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# LICENSING TOPICAL REPORT
# ESBWR HUMAN FACTORS ENGINEERING
# HUMAN PERFORMANCE MONITORING
# IMPLEMENTATION PLAN

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# 1 Introduction

This plan outlines a strategy to address human performance monitoring (HPM) during the operating phase of the ESBWR; employing diverse programmatic inputs and an integrated system of evaluation. It also links human factor engineering (HFE) results developed during the design with methods for monitoring human performance during operation by the COL holder. The human performance monitoring implementation plan (HPMIP) illustrates how the HFE activities performed during the design are used to support the operating phase of the ESBWR. This implementation plan is one of the twelve elements for HFE review identified in NUREG-0711 Rev. 2.

It is anticipated that a COL Owners Group (COLOG) will be established and provide a means for consistently maintaining safety performance levels established through staffing, training, procedures and design as described in the DCD. Individual COL holders' programs may vary in content and level of detail; however, they should follow the standards established by the COLOG.

## 1.1 Purpose

The objective of the ESBWR HPMIP is to ensure that no significant safety degradation occurs due to changes in design, procedures, training or staffing. The HPMIP incorporates a strategy for monitoring the performance of personnel and equipment that integrate with existing programs (Corrective Action Program (CAP), Maintenance Rule, PRA/HRA, In-service Inspection / In-service Testing (ISI/IST), etc., or equivalent programs to support the HPMIP) to provide adequate assurance that the ESBWR HFE design bases remains valid during the operational phase of the plant. This HPMIP outline builds upon the HFE activities employed during the design that can be carried forward into the operational phase. The COL holders are responsible to incorporate their problem identification, CAP, etc. or equivalent programs to support the HPMIP.

## 1.2 Scope

This document illustrates how HPM elements suitable for human performance monitoring by the COL holder make use of HFE information developed during the HSI design. Completion and documentation of the initial plant HFE/HSI Design Verification by the COL holder provides a basis for human performance monitoring when plant operations begin. For example, the HPMIP uses benchmarks for human performance, established during the ESBWR design for specific tasks defined in the function allocation and task analysis steps and verified during simulator testing in the V&V phase. The monitoring of performance relative to these benchmarks ensures sufficient margin to fulfill assumptions supporting the General Design Criteria (GDC).

### 1.2.1 Roles and Responsibilities of GE

GE will provide and maintain the original (certified) design bases; and, as requested by the COLOG provide:

1. Analysis of design issues arising during V&V, start-up testing and plant operation.
2. Analysis of staffing and training issues arising during V&V, start-up testing and plant operation.
3. Analysis of procedure changes arising during V&V, start-up testing and plant operation.
4. Determine if the proposed change(s) (to design, staffing, training or procedures) require a change to the FSAR(s).
5. Prepare and process FSAR change package(s), as required to support safe and economic ESBWR Fleet operation.
6. Support COL holder(s) through NRC review and approval of FSAR change package(s).

### 1.2.2 COL Holders' Roles Responsibilities

The COL holders are expected to follow COLOG recommendations and NRC regulatory guidelines. Key elements of the COL holders' responsibilities, related to the HPMIP strategy, are:

1. Participation in the COLOG (sharing information with GE and the rest of the COLOG).
2. Ensure construction and operation of plant per the DCD/COL.
3. V&V and post installation testing.
4. Operational phase data collection.
5. Screening operating events for importance.
6. Analyzing events to determine the root cause.
7. Trending simulated performance of critical tasks to identify change.
8. Development of corrective actions for significant events.
9. Screening operating data to determine potential impact on the DCD (generic FSAR) (similar to a 10CFR 50.59 screen).
10. Monitoring the effectiveness of the corrective actions.

Where possible these elements of the HPM program draw upon information sources and programs developed during the design process. These elements also fit within typical corrective action (CAP) programs.

### 1.2.3 Proposed COLOG Charter

Suggested roles and responsibilities for the COLOG would be:

1. Evaluate pre-operational V&V and functional test results and determine whether pursuit of a change to the generic FSAR is warranted.
2. Evaluate concerns raised during the operational phase and determine whether pursuit of a change to the generic FSAR is warranted.
3. Determine the type of change (design, staffing, training or procedures) and commission GE to perform formal analysis and generic FSAR change(s) as required.
4. Develop and implement a pilot program to allow deviations (of specific scope and duration) from the generic FSAR.
5. Maintain the HFE Issue Tracking System (HFEITS) to record, track and trend HFE issues, impacts, evaluation and resolution during the operating phase of the ESBWR.

# 2 References:

## 2.1 ESBWR Supporting Documents

1. DCD Chapter 13 (GE 26A6642BL) Rev. 1.
2. DCD Chapter 18 (GE 26A6642BX) Rev. 1
3. DCD Chapter 19 (GE 26A6642BZ) Rev. 0
4. NEDE-33262 Rev. 0, Operational Experience Review (Human Factors) Implementation Plan.
5. NEDO 33217 Rev. 0, Man-Machine Interface System And Human Factors Engineering Implementation Plan.
6. NEDO-33219 Rev. 0, System Functional Requirements Analysis Implementation Plan.
7. NEDO-33220 Rev. 0, Allocation of Functions Implementation Plan.
8. NEDO-33221 Rev. 0, DCIS Task Analysis.
9. NEDO 33229 Rev. 0, Distributed Control and Information System (DCIS) Hardware/Software Development Plan.
10. NEDO-33266 Rev. 0, Human Factors Engineering Staffing and Qualifications Plan.
11. NEDO-33267 Rev. 0, ESBWR Human Factors Engineering Human Reliability Analysis Implementation Plan.
12. NEDO-33268 Rev. 0, Human System Interface Design Implementation Plan.
13. NEDO 33274 Rev. 0, HFE Procedure Development Plan.
14. NEDO 33275 Rev. 0, HFE Training Program Development Plan.
15. NEDO 33276 Rev. 0, HFE Verification & Validation Implementation Plan.

## 2.2 Codes and Standards

1. ANSI/ANS 3.1-1993; R1999: Selection, Qualification, and Training of Personnel for Nuclear Power Plants (American Nuclear Society).
2. ANSI/ANS-3.2-1994; R1999, "Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants."
3. ANSI/ANS-3.4-1996; R2002, "Medical Certification and Monitoring of Personnel Requiring Operator Licenses for Nuclear Power Plants."
4. ANSI/ANS 3.5-1998: Nuclear Power Plant Simulators for Use in Operator Training and Examination (American Nuclear Society).

5. IEEE Std 610 -1991, "IEEE Standard Computer Dictionary, A Compilation of IEEE Standard Computer Glossaries" The Institute of Electrical and Electronics Engineering.

## 2.3 Regulatory Requirements and Guidelines

1. CN Number 05-030: NRC Inspection Manual: Chapter 0609, Significance Determination Process (NRC, 2001).
2. CN Number 05-031: NRC Inspection Manual: Chapter 2515, Light-Water Reactor Inspection Program - Operations Phase (NRC, 2002).
3. IP 71715: Sustained Control Room and Plant Observation. (NRC, periodically updated).
4. NUREG-1649 Rev.3: Reactor Oversight Process (NRC, 2000).
5. INPO 85-017 Rev 2, Guidelines for the Conduct of Operations at Nuclear Power Stations. (10 CFR 50.120: U.S. Code of Federal Regulations, Part 50, "Training and Qualification of Nuclear Power Plant Personnel," Title 10, "Energy").
6. NUREG-0700 Rev. 2, Human-system Interface Design Review Guidelines (NRC, 2002).
7. NUREG-0711 Rev. 2, Human Factors Engineering Program Review Model (NRC, 2004).
8. NUREG-0737, Clarification of TMI Action Plan Requirements Supplement 1 (NRC,1983), Requirements for Emergency Response Capability
9. NUREG-0800: Section 13.2.1 Reactor Operator Training Rev. 2 (NRC, 2005) and 13.2.2 Training for Non-Licensed Plant Staff Rev. 2, (NRC, 2005)).
10. Regulatory Guide 1.149 Rev. 3: Nuclear Power Plant Simulation facilities for Use in Operator Training and Licensing Examination (NRC, 2001).
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 (NRC, 2002).
12. Regulatory Guide 1.8 Rev. 3: Qualification and Training of Personnel for Nuclear Power Plants (NRC, 2000).

## 2.4 Departments of Defense and Energy

1. AD-A226 480, U.S. Army Test and Evaluation Command, Human Factors Engineering, Test Operation Training 1-2-610 (Part 1), May 1990.
2. DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities, DOE Change 2 Oct 2001.

3. MIL-STD 1472F, Human Engineering Design Criteria Standard, Department of Defense. 1999.

4. MIL-HDBK-46855A, Human Engineering Requirements for Military Systems, Equipment and Facilities (Dept. of Defense) May 1999.

## 2.5 Industry and Other Documents

1. EPRI-TR-016780-V2R8, Advanced Light Water Reactor Utility Requirements Document, Vol. II ALWR Evolutionary Plant, Chapter 10, Man-Machine Interface Systems, Rev. 8, 1999

2. EPRI-NP-1567, Human Factor Review of Power Plant Maintainability, 1980.

3. EPRI-NP-2360, Human Factors Methods for Assessing and Enhancing Power Plant Maintainability, 1982.

4. EPRI NP-3659, Human Factors Guide for Nuclear Power Plant Control Room Development, 1984.

5. EPRI-NP-3701 Computer-generated Display System Guidelines Vol. I and II, revised 1984.

6. IAEA INSAG-13 Management Of Operational Safety In Nuclear Power Plants, 1999.

7. IAEA Safety Series No. 75-INSAG-4: "Safety Culture", 1991.

8. IAEA - Technical Report Series (TECDOC-596), "Reviewing operational experience feedback", IAEA, 1991.

9. IAEA- Technical Report Series (TECDOC-525), Guidebook on Training to Establish and Maintain the Qualification and Competence of Nuclear Power Plant Operations Personnel, Vienna, 1989.

10. IAEA- Technical Report Series (TECDOC-668), The Role of Automation and Humans in Nuclear Power Plants, IAEA, Vienna, 1992.

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

# 3 Human Performance Monitoring (HPM) Plan

## 3.1 General Approach

The HFE design team, when allocating specific manual actions to systems and integrated accident management processes, establishes the basic human performance requirements for the ESBWR.

During the V&V portion of design phase the scope of the HPM strategy provides a reasonable assurance that:

1. The HSI design is clearly useable by personnel within the control room; between the control room and local control stations (and support centers) to address expected transients, design basis events, significant industry events and hypothetical accident scenarios identified by the PRA/HRA.
2. The staffing plan and initial training assure that human actions using HSI information, cues and controls are accomplished with margins on time to meet GDC performance criteria used to determine the probability of success assessments for the PRA/HRA.
3. Plant procedures are adequate to ensure critical tasks support GDC requirements and do not contribute to the initiation of an operational event.

During the operational phase of the ESBWR the HPM strategy provides reasonable assurance that:

1. The acceptable level of performance established during the integrated HSI validation is maintained. The methods for evaluation and trending of plant operators' performance will stem from INPO established human performance evaluation system (HPES) approaches.
2. Changes made to the as-built HSIs, procedures, and training are screened for generic FSAR impact and consistently applied at all ESBWRs in a timely manner. Verification that targeted deficiencies have been mitigated and that changes have not created or aggravated personnel performance (e.g., a change that interferes with previously trained skills).
3. Changes made to the HSI are tested in the training simulator prior to implementation in the plant. The screening and processing discussed in Regulatory Guide 1.174 will form the basis of the documentation strategy and any links to the content in Chapter 18 of the generic FSAR or support documents (eg. Results Summary Reports).

### 3.1.1 Gather Data and Evidence

To put measured deviations into the context of safety and plant risk it is necessary to convert single incidents into measures that can be treated in the PRA/HRA. Data from similar deviations is gathered from other events, or human performance task measurements from simulator evaluations are reviewed, to evaluate the importance of the human performance deviations. These sources include:

1. Examination of Operating Experience Review (OER) documents.
2. Review of events in the integrated HFE Issue Tracking System.
3. Evaluation of HRA data sources and tools.
4. Dynamic simulation of plant accident sequences and measurement and trending of operator performance and plant responses.

### 3.1.2 Analyze Cause and Effect Relationships

An important element of human performance monitoring is to understand the impact of deviations on plant operation and safety. A Root Cause analysis is often conducted to determine if a proposed corrective action addresses the best understanding of the cause of the deviation or component failure.

A process that uses precursor analysis, to understand the impact of the deviation where the impact of human deviations and system or component failures are mapped into generic accident sequence event trees as ones and zeros to produce a change in the accident sequence probability under the identified condition. This process is superseded, if the PRA/HRA of the plant is sufficiently detailed to model the deviation, then the standard risk importance measures are used.

Advanced uses of risk and reliability techniques have been developed in the nuclear industry to provide up to date risk and reliability information to the control room. Such tools are used to support asset management by including trip monitors and derate models. The goal of these models is to provide estimates of the trip or derate probability as a function of configuration changes in the plant. This permits operators to more clearly understand complex relationships between systems undergoing maintenance and testing.

### 3.1.3 Develop Solution Recommendations.

After a measured deviation is analyzed and understood to be risk sensitive, a solution is needed to better control the plant risk. The ideas for corrective actions can come from the work team involved, management, designers, or consultants. Enhancements to the plant typically come as changes in the areas of:

1. Training
2. Procedures
3. Changes to HSI software
4. HSI hardware upgrades.

### 3.1.4 Evaluate Operators' Mastery of Changes to HSI.

Once a significant change to the "as built plant" is identified or developed, it needs to be tested for its impact on human performance. It is expected that changes that impact human performance will be modeled into the Full Scope Simulator (FSS) or hardware training to measure and evaluate the impact on the deviation. When the evaluation shows that the change provides enhancement to the plant operation /safety it can be implemented in the plant.

## 3.2 Organizational Responsibility Structure

There are three entities that are tasked with developing and implementing the HPMIP during the ESBWR operating phase:

1. GE will determine and document the scope and structure of the HPMIP and will control the certified ESBWR HFE design basis during the operational life of the ESBWR program. GE will respond to industry request to review operational issues as related to the DCD (generic FSAR) and produce and process generic FSAR amendments that are in the long-term interest of the ESBWR partners. GE will form and chair an advisory owners' group, COLOG, that will address generic ESBWR issues.

2. The COL holder will implement the plant level strategy for HPM by using inputs such as design information, risk importance measures, event experience and training simulator capabilities during the operational life of the plant. It is expected that, the COL holder (one seat per contracted or operating unit) will participate in the COLOG. The COL holder will screen operating events (similar to a 10CFR 50.59 screen) to determine if the DCD (generic FSAR) could be impacted. All events that have the potential to impact the generic FSAR will be forwarded to the COLOG for analysis and review.

3. The COL Owners Group (COLOG) will be initiated and chaired by GE and include representation from GE and each contracted or operating ESBWR unit. The COLOG will be initiated on a timeline consistent with its responsibilities to evaluate plant data beginning with start-up test results following/during construction of the first ESBWR. The COLOG should evaluate and trend data from individual plants; and contract with GE to evaluate DCD (generic FSAR) related issues and/or change the generic FSAR for the long-term benefit of continued safe and economic operation of the ESBWR fleet. The COLOG will take ownership of the HFEITS, with GE support, concurrent with start-up testing on the first ESBWR.

## 3.3 HPM Requirements

The essential elements for developing an HPM strategy include considerations of data collection, screening for importance, analyzing events to determine the cause and for trending, and developing corrective actions. Where possible, the elements of the HPM will draw upon existing information sources and programs to provide the assurances described in Section 3.1. The HFE design team assumes that the COL holder HPM process includes the following essentials:

1. The COL holder will maintain a database of events, significance evaluations, cause determinations and corrective actions taken during the event evaluation to support trending of performance degradation and failures.

2. The HPM strategy will be capable of collecting data for trending human performance (data sources include event reports documented in the NRC licensee event reports, local plant Corrective Action Process (CAP), performance data from the Baseline Specific Simulator (BSS), OER reviews for industry events and root cause analysis for internal events). This data will be used to demonstrate that proposed HSI changes result in performance that is consistent with assumptions in the analyses conducted to justify the initial HSI design.

3. Existing programs such as licensed operator training and/or the CAP should include appropriate data for trending human performance as well as other performance indicators for the plant. In any case, the strategy is to use existing utility or industry programs for data collection, rather than developing new monitoring programs.

4. The strategy elements are implemented through the use of a BSS simulator during periodic training exercises. An assumption for use during the HSI design process is that the simulator control room will be maintained and upgraded to match the actual control room with good interface and dynamic response fidelity. Periodic

evaluation and trending of operators' performance of tasks with respect to time and accuracy goals are performed to demonstrate performance consistent with that developed during the various analysis that support the DCD (generic FSAR ) (or justify/validate changes to the generic FSAR).

### 3.3.1 Pre-operational Requirements

The HPM pre-operational phase strategy is structured to ensure that:

1. Human actions are monitored commensurate with their safety importance as determined by the PRA/HRA.
2. Acceptance criteria and bases are established prior to pre-operational testing.
3. Performance is referenced to baseline performance established by initial V&V testing results.
4. Pre-operational testing of systems and subsystems is performed as early as practical.
5. Integrated simulation testing is performed prior to operational phase. When actual conditions cannot be simulated, monitored, or measured, the available information that most closely approximates performance data in actual conditions is used to assess the impact on risk via the PRA/HRA models and data.
6. Startup testing is performed concurrent with initial heat-up.
7. Start-up/functional test results are promptly evaluated and corrective actions are timely and verified to be effective.
8. Degradation in performance can be detected and corrected before plant safety margin is compromised.
9. Results of V&V, start-up test evaluation and corrective actions are documented in the HFEITS.

### 3.3.2 Operating Phase Requirements

The strategy elements are implemented through the use of a BSS during periodic training exercises. An assumption for use during the HSI design process is that the simulator control room will be maintained and upgraded to match the actual control room with good interface and dynamic response fidelity.

1. Monitor COL holder inputs (to the CAP process) that include:
   a. Industry Operating Experience
   b. Simulator performance of critical tasks supporting the GDCs

c. Maintenance Rule Program

d. PRA/HRA updates

e. In-Service Inspection/ In-Service Testing (ISI/IST) Program

f. INPO/NRC inspection/evaluation results

g. NRC and other regulatory initiatives

2. Collect and Store Data.
3. Trend events and causes.
4. Address the significance of the failure through application of PRA/HRA importance measures.
5. Determine the causes and circumstances surrounding the failure or degraded human performance.
6. Illuminate the characteristics of the failure and develop corrective actions (CA).
7. Determine whether the failure is isolated or has generic or common cause implications; determine extent of condition (EOC).
8. Determine whether the deficiency or the CA affect the DCD (generic FSAR).
9. Determine if a change to the generic FSAR is required.
10. Develop and process (NRC approval) changes to the generic FSAR or support documentation (if required).
11. Implement CA in accordance with the extent of condition.
12. Validate the effectiveness of the CA (no unexpected new issues).

## 3.4 Process for HPM

A process template is provided in Figure 1 to illustrate how HFE information generated during the design and V&V process supports the COL holder in addressing the HPM requirements throughout the life/operating phase of the ESBWR.

1. Generate and process the initial DCD through NRC certification.
2. Construct plant per the COL and FSAR.
3. Form the COL Owners Group (COLOG).
4. COL holder performs start-up testing
5. The COLOG evaluates start-up test results to determine if a change to the generic FSAR is recommended.

6. The COLOG determines what type of change(s) to the generic FSAR are needed and commissions GE to perform a formal evaluation
7. GE evaluates the request for change and determines if a change to the generic FSAR is required.
8. GE prepares the generic FSAR change (including implementation timeline) and routes the change through NRC approval.
9. COL holders implement FSAR changes, and perform V&V per the HPM process beginning with Section 3.4.
10. The COL holder operates the plant per the FSAR and COL.
11. The COL holder monitors the plant and personnel performance during the operating phase.
12. The COL holder collects operating data and determines the significance of operating events.
13. The COL holder determines the root cause of significant operating events.
14. The COL holder stores and trends operating event and cause data.
15. The COL holder determines appropriate corrective actions (CAs) and the extent of condition (EOC) for plant and personnel deficiencies.
16. The COL holder screens Operating Events, Causes and CAs to determine if the generic FSAR could be affected.
17. The COLOG evaluates issues that could impact the DCD (generic FSAR) and decides if a change to the generic FSAR is recommended (the type of change is determined per Section 3.4.6 and implemented per Section 3.4.9).
18. The COLOG determines if a "pilot change" to the FSAR is recommended. A pilot change is a change to the generic FSAR that does not affect all ESBWR plants. A pilot change can be long term or short term to allow deviation from the DCD (generic FSAR) due to issues such as obsolescence, component availability, technology changes etc. The pilot change will allow new plants to employ modern technology while not forcing existing plants to immediately upgrade systems that are performing adequately.
19. The COLOG determines the type, scope and duration of the FSAR pilot change and commissions GE to evaluate the proposed pilot change.
20. GE performs analysis of proposed pilot FSAR change.
21. GE determines if a pilot change to the FSAR is required.

22. GE prepares the pilot FSAR change (including, evaluation and close out implementation timelines) and supports proposed generic FSAR change through NRC review and approval.
23. COL holder obtains NRC approval and implements pilot FSAR change(s).
24. COL holder performs functional testing on pilot change(s).
25. COL holder operates the plant and collects data.
26. The COLOG evaluates data from pilot plant(s).
27. The COLOG recommends applying the pilot changes generically, continuing operation with pilot changes or restoring from pilot to the generic FSAR.
28. Pilot program COL holder restores the FSAR and plant to standard configuration.
29. Pilot COL holder performs V&V testing to assure that the plant has been restored in accordance with the generic FSAR.

# 4 Documentation

## 4.1 Record Retention Schedule

1. The COL holder(s) shall maintain operating event and corrective action data for the full (60 year) term of the COL.
2. The COLOG shall maintain the HFEITS and supporting documents from startup testing of the first ESBWR through the decommissioning of the last ESBWR.
3. GE shall maintain the ESBWR DCD (generic FSAR) records (evaluations and changes) from initial NRC approval until decommissioning is completed on the last ESBWR.

## 4.2 HPM Results Summary Report

1. The activities and results of the HPMIP will be summarized result summary report.

## 4.3 Periodic Reports.

2. The COL holder shall provide to the COLOG operating data per Figure 1 in a timely manner.
3. The COLOG shall publish a periodic operating summary report (documenting ESBWR generic issues, issue resolution, implementation status and operating results) no less frequently than bi-annually.
4. GE will publish an updated generic FSAR, incorporating all approved changes; bi-annually.
5. The reporting frequencies above are the minimum requirements; frequencies are to be commensurate with the seriousness, scope, and urgency of the initiating event and/or issue(s).

**Figure 1 – Human Performance Monitoring Implementation Plan Flow Chart**