GE Energy

David H. Hinds
Manager, ESBWR

PO Box 780 M/C L60
Wilmington, NC 28402-0780
USA

T 910 675 6363
F 910 362 6363
david.hinds@ge.com

MFN 06-177

Docket No. 52-010

June 13, 2006

U.S. Nuclear Regulatory Commission
Document Control Desk
Washington, D.C. 20555-0001

Subject: **ESBWR HFE Licensing Topical Report – NEDO-33276**

The following ESBWR Human Factors Engineering Licensing Topical Report (LTR) is contained in the Enclosure:

- NEDO-33276, "ESBWR HFE Verification and Validation Implementation Plan" – prescribes a plan for comprehensively verifying that MCR, RSS, and LCS designs critical to plant safety conform to HFE design principles, and validates that the designs enable plant personnel to successfully perform their tasks to achieve plant safety and operational goals.

This LTR was identified in the Referenced letter.

If you have any questions about the information provided here, please let me know.

Sincerely,

Kathy Sedney for

David H. Hinds
Manager, ESBWR

D068

Enclosure:

MFN 06-177 – Licensing Topical Report

- NEDO-33276, "ESBWR HFE Verification and Validation Implementation Plan," May 2006

Reference:

MFN 05-140, Letter from David H. Hinds to U. S. Nuclear Regulatory Commission, *Submittal Schedule for Licensing Topical Reports Related to ESBWR (TAC # MC8168),* November 22, 2005

cc:

WD Beckner	USNRC (w/o enclosures)
AE Cubbage	USNRC (with enclosures)
LA Dudes	USNRC (w/o enclosures)
GB Stramback	GE/San Jose (with enclosures)
eDRFs	0000-0051-3917

ENCLOSURE

MFN 06-177

Licensing Topical Report

NEDO-33276, "ESBWR HFE Verification and Validation Implementation Plan," May 2006

GE Energy
Nuclear
3901 Castle Hayne Rd
Wilmington, NC 28401

NEDO-33276
eDRF# 0000-0051-3917
Class I
May 2006

LICENSING TOPICAL REPORT

ESBWR HFE VERIFICATION AND VALIDATION IMPLEMENTATION PLAN

PROPRIETARY INFORMATION NOTICE

This document NEDO-33276, Revision 0, contains no proprietary information.

IMPORTANT NOTICE REGARDING CONTENTS OF THIS REPORT PLEASE READ CAREFULLY

The information contained in this document is furnished for the purpose of obtaining NRC approval of the ESBWR Certification and implementation. The only undertakings of General Electric Company with respect to information in this document are contained in contracts between General Electric Company 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**, General Electric Company makes no representation or warranty, and assumes no liability as to the completeness, accuracy, or usefulness of the information contained in this document.

Table of Contents

List of Tables

List of Figures

1 Introduction

This is the plan for verifying and validating the human factors (HF) engineering of the ESBWR Main Control Room (MCR), the Remote Shutdown System (RSS), and Local Control Stations (LCSs) critical to plant safety. Verification is the process of determining and documenting that an implemented design (a product, process, procedure, method, etc.) meets its specifications. Verification answers the question: Was the design *implemented appropriately*? Validation is the process of determining and documenting that the design effectively serves the purpose for which it was intended. Validation answers the question: Was the *appropriate design* implemented? Verification and validation (V&V) is one element of NUREG-0711, Rev 2, Human Factors Engineering (HFE) Program Review Model. V&V, in the context of HFE, assures that the design of Human-System Interfaces (HSIs)

1. Are complete
2. Conform to HFE principles
3. Are operable
4. Are free of safety issues and human performance issues
5. Are correctly implemented in a final, "as built" form

HSIs are the controls, displays, procedures, data processing, and communication systems to accomplish operation and maintenance tasks and actions as defined by Task Analysis (TA), Emergency Operating Procedures (EOPs), and other procedures, analysis, Probabilistic Risk Assessment (PRA) analysis, and Human Reliability Analysis (HRA).

1.1 Purpose

The purpose of this document is to prescribe a plan for comprehensively verifying that MCR, RSS, and LCS designs, critical to plant safety, conform to HFE design principles, and validating that the designs enable plant personnel to successfully perform their tasks to achieve plant safety and operational goals. This plan prescribes HFE V&V requirements and a program of HFE V&V activities compliant with the requirements. This plan is prescribed and documented with the intent that a utility COL Holder and the US Nuclear Regulatory Commission (NRC) staff find it:

- Effective for understanding how HFE V&V is integrated into the overall HFE design progress
- Complete with acceptable methods for addressing specific elements of HFE V&V
- Consistent with licensing review criteria.

This plan is used to supplement GE Energy Nuclear Engineering Operating Procedures (GEEN EOPs) under which all GE ESBWR Project design work is done.

1.2 Scope

This plan prescribes V&V requirements, and a program of compliant V&V activities, for verifying and validating the human factors engineering of the MCR, the RSS, and any LCSs that are critical to plant safety.

This plan covers the following elements of HFE V&V:

1. Program Management (*how* V&V quality is managed)
2. Requirements and Objectives (*what* V&V is to be done and *why*)
3. Trainees/End-Users as Participants (*including provisions for audits and witnessing*) and (*who* V&V is to be done with)
4. Methods and Procedures, (*how* and *where* V&V is to be done)
5. Test Conditions, Data Collection, and Analysis, (*how* V&V is to be done)
6. Acceptance Criteria and Performance Measures, (*what* the designs are to be V&V'd against)
7. Documenting, Reporting, and Integrating Results, (*how* V&V is to be documented)

The following are verified and validated in accordance with this plan. The validation supports training program development.

1. Human-System Interface (i.e., controls, displays, and alarms including use of Safety Parameter Display System)
2. Layout/configuration and anthropometrics of workstations (including installed equipment such as phones and radios)
3. Automation features
4. Display navigation (efficient information retrieval and access to controls)
5. Crew Communications (i.e., methods and equipment)
6. Procedures (hardcopy and electronically displayed)
7. Operator work environment (e.g., lighting, space, air conditions, floor design, noise mitigation)
8. Provisions for routine tests and maintenance (i.e., cleaning touchscreen displays, testing alarm windows, replacing mimic components)

The incorporation of HFE principles into all phases of HSI design for ESBWR is consistent with the HFE program review model in NUREG-0711, Rev 2. HSI design includes MCR panels as well as panels in locations outside the MCR. These locations

include the Remote Shutdown (RSS) facilities, the Fuel Building (FB), the Radwaste Building and LCSs, to the extent they directly involve actions critical to plant safety.

HSI design also encompasses the Technical Support Center (TSC) and the Emergency Operations Facility (EOF) portions of emergency response facilities. This plan addresses HFE V&V for the TSC and EOF with respect to the following:

1. HSI components (e.g., data and video interfaces) necessary to link the TSC to the MCR and the plant computer system.
2. Equipment to duplicate or to link the EOF to the plant process data base used to support the MCR and the TSC.
3. Scenarios to be evaluated that include critical actions taken outside the MCR and directly involving the TSC and/or EOF.

HFE V&V program management is discussed in Section 3. HFE V&V activities, requirements and implementation are covered in Section 4. The implementation described in this plan is predicated on the use of the following test and evaluation environments:

1. GE Test System (GETS)
2. Baseline Simulator (BS)
3. Full Scope Simulator (FSS)

Section 4 also includes discussion of the GETS, BS, and FSS.

2 Applicable Documents

2.1 Supporting and Supplemental Documents

2.1.1 Supporting Documents

Supporting documents, in conjunction with those documents listed in Sections 2.2 and 2.3, provide a basis for the ESBWR HFE V&V implementation plan (this plan).

1. ESBWR Design Control Document (DCD), Chapter 18, Revision 1 - 26A6642BX
2. ESBWR Man-Machine Interface System and Human Factors Engineering Implementation Plan - NEDO-33217
3. ESBWR System Functional Requirements Analysis Implementation Plan - NEDO-33219
4. ESBWR Allocation of Functions Implementation Plan - NEDO-33220
5. ESBWR Task Analysis (Implementation Plan)- NEDO-33221
6. ESBWR Human-System Interface (HSI) Design Implementation Plan - NEDO-33268
7. ESBWR HFE Procedure Development Plan - NEDO-33274
8. ESBWR Operational Experience Review (Human Factors) Implementation Plan - NEDO-33262
9. ESBWR Human Factors Engineering Human Reliability Analysis Implementation Plan - NEDO-33267
10. ESBWR HFE Training Program Development Plan - NEDO-33275
11. ESBWR HFE Human Performance Monitoring Plan - NEDO-33277
12. ESBWR HFE Design Implementation Plan - NEDO-33278
13. ESBWR I&C Software Management Plan - NEDO-33226
14. ESBWR I&C Software Configuration Management Plan - NEDO-33227
15. ESBWR I&C Software Development Plan - NEDO-33229
16. ESBWR I&C Software Verification and Validation Plan - NEDO-33228

2.1.2 Supplemental Documents

Supplemental documents are those documents that are used in conjunction with this document.

1. GE Energy Nuclear (GEEN) Engineering Operating Procedures NEDE-21109

a. Work Planning and Scheduling – EOP 25-5.00

b. Design Review – EOP 40-7.00

c. Independent Design Verification – EOP 42-6.00

d. Design Record Files – EOP 42-10.00

2. ESBWR QA Plan NEDO-33181

2.2 Codes and Standards

1. IEEE Guide to Evaluation of Man-Machine System Performance in Nuclear Power Generating Stations, 1999 – IEEE-Std-845-1999

2. IEEE Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations, October 2004 - IEEE-Std-1023-2004

3. International Standard: Design for Control Rooms of Nuclear Power Plants, International Electro-mechanical Commission, Bureau Central de la Commission Electrotechnique Internationale, Geneve (Switzerland), IEC-60964-1989

4. American National Standard, Nuclear Power Plant Simulators for Use in Operator Training and Examination - ANSI/ANS-3.5-1998

5. American National Standard: Guide to Human Performance Measurements - ANSI/AIAA-G-035-1992

6. International Standard: Nuclear Power Plants Main Control Rooms – Verification and Validation of Design, IEC-61771-1995

2.3 Guidelines

2.3.1 Regulatory Guidelines

1. Human -System Interface Design Review Guidelines, U.S. Nuclear Regulatory Commission, May 2002 - NUREG-0700, Rev 2

2. Guidelines for the Preparation of Emergency Operating Procedures, U.S. Nuclear Regulatory Commission, 1982 NUREG-0899, Rev 0

3. W.E. Gilmore, Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units, U.S. Nuclear Regulatory Commission, July 1985 - NUREG/CR-4227

4. Lessons Learned from the Special Inspection Program for Emergency Operating Procedures, U.S. Nuclear Regulatory Commission, April 1989 with Supp #1, October 1992 - NUREG-1358

5. Techniques for Preparing Flowchart-Format Emergency Operating Procedures, Vol. 1, U.S. Nuclear Regulatory Commission, January 1989 - NUREG/CR-5228

6. Human Factors Engineering Program Review Model, U.S. Nuclear Regulatory Commission, February 2004 NUREG-0711, Rev 2

7. Integrated System Validation: Methodology and Review Criteria, January 1997 - NUREG/CR-6393

8. Quality Assurance Program Requirements 1978 - Reg Guide 1.33, Rev 2

9. Final Safety Evaluation Report for the ABWR – NUREG-1503

10. BWR Owner's Group, Emergency Procedure and Severe Accident Guidelines (EPGs/SAGs), Rev 2, March 2001

11. Clarification of TMI Action Plan Requirements, January 1983 – NUREG 0737, Supplement 1

12. Study of Control Room Staffing Levels for Advanced Reactors, November 2000 – NUREG/IA-0137

2.3.2 Electric Power Research Institute (EPRI)

1. Verification and Validation for Safety Parameter Display Systems, December 1981 - NSAC-39

2. Computer-Generated Display System Guidelines, Volume 2: Developing an Evaluation Plan, September 1984 - EPRI NP-3701

2.3.3 Department of Defense (DoD)

1. Human Engineering Requirements for Military Systems, Equipment, and Facilities, DoD, 1979 [Note: Currently Section 4 of MIL-HDBK-46855A, Human Engineering Program, Process, and Procedures, 17 May 1999]

2. Human Engineering Procedures Guide, Chapters 5-7, and Appendices A and B, DoD, February 1987 [Note: Has been superseded by MIL-HDBK-46855A, Human Engineering Program, Process, and Procedures, 17 M DoD-HDBK-763

3. Human Engineering Guidelines for Management Information Systems, DoD, September 1989 - MIL-HDBK-761A

4. System Engineering Management Guide (F. Kocler, T., Withers, J. Poodiack, M. Gierman), Defense Systems Management College, January - 1990 AD/A223-168

5. Human Factors Engineering, Part I: Test Procedures, TOP 1-2-610, U.S. Army Test and Evaluation Command, May 1990 - AD/A226480

6. Human Engineering Design Criteria for Military Systems, Equipment and Facilities, DoD - MIL-STD-1472D

7. Defense Acquisition Management Policies and Procedures, DoD - DoD 5000.2

2.4 Publications

1. Meister, David (1985). Behavioral Analysis and Measurement Methods. New York: John Wiley & Sons [ISBN 0-471-89640-3]

3 HFE V&V Program Management

3.1 Program Management Requirements

3.1.1 General Goals and Scope

1. The scope of the program shall encompass the design bases (e.g., ESBWR Design Control Document (DCD) requirements), standard design features of the ESBWR MCR and the results of ESBWR HFE analyses.
2. Facilities within the scope of the program shall include, but not be limited to, the MCR, the RSS, and locations of LCSs critical to plant safety. The FB, the Radwaste Building, the TSC, and the EOF, shall be included to the extent they directly involve actions critical to plant safety (e.g., as defined through Task Analysis, PRA/HRA, safety analyses, etc.).
3. HSIs within the scope of the program shall include operations, accident management, maintenance, test, inspection and surveillance interfaces (including procedures).
4. Plant staff positions addressed in the program shall include those positions identified by the Staffing and Qualifications Plan.
5. Validity of the MCR, RSS and LCS designs shall be determined on the basis of:
   a. ESBWR operator performance (human error, situation awareness, vigilance)
   b. Physical workload and cognitive workload (including diagnosis) imposed on the ESBWR operators
   c. Tolerance to human errors (omitting required actions, committing wrong actions) and machine faults (hardware and software)

3.1.2 Process and Procedures for Quality Assurance

1. Persons managing, leading, and directing HFE V&V activities shall be responsible for:
   a. Developing HFE V&V plans and procedures
   b. Reviewing HFE V&V tests and evaluation activities
   c. Facilitating corrective actions to deficiencies identified during HFE V&V
   d. Confirming the implementation of corrective actions
   e. Assuring that HFE V&V activities comply with this plan
   f. Scheduling HFE V&V activities

2. Responsible Design Organizations (RDOs) or functions within RDOs for the V&V program shall be identified. The lead organization for a particular HFE V&V activity shall be clearly identified if more than one organization is involved. Organizations shall have the authority to ensure that their responsibilities can be met (e.g., controlling further processing, delivery, installation, or use of an HSI until a nonconformance, deficiency, or unsatisfactory condition has been corrected).
3. The composition of the HFE V&V team shall include persons with the qualifications specified in Table 1.
4. Team staffing shall be described in terms of job descriptions and personnel assignments.
5. The HFE V&V process shall be defined, inclusive of input and output relationships with other HFE activities. Critical checking and witnessing points shall be identified so that evaluations of the effectiveness of the HFE V&V can be made.
6. A schedule of HFE V&V activity showing relationships between activities, products, and reviews shall be developed.
7. Documentation items shall be identified and described.
8. HFE V&V requirements, or reference to this document, shall be included in subcontracts and subcontractor compliance shall be auditable.
9. HFE-related issues identified throughout the HFE V&V process shall be documented in the ESBWR Human Factors Engineering Issue Tracking System (HFEITS).

3.2 Program Management Implementation

1. The lead organization for ESBWR HFE V&V is GE.
2. Defining, managing, leading, and executing the HFE V&V program is the responsibility of the HFE Lead. This person coordinates with the procedure development group to establish plans and processes for V&V of procedures. This person also coordinates with the I&C V&V lead to be sure the I&C plans adequately address those portions of the HSI V&V required to fulfill this plan.
3. The HFE V&V program of activities is performed in accordance with the ESBWR QA Plan and GEEN EOPs.
4. Design changes are processed in accordance with GEEN EOPs and ESBWR Project Procedures (EPPs). Other design changes may be verified as part of the ESBWR Project configuration control process.

5. GE uses an internal system for work scheduling and tracking on the ESBWR Project in accordance with GEEN EOP 25-5.00 . Therefore it is not necessary that this V&V plan document contain detailed work schedules for the activities specified herein, although such schedules will be prepared later during the project.

6. The HFE V&V activities are performed to ensure the quality of product design and development and their associated documentation. This type of verification is performed on each design document produced as part of the design and development process in accordance with GEEN EOPs 40-7.00 and/or 42-6.00.

7. The HFEITS shall be managed and maintained by the HFE task lead within GEEN. Status reports of HFE issues shall be maintained and updated monthly throughout the ESBWR project.

4 HFE V&V Requirements, Activities, and Implementation

4.1 HFE V&V Requirements

This section prescribes requirements, activities, and implementation for the following elements of HFE V&V:

1. Operational Condition Sampling - *using a Sampling Strategy to guide the selection of HSIs to review*
2. Human-System Interface (HSI) Task Support Verification - *checking that HSI functions and components are based on HFE analyses*
3. Human Factors Engineering (HFE) Design Verification - *checking that HFE requirements are met*
4. Integrated System Validation - *confirming proper operability*
5. Human Factors Issue Resolution Verification - *resolving issues*

4.2 HFE V&V Activities

This section prescribes the following:

1. The five main activities of HFE V&V (in order of occurrence):
   a. Operational Condition Sampling
   b. Human-System Interface (HSI) Task Support Verification
   c. Human Factors Engineering (HFE) Design Verification
   d. Integrated System Validation
   e. Human Factors Issue Resolution Verification (HED Resolution)
2. Relationship Between HFE V&V and Hardware/Software V&V
3. HFE V&V Team
4. End-Users as Participants and Test Subjects
5. Documentation, Reporting, and Integration of Results

Figure 1 shows the relationship between verification and validation activities.

Figure 2 provides an overview of the integrated HFE V&V activities with their associated inputs and outputs.

4.2.1 Operational Condition Sampling

Sampling of operational conditions to support HFE V&V in new plants is appropriate because of the large number of new individual HSIs. Even for a plant like the ESBWR, evolving from a large base of predecessor BWRs, such as the ABWRs, the number of

individual HSI differences from predecessors is expected to be large. It would be impractical, and perhaps more importantly, unnecessary to review every HSI to achieve satisfactory V&V. Therefore, the ESBWR HFE V&V plan will utilize a sampling strategy for the selection of HSIs to review.

The sampling methodology will be used to identify a range of operational conditions to be included in the V&V activities. Operational conditions will be included that:

1. Are representative of the range of events that would be encountered during plant operation
2. Reflect the characteristics that are expected to contribute to system performance variation
3. Consider the safety significance of HSI components

These sampling characteristics can be identified by using a multidimensional sampling strategy to provide variation of important dimensions for inclusion in V&V activities. Implementation of operational conditions sampling (OCS) using sampling dimensions of plant conditions, personnel tasks and challenging situational factors, as well as development of scenarios based on these dimensions, is discussed further in Section 4.3.1.

4.2.2 HSI Inventory and Task Support Verification

HSI Task Support Verification is verification with a relatively narrow scope (compared to HFE Design Verification described in the next section). Initial HSI Task Support Verification is a document-based, static evaluation process that includes independent verification in accordance with the GEEN EOP requirements.

Task Analysis, PRA/HRA, and emergency operating procedure analysis, identify tasks critical to safety in terms of importance for function achievement, potential for human error, and impact of task failure. Where critical functions are automated, the analyses address the human tasks including the monitoring of the automated functions and the backup manual actions which may be required if an automated function fails. The initial HSI Task Support Verification will review and confirm that the inventory of HSI components (controls, displays, alarms, procedures, and data processing) provides for personnel tasks as defined by these analyses. The inventory will also describe the characteristics of each HSI in the scope of the review.

More detailed HSI Task Support Verification confirms, for various operational tasks, that each HSI component meets the operability (task execution and information access) requirements specified for the end user (e.g., response time, accuracy, precision, etc.).

HSI components are considered deficient if, for example, there are:

1. Unsupported tasks where a required control, display or alarm is missing (i.e., absence of on-screen pushbuttons)
2. Partially supported tasks where HSI characteristics do not fully meet the operability requirements (e.g., poor real-time response and feedback when using a manual/auto controller, or inadequate pushbutton tactile feedback)
3. HSI components that are not required for personnel tasks (e.g., extraneous, nonfunctional, or purely decorative objects in graphical displays)

HEDs are identified for each of these findings.

4.2.3 Human Factors Engineering Design Verification

HFE Design Verification is a form of verification that is broader in scope than HSI Task Support Verification. It is evaluation of the HSI with respect to a particular end user population, and not an evaluation of the end users. Individual HSI components are checked against plant engineering criteria, human engineering criteria, and operating and functional requirements. The verification is performed in accordance with ESBWR GEEN EOP requirements that include requirements for independent verification.

HFE Design Verification verifies that each HSI component design meets personnel task requirements and operational considerations, and reflects HFE guidelines, standards, and principles reflected in the ESBWR style guide. HFE Design Verification covers design aspects such as:

1. HSI characteristics (e.g., coding, conventions, input devices, dialog, display navigation, etc.)
2. Inter-personnel communication systems that support users of the HSI (e.g., functional capabilities, equipment performance, ease of use, etc.)
3. Hardcopy procedures and electronically displayed ("on-line") procedures
4. Room layouts and panel configurations (e.g., anthropometrics, ergonomics, grouping, labeling, etc.)
5. Work environment (e.g., lighting, space, air conditions, floor design, noise mitigation)

Designs are compared to HFE guidelines to determine whether they account for human characteristics and capabilities. Deviations from accepted HFE guidelines, standards, and principles are documented as HEDs for resolution/correction and acceptably justified on the basis of documented rationale such as trade study results, literature-based evaluations, demonstrated operational experience, tests and experiments.

4.2.4 Integrated System Validation

Integrated System Validation is performance-based evaluation of the integrated HSI design and human task performance to ensure the HSI is operable within all performance requirements, and that it supports safe operation of the plant. It is intended to evaluate the acceptability of those aspects of the design that cannot be evaluated with analysis (e.g., task support or HFE design verification activities). HEDs identified during previous verification activities should be corrected prior to integrated system validation to prevent unwanted impact on the integrated validation results. Integrated System Validation is performed using dynamic HSI prototypes and high-fidelity simulators that can facilitate regulatory reviews and witnessing. Integrated System Validation confirms the following:

1. Adequacy of the entire HSI configuration for achieving HFE program goals consistent with HFE practices and principles
2. Allocation of functions and the degree of task dependence on procedures
3. Adequacy of the HSI to support the crew in accomplishing critical functions and tasks
4. Human performance assumptions in PRA/HRA
5. Tolerance to human error and system faults
6. HSI facilitates efficient search and retrieval of information and controls
7. The effect of HSI characteristics on operator workload
8. Adequacy of staffing
9. Adequacy of procedures

Procedure validation confirms that the procedures

1. Are consistent with the HSI in terms of controls, displays, alarms, and data processing
2. Are useable
3. Function as intended in the integrated HSI design

Validation can lead to design changes and design changes are handled as part of the formal design change control process. The following are taken into account during the design change process:

1. HSI Task Support Verification and HFE Design Verification for minor design changes.

2. Extensive or significant changes may require re-verifying that functional uses of the original design have been addressed, evaluating the change once it has been implemented and integrated into the overall HSI, and evaluating the change with respect to impact on procedures and training.

3. Major design changes require re-validation to confirm that the change corrected the deficiency.

Integration concerns integration/interfacing of HSI elements (controls, displays, alarms, communication devices, etc.) and integration/interfacing of system functions and dynamic performance. Validation of dynamic and time-dependent performance typically involves at least a fully functional thread of the total system. The Distributed Control and Information System (DCIS) is the total, fully integrated system and final, complete validation can only be achieved with the entire DCIS. However, validation is a progressive, cumulative activity. Hence validation at any stage in the overall V&V process is partial validation, using integrated subsystems of DCIS. For instance, the non-safety portion of DCIS is an integration of different process system controls and several HSIs (displays, mimic, alarms, large variable display, switches). It is testable and it can be partially validated separately of other DCIS portions, including safety-related portions. Each of the following are therefore treated as an "Integrated System" in the context of this plan document:

1. The entire DCIS
2. The non-safety, related portion of DCIS,
3. The safety-related portion of DCIS (i.e., DCIS Essential Controls) consisting of:
    a. Safety System Logic and Control (SSLC) Reactor Trip and Isolation Functions (RTIF) subsystem
    b. SSLC Engineered Safety Features (ESF) subsystem
4. The RSS
5. Any LCS critical to plant safety
6. Any "HSI thread" (i.e., operationally useful HSI function) of the above.

4.2.5 Human Factors Issue Resolution Verification

HED Resolution shall be performed iteratively with V&V activities. Issues that are identified will be addressed and resolved prior to conducting other V&V activities that could be affected by the identified issue. The following will be performed for each identified issue:

1. Issue evaluation to determine the need for correction

2. For significant HEDs, identify a design solution

3. Verify implementation of design solutions

HEDs/Issues will be tracked in the ESBWR HFEITS which will be maintained throughout the ESBWR project. Details of this can be found in separate documentation of the ESBWR HFEITS.

4.2.6 Final Plant HFE/HSI Design Verification

Final Plant HFE/HSI Design Verification is a check of the final, actual "as built" HSIs against design description documents. This portion of the HFE/HSI V&V activities is described in the separate document, ESBWR HFE Design Implementation Plan, NEDO-33278.

4.2.7 Relationship Between HFE and Hardware/Software V&V Processes

HFE V&V is a process for assuring HFE-related quality of the HSI and operating procedures. Among other things, HFE V&V identifies, documents, and facilitates resolution of defects in the HSI. Resolution could impact hardware/software design (e.g., component type or technology, graphic display performance) depending on the specific nature of the defect. Likewise, the hardware/software V&V process could impact HSI design (e.g., component dimensions, graphic display layout). The relationship between the two V&V processes is a process interface whereby resolution of V&V findings from both processes are integrated into the design and implementation phases of HSI, hardware, and software.

Because the ESBWR DCIS is primarily based on digital technology, the HSIs will primarily be implemented as such. The development and design of the HSI hardware and software conducted in accordance with ESBWR GEEN EOPs, will incorporate HFE HSI engineering as design input and follow these plans:

The ESBWR I&C Software Management Plan (SMP) provides the technical and administrative direction to implement the design of, and also establishes the design and quality standards for, the software-based I&C systems. This includes all safety and nonsafety-related I&C systems which perform the monitoring, control, and protection functions associated with all modes of plant conditions.

The ESBWR I&C Software Configuration Management Plan (SCMP) describes the software configuration management activities to be implemented during the development of software-based I&C systems. The SCMP Plan establishes a formal set of standards and methodology used to administer and control the configuration of all software-based products.

The ESBWR I&C Software Development Plan (SDP) specifies the management processes for the design and delivery activities for the I&C Essential Controls software

and hardware. The SDP is based on applicable IEEE, GE and GEEN standards and procedures.

The ESBWR I&C Software V&V Plan (SVVP) establishes the formal set of standards and procedures necessary to comprehensively verify and validate Quality Class Q and Class N DCIS software-based products during all phases of the software development life cycle. The SVVP establishes the specific V&V steps required during the software development process that will ensure that:

1. The design documents meet the requirements of the ESBWR MMIS and HFE Design Implementation Plan and the plans listed above,
2. The developed software meets its specified requirements,
3. The developed software performs it intended functions correctly,
4. The developed software performs no unintended functions, and
5. The quality and reliability standards for the software-based products are achieved.

The SVVP establishes that verification and validation activities shall be performed as part of the ongoing software development process to facilitate the timely detection of errors. The SVVP also establishes that for the DCIS software-based products, software V&V activities shall also be included to analyze and test the software with respect to its hardware interfaces and user interactions.

The V&V activities performed by ESBWR Software Project Engineering (SPE) are to ensure the quality of the design and development of software-based products and their associated documentation, as prepared by both GE and GE vendors for the ESBWR DCIS. The SVVP establishes the performance of Independent V&V that is fully documented, including:

1. An Independent V&V report for each V&V activity performed,
2. Reporting of all anomalies discovered during a V&V activity in the verification report as specified by the GEEN EOP, or in the V&V test report (where an anomaly is anything observed in the documentation or operation of software that deviates from expectations based on previous verified software products or reference documents),
3. Preparation of Engineering Management Reports to summarize V&V activities and status, including unresolved anomalies and resolution plans, specific V&V milestones, and recommendations, and
4. Preparation of a final Independent V&V report that includes a summary of all tasks and results, summary of all anomalies and resolutions for Quality Class Q

software, an assessment of overall software quality, and any final V&V recommendations.

The ESBWR I&C Software V&V activities, as provided in the SVVP and supported by the related software plans referenced above, are comprehensive and fully consistent with the HFE V&V plan. The results of any of the V&V activities conducted in accordance with the I&C SVVP, may be utilized to fulfill applicable portions of the HFE V&V Plan. Therefore, it will not be necessary to repeat such V&V activities as part of the HFE V&V tasks.

4.2.8 HFE V&V Team

There is no single HFE V&V team responsible for all of the activities in this plan. The term "HFE V&V Team" is used herein as a general term to refer to the persons that conduct an HFE V&V activity. Those persons may be from a single organization or more than one organization. Table 1 lists some typical expertise and contributions of the HFE V&V team. A team member may contribute a combination of expertise and qualifications.

4.2.9 Integrated System Verification

The HFE V&V Activity Lead is responsible for the following:

1. Overall administration and review of the activities
2. Approving HFE Verification & Validation Test Plans (HFEVVTPs)
3. Planning and coordinating the HFE V&V activity with the activity of another group if the two activities require shared used of the mockup or simulator
4. Reviewing and approving HFE issues
5. Report documentation
6. Maintaining records

The HFE V&V Activity Director is responsible for the following:

1. Lead representative and spokesman while conducting the HFE V&V activity
2. Scheduling the HFE V&V activity and managing personnel assignments
3. Producing timely, accurate records
4. Support reviews of HFEVVTPs to ensure consistent objectives within the scope of HFE V&V
5. Reviewing and approving HFE issues

4.2.10 End-Users as Participants and Test Subjects

Participants conduct an HFE V&V activity jointly with GE. COL Holder personnel are participants in the following HFE V&V activities:

1. Human-System Interface (HSI) Task Support Verification
2. Human Factors Engineering (HFE) Design Verification
3. Integrated System Validation
4. Final Plant HFE/HSI Design Verification (beyond this plan)

The training programs administered by GE and the COL Holder will include personnel participating in V&V activities. Test Subjects are evaluated as part of an HFE V&V activity. COL Holder personnel are test subjects in the Integrated System Validation activity.

4.2.11 Documentation, Reporting, and Integration of Results

Documentation facilitates identifying HFE-related deficiency categories in terms of HSI components and the level of task support. Results of the HFE V&V activities are documented in reports that address the following:

1. Objectives
2. Participants (name, position, experience/qualifications, relevant demographics)
3. Descriptions of HSIs involved (or references to applicable documents)
4. Test Conditions
5. Personnel performance issues (if any) as applicable to the activity
6. Methods and procedures used (by reference to this plan document)
7. Deviations (if any) from test methods, procedures, and acceptance criteria
8. Documentation and administration of deviations (i.e., recorded, assessed for impact, resolved, justified, etc.)
9. Presentation and discussion of test data (e.g., performance measurements), test results, and findings
10. HFE issues (if any), including training-related issues to be examined with respect to learning objectives and post-training performance
11. Conclusions
12. Recommendations such as design changes or corrective actions (e.g., by reference to corresponding HFEITS record)

13. Recommendations for the verification and validation efforts of the Design Implementation activity (described in the referenced plan of the same title) to address issues which were not feasible to perform in this V&V activity due to the state or nature of the simulated environment.

The final design, as implemented in the FSS, is documented in accordance with the QA requirements. Proceedings and results of the HFE V&V program are recorded and documented in a manner that allows effective review and understanding by reviewers in accordance with GEEN EOPs and in an HFE Results Summary report.

4.2.11.1 HFEITS

The ESBWR HFE issues tracking system (HFEITS) will be used to identify, record, track, and document issue evaluation and resolution consistent with NUREG-0711, Rev 2.

4.3 HFE V&V Implementation

This section prescribes implementation of the five main HFE V&V activities and the HFEITS. The following are addressed for each HFE V&V activity, to the extent applicable:

1. Scope, e.g., Items to be tested and evaluated (T&E'd), including justification for features of the item not to be T&E'd (i.e., the scope of HSI that the respective HFE V&V activity applies to)
2. Objectives
3. Participants, Test Subjects, and Observers, e.g.,
   a. Staffing needs and personnel skills/experience
   b. Personnel roles and responsibilities
   c. Provisions for audits and witnessing
4. Methods and Procedures, e.g.,
   a. Task Performance Diagrams
   b. Interviews and Questionnaires
   c. Checklists
   d. Walkthroughs and talkthroughs
5. Test and Evaluation (T&E) Conditions
   a. Test environment, test equipment and tools (including any requiring development and qualification)
   b. Test sequencing and T&E time estimates

6. Acceptance Criteria (for making pass/fail/retest decisions for each test) for each performance measure (e.g., safe operating ranges, alarm conditions, and personnel response times per plant Technical Specifications)
7. HSI Equipment Performance Measures, e.g.,
   a. Dynamic response
   b. Display navigation
8. Operator Performance Monitoring (qualitative and quantitative)
   a. Operational performance relevant to plant safety (i.e., error avoidance, avoiding alarm conditions and Technical Specification violations)

4.3.1 Implementation of Operational Conditions Sampling

4.3.1.1 Scope

The sampling methodology will identify a wide range of operational conditions to guide V&V activities. The scope includes addressing various dimensions to be used to identify and select conditions, and their integration into scenarios.

4.3.1.2 Objectives

The objective is to identify a sample of operational conditions that (1) includes conditions that are representative of the range of events that could be encountered during operation of the plant, (2) reflects the characteristics that are expected to contribute to system performance variation, and (3) considers the safety significance of HSI components. Then, prepare test scenarios based on integration of these sample conditions.

4.3.1.3 Participants, Test Subjects, and Observers

Participants are GE; test subject and observers are not applicable.

4.3.1.4 Methods and Procedures

4.3.1.4.1 Sampling Dimensions

1. Select samples from each of the following plant conditions:
   a. Normal operational events including plant startup, plant shutdown or refueling, and significant changes in operating power
   b. Failure events:
      - Instrument failures [e.g., safety-related system logic and control unit, fault tolerant controller, local multiplexing "field unit", and break in a multiplexing communications line] including I&C failures that exceed

the design basis, such as a common mode I&C failure during an accident

- HSI failures (e.g., loss of processing and/or display capabilities for alarms, displays, controls, and computer-based procedures)

c. Transients and accidents:

- Transients (e.g., turbine trip, loss of off-site power, station blackout, loss of all feedwater, loss of service water, loss of power to selected buses or main control room (MCR) power supplies, and safety and relief valve transients)
- Accidents (e.g., main steam line break, positive reactivity addition, control rod insertion at power, anticipated transient without scram, and various-sized loss-of-coolant accidents)
- Reactor shutdown and cooldown using the remote shutdown system

d. Reasonable, risk-significant, beyond-design-basis events, determined from the ESBWR PRA

e. Consideration of the role of the equipment in achieving plant safety functions [as described in the ESBWR DCD] and the degree of interconnection with other plant systems, where the initial failure could propagate over the connections (important when assessing non-class 1E electrical systems)

2. Select samples from each of the following types of personnel tasks:

a. *Risk-significant HAs, systems, and accident sequences* - All risk-important HAs will be included in the sample. These include those identified in the ESBWR PRA and those identified as risk-important in safety evaluation reports. Situations where human monitoring of an automatic system is risk-important will be considered. Additional factors will be sampled that contribute highly to risk, as defined by the PRA, including:

- Dominant human actions (selected via sensitivity analyses)
- Dominant accident sequences
- Dominant systems (selected via PRA importance measures such as Risk Achievement Worth or Risk Reduction Worth)

b. *OER-identified difficult tasks* - The sample will include all personnel tasks identified as problematic in review of operating experience.

c. *Range of procedure guided tasks* - These are tasks that are well defined by normal, abnormal, emergency, alarm response, and test procedures. The sample will include appropriate procedures in each relevant category:

- Administrative procedures
- General plant operating procedures
- Procedures for startup, operation, and shutdown of safety-related systems
- Procedures for abnormal, off normal, and alarm conditions
- Procedures for combating emergencies and other significant events
- Procedures for control of radioactivity
- Procedures for control of measuring and test equipment and for surveillance tests, procedures, and calibration
- Procedures for performing maintenance
- Chemistry and radiochemical control procedures

d. *Range of knowledge-based tasks* - these are tasks that are not as well defined by detailed procedures. A situation may require knowledge-based decision-making if the rules do not fully address the problem, or the selection of appropriate rule is not clear. Errors in knowledge-based decision-making result from mistakes in higher-level cognitive functions such as judgment, planning, and analysis. The latter are more likely to occur in complex failure events where the symptoms do not resemble the typical case, and thus, are not amenable to pre-established rules.

e. *Range of human cognitive activities*:

- Detection and monitoring (e.g., of critical safety-function threats)
- Situation assessment (e.g., interpretation of alarms and displays for diagnosis of faults in plant processes and automated control and safety systems)
- Response planning (e.g., evaluating alternatives for recovery from plant failures)
- Response implementation (e.g., in-the-loop control of plant systems, assuming manual control from automatic control systems, and carrying out complicated control actions)
- Obtaining feedback (e.g., of the success of actions taken)

f. *Range of human interactions* – from independent action to a crew team, including:

- Main control room operators (e.g., operations, shift turnover walkdowns)
- Main control room operators and auxiliary operators
- Main control room operators and support centers (e.g., the technical support center and the emergency offsite facility)
- Main control room operators with plant management, NRC, and other outside organizations

g. *Tasks that are performed with high frequency.*

3. Select samples from each of the following situational factors that are known to challenge human performance, such as:

a. *Operationally difficult tasks* - Tasks that have been found to be problematic in the operation of NPPs, e.g., procedure versus situation assessment conflicts, as reflected in the operating history of BWRs.

b. *Error-forcing contexts* - Situations specifically designed to create human errors to assess the error tolerance of the system and the capability of operators to recover from errors should they occur.

c. *High-workload conditions* - Situations where human performance variation due to high workload and multitasking situations can be assessed.

d. *Varying-workload situations* - Situations where human performance variation due to workload transitions can be assessed. These include conditions that exhibit (1) a sudden increase in the number of signals that must be detected and processed and (2) a rapid reduction in signal detection and processing demands following a period of sustained high task demand.

e. *Fatigue and circadian factors* - Situations where human performance variation due to personnel fatigue and circadian factors can be assessed.

f. *Environmental factors* - Situations where human performance variation due to environmental conditions such as poor lighting, extreme temperatures, high noise, and simulated radiological contamination can be assessed.

4.3.1.4.2 Identification of Scenarios

1. The results of the sampling will be combined to identify a set of scenarios to guide subsequent analyses. A given scenario may combine many of the characteristics identified by the operational event sampling.
2. The scenarios should not be biased in the direction of over representation of the following:
   a. Scenarios for which only positive outcomes can be expected
   b. Scenarios that for integrated system validation are relatively easy to conduct administratively (scenarios that place high demands, data collection or analysis are avoided)
   c. Scenarios that for integrated system validation are familiar and well structured (i.e., which address familiar systems and failure modes that are highly compatible with plant procedures such as "textbook" design-basis accidents)

4.3.1.5 Test and Evaluation Condition

Not applicable – in later testing.

4.3.1.6 Acceptance Criteria

Not applicable – in later testing.

4.3.1.7 Performance Measures

Not applicable – in later testing.

4.3.1.8 Data Collection and Analysis

Not applicable – in later testing.

4.3.2 Implementation of HSI Inventory and Task Support Verification

4.3.2.1 Scope

HSI Task Support Verification applies to:

1. Panel drawings (covering fixed-position controls, indications, and alarms)
2. Room layout/arrangement drawings
3. Computer-generated displays (providing controls, indications, and alarms)

4.3.2.2 Objectives

The objectives of HSI Task Support Verification are to verify:

1. That the HSI inventory and characterization are consistent with the HFE analyses (SFRA, AOF, TA, HSI Design)
2. That, in addition to initial TA results, the HSI design accommodates operator tasks as confirmed through EPG/EOP analysis and PRA/HRA of critical operator actions
3. That each HSI component meets the user operability requirements associated with a given task
4. That the overall HSIs provide all alarms, information, and control capabilities required for personnel tasks

4.3.2.3 Participants, Test Subjects, and Observers

COL Holder participation with GE is expected in these areas:

1. Panel drawings,
2. Room layout/arrangement
3. Computer-generated displays

4.3.2.4 Methods and Procedures

An inventory of all HSI components associated with the personnel tasks based on the identified operational conditions will be prepared. The inventory will also include aspects of the HSI that are used for navigation and display retrieval in addition to only those that control the plant. The inventory will describe the characteristics of each HSI component within the scope of the review including information such as:

1. A unique identification code number or name
2. Associated plant system and subsystem
3. Associated personnel functions/subfunction
4. Type of HSI component.
    a. Computer-based control (e.g., touch screen or cursor-operated button and keyboard input)
    b. Hardwired control (e.g., J-handle controller, button, and automatic controller)
    c. Computer-based display (e.g., digital value and analog representation)
    d. Hardwired display (e.g., dial, gauge, and strip chart recorder)
5. Display characteristics and functionality [e.g., plant variables/parameters, units of measure, accuracy of variable/parameter, precision of display, dynamic response, and display format (bar chart, and trend plot)]

6. Control characteristics and functionality [e.g., continuous versus discrete settings, number and type of control modes, accuracy, precision, dynamic response, and control format (method of input)]
7. User-system interaction and dialog types (e.g., navigation aids and menus)
8. Location in data management system (e.g., identification code for information display screen)
9. Physical location in the HSI (e.g., control panel section), if applicable

Photographs, copies of VDU screens, and similar samples of HSI components will be included in the HSI inventory and characterization.

The HSI design during initial HSI Task Support Verification may be preliminarily based upon Task Analysis and initial versions of issued specifications such as System Design Descriptions (SDDs), P&IDs, Logic Diagrams, and Hardware/Software Specifications (HSSs). More detailed HSI Task Support Verification applies to the HSI components. Mockups can be used for HSI Task Support Verification if, in lieu of panel drawings and room layout drawings (i.e., the two-dimensional form), they mock the HSI components in three-dimensional form.

PRA/HRA determines risk profiles using best-estimate Human Error Probabilities (HEPs) that are based on analysts' understanding of the HSI design and its operability. PRA/HRA identifies critical operator actions and their error probabilities. PRA/HRA models the role of operators and other personnel in response to accident sequences. Task Analysis and HSI design account for PRA/HRA results. Design changes required, based on PRA/HRA, Task Analysis, and HSI design, are propagated throughout the plant design and systems designs via the normal engineering, design change, and verification processes. Documented PRA/HRA assumptions about the HSI design and procedures are available for implementation considerations by designers and procedure developers.

Task performance requirements (e.g., HSI Design Implementation Plan, Style Guide for Graphical User Interfaces, and Display Primitives Design Specification) are imposed on the various HSI hardware and software components. These requirements are included (directly or by reference) in hardware and software specifications (e.g., DCIS Hardware/Software Specification). Verification equivalent to detailed HSI Task Support Verification concerning task performance requirements occurs during DCIS factory acceptance tests. These tests are performed in accordance with test specifications (e.g., Software Test Plan and Acceptance Criteria.

The HSIs and their characteristics (as defined in the HSI inventory and characterization) will be compared to the personnel task requirements identified in the task analysis.

HEDs will be identified when:

1. An HSI needed for task performance (e.g., a required control or display) is not available
2. HSI characteristics do not match the personnel task requirements, e.g., a display shows the necessary plant parameter but not the range or precision needed for the task

An HED will be identified for any HSIs that are available but are not needed for any task. Unnecessary HSIs introduce clutter and can distract personnel for the selection of appropriate HSIs. However, it is important to verify that the HSI is actually unnecessary. If an HSI component has no associated personnel tasks because the function and task analysis was incomplete, this will also be identified and any shortcomings in that analysis will be resolved.

4.3.2.4.1 Panel and Room Layout/Arrangement Drawings

HSI Task Support Verification of panel drawings is achieved through an iterative process of reviews by several groups and organizations. The groups and organizations include the CRDT, individual system designers, independent verifiers, HFE analysts, procedure developers, and COL Holder. The results of HSI analyses for individual plant systems are checked for consistency with the drawings. Collaborative reviews by these groups and organizations during the development of the ESBWR Safety Analysis Report provide additional accountability for critical operator actions in the panel designs. HSI Task Support Verification of layouts for the MCR, RSS, and LCSs are accomplished in a similar manner.

4.3.2.4.2 Computer Generated Displays

The HSI inventory is analyzed and specified (on a per-system basis) in HSI Design Reports. The analyses and documentation are done in accordance with the QA program that includes internal independent verification. This process includes reviews by the respective system RE's to ensure the analyses support, and are supported by, the system design specifications (System Design Description (SDD), Logic Diagrams, P&IDs). In some cases, COL Holder members also review selected reports.

4.3.2.5 Test and Evaluation (T&E) Conditions

Test conditions are defined in test plans and test specifications.

4.3.2.6 Acceptance Criteria

The Acceptance Criteria is that the objectives are met.

4.3.2.7 Performance Measures

There are no performance measures associated with initial HSI Task Support Verification because the verification concerns completeness of the HSI inventory and

characterization. Performance measures associated with detailed HSI Task Support Verification are the performance requirements (e.g., from applicable hardware/software design specifications) and HFE design guidelines (e.g., Style Guide for Graphical User Interfaces. These requirements cover quantitative parameters, limits, tolerances, etc., concerning performance such as completion time, range, accuracy, precision, frequency, and percent completion.

4.3.2.8 Data Collection and Analysis

The document reviews and analyses discussed above constitute the data collection and analysis portion of HSI Inventory and Task Support Verification.

4.3.2.9 Documentation and Integration of Results

Deficiencies identified by evaluators are documented. A deficiency is logged into the HFEITS if it matches at least one of the HFE issue entry criteria.

4.3.3 Implementation of HFE Design Verification

4.3.3.1 Scope

HFE Design Verification applies to:

1. HFE analyses (SFRA, AOF, TA, HSI Design)
2. Panel anthropometrics
3. Operating procedures (including abnormal and emergency)
4. HSI components (e.g., controls, displays, alarms, data processing, communications equipment) required to accomplish human tasks and actions (as defined by the TA, EOP analysis, and PRA/HRA critical operator actions)
5. Industrial Television equipment in the MCR
6. Work environment and workplace layout (MCR, RSS, LCS critical to safety)

4.3.3.2 Objectives

The objectives of HFE Design Verification are to verify that:

1. HFE analyses (including documentation) meet QA requirements
2. HFE analyses are accomplished in accordance with the implementation plan requirements for the respective analyses
3. HSI component design specifications incorporate applicable HFE requirements (guidelines, standards, criteria)
4. HSI components are implemented per the specified HFE requirements, including the ESBWR style guide

HFE Design Verification is comprehensive enough to provide objective evidence that the following are addressed:

1. Operator tasks under normal, abnormal, and emergency conditions:
   a. Status monitoring and situation awareness of automatic safety functions
   b. Surveillance testing and maintenance (e.g., equipment blocking, tagging, and bypass)
   c. Alarm monitoring, analysis, and response
   d. Fault detection, analysis, diagnosis, and mitigation
   e. Override of automated systems and their direct control
   f. Risk-significant interactions as defined by PRA/HRA
2. Operator tasks guided by procedures of varying complexity
   a. Rule-based tasks (procedure intensive)
   b. Knowledge-based tasks (requiring judgment, planning, analysis, and reasoning based on observed symptoms)
3. Operator tasks involving the different types of interactions with the HSI
4. Particular operator tasks, if any, identified from operating experience reviews (OERs)
5. Crew interactions
   a. During operations, shift turnovers, walkdowns, maintenance, etc.
   b. With the Technical Support Center during accident management
   c. With management, and other outside organizations during emergency management (e.g., from the EOF)

4.3.3.3 Participants, Test Subjects, and Observers

Participation is as follows:

1. HFE team members perform and verify HFE analyses
2. COL Holder participates with GE in verifying partially dynamic graphic display images (i.e., displays not connected to a simulator).

4.3.3.4 Methods and Procedures

4.3.3.4.1 HFE Analyses

SFRA, AOF, TA, and HSI analyses (and associated reports) for individual plant systems are developed in accordance with the GEEN EOPs and ESBWR plans and QA program.

Each report is reviewed by the respective RDO for that system, and review comments are documented in the preparer's DRFs.

4.3.3.4.2 Panel Anthropometrics

Verification of the anthropometrics is accomplished as an integral part of the HFE evaluations performed with mockups and simulator versions of the MCR and RSS panels. This data is validated via measurements of a sample of personnel from the COL Holder.

4.3.3.4.3 Operating Procedures

Operating procedures include the following:

1. Integrated Operating Procedures (IOP)
2. System Operating Procedures (SOP)
3. Abnormal Operating Procedures (AOP)
4. Emergency Operating Procedures (EOP)
5. Annunciator Response Procedures (ARP)
6. Surveillance Test Procedures (STP)

EOPs are based upon the ESBWR Plant Specific Technical Guidelines (PSTGs) that, in turn, are derived from the BWR Owners' Group Emergency Procedure and Severe Accident Guidelines (EPGs/SAGs), Revision 2, dated March 2001. (See ESBWR Chapter 18 DCD appendices A, B & C). The EOPs consist of EOP Support Procedures and EOP Flowcharts. The EOP Support Procedures may consist of certain SOPs and AOPs containing detailed instructions for abnormal system operation or abnormal overrides of interlocks. EOP flowcharts address the four main guideline controls (RPV Control, Primary Containment Control, Reactor Building Control, and Radioactivity Release Control) and the three contingencies (Emergency RPV Depressurization, RPV Flooding, and Level/Power Control). The flowcharts also include EOP graphs.

Verification of written procedures is performed in accordance with the procedure writer's approved QA program. Procedures are checked for:

1. Compliance with the Procedure Development Implementation Plan, ESBWR Procedure Writer's Guide and other requirements and guidelines (e.g., BWR Owners Group Emergency Procedure Guidelines and Severe Accident Guidelines, BWROG EPGs/SAGs)
2. Technical accuracy and format quality
3. Correct references to HSI components

4.3.3.4.4 HSI Components

Verifications of HSI component designs and implementations are checks that the components are built as specified. Design specifications (e.g., P&IDs, Logic Diagrams, Display Descriptions and associated Change Descriptions (CDs), and unincorporated Engineering Change Notices) are consulted as needed for understanding component operation, design changes, and investigation of findings.

For example, display image specifications (part of HSI reports and display building specifications, are developed in accordance with the HSI Implementation Plan. The simulator display builder uses these to build partially dynamic graphic display images (i.e., displays not yet connected to a simulator). The images are verified through a collective effort by the display builder, GE, COL Holder and subcontractors , to ensure display readiness for validation. Partially dynamic displays are verified for consistency and correctness as follows:

1. Visually checking whether or not the FPD image replicates the DCT image
2. Visually checking for compliance with the Style Guide for Graphical User Interfaces
3. Dynamically checking that each Display Primitive on an FPD image correctly assumes each of its states in accordance with the Display Primitives Design Specifications (DPDS) and the Display Descriptions

Other HSI components subjected to HFE Design Verification include the following:

1. Fixed-position (hard) switches
2. Fixed-position (hard) indicators such as meters and status lights
3. Labeling
4. Alarm tiles
5. Alarms displayed via FPDs
6. FPDs
7. Large variable display
8. Mimics (on WDP and RSS)
9. Communication systems
10. Data and video interfaces necessary to link the TSC to the MCR and the plant computer system
11. Equipment to duplicate or to link the EOF to the plant process database used to support the MCR and the TSC

Verification of MCR and RSS HSI components (i.e., switches, indicators, labeling, alarm tiles and displays, FPDs, large variable display, mimic, communication systems) occurs as part of the normal course of engineering design in accordance with ESBWR Software Management Plan requirements that include requirements for independent verification.

The functionality of data and video interfaces with the TSC, and equipment to duplicate or link the EOF to the plant process database, are verified during I&C V&V process and tests. Verification of these components is completed during integrated system validation testing at the site as part of the Final Plant HFE/HSI Design Verification activity.

4.3.3.4.5 Industrial Television

Industrial Television (ITV) is a stand-alone system with a user console adjacent to the Shift Supervisor Console and two television units mounted in the Wide Display Panel (WDP). The ITV system is verified in accordance with ESBWR GEEN EOPs that include requirements for verification. HFE Design Verification confirms that the console design, and televisions at the WDP, meet user requirements, exhibit proper HFE design practices, and effectively integrate with the MCR arrangement and work environment. The HSI at the ITV user console is not subjected to HFE V&V because it is an off-the-shelf product that does not perform process control and monitoring functions.

4.3.3.4.6 Work Environment

HFE design verification of MCR, RSS, and LCSs critical to safety work environment aspects (e.g., lighting, space, air conditions, floor design, noise mitigation) is part of the normal engineering, design change, and verification process. Final verification against HFE guidelines such as those in NUREG-0700 occurs at the site as a COL Holder responsibility.

4.3.3.4.7 Workplace Layout

HFE design verification of MCR, RSS, and LCSs critical to safety workplace layout is part of the normal engineering, design change, and verification process. Final verification against HFE guidelines such as those in NUREG-0700 occurs at the site with the COL Holder.

4.3.3.5 Test and Evaluation (T&E) Conditions

4.3.3.5.1 Mockup

A full-scale, foam core mockup of the MCR panels is staged to facilitate design, verification, and evaluation activities. The staging area is large enough that portable partitions can be used to mock up the boundaries and layout of Control Building walls of the MCR. Full-scale panel arrangement drawings are attached to the mockup. The mockup is not populated with any HSI hardware.

4.3.3.5.2 General Electric Test System (GETS)

The GETS is a partial-scope ESBWR simulation and test system for developing, testing, verifying, and partially validating the following:

1. Plant simulation models
2. Control systems
3. Operator displays
4. Procedures

GETS hardware includes:

1. Flat Panel Displays (FPD) with capacitive touchscreens
2. Workstations to store and display the graphics for the FPDs
3. Simulation computers
4. Ethernet network controllers and node bus interface units that interconnect the workstations

GETS simulation software includes:

1. Process modeling of hydraulic and thermal networks (P&ID equivalents)
2. Modeling of analog and binary control logic schemes (Logic Diagram equivalents)
3. Transient Analysis Code (TRAC) for modeling core kinetics and NSSS for the reactor pressure vessel

The initial GETS configuration does not include:

1. Hardware switches (but they are emulated at the Instructor Station to facilitate display evaluations using operating procedures)
2. Alarms
3. Online procedures
4. Maintenance/test/surveillance/diagnostic displays
5. Wide Display Panel
6. Simulator sequence-of-events recording/playback

GETS is used to HFE design verify operator displays.

4.3.3.5.3 Baseline Simulator (BS)

The ESBWR Baseline Simulator (BS) is the earliest available simulator that meets the model software requirements of ANSI/ANS-3.5-1998. It is characterized by the following HSI:

1. Fully prototypic MCR panels (excluding communication equipment and closed-circuit television equipment)
2. Fully prototypic RSS panels
3. Some fully prototypic LCSs (e.g., RCIS)
4. Operator displays covering representative plant systems, inclusive of all necessary safety-related systems
5. Prototypic operator displays for Safety Parameter Display System (SPDS)
6. Historian function
7. General Displays - This includes Operator Aid displays (i.e., Near-Criticality Trends, Low-Power Water Level Control, Power Flow Map, Reactor Heat Up Rate, Safety Systems Bypassed and Inoperable Status Indication, and Post Scram Status)
8. Balance of necessary displays available in non-prototypic, yet animated form
9. Geographical representation of the alarm system with static alarm prioritization

The BS is updated with more recent design input data after the full scope simulator is completed and prior to operator training at the site.

The BS is used to HFE design verify the following:

1. Panels (MCR, RSS, LCSs critical to safety)
2. Displays
3. Alarms
4. Procedures

4.3.3.5.4 Full Scope Simulator (FSS)

The FSS contains the full functionality of the MCR and RSS HSIs that is not available in the BS. It is used to verify the fully integrated HSIs including any changes to procedures and training. FSS functions that may not be in the BS such as the following:

1. Plant Automation System
2. OLPS (a "job performance aid")
3. Dynamic alarm prioritization

4. Graphic Displays for BOP and auxiliary plant systems
5. Group Point Displays (part of Transient Recording and Analysis function)
6. Sequence of Events (SOE) monitoring

4.3.3.6 Acceptance Criteria

The HFE guidelines of the ESBWR style guide, which will be based on NUREG-0700, Rev 2, will be used for HFE Design Verification. The guidelines are criteria for verifying the design and their applicability depends on the specific design feature being verified. The ESBWR style guide is also used when developing design-specific HFE guidelines documents and checklists. Design-specific HFE guidelines documents are identified whenever such documents are used as criteria for HFE V&V activities.

4.3.3.7 Performance Measures

Performance measures concern performance of the HSI. The measures are embodied in requirements contained in design specifications.

4.3.3.8 Data Collection and Analysis

Verifications using the BS are recorded on checklists.

4.3.3.9 Documentation and Integration of Results

The HSI component characteristics are compared with HFE guidelines throughout the HFE Design Verification process. For each guideline, it will be determined if the HSIs are acceptable or discrepant. Any noncompliance, full or partial, is deemed discrepant, and the nature of the discrepancy will be documented. Discrepancies will be evaluated as potential indicators of additional issues.

Deficiencies identified by evaluators are documented. A deficiency (HED) is logged into the HFEITS if it matches at least one of the HFE issue entry criteria.

4.3.4 Implementation of Integrated System Validation

4.3.4.1 Scope

A simulator will be used by plant personnel to perform operational events to determine adequacy to support safe plant operations. This will be performed after significant HEDs from HFE verification have been resolved.

Integrated System Validation applies to:

1. Panel layouts (anthropometrics) and labeling
2. HSI components (controls, displays, alarms, data processing, communications equipment) that include:
   a. Operator displays and their associated FPDs

b. Fixed-position (hard) switches

c. Fixed-position (hard) indicators such as meters and status lights

d. Alarm tiles

e. Alarms displayed via FPDs

f. Large variable display

g. Mimics

h. Electronic (on-line) procedures [Joint GE and COL Holder responsibility]

i. Phone, radio, page party, and public address devices

3. Hardcopy procedures [COL Holder responsibility]

4. Portable utility board for EOP flowcharts (and perhaps shift turnover information) [COL Holder responsibility]

5. Portable cart for hardcopy procedures [COL Holder responsibility]

6. The standard design features of the ESBWR Main Control Room HSI (see ESBWR DCD Chapter 18)

4.3.4.2 Objectives

The objectives are to confirm:

1. HFE-adequacy of the integrated HSI configuration

2. Automation (allocation of functions and the degree of task dependence on procedures)

3. Adequacy of the HSI (equipment performance, dynamic and time-dependent aspects) to support the crew in accomplishing critical functions and tasks (e.g., evaluating plant status, diagnosing transients, performing control actions to maintain safety) during normal operation, transients, accidents, and risk-significant events beyond design basis

4. Human performance assumptions in PRA/HRA

5. Tolerance to human error and system faults

6. That the HSI facilitates efficient search and retrieval of information and controls

7. The effect of HSI characteristics on operator workload

8. Adequacy of staffing

9. Adequacy of procedures

4.3.4.3 Participants, Test Subjects, and Observers

4.3.4.3.1 Validating Displays Using GETS

The HFE V&V teams performing qualitative validation of display usability with GE include *COL Holder* personnel (operations, maintenance, training, QA, etc.), and GE subcontractors. Some of the GE personnel are BWR/ESBWR trainers and some participated in startup of the predecessor ABWRs.

4.3.4.3.2 Validations Using BS and FSS

The HFE V&V teams performing validations with BS or FSS include GE personnel, GE subcontractors, and *COL Holder* personnel.

4.3.4.4 Methods and Procedures

Performance evaluations cover human performance and integrated HSI performance. Performance is evaluated on the basis of whether the acceptance criteria are met. The following outlines typical steps to be taken to prepare, and produce evaluation procedures, for HFE V&V activities using the simulators:

1. Define the evaluation team (participants)
2. Identify the operating crew (test subjects) and support staff to operate simulators and recording apparatus (e.g., video cameras)
3. Identify required witnesses and authorized observers
4. Train (or rehearse with) the evaluation team and operating crews (as necessary)
5. Obtain operating crew biographical information (age, anthropometrics, qualifications, experience, age, license held, etc.)
6. Define the scenarios (including initial conditions)
7. Define evaluation criteria
8. Document assumptions (e.g., concerning plant operating conditions, tasks such as tagouts performed by other plant staff personnel, automation, etc.)
9. Brief the evaluation team and operating crew on purpose, objectives, and how evaluations are to be conducted
10. Explain the scenarios and test conditions to the evaluation team and operating crew
11. Acquire the materials and resources for data collection methods (interview guides, questionnaires, observation forms, recording equipment and user manuals, etc.)

12. Identify source documents (e.g., procedures, PRA/HRA, Technical Specifications, etc.) that delineate expected operator responses and expected plant behavior
13. Schedule the evaluation

4.3.4.4.1 Evaluating Operational Safety and Task Performance

Operator crews are subjected to a set of test scenarios run on the simulator. The test scenarios have predefined initial conditions, applicable symptoms, and expected system responses and plant behavior. Each crew is subjected to a given scenario at least twice. Each crew is also subjected to the same set of scenarios for purposes of comparing crew performance under similar uses, and conditions, of the HSI. Test subjects are not told what particular scenario is going to be simulated. The evaluation team observes the simulated exercise and documents crew performance. Debriefings and structured interviews are held after the simulated scenarios. Evaluators take notes on these discussions to supplement video recordings and visual observations.

It is recognized that simulator testing environments cannot fully replicate the influence that Performance Shaping Factors (PSFs) such as stress and noise have on operator human performance in real situations. Simulator testing environments can also bias operator behavior. For example, during a simulator test scenario, the operator anticipates an abnormal situation occurring. The anticipation heightens the operator's attention and alertness to an abnormal event. Operator responses are also shaped by adherence to procedure and the absence of potential conflicts between rote procedure compliance and economic demands (e.g., maximizing the unit's capacity factor).

Validation is a progressive, cumulative activity. Applicable ESBWR specific procedures, if available, are used as necessary when simulating validation scenarios. Non-ESBWR specific procedures and/or the experience of test subjects and participants can also be used. Some Integrated System Validation can be conducted without operating procedures. For example, validation of display navigation and validation of HSI component layouts on consoles are not dependent on operating procedures and scenario simulations.

A standard design feature of the ESBWR is the Safety Parameter Display System (SPDS) function integrated into the MCR HSI as displays and fixed-position indicators at the Wide Display Panel. Validation demonstrates that the ESBWR SPDS aids operators during abnormal and emergency conditions in (a) determining the unit safety status, (b) assessing whether abnormal conditions warrant corrective actions by operators to prevent core damage, (c) monitoring the impact of engineered safeguards or mitigation activities, and (d) executing symptom-based emergency operating procedures.

4.3.4.4.2 Detecting Human Error

Errors are detected by comparing operator actions (observed and recorded) to reference (predefined) responses. Observed and recorded actions include crew communications and test subjects describing their observations and intended actions during the testing.

Documented PRA/HRA assumptions regarding operator performance and the HSI are validated. The assumptions relate to the tasks definition, time allowed for each task, and the probability of operator success to perform the task in the allowed time. The following are samples of assumptions:

1. Intentional deviation from standard operating procedures is due to misdiagnosis or misleading indication and operator discretionary decision to deviate.
2. Procedures exist for providing backup DC power to ADS valves under station blackout conditions.
3. Control room staffing is:
    a. Unit Control Room Supervisor
    b. Unit Senior Reactor Operator (Shift Supervisor)
    c. Unit Reactor Operator
    d. Unit Auxiliary Operator
4. Procedures are available in a clear written form.
5. Information is available to help operators diagnose events and carryout mitigating actions for those credited in the PRA.
6. Accessibility of control is available for successful action in an appropriate time frame.

4.3.4.4.3 Evaluating Situation Awareness

The HSI is an integration of proven technologies based on human factors principles and human-centered automation. Validation to confirm situation awareness does not require defining or developing a cognitive model. Instead, simulated operator test scenarios inherently involve many features of the HSI that reinforce situation awareness. Table 3 describes these features. Operator situation awareness is qualitatively evaluated based on acquired test data (recordings and observations). Test data is expected to provide evidence regarding whether or not (a) mental and physical tasks are within operator performance capabilities, (b) situation awareness and vigilance is acquired and maintained, and (c) potentially new types, and possibilities, of human error are not being introduced.

Situation awareness is evaluated using a method similar to the Situation Awareness Control Room Inventory (SACRI) method developed by OECD Halden Reactor Project of Institutt for Energiteknikk. [NUREG/IA-0137] The SACRI method is based on the Situation Awareness Global Assessment Technique (SAGAT) used in the aviation industry. A simulated scenario is suspended at preselected points unbeknown to the operators. Operators are requested to turn away from displays and answer questions (about process parameters) deemed highly relevant to situational awareness. The questions concern the qualitative status of each parameter (e.g., increasing, decreasing, no change) over time (past, present, and future). Examples of questions: Compared to initial water level, how has water level changed? Compared to expected water level under normal conditions, how has current water level changed? Compared to the current water level, what do you expect to happen to water level? Supplementary information to support the assessments is obtained by questioning the operators (during the suspended scenario) on how they perceive the different situations with respect to their task objectives. Operators can be "walked back through" the scenario at a slower pace. The recorded operator responses are compared to time-tagged simulator data logs to assess correctness, gauge operator situational awareness, and critique crew performance.

Equally important (as HSI design) to situation awareness (and reliable operator performance in general) are training and procedures. The following are undertaken to promote and maintain situation awareness:

1. Using simulators to test for overdependence on automation (i.e., identify conditions when operators are reluctant to act despite being certain about abnormal conditions). The goal of such tests is to encourage operator discretion, reinforce the operator being "in the loop", promote learning from potential mistakes, and motivate operators to learn by giving them the opportunities to experiment.
2. Training operators on what the automation does, both well and not well, and what the automation does not do. This includes understanding the operator's supervisorial, or mission manager, decision-making role.
3. Confirming adherence to procedures expressly developed for effective transfer and communication of unit information during shift changeovers.

4.3.4.4.4 Assessing Operator Workload

Workload (physical and cognitive) concerns the magnitude of task loading placed on operators during operational conditions (normal and abnormal). Operator performance could be adversely impact if processing and response task demands of the system exceed operator capacity to perform the tasks. Workload is a function of:

1. Time available to complete the tasks

2. The number of tasks
3. Task duration
4. Task difficulty

Workload assessment methods are discussed in the Task Analysis Implementation Plan.

4.3.4.4.5 Evaluating Crew Communication and Coordination

Crew communication and coordination are subjectively evaluated on the basis of the crews' demonstrated performance during training exercises (e.g., emergency response drills).

Inoperable communication equipment (phone, radio, page party, public address) will be installed in the simulator. This is the first opportunity to evaluate the equipment for effective integration with the MCR panel arrangement and work environment. Operable communication equipment is installed in the MCR panels at the site. Evaluating use of the operable equipment with plant staff outside the MCR is part of the Final HFE/HSI Design Implementation activity.

4.3.4.4.6 Validating Anthropometrics

Anthropometrics are validated as part of the performance evaluations using test scenarios. Additional, predefined scenarios and tasks are used (as necessary) to ensure coverage of all HSI components. The validation relies on detecting problems (during use of the HSI) that may not have been evident when HSI components were verified without reference to specific tasks.

4.3.4.4.7 Evaluating Automation

Automation is evaluated for human-centered automation principles as part of the performance evaluations using test scenarios. Additional, predefined scenarios and tasks are used (as necessary) to ensure coverage of automation features and modes.

4.3.4.4.8 Validating Operating Procedures

Initial validation of hardcopy SOPs is performed with the GETS. The validation is partial because it is limited to examining consistency between operator display content and those procedure steps involving use of displays.

Validation of hardcopy procedures continues with the BS and the FSS. The validation is more structured and comprehensive because it is conducted under defined test conditions (scenarios or situations) and it includes other procedures (i.e., IOP, AOP, EOP, ARP) and the remaining HSI components (hard switches, alarm tiles, mimic, etc.). Validation of procedures (hardcopy and electronic) is completed during operator training phases on the BS and FSS. The procedures are adapted and finalized for implementation in the MCR and the simulator procedure computerized system (i.e., in OLPS) before plant start up.

Validation confirms that a portable cart for hardcopy procedures and a portable utility board for EOP flowcharts effectively integrate with the MCR arrangement and work environment. The top surfaces of the Main Control Console and Shift Supervisor Console are purposely designed for layout of multiple drawings and procedures. However, a portable (e.g., wheeled), dual-sided utility board is one option considered for mounting EOP flowcharts in the MCR. The side not used for mounting flowcharts can be a whiteboard for shift turnover information purposes. This option can be validated during procedure validation activities with the BS and the FSS.

4.3.4.4.9 Validating Displays Using GETS

The qualitative validation of display usability is referred to as a Dynamic Walkthrough. Initial Dynamic Walkthroughs are one-system-at-a-time evaluations for normal operational sequences using the respective System Operating Procedure (SOP) as a guide for task execution. These initial walkthroughs do not address integrated system operation or abnormal operations.

4.3.4.4.10 Validating Displays Using BS and FSS

Display validation with the BS is similar to previous Dynamic Walkthroughs except that the displays are evaluated under use simulator exercises (Normal Evolutions, Malfunctions, Surveillances, Transients, and Automatic actions).

4.3.4.4.11 Validating Displays Without Simulation

The BS and FSS may not have prototypic operator displays for certain BOP and auxiliary systems until the BOP design permits displays to be available for installation in the simulators.

Once installed in the simulator, the displays for these BOP and auxiliary systems can be driven with "dummy" variables. Final validation of systems that are not simulated therefore occurs after the systems are installed at the site and are testable.

4.3.4.5 Test and Evaluation (T&E) Conditions and Scenarios

Scenario selections are based upon a wide range of samples of operational conditions as discussed in Section 4.3.1. Specific HSI equipment failure scenarios also consider input from PRA/HRA and supporting reliability analyses.

The operational conditions selected for inclusion in the validation tests will be developed in sufficient detail to be performed on a simulator. The following information will be defined to provide reasonable assurance to allow scenarios to be accurately and consistently presented for repeated trials and to address important performance dimensions:

1. Description of the scenario and any pertinent "prior history" necessary for personnel to understand the state of the plant upon scenario initiation.

2. Specific initial conditions (definition provided for plant functions, processes, systems, component conditions and performance parameters, e.g., similar to plant shift turnover).
3. Events (e.g., failures) to occur and their initiating conditions, e.g., time, parameter values, or events.
4. Definition of workplace factors, such as environmental conditions.
5. Task support needs other than HSIs (e.g., procedures and technical specifications).
6. Staffing objectives.
7. Communication requirements with remote personnel (e.g., load dispatcher via telephone).
8. The specification of what, when and how data are to be collected and recorded.
9. Criteria for terminating the scenario.

Scenarios will have appropriate task fidelity so that realistic task performance will be observed in the tests and so that test results can be generalized to actual operation of the real plant.

When evaluating performance associated with operations remote from the main control room, the effects on crew performance due to potentially harsh environments (i.e., high radiation) should be realistically simulated (i.e., additional time to don protective clothing and access radiologically controlled areas).

4.3.4.5.1 GETS

The T&E conditions are one-system-at-a-time evaluations against normal operational sequences.

4.3.4.5.2 BS

The T&E conditions are those of the normal evolutions, malfunctions, surveillances, transients, and automatic actions, for the simulator testing program.

4.3.4.5.2.1 FSS

The T&E conditions are similar to that for the BS except that the FSS includes the full simulation of the capabilities that will be provided in the MCR. The complete range of events and scenarios planned for integrated system validation, as well as operator training facilities, will be available.

4.3.4.6 Acceptance Criteria

4.3.4.6.1 Operational Safety and Task Performance

Acceptable human performance is based, in part, on success with the measures for operational safety and task performance.

4.3.4.6.2 Human Error

Acceptable human performance is partly based on successful operator performance with respect to human error performance measures. Acceptable HSI performance is partly based on the HSI not being a root cause of operator failure with respect to human error performance measures.

4.3.4.6.3 Situation Awareness

An acceptable level of situation awareness is based, in part, on operator success with the performance measures for situation awareness.

4.3.4.6.4 Operator Workload

An acceptable workload would be the result of:

1. Positive ratings by crews
2. Successful accomplishment of needed operator tasks in time and precision
3. Adequate situation awareness (as more workload implies less situation awareness or less time available to assess plant situations)

The Task Analysis Implementation Plan indicated that as a "rule of thumb" 50% to 75% is an acceptable average physical workload [*(time occupied / task time) * 100*]. Meister [Reference 2.4] notes that, although supporting empirical data is lacking,

1. Physical workloads of 75-100% are undesirable
2. Physical workloads <75% are acceptable provided the operator remains reasonably occupied
3. Inaccuracy of most physical workload estimates is +/- 20%

Physical workload estimates are to be used to investigate potential improvements (e.g., to HSI, to procedures, to training, etc.) rather than reject the design.

4.3.4.6.5 Crew Communications and Coordination

Acceptable human performance is based, in part, on operator success with the performance measures for crew communication and coordination.

4.3.4.6.6 Anthropometrics

The acceptance criteria are the same as those used for HFE Design Verification.

4.3.4.6.7 Automation

Human-centered automation is automation to any extent provides that safe, economic plant operation and maintenance remain within the capabilities of the operators and maintainers. Acceptance of the integrated HSI is based, in part, on the HSI exhibiting the following general human-centered automation design principles:

OPERATOR (or MAINTAINER)	AUTOMATION
• Retains ultimate authority and decision-making responsibility	• Facilitates control and operation in appropriate modes (full auto, semi-auto, manual) and at appropriate levels (plant, system, component)
• Remains involved and is able to accomplish tasks within time, performance, and workload criteria	• Provides quality, timely information.
• Is well-informed	• Provides task-relevant information, and explains actions (taken, pending, anticipated)
• Is able to effectively anticipate problems	• Supports a high degree of operator vigilance and "situation awareness" (e.g., monitors trends, aids operator decision-making, and provides fault detection, identification, verification, and recovery)
• Understands the automation	• Is human-engineered for simple, cognitive, and intuitive operation (i.e., low probability of human error)
• Is able to manage task support resources	• Effectively integrates task support resources and the HSIs for NSSS, BOP, and T/G

4.3.4.6.8 Operating Procedures

Acceptance criteria for operating procedures include:

1. Correct execution of the procedure meets the intended purpose of the procedure
2. Procedures are conveniently accessible and retrievable
3. EOPs can be navigated effectively
4. ARPs meet the criteria of NUREG-0700, Rev 2
5. Electronic procedures aid the operator
6. User acceptance

4.3.4.6.9 Validating Displays Using GETS

The acceptance criteria for operator displays on the GETS are:

The displays enable normal operating procedure tasks to be accomplished effectively, and

Displays are complete

1. There is good 1-to-1 correspondence with operating procedure tasks and information
2. System process images correlate well with P&IDs, PFDs, and DCTs

Displays are compatible with operators (and other applicable end users)

1. Readable
2. Touchscreens work effectively
3. Active touch areas are suitably sized
4. Easy to navigate
5. Multiple FPDs can be used simultaneously

Displays are understood by the operator (and other applicable end users)

1. Consistent "look and feel"
2. Colors and color coding scheme are effective
3. Dynamic behaviors are easily recognized and understood
4. Appropriate units, number of significant digits, decimal places
5. Easy to learn

Displays are not a cause of human error

Display operability is validated and includes aspects such as:

1. Effective control using on-screen Manual/Auto (M/A) stations
2. Clear status feedback (e.g., valve open/closed, pump on/off, etc.) from color coding and labeling
3. Ability to abort actions or retract inputs without adverse effects
4. Navigation features function effectively
5. Touch screen responsiveness and ease of selecting touch points correctly

4.3.4.6.10 Validating Displays Using BS and FSS

The acceptance criteria for operator displays on the BS and FSS is the same criteria as displays on the GETS with the additional criteria that the displays enable abnormal and emergency procedure tasks to be accomplished effectively.

Acceptance criteria for SPDS displays is compliance with NUREG-0737 (Supplement 1) including incorporation of applicable results of ESBWR PRA/HRA, and that SPDS is addressed in training programs for abnormalities and emergencies.

4.3.4.7 Performance Measures

Performance measures cover human performance and HSI performance.

4.3.4.7.1 Operational Safety and Task Performance

Human performance measures include:

1. Error avoidance
2. Avoiding alarm conditions
3. Avoiding technical specification violations
4. Response time
5. Task completion time
6. Procedure compliance

4.3.4.7.2 Human Error

Human errors in various industries (i.e., power generation, aerospace, naval, communication) fit six general categories as follows:

1. Observing the state of the unit or system
2. Diagnosis (making hypotheses, judgments, assumptions, guesses)
3. Testing their diagnosis
4. Deciding on their goal/objective
5. Selecting a procedure
6. Executing a procedure (adhering to instructions and executing the tasks)

The errors are errors of commission (i.e., *doing* what should not have been done) and errors of omission (*not doing* what should have been done). Failure to perform the tasks listed in the Situation Awareness section are examples of errors.

4.3.4.7.3 Situation Awareness

Situation awareness is subjectively evaluated partly on the basis of the correctness of test subject responses to questions asked during test scenarios. Situation awareness is also subjectively evaluated on the basis of how well crews exhibit the following skills and capabilities:

1. Locating and interpreting information correctly and efficiently to ascertain vital symptoms and system status
2. Properly assessing the implications of alarm states

3. Demonstrating an understanding of how the plant, systems, and components were operating, and the status of key setpoints, interlocks, and automatic actions
4. Demonstrating an understanding of how their actions (or inaction) affected the plant and individual systems (including discretionary decisions to assume manual control)

Measures of performance are the operator's effectiveness at tasks that include:

1. Observing the state of the unit or system
    a. Recognizing off-normal trends before the onset of a significant upset condition
2. Diagnosis (making hypotheses, judgments, assumptions, guesses)
    a. Classifying symptoms and events correctly
    b. Diagnosing conditions in a timely and accurate manner
    c. Use of information and reference material (drawings, books, charts, emergency response procedures, etc.) appropriately and effectively
3. Testing a diagnosis
    a. Informing others of intended action and executing appropriate if-then-else steps in abnormal operating procedures
4. Deciding on a goal/objective
    a. Making decisions correctly (e.g., while following emergency procedures)
5. Selecting a procedure
    a. Referring to, and transitioning between, the appropriate procedures in a timely manner
6. Executing a procedure (with or without OLPS):
    a. Strict adherence to procedures, cautions, and limitations (i.e., no deviating even if the deviation appears to have no detrimental consequences)
    b. Executing procedural steps in correct sequence
    c. Locating and accessing controls and information correctly and efficiently
    d. Using controls in a timely and effective manner

4.3.4.7.4 Operator Workload

Data acquired from test scenarios is analyzed to determine physical workloads that are *average* workloads per task over defined task time periods. Cognitive workload is

evaluated qualitatively using a rating method that considers operator views of task loading and difficulty, and actual operator performance during test scenarios.

Workload is assessed from test scenarios by means of:

1. Evaluating navigation, which includes all actions indicating that the operator actively searches and answers demands from the system, or follows procedure logic.
2. Evaluating information gathering, which includes the monitoring of plant parameters to evaluate plant status, depending on the plant situation.
3. Evaluating plant operations, which include all actions that have a direct effect on the simulated process (opening or closing valves, or switching on/off automatic programs.
4. Evaluating alarm interaction, which involves acknowledging incoming alarms.
5. Analyzing the information that is needed to assess plant situation and step logic while performing other activities per task over defined task time periods.
6. Analyzing the memory demands to perform operational tasks.
7. Evaluating the crew's subjective ratings (an output from questionnaires and interviews concerning task loading, difficulty, and operator performance during test scenarios).
8. Evaluation of results using crew ratings to NASA TLX scales that are composed of six factors: mental demand, physical demand, temporal demand, own performance, own effort and own frustration. More details about NASA TLX dimensions are included in Table 2.

4.3.4.7.5 Crew Communications and Coordination

Crew communication and coordination are subjectively evaluated on the basis of how well crews exhibit the following:

1. Effective leadership and clear chain of command. Cooperation and composure under supervisor's direction without micromanagement.
2. Well-defined roles and responsibilities
3. Teamwork. The crew performs as an integrated unit and interacts effectively (i.e., everyone contributing, supporting and backing each other up as needed, ease of task delegation, using a consensus approach to problem solving and decision making, informing key personnel outside the control room).
4. Open dialogue (sharing information and knowledge)
5. Use of same information (displays, alarms, procedures)

6. Clear directions and repeatbacks (confirmations, acknowledgements)
7. Correct, accurate, concise, and relevant information exchange (e.g., always designating the specific unit, division, train, etc.)
8. Proactive monitoring and observation (for situation awareness and progress assessment)
9. Efficient movement between panels and workstations

4.3.4.7.6 Anthropometrics

The performance measure primarily concerns reachability and operability of controls, and viewability of indicators, from the expected user position(s). Variability of the task execution envelope is investigated if interference among users occurs.

4.3.4.7.7 Automation

Performance measures include:

1. Operability (i.e., effective operator use) of PAS during automation modes (startup from cold shutdown or hot shutdown conditions to rated power operation, power maneuvers in the normal operating range, and shutdown from rated power level to shutdown of the turbine gland sealing system)
2. Operator cognition (e.g., mode awareness)
3. Correct confirmations during pre-programmed automation break points

4.3.4.7.8 Operating Procedures

Refer to operator performance measures regarding situation awareness.

4.3.4.7.9 Display Validation

There are no performance measures for graphical displays because the behavior of the graphics is a function of software programming, hardware performance, and overall system throughput and response.

4.3.4.8 Data Collection and Analysis

Validation activities with the BS and the FSS use the following:

1. Videotaping and data collection forms
2. Interviews using the NASA Task Load Index (TLX) to supplement analytic data..
3. Questionnaires
4. Simulator recording of chronological event logs (e.g., operator actions with screen displays and hard controls, occurrence of alarms, etc.)
5. Simulator recordings (logs) of process variables

6. Written observations, notes and commentary

Validation activities with the FSS also use the following:

1. Operator activity timelines of expected operator tasks (developed in advance based on TA and PRA/HRA to identify periods of overloading and underloading). The timelines show phasing, frequency, durations, and time limits for tasks. Other actions (reactions to secondary effects, diagnostic actions), if defined, can be included in the timeline. These timelines become baselines for expected operator task execution.
2. Expected operator movement pattern diagrams (developed following validations with the BS) to establish a baseline movement pattern for each scenario. Only the most essential key actions are reflected in these movement pattern diagrams.

Time data (measured, calculated and estimated) includes:

1. Elapsed time from occurrence of first alarm to awareness of that alarm
2. Elapsed time from first significant alarm to first manual safety-related action
3. Time used to navigate to the appropriate screen display
4. Time used to find and access the correct procedure (hardcopy and electronic)

Timelines and movement pattern diagrams for each crew are developed for each simulated scenario. Movement pattern diagrams are constructed from video recordings and visual observation records. Timelines and movement pattern diagrams are compared against baseline timelines and movement pattern diagrams to assess correctness, timeliness, and completeness of responses to scenarios. Findings are compared to performance criteria and requirements. Tests subjects support the evaluation team by interpreting videotaped sessions and interrelating recorded events with test data.

Human errors are analyzed for root cause.

4.3.4.9 Documentation and Integration of Results

1. Design specifications, procedures, training, etc., are revised accordingly, if necessary, to reflect the validation results.
2. Results can be used to modify baseline timelines and movement pattern diagrams for use as operator training tools and baseline Human Performance monitoring.
3. Reports include discussion of the type and frequency of human errors detected, error consequences, root cause analysis of errors, and corrective measures to address the errors.
4. Multimedia records are retained in accordance with GEEN EOPs.

5. Deficiencies identified by evaluators are documented HEDs. A deficiency is logged into the HFEITS if it matches at least one of the HFE issue entry criteria.

4.3.5 Implementation of Human Factors Issue Resolution Verification

4.3.5.1 Scope

The verification applies principally to significant issues in the HFEITS requiring resolution (i.e., those with potential for risk-significant human error and adverse impact on plant safety or performance).

4.3.5.2 Objectives

The objective is to ensure that issues are acceptably resolved and corrections are implemented (if applicable).

4.3.5.3 Participants, Test Subjects, and Observers

GE, as custodian of the HFEITS, performs verification for the issues that are resolved prior to plant startup. *COL Holder* performs verification of any issues thereafter.

4.3.5.4 Methods and Procedures

Verifications by GE are performed in accordance with the GEEN EOPs and QA requirements

4.3.5.5 Test and Evaluation (T&E) Conditions

Not applicable.

4.3.5.6 Acceptance Criteria

Acceptance is obtained through formal design change and verification processes in accordance with QA requirements and program requirements specified in Section 3. For significant issues, the criteria for acceptance includes

1. Reducing, or eliminating, the potential for risk-significant human error and adverse impact on plant safety or performance
2. Independent review determines the resolution to be adequate
3. Approval by licensee and licensor

4.3.5.7 Performance Measures

Not applicable.

4.3.5.8 Data Collection and Analysis

Not applicable.

4.3.5.9 Documentation and Integration of Results

HFEITS contains traceable references to issues, resolutions and implementation.

4.3.5.10 Implementation of HFEITS

The HFEITS tool is a database that is used to record and track HEDs and their resolution. Records within the database include the following (as fields within a record). An example of an HFEITS database record:

1. HFE Issue tracking identifier
2. Design lifecycle process (or activity thereof) that led to the issue being identified
3. Area (of MCR, RSS, Simulator, or LCS) affected by the issue
4. HFE principle or guideline pertinent to the issue (e.g., workspace, legibility, screen content, etc.)
    a. Plant system(s) affected
    b. Control panel(s) affected
    c. Component(s) or feature affected (e.g., switch, mimic, display, lighting)
    d. Operator task(s)/function(s) affected
    e. Human performance characteristic affected (e.g., vision, hearing, cognitive, motor skill, etc.)
5. Date that the issue was identified
6. Brief description of the issue
7. Name of person (or group, or organization) identifying the issue
8. Qualified evaluator's "Yes/No" designation that the issue requires corrective action
9. Qualified evaluator's justification statement if no corrective action is needed
10. Date when the need for corrective action was evaluated
11. Name of the qualified evaluator
    a. Significance Category (see below)
12. Description of the proposed corrective action
13. Date that the corrective action was proposed
14. Name of engineering discipline responsible for proposed corrective action
15. Organization responsible for evaluation of proposed corrective action

16. Date that the evaluation was completed
17. Statement (and/or summary of findings) confirming completion of corrective action
18. Name of person confirming completion of corrective action
19. Date of confirmation statement
20. Name of HFE Group Member authorized to signify that the issue has been closed
21. Date of closure

Significance Category is a temporary field for potentially future HED compilation, ranking and screening purposes. It is a methodology to rank or prioritize new and unresolved issues in terms of their significance and potential impact on plant safety and performance. The intent is to facilitate evaluation and resolution of HEDs in a manner consistent with the guidelines of NUREG-0700 and NUREG 0711. The Significance Category methodology is depicted in Figure 3.

However, in order to assure that resources are applied in a risk informed manner, it is important to first evaluate the safety significance of each HFE issue. If it is determined that the issue is not significant to safety, further evaluation to determine the need for corrective action may not be needed.

Table 1 HFE V&V Team Composition

Note: This table presents typical functions, qualification and expertise that will be available in the ESBWR project but does not mean that there is an "HFE Team" organizational entity. Also, the composition does not apply in its entirety to any single HFE V&V activity.

Scope/Function	Minimum Qualifications	Expertise/Contribution (Typical)
(a) Technical Project (or Program) Management	Bachelor of Science degree, and 5 years experience in nuclear power plant design operations, and 3 years management experience.	Define, Plan, Lead, Monitor and Complete the project (or program)
(b) Systems Engineering	Bachelor of Science degree, and 4 years cumulative experience in at least 3 of the following areas of systems engineering; design, development, integration, operation, and test and evaluation.	Knowledge of • The purpose, operating characteristics, performance, and technical specifications of plant systems • Statistical data analysis methods • V&V methods
(c) Nuclear Engineering	Bachelor of Science degree, and 4 years nuclear design, development, test or operations experience.	Knowledge of • Reactor physics • Nuclear systems operability and performance
(d) Instrumentation and Control (I&C) Engineering	Bachelor of Science degree, and 4 years experience in design of process control systems, and experience in at least one of the following areas of I&C engineering; development, power plant operations, and test and evaluation.	Knowledge of • HSI component design and technologies • HSI component functionality and performance • HSI O&M and installation • Scenarios involving HSI malfunctions
(e) Architectural and Civil Engineering	Bachelor of Science degree, and 4 years power plant control room design experience.	Knowledge of • The overall design, layout, and structure of the plant and its facilities

Table 1 HFE V&V Team Composition (continued)

Note: This table presents typical functions, qualification and expertise that will be available in the ESBWR project but does not mean that there is an "HFE Team" organizational entity. Also, the composition does not apply in its entirety to any single HFE V&V activity.

Scope/Function	Minimum Qualifications	Expertise/Contribution (Typical)
(f) Human Factors Engineering	Bachelor of Science degree in human factors engineering, engineering psychology or related science, and 4 years cumulative experience related to the human factors aspects of human-computer interfaces. Qualifying experience shall include experience in at least 2 of the following human factors related activities; design, development, and test and evaluation, and 4 years cumulative experience related to the human factors field of ergonomics.	Knowledge of • Human performance • HF design and evaluation practices • HF principles, guidelines, and standards • HF analyses • Resolving HF issues • V&V methods
(g) Plant Operations	Have or have held a Senior Reactor Operator license; 2 years experience in relevant (BWR preferred) nuclear power plant operations.	Knowledge of • Operational activities and requirements • O&M personnel tasks and characteristics • HSI characteristics • Environmental characteristics • Scenarios for validation
(h) Computer System Engineering	Bachelor of Science degree in Electrical Engineering or Computer Science, or graduate degree in other engineering discipline (e.g., Information Technology, Mechanical Engineering or Chemical Engineering), and 4 years experience in the design of digital computer systems and real time systems applications.	Knowledge of • V&V methods • Software functions (e.g., data processing) • Display and alarm design and implementation • Scenarios involving HSI malfunctions

Table 1 HFE V&V Team Composition (continued)

Note: This table presents typical functions, qualification and expertise that will be available in the ESBWR project but does not mean that there is an "HFE Team" organizational entity. Also, the composition does not apply in its entirety to any single HFE V&V activity.

Scope/Function	Minimum Qualifications	Expertise/Contribution (Typical)
(i) Plant Procedure Development	Bachelor's degree, and 4 years experience in developing nuclear power plant operating procedures.	Knowledge of • Operational tasks • Procedures of current plants • Procedure writing • Emergency procedure guidelines
(j) Personnel Training	Bachelor's degree and 4 years experience in the development of personnel training programs for power plants, and experience in the application of systematic training development methods.	Knowledge of • Training programs • Training issues arising from HSI design and procedure design • The HSI • Scenarios for training and validation
(k) System Safety Engineering	Bachelor's degree in engineering/technology and 4 years experience in developing and/or performing system safety engineering design, analysis or evaluation.	Knowledge of • Nuclear safety systems • Safety system design/operation • Plant technical specifications • System requirements

Table 1 HFE V&V Team Composition (continued)

Note: This table presents typical functions, qualification and expertise that will be available in the ESBWR project but does not mean that there is an "HFE Team" organizational entity. Also, the composition does not apply in its entirety to any single HFE V&V activity.

Scope/Function	Minimum Qualifications	Expertise/Contribution (Typical)
(l) Reliability/Availability/ Maintainability/Inspectabilit y Engineering	Bachelor's degree in engineering/ technology and 4 years experience in developing and/or performing equipment reliability, maintenance or inspection engineering activities.	Knowledge of • Reliability evaluation tools for measurement, evaluation and statistical analysis • Reliability practices/programs • Human-machine interaction on reliability evaluation • Equipment maintenance or inspection principles • Maintenance or inspection standards and practices
(m) Quality Assurance	Bachelor's degree in technically related field and 4 years experience in developing and/or performing QA activities.	Knowledge of • QA practices, tools and programs • QA standards
Note: The composition is based on the same composition defined for the certified U.S. ABWR design and is consistent with NUREG-0711. The USNRC staff, during it's review of the HFE program plan for the ABWR, recognized the absence of system safety engineering, maintainability/inspectability engineering, and reliability/availability engineering expertise. However, the USNRC staff found the composition acceptable, because the USNRC recognized that these particular areas of engineering expertise were applicable to the HSI design rather than the other HFE elements of the overall design and implementation process (NUREG-1503, USNRC Final Safety Evaluation Report for the ABWR). System safety engineering, reliability/availability/maintainability/inspectability engineering, and quality assurance expertise are included as part of the ESBWR MMIS HFE Implementation Plan.		

Table 2 NASA TLX Scale

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?

Table 3 Features of the ESBWR MCR HSI That Reinforce Situation Awareness

Potential Deficiencies of Automation Design and HSI Design Associated with Loss of Situation Awareness	
	Features
Mode confusion	• Mode changes invoked through manual actions to keep the operator "in the loop" • Alarm suppression based on operating modes (e.g., plant modes, system modes, equipment modes) to eliminate irrelevant and ambiguous information • Electronic display of mode status, equipment local control status, and component tagout status.
Operator has difficulty managing task support resources. Provisions for detecting and recovering from human error are limited. There are inadequate provisions for manual aids.	• A "job performance aid" referred to as Operator aid displays (e.g., T/G Warming and Startup, Near-Criticality Trends, Low-Power Water Level Control, Feedwater Pump Switchover, Power Flow Map, NSSS Heat Balance and Reactor Heat Up Rate, Safety Systems Bypassed and Inoperable Status Indication, Post Scram Status, and Summaries of ECCS, Feedwater/Condensate, Radiation, Primary Containment) • A "job performance aid" in the form of electronically displayed procedures (in logic or flow chart form) with the following features: – Ability to check operator decisions (but operator retains ultimate authority and control) – Automatic logging of operator deviations from the procedural options available to them on the displays – Ability to retrace certain procedure steps (except operator control actions) to assure proper state of systems/components is maintained – Operator can access a particular control from either a system standpoint (e.g., from a P&ID-type display) or from a functional standpoint (e.g., a procedure display). – Automated tracking for Emergency Operating Procedures • Monitoring of plant Technical Specifications for violations of Limiting Conditions of Operation and presenting recovery actions • The control room HSI design and control room layout accommodate operator use of hardcopy procedures, large engineering drawings, clipboards, notepads, etc.
The operator has difficulty understanding the actions and status of the automation. There is inadequate time for operator interpretation, evaluation, and response.	• Operating crew is provided with task-relevant information and automated actions (taken, in progress, and pending) status. • Automated unit startup and shutdown sequences include hold points (break points) that provide ample time for operator decision-making. Display designs are intuitive (for ease of use) and highly discriminating (by mode, by function, by system, etc.). • System operations (i.e., procedures for pre-operations, operation, shutdown, and surveillance testing) do not require complex or time-consuming "programming" (e.g., logical settings of modes, inhibits, interlocks, data entry, reading and interpreting displays).

Table 3 Features of the ESBWR MCR HSI That Reinforce Situation Awareness (continued)

Potential Deficiencies of Automation Design and HSI Design Associated with Loss of Situation Awareness	
	Features
Presentation of information is highly serial (sequential) making it difficult to navigate, assimilate, and share views of information (i.e., a "keyhole" or "tunnel" effect)	• The operator crew is provided with both serial data presentation (primarily at the operator Main Control Console) and parallel data presentation (primarily at the Wide Display Panel, WDP). • The spatial arrangement of the control room panels allows the entire control room operating crew to conveniently view information presented on the WDP. The crew size and panel arrangement are conducive to teamwork and crew interaction (joint monitoring, sharing of information, task delegation, notification of key actions taken at control panels).
The automatic controls design (by intention or arbitrarily) limit the extent of human operability and direct ("hands on") control of equipment. Operators experience complacency, lack of vigilance, boredom, etc.	• The HSI is designed for the capability to conduct all plant operations in an operator manual mode, and for operators to assume manual control by normal procedural methods and whenever operators elect to do so at their discretion. The operators retain ultimate authority and decision-making responsibility. • Operator preferences, experience, familiarity, and acceptance are factored into the design by having UTILITY operations personnel participate in the control room design development (from specification through verification).
There is insufficient feedback and warnings to effectively anticipate problems, and computer displays are the only sensory input media for the operator.	• The Wide Display Panel provides fixed-position, plant-level and system-level alarm tiles needed by the operators. • Safety Parameter Display System (SPDS) aids operators during abnormal and emergency conditions in (a) determining the unit safety status, (b) assessing whether abnormal conditions warrant corrective actions by operators to prevent core damage, (c) monitoring the impact of engineered safeguards or mitigation activities, and (d) executing symptom-based emergency operating procedures. • Information available to the operator includes diagnostic and trend monitoring data (e.g., equipment vibration monitoring), and information regarding system fault detection, identification, verification, and recovery. • The operator crew has closed circuit television (CCTV) and intraplant voice communication systems.

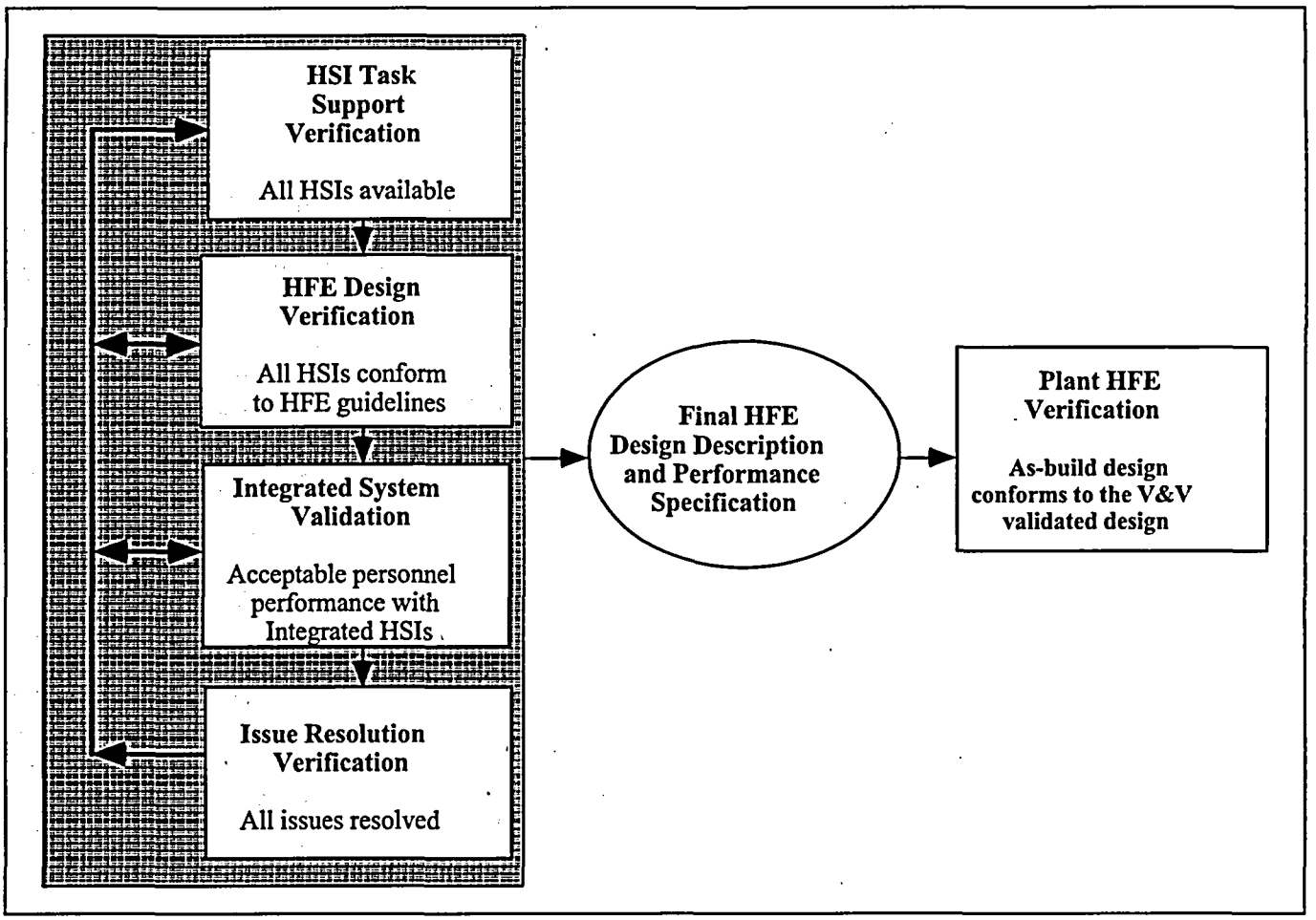

Figure 1 Relationship Between Verification and Validation Activities

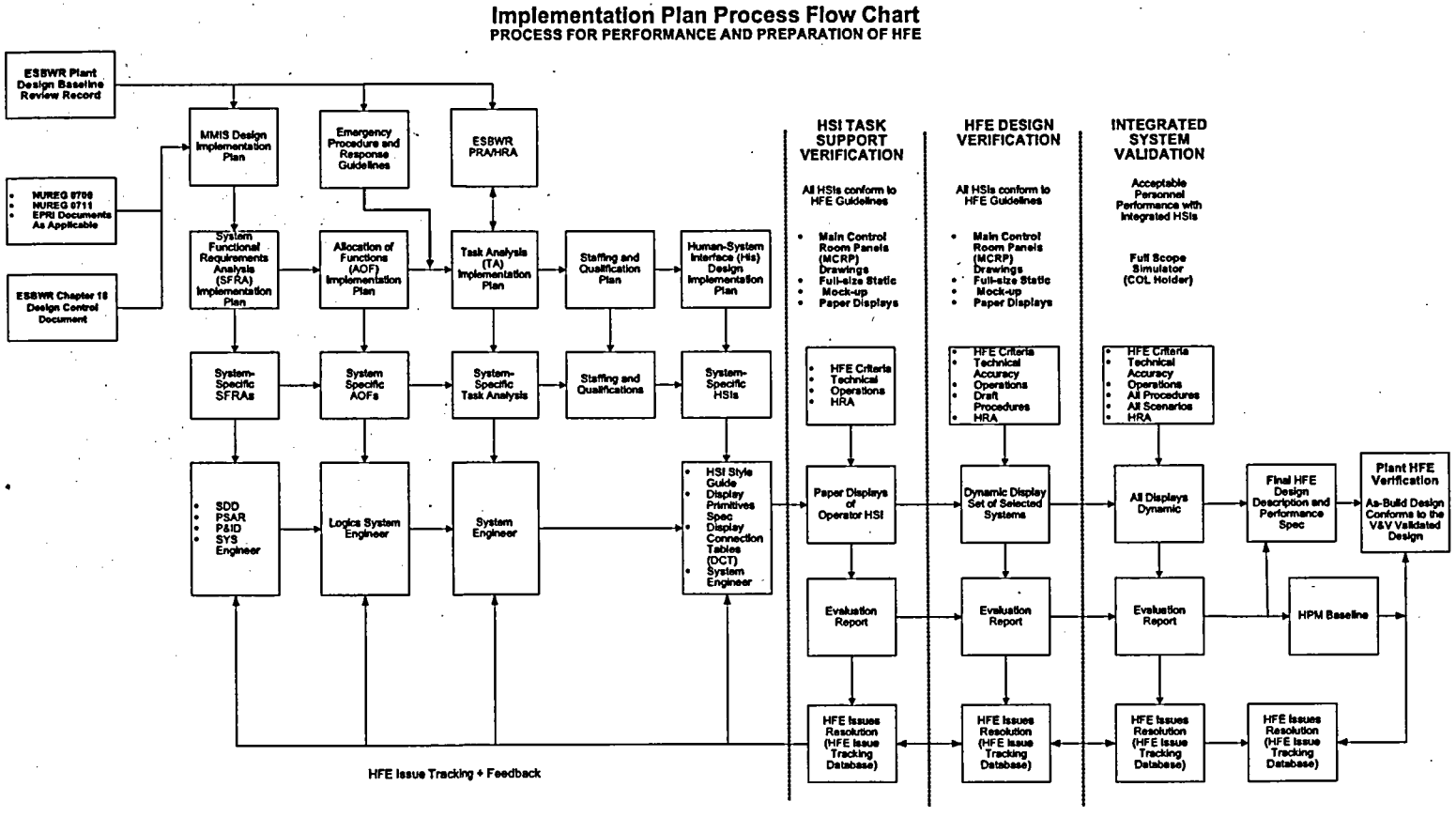

Figure 2 Integrated HFE V&V Activities With Associated Inputs and Outputs

SIGNIFICANCE CATEGORY	REPORTED ERROR IN OTHER PLANTS	POTENTIAL FOR ERROR
0	NO or UNKNOWN	UNCONFIRMED
1	YES	----
2	NO	YES (high)
3	NO	YES (low)
4	NO	NO

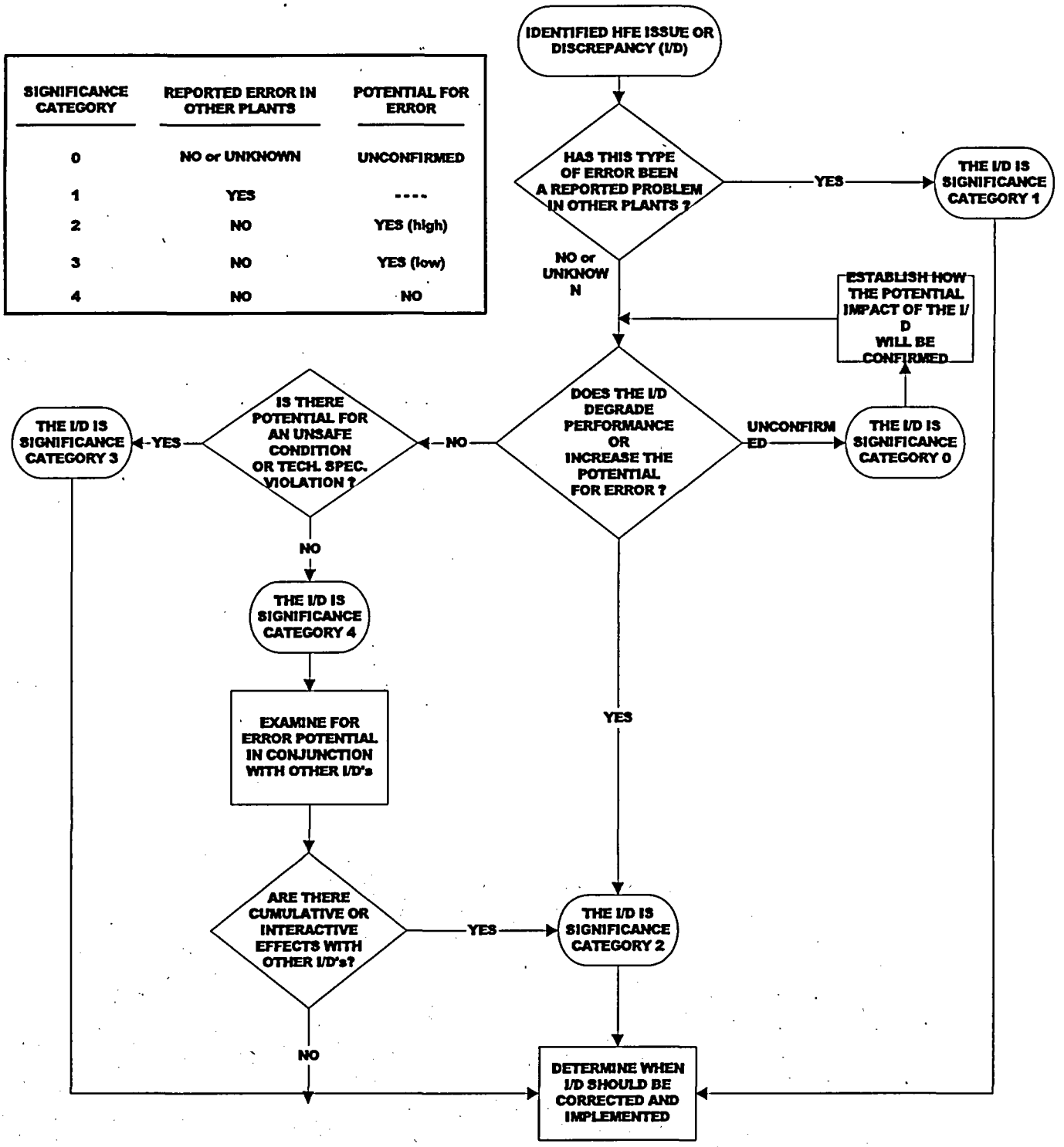

Figure 3 Significance Category Methodology