G33-F033
T04	Put out of service vessel drain	System temperature similar to coolant temperature	Drain not aligned	
T05	Line up RWCU heaters to provide a flow path	Operating practice	Flow path available	
T06	Put in service F/D bypass to protect Filter/Demineralizers at low flow condition	Operating practice and filter character	Bypass valve open	
T07	Line up the return to feedwater line A to provide a return flow path to vessel	Operating practice	Return flow path available	The effects on the temperature of the coolant must be taken into account
T08	Start pump A to obtain pumping capability	Operating practice	Pump running	
T09	Put in service F/D chain A to clean up the RPV water	System flow stable	F/D valves both open	Local activity precaution with the filtering layer
T10	Put out of service F/D bypass to obtain maximum flow through Filter/Demineralizers chain	System flow stable	Bypass valve closed	

Figure 10 Task Sequence Chart for a RWCU Function

Operating Sequence: **Operating Sequence ID:**			**Task:** **Task ID:**	
Act. No.	Component	Element	Indication	Remarks

Figure 11 Format for Task Breakdown to Individual Activities

Operating Sequence: **Starting RWCU at high coolant temperature** Operating Sequence ID: **G33-F01-S01**			Task: **Put in service vessel drain for heating system pipes and components** Task ID: **G33-F01-S01/T03**	
Act. No.	Component	Element	Feedback (indication)	Remarks
1	MOV-F042	Position valve to close	Status indication CLOSE	
2	AOV-F041	Position valve to open	Status indication OPEN	
3	MOV-F046	Position valve to open	Status indication OPEN	
4	MOV-F028	Position valve to open	Status indication OPEN	Isolation reject line valve
5	MOV-F034	Position valve to open	Status indication OPEN	Isolation reject line valve
6	AOV-F033	Adjust valve to open	Position indication FULLY OPEN	
7	PUMP A	Directs for pump vent and priming	Receive pump status information	Local Action
8	HOV-F043A	Directs for valve open	Receive valve status information	Local Action
9	HOV-F045A	Directs for adjust valve position	Request for pump temperature	Local Action
10	TI-R607	Observe	Heat exchangers inlet temperature	Position 2 in selector

Figure 12 Individual Activities Sequence Chart for Task T03

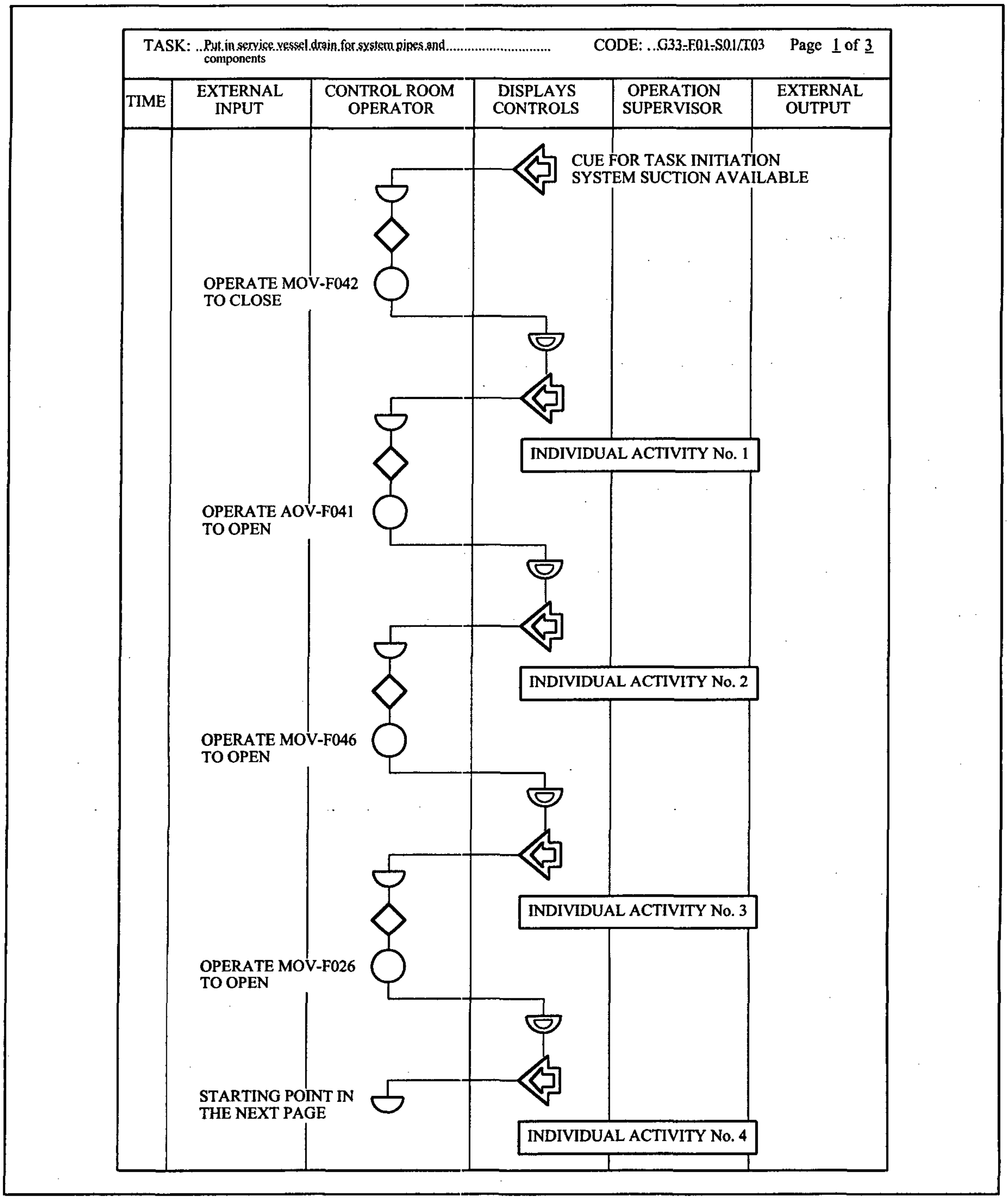


Figure 13 Task G33-F01-S01/T03 OSD (Sheet 1/3)

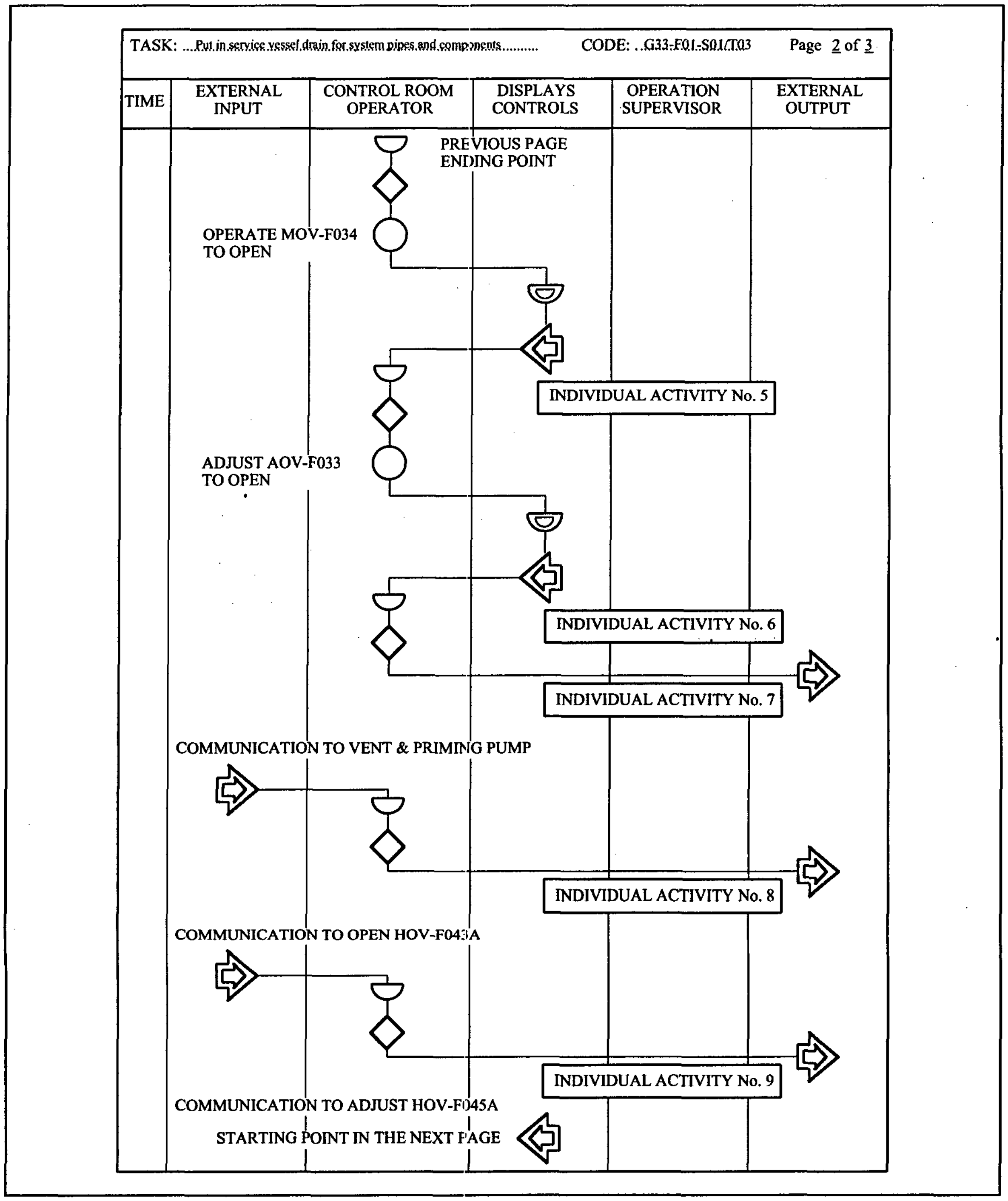


Figure 13 Task G33-F01-S01/T03 OSD (Sheet 2/3)

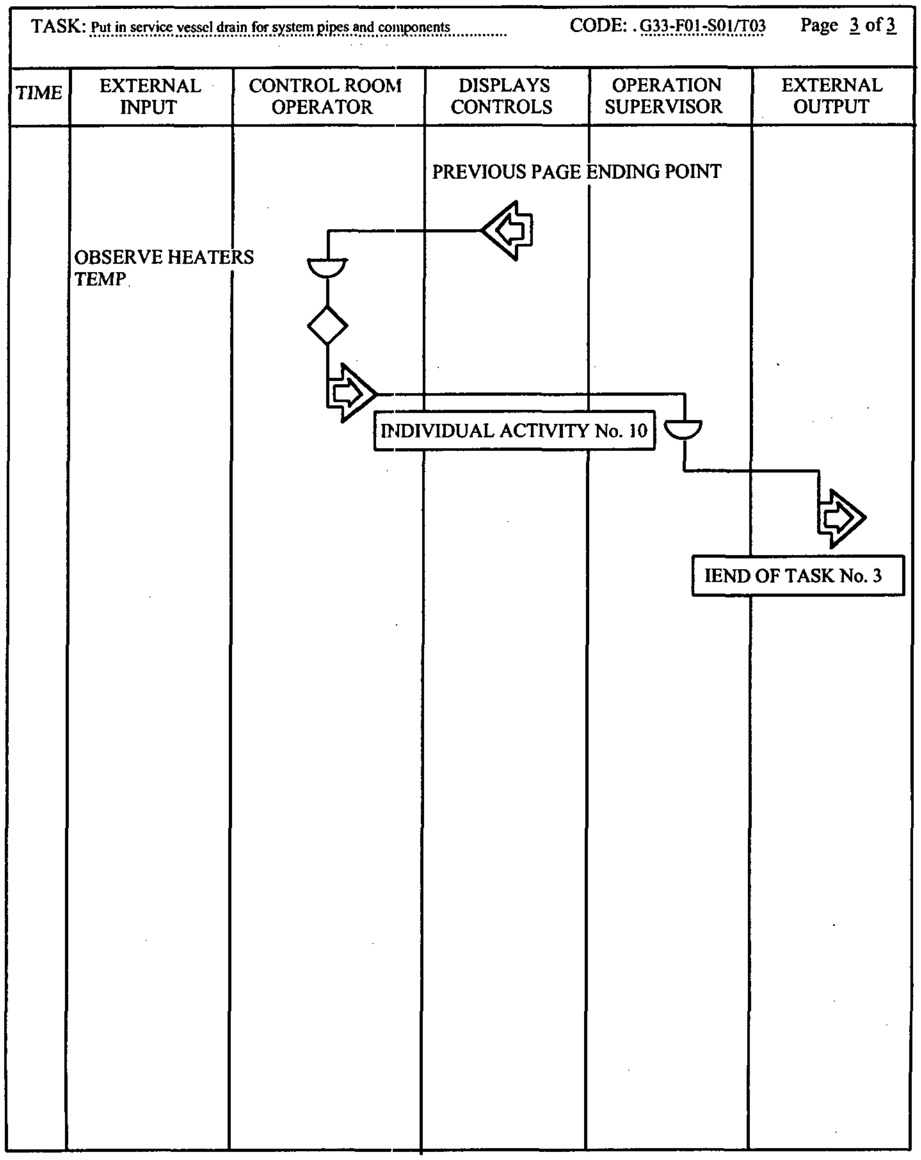


Figure 13 Task G33-F01-S01/T03 OSD (Sheet 3/3)

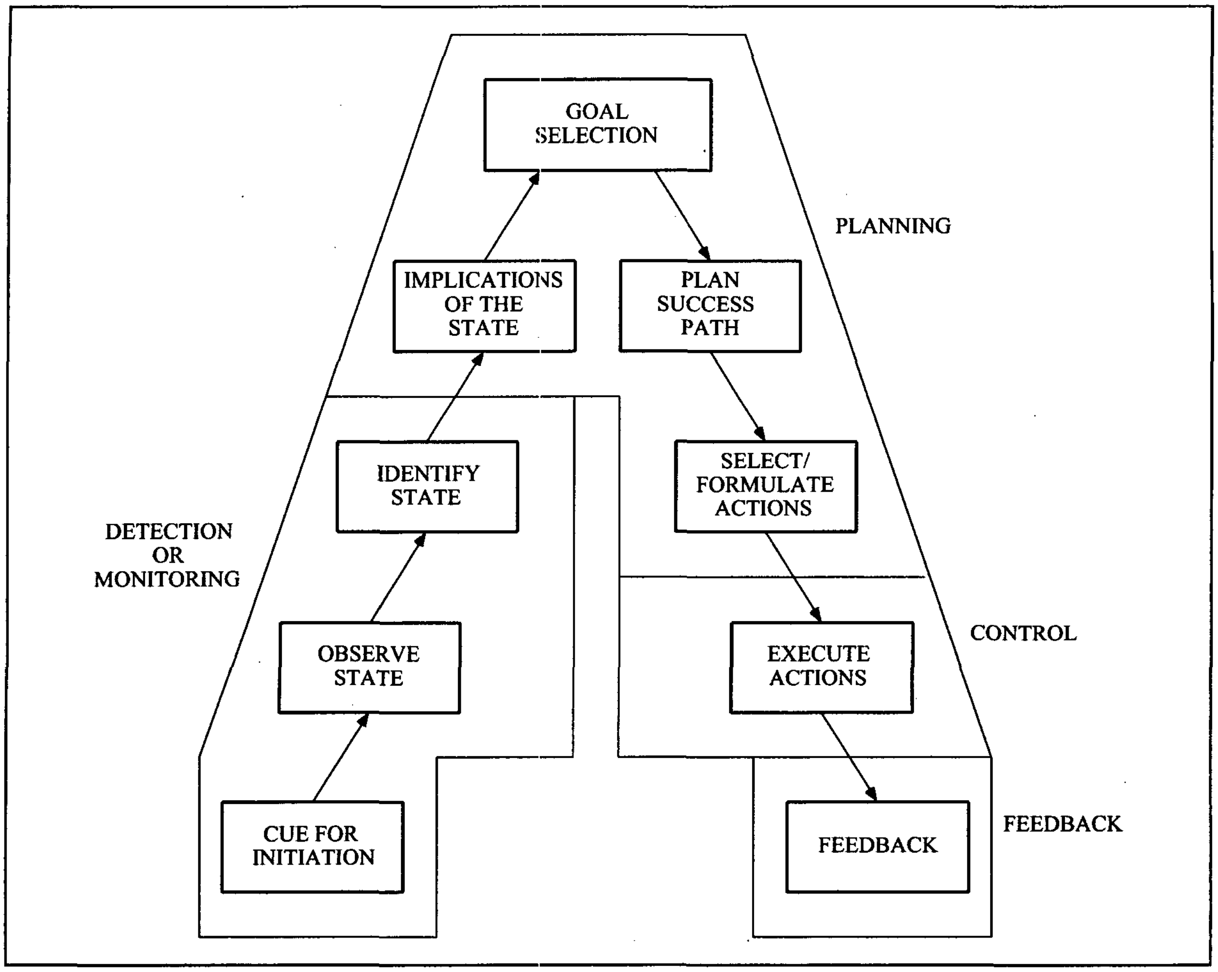


Figure 14 Rasmussen's Operator Decision Making Model

NASA TLX Scale: Rating Scale Definitions		
Title	**Endpoints**	**Descriptions**
Mental Demand	Low/High	How much mental and perceptual activity was required? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand	Low/High	How much physical activity was required? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand	Low/High	How much time pressure did you feel due to the rate or pace at which the task or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
Performance	Perfect/ Failure	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
Effort	Low/High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
Frustration Level	Low/High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

Figure 15 NASA TLX Scale

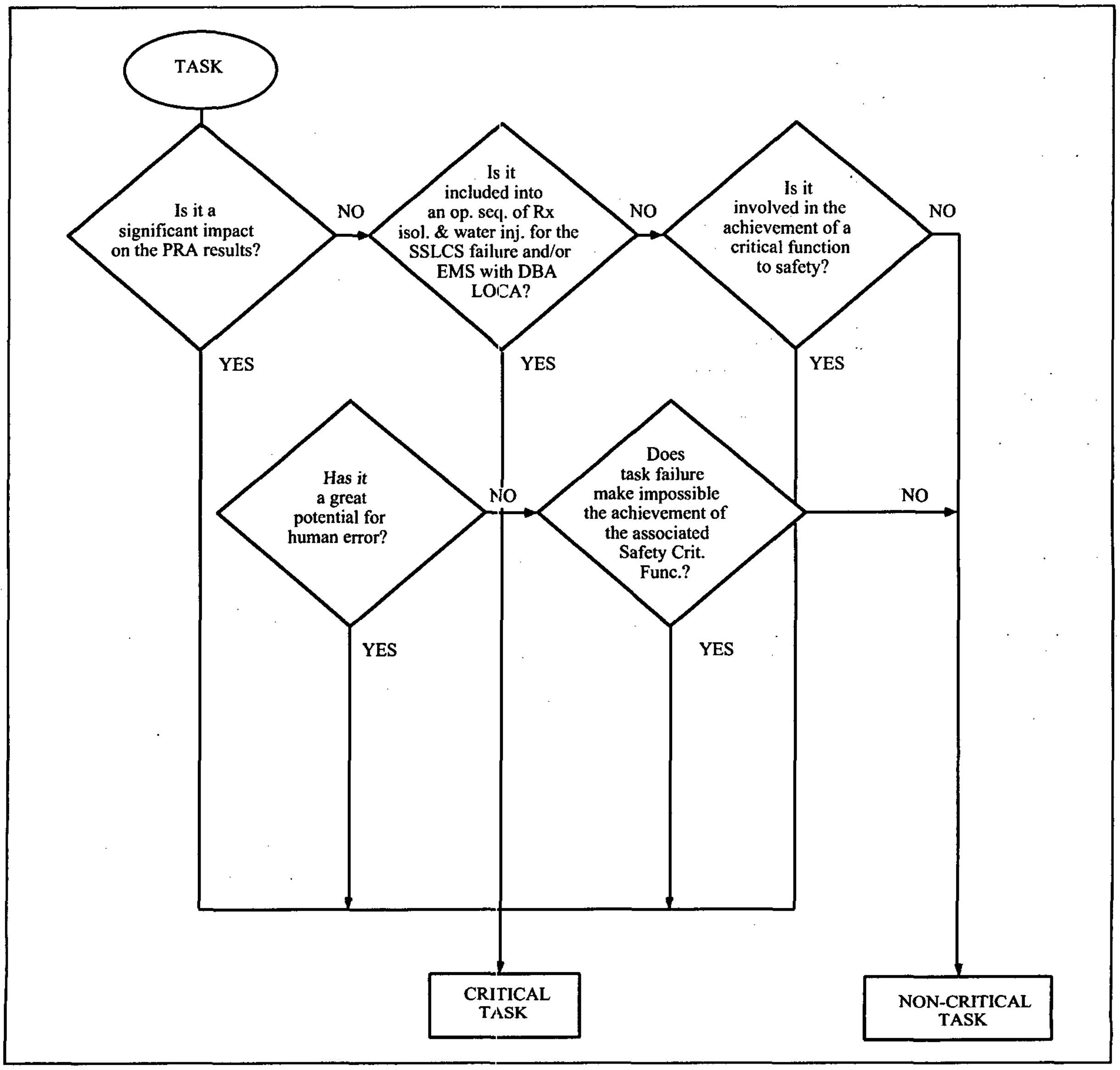


Figure 16 Block Diagram for Critical Tasks Identification

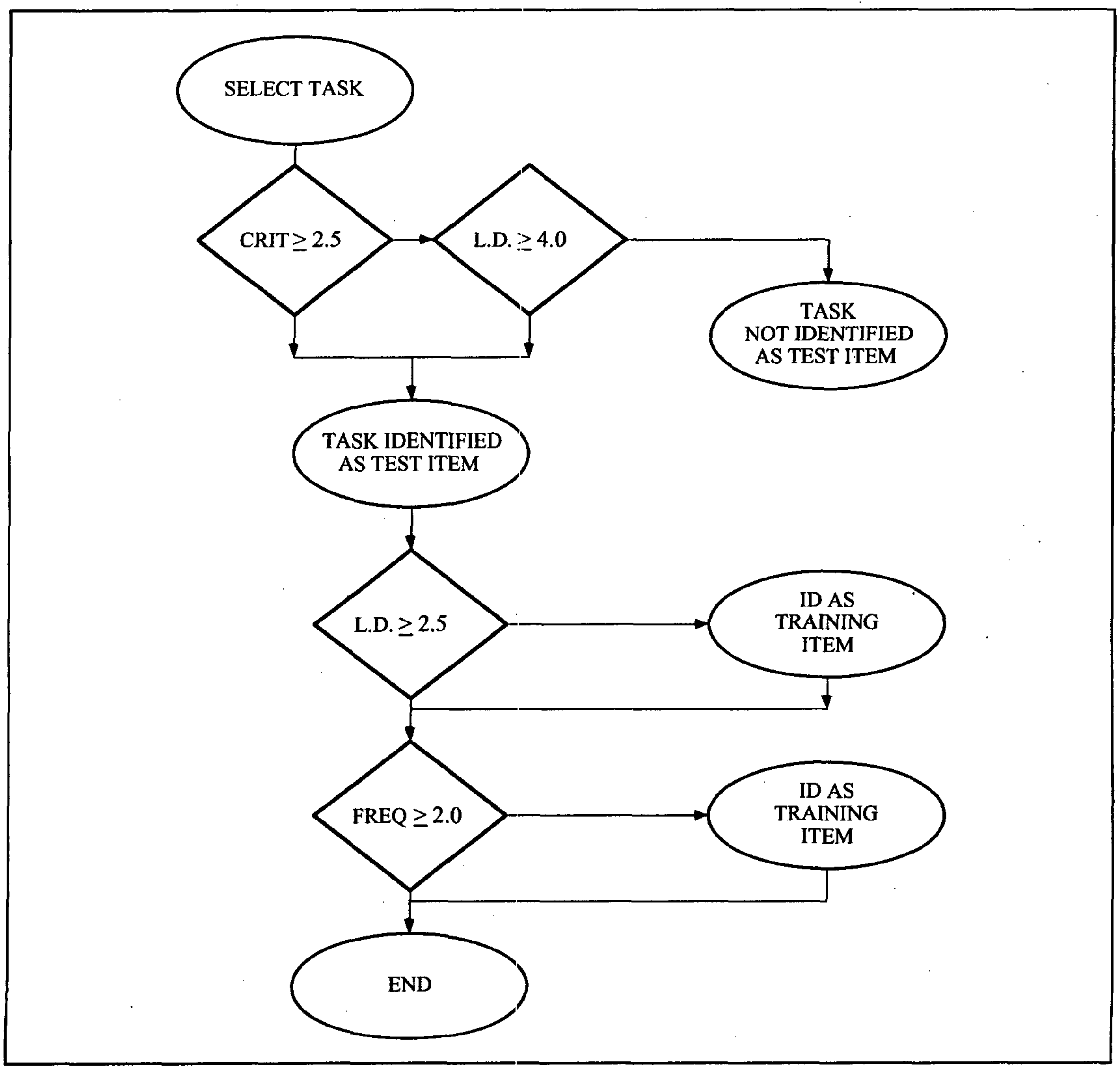


Figure 17 Training Requirements Identification

Appendix A: Data Form
Table A-1 Table Data Form

Task ID:	Behavior	Object of Action						Means of Action	Information Requirements			Time		Skill and Knowledge Requirements
Who Takes Action	Element	Component	Parameter	State	Other OBJ	Plant System	INPO Code		Information and Control Capability Required	Information Available	Evaluation Process	Start	Stop	

Table A-1 Table Data Form (Continued)

Frequency of Action	Difficulty of Task Performance	Learning Difficulty	Potential for Error	Connected with Others Tasks	Feedback Requirements	Feedback Time	Job Performance Aids	Tools and Equipment	Location	Communications			Any Hazards Involved	Com
									Workspace	From/To	How	Content		