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Subject: Submittal of Licensing Topical Report NEDO-33266, "ESBWR Human Factors Engineering Staffing and Qualifications Implementation Plan," Revision 3

The purpose of this letter is to submit Revision 3 of the GE Hitachi Nuclear Energy (GEH) Licensing Topical Report NEDO-33266, "ESBWR Human Factors Engineering Staffing and Qualifications Implementation Plan" in accordance with the corresponding HFE program element identified in Reference 1.

Enclosure 1 contains Licensing Topical Report NEDO-33266, "ESBWR Human Factors Engineering Staffing and Qualifications Implementation Plan," Revision 3.

If you have any questions or require additional information, please contact me.

Sincerely,

Richard E. Kingston

Richard E. Kingston
Vice President, ESBWR Licensing

D068
NRO

Reference:

1. NUREG-0711, Revision 2, Human Factors Engineering Program Review Model, issued February 2004

Enclosure:

1. MFN 10-023 - Licensing Topical Report NEDO-33266, "ESBWR Human Factors Engineering Staffing and Qualifications Implementation Plan," Revision 3

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Enclosure 1

Licensing Topical Report NEDO-33266

ESBWR Human Factors Engineering Staffing and Qualifications Implementation Plan

Revision 3

HITACHI

GE Hitachi Nuclear Energy

**NEDO-33266**

**Revision 3**

**Class I**

**DRF Section 0000-0050-9818 R6**

**January 2010**

Licensing Topical Report

# ESBWR HUMAN FACTORS ENGINEERING STAFFING AND QUALIFICATIONS IMPLEMENTATION PLAN

## PROPRIETARY INFORMATION NOTICE

This document NEDO-33266, Revision 3, contains no proprietary information.

## IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT

**Please read carefully**

The information contained in this document is furnished as reference to the NRC Staff for the purpose of obtaining NRC approval of the ESBWR Certification and implementation. The only undertakings of GE Hitachi Nuclear Energy (GEH) with respect to information in this document are contained in contracts between GEH and participating utilities, and nothing contained in this document shall be construed as changing those contracts. The use of this information by anyone other than that for which it is intended is not authorized; and with respect to any unauthorized use, GEH makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

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# 1. OVERVIEW

Plant staff and their qualifications are important considerations throughout the design process. The planned initial staffing level is established based on experience with predecessor BWR plants, staffing goals, such as optimizing the staffing levels and their qualification, initial safety function allocation, task analyses, and regulatory staffing requirements for nuclear reactors.

As shown in Figure 1, the human factors engineering (HFE) ESBWR staffing and qualifications (S&Q) plan is used to re-examine the ESBWR assumptions during task analysis (TA), human reliability analysis (HRA), and human system interface (HSI) design. Features of the ESBWR, such as passive safety systems and simplified Human System Interface (HSI), information systems, and content, leads to a modification of staff size and qualifications relative to previous BWRs.

TA may show that the extended time for safety actions may reduce the number of staff needed for local actions. The HRA may show that some actions that were important in previous BWR designs are eliminated in the passive design. Improved display features may help clarify the plant state during transient events and possibly reduce the size of the control room staff. Moreover, tasks that have no direct interface to the allocated safety functions may be screened from HFE evaluation.

The details and content of the procedures and training for safety-related tasks are matched to the final baseline staff and qualifications developed during this HFE task.

## 1.1 PURPOSE

The purpose of this plan is fivefold:

(1) To establish an initial baseline shift operations staff appropriate for managing plant safety during normal operation of the ESBWR.

(2) To provide guidance, for the use of the initial staffing assumptions, in systematic evaluations of staffing needs and qualifications throughout the design effort.

(3) To recommend a refined description of baseline staffing needs and qualifications for using the ESBWR HSI.

(4) To address staff HSI needs. A screening process is used to focus the HFE effort on the tasks and staff needed to support reactor safety functions.

(5) To provide baseline ESBWR S&Q inputs for systematic verifications of the HSI design and development of procedures and the training program.

The detailed evaluation of HSI requirements for maintaining plant safety and availability goals over the complete range of transient event conditions clarifies the basis for the staffing and qualifications of the baseline ESBWR. The evaluation is accomplished through the systematic examination of the design specific ESBWR functions, tasks, known priorities, risk importance of Human Actions (HAs), and baseline procedures. Recommendations for changes in the baseline ESBWR plant S&Q is provided in a results summary report. The recommended staffing level is reflected in ESBWR procedures and training program design.

## 1.2 SCOPE

The scope of this task recommends a baseline staff and their qualifications for safely operating the ESBWR during normal power operation, as well as during transient and accident events included in the plant design basis. The applicable plant personnel, who are addressed by the HFE program prior to plant startup, include licensed control room operators as defined in 10 CFR 50.54m and 50.55.

The categories of personnel defined by 10 CFR 50.120, who perform tasks related to plant safety through the HSI, are screened for tasks involving reactor safety functions allocated to manual operation that are monitored and controlled through the HSI. The personnel include non-licensed operators, shift supervisor, shift technical advisor, instrument and control technicians, electrical and mechanical maintenance personnel, radiological protection technicians, chemistry technicians, and engineering support personnel.

In addition, any other plant personnel who perform tasks that are directly related to plant safety are addressed. The tasks they perform include:

- Qualification
- Repair
- Maintenance
- Record keeping
- Configuration control
- Monitoring, automatic actions
- Surveillance and testing

These tasks are performed on plant equipment during startup, normal operations, abnormal operations, transient conditions, low power, and during shutdown conditions.

The initial focus of this task during the design stage is on the shift personnel controlling the plant during normal operations through the applicable HSIs needed for operations and response to transient events, including, operator interface in the Main Control Room (MCR), the Remote Shutdown Systems (RSSs) panels, and Local Control Stations (LCSs) with a safety-related function or as determined by task analysis.

The initial proposed baseline staff for plant operation during shifts is expanded to include personnel who perform tasks related to plant safety as the design progresses to the combined operating license (COL) applicant and plant operation. The overall staffing analysis prior to plant start up recommends the number and background of personnel for the full range of plant conditions and operational tasks (normal, abnormal, and emergency), plant maintenance, and plant surveillance and testing.

A COL organizational staff is recommended by the utility using input from past operational S&Q experience and the HFE program on specific safety-related tasks to address the full range of activities at the plant.

During initial design, it is assumed that personnel needed to accomplish activities are available as part of baseline operational staff for normal shifts. As the design progresses, tasks using the HSI are identified during the HFE analysis and recommendations for refinement to the staff and their qualifications will be provided. The operational staffing organization is under the authority of the COL applicant.

External personnel brought in for special maintenance and repair are assumed to also use elements of the HSI during outages, refueling, and waste handling. Tasks for external personnel may be identified during the HFE process; however, personnel for these tasks are not included in the baseline staffing for plant operations.

## 1.3 DEFINITIONS AND ACRONYMS

### 1.3.1 Definitions

Several terms are defined to provide a common basis for developing S&Q recommendations referred to in this plan.

**Accident Sequence**: a representation in terms of an initiating event followed by a combination of system, function and operator failures or successes, of an accident that can lead to undesired consequences, with a specified end state (e.g., core damage or large early release). An accident sequence may contain many unique variations of events (minimal cut sets) that are similar. (ASME PRA Std.)

**Action Task**: The "doing" portion of a task, performed by the control room operators or the plant technicians. This involves use of the HSI to perform physical actions in operating control room switches by the control room operators or manipulating or repairing equipment in the plant by the technicians.

**At power**: those plant operating states characterized by the reactor being critical and producing power, with automatic actuation of critical safety systems not blocked and with essential support systems aligned in their normal power operation configuration.

**Component:** An individual piece of equipment such as a pump, valve, or vessel; usually part of a plant system.

**Consequences**: The results of (i.e., events that follow and depend upon) a specified event.

**Control Function**: "Keeping measured functional parameters within bounds through a process of manipulating low level functions to satisfy a higher level function" (NUREG-0711).

**Crew**: qualified operations staff at the plant during a shift that manages and performs activities necessary to operate the plant and maintain its safety.

**Diagnosis**: examination and evaluation of data from the HSI to determine either the condition of a system structures and components (SSC) or the cause of the condition (ASME PRA Std.)

**Front-Line System**: an engineered safety system used to provide core or containment cooling, reactivity control or pressure control, and to prevent core damage, reactor coolant system failure, or containment failure (ASME PRA Std.)

**Function**: An activity or role performed by a human, structure, or automated system to fulfill an objective (NEDO-33219, System Functional Requirements Analysis Implementation Plan).

**HFE Design Team**: The HFE Design Team (Design Team) is a team of engineers, as defined in Reference 2.1.1(2), Man-Machine Interface System And Human Factors Engineering Implementation Plan, responsible for the design of the HSI systems.

**Human Action (HA):** A manual response to a cue involving one person to achieve one task or objective. Potentially risk important actions affect equipment or physical systems. Single human actions can be represented as an event in a fault tree or branch point in an event tree.

**Human Error Probability (HEP):** a measure of the likelihood that plant personnel will fail to initiate the correct, required, or specified action or response in a given situation, or by commission performs the wrong action (ASME PRA Std.)

**HFE Issue Tracking System (HFEITS):** An electronic database used to document human factors engineering issues not resolved through the normal HFE process and human engineering discrepancies (HEDs) from the design verification and validation activities. Additionally, the database is used to document the problem resolutions.

**Human Interaction (HI):** A human action or set of actions that affects equipment or physical systems, or an action that influences other human actions. Human interactions can be represented as an event in a fault tree or branch point in an event tree.

**Human Reliability Analysis (HRA):** a structured approach used to identify potential human failure events and to systematically estimate the probability of those errors using data, models, or expert judgment. (ASME PRA Std.)

**Human Task**: The activity of a human required to accomplish a function. For example the human user conserves, reduces, or adds information, and supplies or controls energy.

**Human-System Interface** (HSI): The organization of inputs and outputs used by personnel to interact with the plant, including the alarms, displays, controls, and job performance aids. Generically, this includes maintenance, test, and inspection interfaces as well.

**Inherent Design Features:** Reliance on physical properties of systems, structures, and components to meet design goals rather than relying on supplemental systems to achieve the design goal functions. For example, using properties associated with neutron flux in reactor cores to control reactivity via introduction of voids in the core versus changing control rod position.

**Local Control Station (LCS):** An operator interface related to nuclear power plant (NPP) process control that is not located in the main control room. This includes multifunction panels, as well as single-function HSIs such as controls (e.g., valves, switches, and breakers) and displays (e.g., meters) that are operated or consulted during normal, abnormal, or emergency operations.

**Maintenance:** Activities carried out to keep systems and equipment available. Specific types of maintenance include preventive, and corrective. Activities associated with preventive maintenance include testing, surveillance, inspection, and calibration. Activities associated with corrective maintenance include repair, replace, and modify.

**Operating Experience Review (OER):** A systematic review, analysis and evaluation of operating experience that can apply to the development of the HSI design.

**Operational Failure Event**: an integrated logic description of HEPs based on the error modes, performance shaping factor assessment, and other qualitative information needed to justify a single input to the risk model (ASME PRA Std. - Old HFE definition)

**Passive Safety System**: The design of systems and barriers to achieve a function (safety or al) or increase a safety margin without using active components (such as pumps, valves that change state, use of external electric power, or a human action to operate the system). For example, use of natural circulation versus forced cooling to remove heat.

**Personnel Assigned**: other non-licensed personnel identified in Section 4, "Input-Existing Staff & Qualifications" can also manage and perform the task. (See Table 2 Note: 4)

**Primary Tasks:** Those tasks performed by the operator to supervise the plant; i.e., monitoring, detection, situation assessment, response planning, and response implementation (NUREG-1764).

**Reactor Safety**: The development of a reactor design that is built and operated to pose no undue risk to public (ANS position paper). This means that the core is protected from damage under design basis events and the risk from PRA core damage sequences is mitigated through design features, backup systems and operator actions. Additional protection from radiation release is through the use of the containment barrier.

**Risk-Important Human Action:** Actions that are performed by plant personnel to provide assurance of plant safety. Actions may be made up of one or more tasks. There are both absolute and relative criteria for defining risk-important actions. From an absolute standpoint, a risk-important action is any action whose successful performance is needed to provide reasonable assurance that predefined risk criteria are met. From a relative standpoint, the risk-important actions may be defined as those with the greatest risk in comparison to all human actions. The identification can be done quantitatively from risk analysis and qualitatively from various criteria such as task performance concerns based on the consideration of performance shaping factors.

**Safety Functions:** Those functions that serve to ensure higher-level objectives and are often defined in terms of a design basis event (a boundary or entity that is important to plant integrity and the prevention of the release of radioactive materials) (adapted from NUREG-1764).

**Safety Related Task**: a task that is required to be performed to achieve a safety function defined in the design basis events. Safety-related operator tasks qualitatively include those required to start, control and stop equipment in order to meet the design basis event radiological limits. The use of automated systems for starting, controlling and stopping systems in design basis events limits the need for a safety-related task.

**Safety Related Operator Action:** A manual action required by plant emergency procedures that is necessary to cause a safety-related system to perform its safety-related function during the course of any Design Basis Event. The successful performance of a safety-related operator action might require that discrete manipulations be performed in a specific order (NUREG-1764). Use of passive and automated systems removes the need for potentially all safety-related operator actions.

**Safety Systems**: those systems that are designed to prevent or mitigate a design-basis accident. (ASME PRA Std. amplified)

**Screening Criteria**: the values and conditions used to determine whether an item is a negligible contributor to the probability of an accident sequence or its consequences (ASME PRA Std.)

**System:** An integrated collection of plant components and control elements that operate alone or with other plant systems to perform a function (NUREG-1764).

**System Failure**: termination of the ability of a system to perform any one of its critical design functions. Note: Failure of a line/train within a system may occur in such a way that the system retains its ability to perform all its required functions; in this case, the system has not failed. (ASME PRA Std.)

**Task**: A collection of activities with a common purpose, often occurring in temporal proximity, with an identifiable start and end point for which human actions are performed using displays and controls.

**Transients**: initiating events that can result in emergency conditions, where prompt operator actions might be required to avoid damage, or accidents where structures, systems or components are damaged.

**Workload:** The physical and cognitive demands placed on plant personnel (NUREG-1764).

### 1.3.2 Acronyms

The following is a list of acronyms used in this plan:

| **Acronym** | **Description** |
|---|---|
| AEO | Auxiliary Equipment Operator |
| AOF | Allocation of Function |
| BRR | Baseline Review Record |
| COL | Combined Operating License |
| D3 | Defense-in-Depth and Diversity |
| DCD | Design Control Document |
| FRA | Functional Requirements Analysis |
| HA | Human Action |

| | |
|---|---|
| HED | Human Error Discrepancy |
| HEP | Human Error Probability |
| HFE | Human Factors Engineering |
| HFEITS | Human Factors Engineering Issues Tracking System |
| HI | Human Interaction |
| HRA | Human Reliability Analysis |
| HSI | Human System Interface |
| LCSs | Local Control Stations |
| MCR | Main Control Room |
| NPP | Nuclear Power Plant |
| OER | Operating Experience Review |
| PRA | Probabilistic Risk Assessment |
| RSS | Remote Shutdown System |
| SDC | Shutdown Cooling |
| SFRA | System Functional Requirements Analysis |
| SRO | Senior Reactor Operator |
| S&Q | Staffing and Qualifications |
| TA | Task Analysis |
| V&V | Verification and Validation |

# 2. APPLICABLE DOCUMENTS

Applicable documents include supporting documents, supplemental documents, codes and standards and are given in this section. Supporting documents provide the input requirements to this plan. Supplemental documents are used in conjunction with this plan. Codes and standards are applicable to this plan to the extent specified herein.

## 2.1 SUPPORTING DOCUMENTS AND SUPPLEMENTAL GEH DOCUMENTS

### 2.1.1 Supporting Documents

The following supporting documents were used as the controlling documents in the production of this plan. These documents form the design basis traceability for the requirements outlined in this plan.

(1) ESBWR DCD, Chapter 18 (GEH 26A6642BX).

(2) NEDE-33217P and NEDO-33217, ESBWR Man-Machine Interface System and Human Factors Engineering Implementation Plan.

(3) NEDO-33251, ESBWR I&C Defense-in-Depth and Diversity Plan.

### 2.1.2 Supplemental Documents

The following supplemental documents are used in conjunction with this document Plan.

(1) NEDO-33262, ESBWR HFE Operating Experience Review Implementation Plan.

(2) NEDO-33267, ESBWR HFE Human Reliability Analysis Implementation Plan.

(3) NEDO-33219, ESBWR HFE System Functional Requirements Analysis Implementation Plan.

(4) NEDE-33220P and NEDO-33220, ESBWR HFE Allocation of Function Implementation Plan.

(5) NEDE-33221P and NEDO-33221, ESBWR HFE Task Analysis Implementation Plan.

(6) NEDE-33268P and NEDO-33268, ESBWR HFE Human System Interface Design Implementation Plan.

(7) NEDO-33274, ESBWR HFE Procedures Development Implementation Plan.

(8) NEDO-33275, ESBWR HFE Training Development Implementation Plan.

(9) NEDE-33276P and NEDO-33276, ESBWR HFE Verification and Validation Implementation Plan.

(10) NEDO-33277, ESBWR HFE Human Performance Monitoring Implementation Plan

## 2.2 CODES AND STANDARDS

The following codes and standards are applicable to the HFE program to the extent specified herein.

(1) ANSI/IEEE 1023, IEEE Recommended Practice for the Application of Human Factors Engineering to Systems, Equipment and Facilities of Nuclear Power Generating Stations and Other Nuclear Facilities, 2004.

(2) ANSI/ANS 58.8, Time Response Design Criteria for Safety-Related Operator Actions, 1994, R2001.

(3) ASME RA-S, Standard for Probabilistic Risk Assessment For Nuclear Power Plant Applications, 2002.

(4) IEEE 497, Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations, 2002.

## 2.3 REGULATORY GUIDELINES

(1) NUREG-0654, Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants,. 1980 (FEMA-REP-1, Rev. 1 Addenda, 2002).

(2) NUREG-0700, Rev.2, Human-System Interface Design Review Guidelines, 2002.

(3) NUREG-0711, Rev.2, Human Factors Engineering Program Review Model, 2004.

(4) NUREG-0737, Clarification of TMI Action Plan Requirements, 1980, and Supplement 1, 1983.

(5) NUREG-0800, Rev 1,Standard Review Plan: Chapter 18, Human Factors Engineering, 2004.

(6) NUREG-0800, Rev 1, Standard Review Plan: Chapter 19, Use of Probabilistic Risk Assessment in Plant-Specific, Risk-Informed Decisionmaking: General Guidance, 2002.

(7) NUREG-0933, A Prioritization of Generic Safety Issues, 2006.

(8) NUREG-1123, Rev. 2, Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Boiling Water Reactors, 1998.

(9) NUREG-1649, Rev. 3, Reactor Oversight Process, 2000.

(10) NUREG-1764, Rev. 0, Guidance for Review of Changes to Human Actions, 2004.

(11) Regulatory Guide 1.174, Rev.1, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis, 2002.

(12) Regulatory Guide 1.8, Rev.3, Qualification and Training of Personnel for Nuclear Power Plants, 2000.

(13) Regulatory Guide 1.97, Rev 4, Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants. 2006.

(14) 10 CFR 50.120, Training & Qualifications of Nuclear Power Plant Personnel.

(15) 10 CFR 50.47, Emergency Plans.

(16) 10 CFR 50.54m, Conditions of License- SRO and Licensed Operator Staffing Requirements.

(17) 10 CFR 50.55, Conditions of Construction Permits, Early Site Permits, Combined Licenses, and Manufacturing Licenses.

## 2.4 DOD AND DOE DOCUMENTS

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

(2) DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities.

## 2.5 INDUSTRY / OTHER DOCUMENTS

(1) IP 71715, Sustained Control Room and Plant Observation 2000, periodically updated

(2) NRC IN 95-48, Results of Shift Staffing Study, 1995.

(3) NRC IN 97-78, Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times, 1997.

# 3. METHODS

## 3.1 ESBWR BASELINE STAFFING

The number of qualified staff for the ESBWR must be adequate to provide safe operation under design basis and risk important accident conditions. To meet this goal, consideration is given to the numbers and functions of the staff needed to safely perform all required plant operations, maintenance, and technical support for each operational mode, and the minimum qualifications of plant personnel in terms of education and training, skill, knowledge, experience, and fitness for duty.

### 3.1.1 Background

#### 3.1.1.1 *Recommended Pre-design Initial Staffing*

The recommended baseline S&Qs come from the ESBWR DCD, Chapter 18. The preliminary operational staffing assumption for reactor control and monitoring will consist of the assignments shown in Table 1. Two licensed control room operators and one licensed control room shift supervisor (manager) operate the ESBWR during all phases of normal plant operation, abnormal events, and emergency conditions.

The operating crew also includes one licensed shift manager. Additional operational staff also includes non-licensed auxiliary equipment operators. The number and qualifications required for ESBWR staffing is determined during TA.

During abnormal events or emergency conditions, technical assistance is available to the operating crew from personnel in the technical support center. Four licensed operators are on shift at all times, consistent with the staffing requirements of 10 CFR 50.54m.

### 3.1.2 Goals

The MCR shift staff size and roles are re-evaluated through HFE analysis during the detailed design to determine if the original plan for the crew size is sufficient to manage design basis and beyond design basis accident sequences as modeled in the PRA. The demands of operating and maintaining the MCR and other HSIs using procedures are assessed for their personnel skills and qualifications implications.

### 3.1.3 Basis and Requirements

#### 3.1.3.1 *Assumptions for Staffing and Qualification*

Throughout the design phases the following assumptions support development of the recommended staffing levels needed to accomplish the key safety functions with high levels of reliability:

- A licensed control room operator remains in control of plant operation during all states of operation. During normal operation, the licensed control room operator monitors the automated control functions.
- The licensed control room operator is able to assume manual control of those functions that have been automated for reasons other than regulatory requirements. Each operating crew's training includes manual operation of any automated function that has been returned to manual monitoring and control.
- During outage periods, the licensed control room operators remain in control of plant operations by monitoring the systems that are unavailable during repairs and maintaining sufficient system availability to ensure protection of fuel integrity.
- The shift team observes appropriate limits and conditions for shift work including overtime, shift duration, and shift rotation.
- The HSI design minimizes the potential for human factor problems that could negatively affect plant safety and performance, for example:
  - Knowledge, skills and ability of recommended staff can operate and maintain the HSI
  - The HSI is consistent throughout the MCR, RSSs, and LCSs with a safety related function or as defined by task analysis
  - Maintenance, surveillance, and calibration activities using the HSI are not complex.

### 3.1.4 General Approach

#### 3.1.4.1 *ESBWR Design Changes*

After the ESBWR design is finalized prior to COL acceptance, possible changes to the HSI may be proposed. These post-design plant modifications, occurring prior to COL issue that impact or generate actions that are classified as risk-important HAs, will be analyzed to determine impact on Staffing & Qualifications.

For these post design plant modifications, the HFE program in conjunction with the operating license holder, will include the involvement of experienced plant personnel to provide reasonable assurance that the user's perspective is considered in establishing modification requirements and evaluating the design process's outputs. For example, in the case of shared sites with previous BWR designs, modifications and updates of the ESBWR will include the consideration of:

- User understanding of how plant systems are structured and operate
- Task demands and constraints of the existing work environment
- Impact on existing work processes

Furthermore, the impact of these ESBWR design modifications on the operational staff will be examined by screening or analysis for their impact on implementation and goals for the COL applicant. The staffing examination will re-evaluate the number and background of personnel for the full range of plant conditions and tasks including operational tasks (normal, abnormal, and emergency), plant maintenance, and plant surveillance and testing when implementing a modification to the ESBWR base design.

### 3.1.5 Application

N/A

# 4. IMPLEMENTATION

## 4.1 STAFFING AND QUALIFICATIONS EVALUATION PLAN

The general staffing analysis process with feedback for developing recommendations for S&Q is outlined in Figure 2. This figure shows interactions with other HFE tasks that support the staffing analysis process. Figure 3 provides a set of questions for analyzing specific HFE issues relative to the staffing requirements in a risk based approach.

Starting with knowledge from past BWR plant operations, the S&Q analysis process addresses HFE interactions in five phases that permit feedback and updating. These Phases are:

- Develop initial baseline S&Qs
- Apply deterministic rules for S&Qs to ESBWR Design
- Apply probabilistic evaluation to ensure acceptable risk profile
- Recommend S&Qs for ESBWR generic HSI design
- Refine S&Qs for customer specific ESBWR conditions.

## 4.2 PHASE 1 (ϕ1) INITIAL BASELINE S&QS

### 4.2.1 Assumption

This phase is represented by the initial ESBWR safety analysis reports submitted to the NRC. Based on an operating experience review, which examines operational problems and strengths that resulted from staffing levels in predecessor BWR systems, the starting point for a baseline shift S&Qs is provided in Table 1.

These initial staffing goals and their bases stem from staffing levels for the ABWR predecessor plants, assuming system level similarities. Where the ESBWR design features give rise to significant differences in plant systems from previous designs, described in the Baseline Review Records, reexamination of the S&Q is performed.

### 4.2.2 Input

The baseline shift staffing recommendations account for considerations discussed in NRC IN 95-48 and NRC IN 97-78 through a gap analysis. These inputs include:

- DCD requirements
- Operating Experience Reviews
- Baseline Review Record plan
- Defense-in-Depth and Diversity report
- HRA and PRA

#### 4.2.3 Output

ESBWR Baseline S & Q from previous ABWR designs and regulatory requirements.

### 4.3 PHASE 2 (ϕ2) DETERMINISTIC CONSIDERATIONS FOR S&QS

#### 4.3.1 Assumption

The second phase for determining that the recommended baseline S&Qs are adequate to maintain ESBWR safety is to consider the deterministic rules established in regulations and by previous nuclear plants. Previous ABWR systems have addressed human factors considerations that have been explicitly defined for consideration in the design process of new plants as a result of the lessons learned from worldwide operating experience of all reactors and specifically BWRs.

#### 4.3.2 Input

The deterministic rules for S&Qs are taken from NRC and industry reports, such as NUREG 0711, Rev 2 and NUREG 0800. As shown in Figure 2, the systematic process for evaluating S&Qs relative to the deterministic rules involves the three technical elements applied during the design process that are discussed below. These inputs include:

- System functional requirements analysis
- Allocation of functions
- Task Analysis

##### 4.3.2.1 *System Functional Requirements Analysis*

The ESBWR design provides significant improvements in operational simplicity and passive safety features. The development of specific System Functional Requirements Analysis (SFRA) for the detailed design can establish a basis for reducing operational staffing requirements. A gap analysis is used to identify changes to operational staffing requirements compared to the ABWR predecessor designs.

##### 4.3.2.2 *Allocation of Function*

The simplification of systems for the ESBWR will permit additional automation and reduced requirements for human decision-making and manual operation. The Allocation of Function (AOF) process will identify mismatches between functions allocated to personnel and their qualifications. This can result in changes to roles of personnel due to plant system and HFE modifications. Adjustment of the roles and responsibilities will depend on the use of automatic versus manual operations.

#### 4.3.2.3 *Task Analysis*

ESBWR design includes natural circulation and passive cooling. As such, there is additional time for on-site staff to react and off-site personnel to reach the plant during a significant transient event defined in the design basis and risk assessment. Therefore, the number of onsite and control room staff might be adjusted for a normal ESBWR shift, as compared to that for ABWR plants. The adjustments to requirements are addressed by the Task Analysis (TA) in the following areas:

- Personnel response time and workload
- Personnel communication and coordination, including their interactions for diagnosis, planning, and control activities, and interactions among personnel for administrative, communications, and reporting activities
- Job requirements resulting from the sum of all tasks allocated to each individual, both inside and outside the control room
- Ability of personnel to coordinate their work through the plant HSI, such as, directing local valve control from a remote display monitor
- Availability of personnel, considering other activities that may be ongoing, and for which licensed control room operators may take on responsibilities outside the control room (e.g., fire brigade)
- Staffing considerations described by the application of ANSI/ANS 58.8-1994, R2001
- Adequate planning to ensure that the information systems, personnel knowledge, procedures, and emergency planning actions identified in 10 CFR 50.47 and NUREG-0654 provide initial accident response in key functional areas as identified in the ESBWR emergency plan.

### 4.3.3 Output

ESBWR refined S & Q through the screening process.

## 4.4 PHASE 3 (ϕ3) PROBABILISTIC EVALUATION

### 4.4.1 Assumption

The third Phase in verifying the adequacy of the recommended S&Qs involves the use of risk assessment tools that are initially applied during the design and updated in future phases. An evaluation of the impact of changes to the baseline S&Qs is used to adjust, where appropriate, the HRA assumptions and quantification. These changes are re-evaluated in the PRA/HRA model accident sequences to determine changes in the importance of key human actions. This requires both qualitative and quantitative assessments within the HRA models and re-quantification of the baseline PRA/HRA model to produce an updated importance listing. By demonstrating that the change in risk from the baseline risk is within acceptable limits, the recommended S&Qs pass a risk-informed test.

### 4.4.2 Input

There are two connected technical elements needed to evaluate the risk importance and change in risk. These are the human reliability analysis and the PRA/HRA ESBWR model. Design improvement / feedback on ESBWR specifications provides feedback into probabilistic evaluation.

#### 4.4.2.1 *Human Reliability Analysis*

One of the considerations in evaluating actions such as maintaining or restoring shutdown cooling (SDC) is the number of operators available and their qualifications in terms of skills, knowledge and training, and applicability of procedures. The required level of skill and knowledge can vary significantly depending on the accident sequence.

For example, restoration of the SDC during a normal shutdown is considered routine, whereas the same action during a loss of station electric power or during a fire is more challenging and requires a significant level of adaptability to effectively use the procedures. This difference is due to the specific HSIs used to provide cues for action and feedback, available crewmembers, their skill and knowledge, and the time allowed for the action. When modeled in the PRA, these factors are reflected in the qualitative human action logic and application of sublevel human error probabilities (HEP) to identify overall HEP-related changes to the HRA inputs to the PRA/HRA model.

Updates to the HRA models provide a means for evaluating the impact of staffing levels and crew coordination on risk-important HAs. Also, the effect of overall staffing levels and the coordination of personnel on human errors associated with the use of advanced technology can be evaluated for its' impact on risk-important HAs combined with the PRA/HRA baseline models.

#### 4.4.2.2 *PRA/HRA Model*

The baseline PRA/HRA model, which is based on screening HEP values for many human actions that are modeled, is adjusted to reflect improvements to the HSI through changes in the HRA data, possible logic adjustments within systems or accident sequences, and fine-tuning the analysis of dependencies between actions. Thus, the effect of overall staffing levels on plant risk and reliability is assessed through both relative and absolute importance ranking and measures as applied to the PRA/HRA model.

### 4.4.3 Output

ESBWR refined S & Q through the HRA and PRA/HRA model screening process

## 4.5 PHASE 4 ($\phi$ 4) S&Q RECOMMENDATIONS

### 4.5.1 Assumption

Everyone who works in a nuclear power plant has a role in safety from the safety culture viewpoint. For example, some staff members have a major role involving public safety in responding to events, whereas others must address their own personal safety. The focus for HFE support of the HSI design addresses the management and control of reactor safety for those key actions allocated to manual tasks.

The ESBWR design represents a major shift in management of reactor safety from active systems that are controlled by both automation and operational staff to passive safety functions that rely primarily on inherent features of the design. These inherent features shift the fundamental operator tasks from manual backup on many active systems to monitoring and supporting operation of the natural circulation systems during transient events. Thus, development of the S&Qs for personnel involved in reactor safety is expected to change to meet different needs for the ESBWR. The inputs for this phase include:

- Existing staff and qualifications
- Qualitative assessment of safety functions
- Quantitative evaluation by risk assessment

### 4.5.2 Input

#### 4.5.2.1 *Existing staff and qualifications*

The first step in screening is to determine the staffing requirements to interact with the plant systems. By regulation, any nuclear power plant must establish and maintain a training program as defined in 10 CFR 50.54m and 10 CRF 50.120. The training program must provide for the training and qualification of the following categories of nuclear power plant personnel:

(1) Reactor Operator

(2) Senior Reactor Operator (Shift Manager)

(3) Shift Technical Advisor

(4) Shift Supervisor (Control Room Supervisor)

(5) Non-licensed operator (Auxiliary Operator)

(6) Instrument and control technician

(7) Electrical maintenance personnel

(8) Mechanical maintenance personnel

(9) Radiological protection technician

(10) Chemistry technician

(11) Engineering support personnel

#### 4.5.2.2 *Qualitative assessment of manual tasks*

The second step in the screening is to evaluate the ESBWR staff's ability to perform important manual tasks defined in operational analysis and identified using other tools such as the HRA/PRA and D3. Table 2 provides examples of screening criteria for evaluating whether to assign tasks to the normal control room staff or to additional station personnel. The generic tasks listed in Table 2 are derived from IEEE 497 and S&Q regulatory requirements and are provided as example tasks to demonstrate the screening structure.

The screening process uses the HFE implementation plans, for example FRA, AOF, TA, and Training, to perform detailed analysis of function based tasks and the ESBWR staff position and qualifications required to perform them. Additionally, analysis determines when in various phases of plant operation the tasks may be performed. Workload analysis is then performed by analyzing the aggregate task loading for each staff position. This analysis ensures that staff workload (both cognitive and physical) is within the bounds of human capabilities and accounts for human limitations. If analysis dictates, lower safety significance tasks may be screened in accordance with Table 2 and assigned to other staff positions or be redesigned in accordance with the HFE design process shown in Figure 1.

Analysis continues until the workload for each ESBWR staff position (for all modes of plant operation) is within the capabilities and qualifications of the position and can therefore be shown to support the safe and efficient execution of tasks.

#### 4.5.2.3 *Quantitative evaluation by risk assessment*

The HFE program identifies specific qualifications of the staff needed to address reactor safety issues by doing the following:

- Reviewing the issues that are listed in the HFE issues tracking (HFEITs) program.
- Through interactions with the PRA to determine the quantitative importance of specific manual actions that can impact the risk profile.

The process for using the PRA/HRA model is described in the NEDO-33267, ESBWR HFE HRA Implementation Plan. Specific training and qualifications will be identified through the methodology presented in NEDO-33275, ESBWR HFE Training Development Implementation Plan..

### 4.5.3 Outputs

S & Q staff level required for HSI design (tasks impacting safety).

## 4.6 PHASE 5 ($\phi$5) S&Q LEVEL FOR HSI DESIGN (TASKS IMPACTING SAFETY)

### 4.6.1 Assumption

As shown in Figure 2, the HFE S& Q development process includes a fifth phase. This phase determines if the recommended S&Qs are adequate to safely operate the ESBWR. The HFE design team verifies that the recommended plant staffing is adequate for using information available through the HSI to identify abnormal situations, take corrective actions, and to obtain feedback on the impact of corrective actions taken.

### 4.6.2 Input

S & Q recommendations from phase 4.

### 4.6.3 Output

#### 4.6.3.1 *S&Qs for the baseline ESBWR*

Adequacy of the recommended S&Q level for the baseline ESBWR is demonstrated by showing that:

- The staffing level is adequate to meet operational and accident demands resulting from the locations and use (especially concurrent use) of controls and displays.
- The HSI supports coordinated actions among individuals at different strategic locations.
- The plant system HSI (with HFE modifications) provides timely information that is accessible and focused as needed by qualified personnel.
- The physical configuration of the control room and control consoles supports the organization and number of recommended staff.
- The plant information from HSI individual workstations and group-view interfaces is available during transient events to the baseline staff as well as technical support centers.

The use of the HSI during V&V (i.e., full scope simulator) establishes that the staffing level and personnel qualifications are adequate according to Reference 2.1.2(9), ESBWR HFE V&V Implementation Plan.

#### 4.6.3.2 *Procedure Development*

During procedure development and refinement from previous designs, the adequacy of the recommended S&Qs is checked by:

- Confirming that the staffing levels are adequate to execute the procedures necessary to meet normal operational or transient event requirements.
- Confirming that the level of personnel skills, knowledge, abilities, and authority for each crewmember is suitable to identify, evaluate, and carry out tasks identified in the procedures.

#### 4.6.3.3 *Training Program Development*

During development of the training program, issues for refinement of the recommended S&Qs through HFE review can be identified by:

- Addressing the ability of the crew to communicate and coordinate successfully using the HSI to carry out the tasks and actions that protect the plant assets and public safety.
- Developing training modules that continually enhance and reinforce the skills, knowledge, and abilities needed to accomplish each task identified in the procedures.

#### 4.6.3.4 *S&Qs for Customer Specific ESBWR*

The baseline S&Qs adequacy also involves the utility customer and is developed after the baseline HSI design approach is determined. At this point the baseline S&Qs for operational staff is well established, but other plant staff can be added to address other staffing needs. In addition, the plant specific procedures and training are developed for the shift operations staff and other support staff. As shown in Figure 2, adequacy of the recommended S&Qs will be systematically checked during procedure development and training programs.

# 5. RESULTS

## 5.1 RESULTS SUMMARY REPORT

The results of the Staffing and Qualifications are summarized in a Results Summary Report (RSR). This report is the main source of information used to demonstrate that efforts conducted in accordance with the implementation plan satisfy the applicable review criteria of NUREG-0800. The report contains the following:

- The scope of the S&Q activity
- The final staffing levels and qualifications
- The basis for the S&Q concluding that issues and concerns raised in other HFE activities are addressed

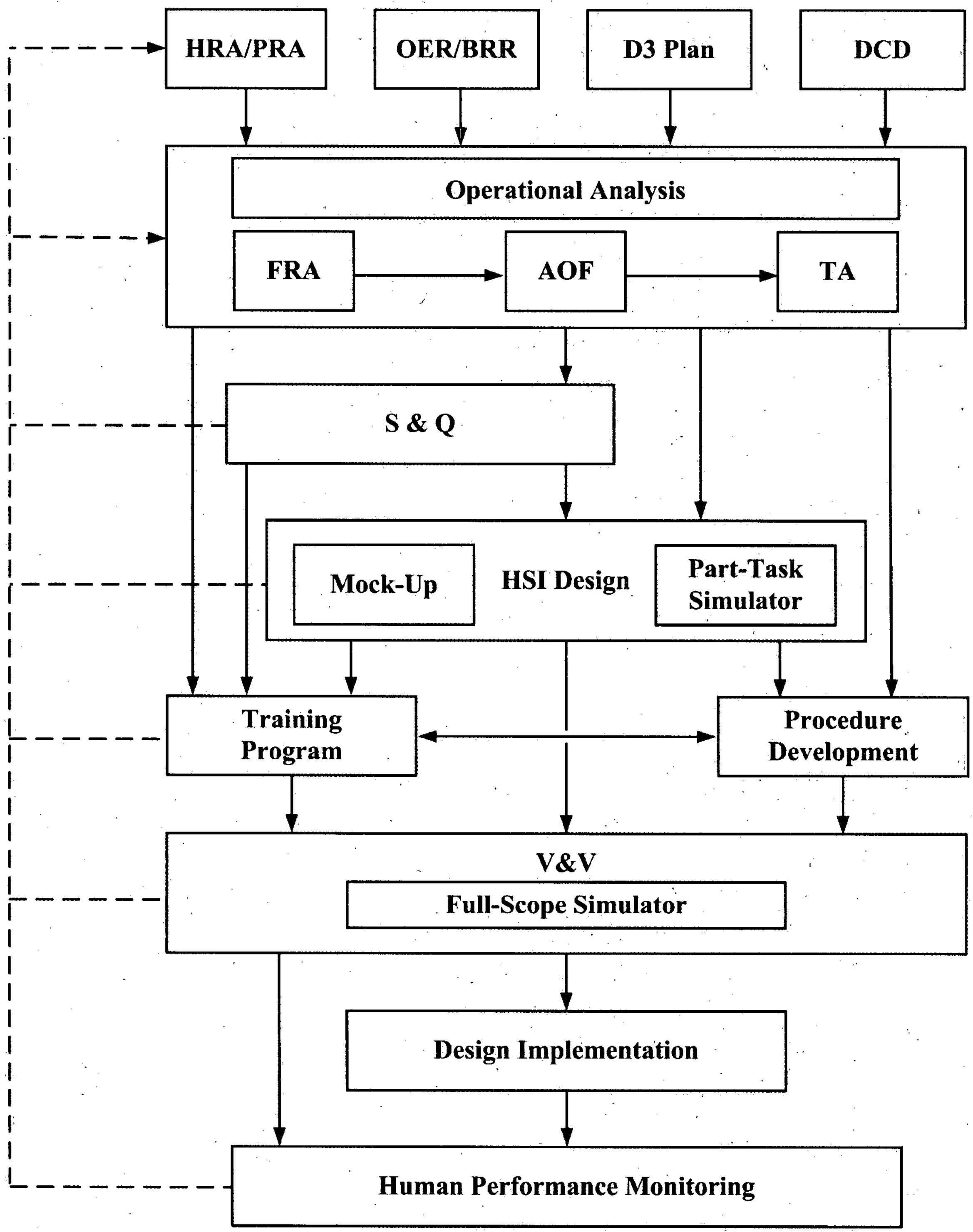


**Figure 1 HFE Implementation Process**

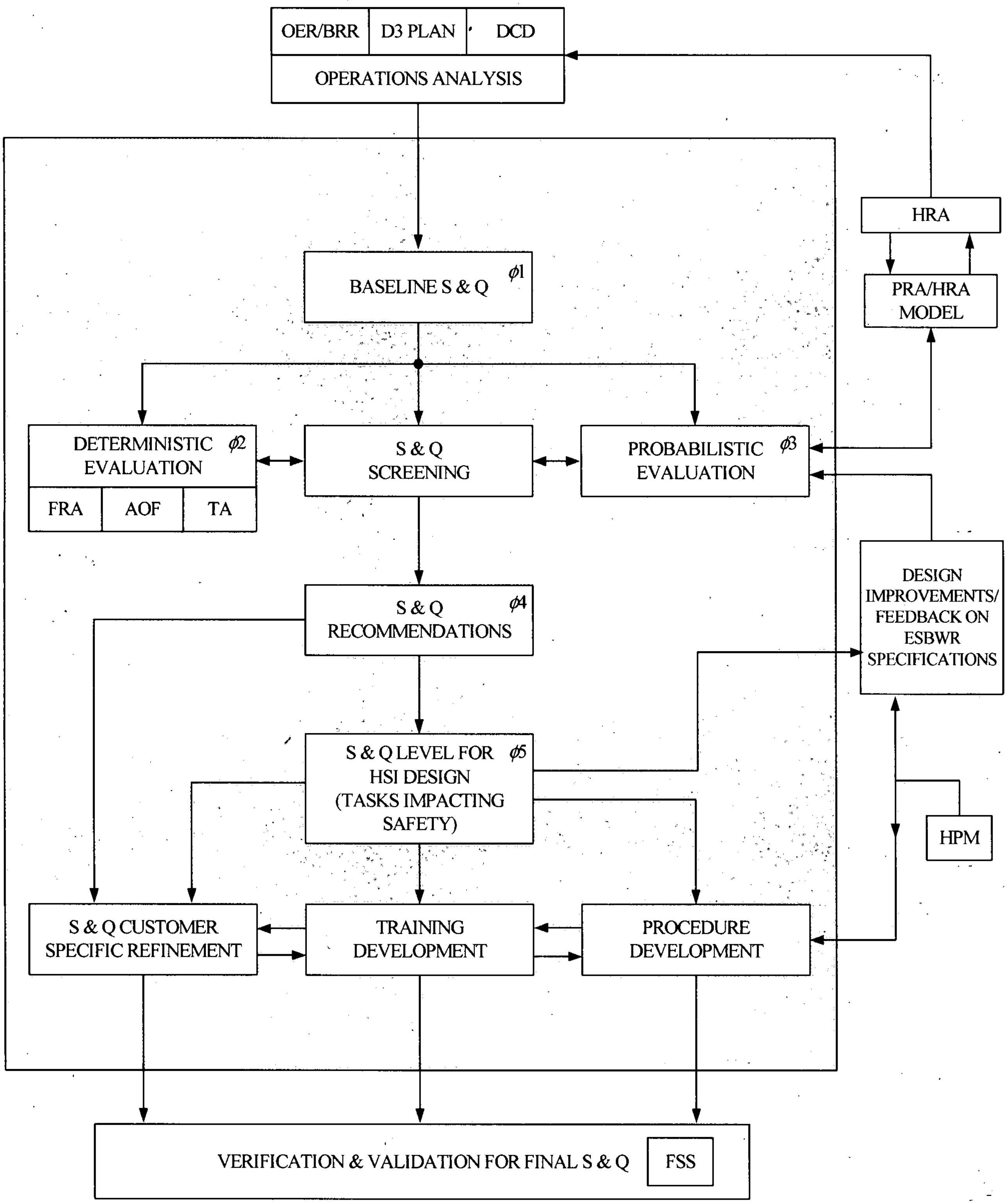


**Figure 2 Process for development of ESBWR Staffing and Qualification Recommendations**

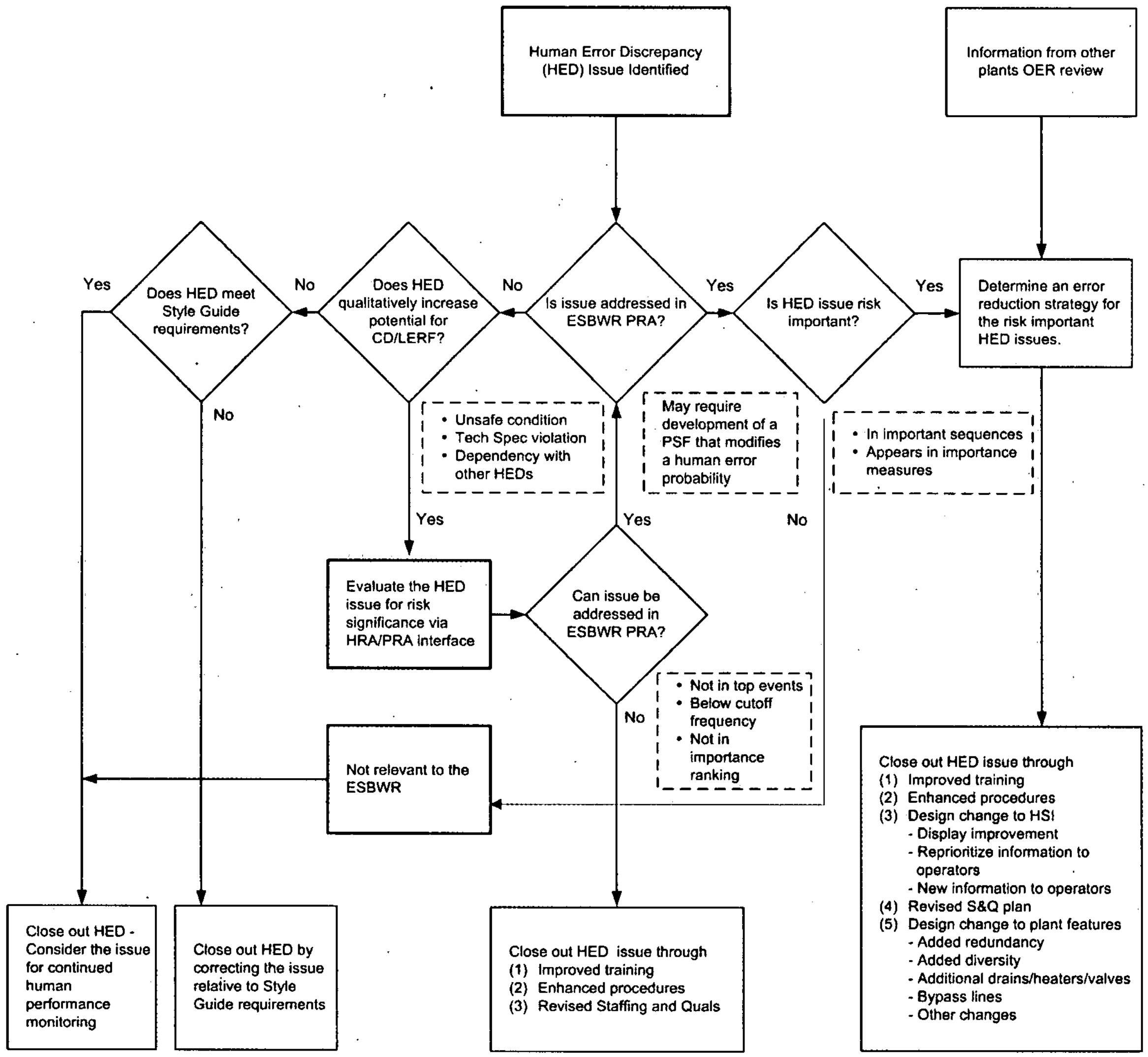


**Figure 3 HFE Issue Evaluation Process Relative to Staffing Requirements**

**Table 1 Initial Baseline Shift Staffing and Qualifications Matrix**

| Quantity | Qualifications | Assignments |
|---|---|---|
| 1 | Control Room Supervisor[1] | Provides overall supervision of control room operations |
| 2 | Reactor Operators[2] | First operator is assigned to normal control actions at MCR HSI. Second operator is assigned to control of testing, surveillance and maintenance activities, including blocking and tagging permits. |
| 1 | Senior Reactor Operator (Shift Manager)[1] | Assigned to shift but not necessarily in the Main Control Room (MCR). Acts as manager of and relief for shift supervisor. |
| 2 | Auxiliary Operators[3] | Qualified to operate equipment in the plant. |

[1] Licensed by the NRC as a Senior Reactor Operator (SRO)
[2] Licensed by the NRC
[3] Non-Licensed, often called Auxiliary Equipment Operators (AEOs)

**Table 2 Example manual task screening matrix for HFE design importance**

| | | | Human Factors Engineering Screening Attributes | | | |
|---|---|---|---|---|---|---|
| | Generic Task Description [1] | Example | TA [2] | HRA/PRA [3] | S&Q [4] | HSI [5] |
| | | | | | | |
| 1 | Operator tasks required to start, control and stop equipment to prevent core damage or limit significant radioactive release | Manual control of containment venting to reduce steam pressure in containment to prevent containment failure and resulting uncontrolled releases | Yes | Yes | Yes | Yes |
| 2 | Operator tasks that backup automated systems used to prevent core damage or limit significant radioactive release | Manual control rod insertion should the automated system fail to respond | Yes | Yes | Yes | Yes |
| 3 | Operator tasks for short term surveillance and testing of active equipment to prevent tripping the reactor or electrical systems | Monitor turbine generator vibration | Yes | In failure data | Personnel assigned | Yes |
| 4 | Operator tasks for surveillance and testing of standby equipment to verify availability | Test for diesel generators operability | Yes | Depend on response time | Personnel assigned | Yes |
| 5 | Tasks for surveillance and testing of structures to verify that protective margins are maintained | Verify piping thickness and welds meet the code requirements for the pressure used | Depends upon task details | In failure data | Personnel assigned | Yes |
| 6 | Operator tasks for repair or replacement of systems, structures and components | Replace a feedwater pump | Depends upon task details | In failure data | Personnel assigned | Yes |

**Note [1]:** The tasks are derived from IEEE 497 and requirements for staffing in 10CFR50.54m, 50.55, 50.120 and 50.47. When used for manual task screening, ESBWR specific tasks will be used.

**Note [2]:** Indicates if task is assessed by task analysis. The task analysis data structure contains task workload information if specified.

**Note [3]:** Indicates if task is modeled in HRA/PRA and risk information is contained in the HRA/PRA data structure, if applicable.

**Note [4]:** "Yes" indicates that personnel assigned to perform the tasks are selected from the list in Table 1 if applicable. "Personnel assigned" means that other personnel identified in Section 4 "Input-Existing Staff & Qualifications" will perform the task.

**Note [5]:** "Yes" means that a HSI is expected to support this type of task for the ESBWR standard plant. For ESBWR specific tasks, the actual HSI and location will be included.