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LICENSING TOPICAL REPORT

ESBWR HUMAN FACTORS ENGINEERING VERIFICATION AND VALIDATION IMPLEMENTATION PLAN

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1. OVERVIEW

The process of Verification and Validation (V&V) is an integral part of the overall ESBWR Human Factors Engineering (HFE) design process. V&V evaluates completed design features including alarms, controls, indications, and their associated hardware. Design features are compared with regulatory requirements and guidance, HFE requirements, and the requirements generated during analysis of operator tasks. Ultimately, V&V confirms that the ESBWR Human-System Interface (HSI) enables plant personnel to safely and successfully perform the tasks necessary to meet the plant safety and operational goals defined in the ESBWR Plant Functional Requirements Analysis (PFRA).

V&V is conducted in two major activities: HFE design and task support verification, and integrated system validation. Both of these activities, as well as the operational condition sampling and Human Engineering Discrepancy (HED) resolution processes that support them, are presented in detail in this document.

As shown in Figure 1, HFE Process, the ESBWR is designed using a systematic process for integrating HFE principles into system design, training, procedures, staffing and qualifications, and HSI design (including software). Figure 1 depicts the system and HSI designs, procedures, and trained staff are examined using the V&V process to ensure that both individually and as an integrated whole, they meet the criteria presented in this plan. Tested attributes (HSIs, procedures, training elements, etc.) that do not meet pass/fail criteria, or that fail to meet supplemental criteria and are determined to warrant further consideration, are entered into the HFE Issue Tracking System (HFEITS). HFEITS documents the HED, tracks it through resolution, and documents the HED closure.

1.1 PURPOSE

The purpose of this plan is to provide the processes, methods, and criteria for performing the HFE design and task support verification and the integrated system validation. Additionally, this plan provides the processes, methods, and criteria for performing activities that support efforts like operational condition sampling and HED identification and resolution.

HFE design verification evaluates whether or not HSI design features meet design, regulatory, style guide, and HFE requirements. Task support verification evaluates whether or not all the HSI requirements identified in the Task Analysis (TA) for a given task are present in the design and possess the required characteristics.

Integrated system validation uses dynamically simulated scenarios to evaluate whether or not the integrated ESBWR HSI can adequately utilize human capabilities and accommodate human limitations. Performance during selected scenarios is evaluated to ensure that the integrated system design meets the performance requirements and criteria presented in this plan and supports the safe operation of the plant.

Operational conditions sampling is a process for determining and documenting the appropriate combination of operational conditions to be evaluated during the integrated system validation. These conditions are used within the integrated system validation process to select the appropriate combination of scenarios to validate the integrated system design.

V&V HED resolution is the process for identifying, documenting, and formally resolving HEDs identified during all stages of the HFE design process. During HFE design and task support verification, HEDs are identified and entered into HFEITS when:

- HSIs or design features do not meet regulatory, design, or style guide requirements
- HSIs or design features are not consistent with HFE guidelines
- Task support requirements identified in TA are not fully met
- HSIs are present in the design which do not support any task identified in TA and may not support any personnel task

During integrated system validation, HEDs are identified and entered into HFEITS when pass/fail acceptance criteria are not met. Additionally, HED identification is considered when supplemental acceptance criteria are not met.

1.2 SCOPE

The scope of this plan encompasses V&V requirements and program activities for verifying and validating the HFE elements of the ESBWR HSIs.

The V&V process elements presented include:

- HSI inventory and characterization
- Task support verification
- HFE design verification
- Operational conditions sampling
- Integrated system validation
- HED identification, documentation, and resolution

The following represent areas that are verified and/or validated in accordance with this plan:

- HSIs (alarms, controls, and indications) used for normal, abnormal, and emergency operations, maintenance, test, inspection, and calibration
- Layout/configuration and anthropometrics of workstations, including ergonomic considerations
- Automated features and processes
- Display navigation (access to controls and efficient information retrieval)
- Adequacy of staffing and qualification requirements identified by NEDO-33266, ESBWR Staffing and Qualifications Implementation Plan.
- Crew communications
- Procedures
- Training
- Software design

- Operator work environment (e.g., lighting, space, air conditions, floor design, noise mitigation)
- Provisions for routine tests and maintenance (e.g., cleaning touch-screen displays, testing alarms, and other similar activities)

The provisions of this plan apply to the main control room, the remote shutdown system, and risk significant local control stations.

HSI data and screens used for monitoring plant parameters in the emergency response facilities (e.g., the Technical Support Center (TSC) and the Emergency Operations Facility (EOF)) are within the scope of this plan. However, the COL applicant performs the integrated V&V of the TSC and EOF because these facilities are not part of the ESBWR standard design.

The activities in this plan are conducted using the following resources:

- Part task simulators
- Full scope simulator (FSS)
- Site specific training simulator

Administrative aspects of V&V within the scope of this plan include:

- Division of responsibilities for persons managing, leading, and directing HFE V&V activities includes:
  - Developing HFE V&V plans and procedures
  - Reviewing HFE V&V tests and evaluation activities
  - Facilitating corrective actions to deficiencies identified during HFE V&V
  - Confirming the implementation of corrective actions
  - Assuring that HFE V&V activities comply with this plan
  - Scheduling HFE V&V activities
- Identifying responsible design organizations or functions within the organizations for the V&V program. If more than one organization is involved, the lead organization for a particular HFE V&V activity is clearly identified. Organizations have the authority to ensure that responsibilities are met.
- Ensuring the composition of the HFE V&V team includes persons with the qualifications specified in NEDO-33217, ESWBR Man-Machine Interface System and Human Factors Engineering Implementation Plan.
- Defining the HFE V&V process which includes the input and output relationships with other HFE activities.
- Scheduling HFE V&V activities showing relationships among activities, products, and reviews.
- Identifying and describing items for documentation.

- Identifying and documenting HEDs throughout the HFE V&V process in the ESBWR HFE Issue Tracking System (HFEITS).

1.3 DEFINITIONS AND ACRONYMS

1.3.1 Definitions

The following terms are defined to provide clarity through a common ESBWR V&V language.

Accident: Event that has the potential for release of significant amounts of radioactive material.

Action: Involves observable movement during task performance.

Alarm: The term alarm is used in the broad sense, that is, a plant parameter, component, system, or function that is currently in a state requiring the attention of plant personnel. For example, a monitored parameter exceeds a specified limit (set point), the deviation is evaluated by the processing portion of the alarm system, and a message is conveyed to the operator via the display portion of the alarm system.

Allocation of Functions (AOF): Assignment of responsibility for performing operations required for accomplishing functions to humans, machines, or some combination of both.

Anthropometrics: Static and dynamic evaluations of measurements, angles, and usability in the MCR and RSS in relation to a user population in order to confirm the reach and accessibility of control devices, visibility of indication, seating comfort, etc.

Apparent Cause: A HED cause determination based on the evaluator's judgment and experience, and where reasonable effort is made to determine why the problem occurred. This might include fact-finding, analysis, interviewing, benchmarking, reviewing data, or other methods as appropriate.

Component: The meaning of the word component depends on its context. In context of the entire plant, it is an individual piece of equipment such as a pump, valve, or vessel; usually part of a plant system. In a human-system interface context, a component is one part of a larger unit, such as a meter in a control board. In a maintenance context, a component is a subdivision of a unit of equipment that can be treated as an object by the maintainer, but which can be further broken down into parts. A mounting board together with its mounted parts is an example of a component.

Crew: The group of people at the plant who manage and perform activities necessary to operate the plant and maintain its safety as performed during simulations.

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Detailed features: HSI features that represent the aspects of individual HSIs not addressed by HFE guidelines. Detailed features are more variable than standardized design features, and thus the generality and applicability of HEDs concerning detailed features are considered.

Emergency Procedures: A simplified description of the post event procedures that include the EOPs, ARPs, and AOPs that provide instructions for controlling events with the potential for a release of radioactive material.

Event: Any planned (for example, power change) or unplanned (for example, process system component failure) occurrence that impacts operation of process systems in such a way that achievement of required safety and productivity levels is jeopardized.

EPG/SAG: Emergency Procedure Guidelines are documents that identify the equipment or systems to be operated and list the steps necessary to mitigate the consequences of transients and accidents and restore safety functions. Severe Accident Guidelines define strategies for responding to emergencies and severe accidents when primary containment flooding is required.

Extent of Condition: The extent to which the HED condition exists with other processes, HSIs, or human performance. It is expected that the level of effort in determining and documenting the extent of condition is commensurate with the significance of the HED.

Feedback: System or component response (for example, visual, auditory, and/or tactile) indicating the extent to which the user's desired effect was achieved. Feedback can be either intrinsic or extrinsic. Intrinsic feedback is what the individual senses directly from the operation of the control devices (for example, clicks, resistance, and/or control displacement). Extrinsic feedback is what the individual senses from an external source that indicates the consequences of the control action (for example, indicator lights, display changes, and/or aural tones).

Full-Scope Simulator (FSS): A high-fidelity simulation environment that includes physical and environmental aspects, and HSIs of the operating environment. Typically this refers to the main control room simulator and meets the requirements of Regulatory Guide 1.149 and ANS-3.5.

Functional requirements: Quantitative performance criteria that systems must satisfy.

Functional requirements analysis: The examination of plant or system goals to determine what functions are needed to achieve them.

Global features: HSI features relating to the configurational and environmental aspects of the HSI, such as MCR layout, general workstation configuration, lighting, noise, heating, and ventilation. Global feature HEDs relate to general problems concerning human performance.

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

Human Engineering Discrepancy (HED): A departure from some benchmark of system design suitability for the roles and capabilities of the human operator. This may include a deviation from a standard or convention of human engineering practice, an operator preference or need, or an instrument/equipment characteristic that is implicitly or explicitly required for an operator's task but is not provided to the operator. (NUREG 0700, Rev 2)

Human Factors: A discipline concerned with the systematic study and application of what is known about human behavior to system development decisions.

Human Factors Engineering (HFE): The application of knowledge about human capabilities and limitations to plant, system, and equipment design. HFE ensures that the plant, system, or equipment design, tasks, and work environment are compatible with the sensory, perceptual, cognitive, and physical attributes of the personnel who operate, maintain, and support it (see human factors).

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

Human-System Interface (HSI): The human-system interface (HSI) is that part of the plant through which personnel interact to perform their functions and tasks. Major HSIs include alarms, information displays, controls, and procedures. Use of HSIs can be influenced directly by factors such as,

(1) The organization of HSIs into workstations (for example, consoles and panels).

(2) The arrangement of workstations and supporting equipment into facilities such as a main control room, remote shutdown station, local control station, technical support center, and emergency operations facility.

(3) The environmental conditions where the HSIs are used, including temperature, humidity, ventilation, illumination, and noise. HSI use can also be affected indirectly by other aspects of plant design and operation such as crew training, shift schedules, work practices, and management and organizational factors.

Input: The term input is context contingent and may take these forms:

(1) Information entered into a system for processing.

(2) The process of entering information.

(3) Pertaining to the devices that enter information.

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

Monitoring: Purposefully observing displays to assess plant operations. If available information suggests abnormality, additional information is sought and a diagnosis of the difficulty is performed.

Panel: Any surface upon which measures of equipment behavior are displayed or controls that directly affect equipment operations are contained. This includes display pages presented on video display units (VDUs), as well as conventional console panels containing hard controls.

Parameter: Any physical property whose value reflects a plant condition.

Plant safety: Also called "safe operation of the plant." A general term used to denote the technical safety objective of preventing accidents in nuclear plants. This includes verifying that, for all accidents taken into account in the design of the plant, even those of very low probability, any radiological consequences would be minor. This also includes providing reasonable assurance that the likelihood of severe accidents with serious radiological consequences is extremely small.

Probabilistic risk assessment (PRA): A qualitative and quantitative assessment of the risk associated with plant operation and maintenance that is measured in terms of frequency of occurrence of risk metrics, such as core damage or a radioactive material release and its effects on the health of the public.

Procedures: Written instructions providing guidance to plant personnel for operating and maintaining the plant and for handling disturbances and emergency conditions.

Risk Significant Local Control Station: A local control station at which risk-important human actions are performed or which control safety related equipment.

Root Cause: The fundamental cause(s) and associated corrective action(s) that, if corrected, will prevent recurrence of an HED.

Safety function: Safety functions are those functions that serve to verify higher-level objectives and are often defined in terms of a boundary or entity that is important to plant integrity and the prevention of the release of radioactive materials. A typical safety function is "reactivity control." A high-level objective, such as preventing the release of radioactive material to the environment, is one that designers strive to achieve through the design of the plant and that plant operators strive to achieve through proper operation of the plant.

Safety system: System required to minimize the probability and magnitude of release of radioactive material into the environment by maintaining plant conditions within allowable limits established for each design basis event.

Safety-related: A term applied to those plant structures, systems, and components (SSCs) that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. These are the SSCs on which the design-basis analyses in the safety analysis report are performed.

Simulator: A computer driven system that physically represents the human-system interface configuration of the main control room or other control interface and that dynamically represents the operating characteristics and responses of the plant in real time. Simulators include both part-task models that represent specific aspects of one or more systems and full scope models that integrate the dynamic behavior of all plant systems and HSIs working together to match the real world performance of the main control room.

Standardized features: HSI features designed using the guidelines established in the HFE style guide and applied across controls and displays (for example, display screen organization, display format conventions, and coding conventions). The implementation of standardized features is more consistent across interfaces than features not designed using these guidelines. Because a single guideline is used across many design aspects, a single standardized feature HED could be applicable to many personnel tasks and plant systems.

Task: Operations that must be performed by personnel and have identifiable initiating and terminating cues.

Task Analysis: A method for describing what plant personnel must do to achieve the purposes or goal of their tasks. The description can be in terms of cognitive activities, actions, and supporting equipment. (NUREG 0711, Rev 2)

Test participants: Personnel who act as crewmembers during validation and other evaluation scenarios.

Test personnel: Any V&V team members, test conductors, console operators, training instructors, evaluators, and/or trained observers taking part in the administration of V&V testing activities.

1.3.2 Acronyms

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

Acronym	Description
AOF	Allocation of Function
AOO	Abnormal Operational Occurrence
AOP	Abnormal Operating Procedure
ARP	Annunciator Response Procedure
BOL	Beginning of Life
BRR	Baseline Review Record
COL	Combined License
CRO	Control Room Operator
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D3	Defense-in-Depth and Diversity
DCD	Design Control Document
ECCS	Emergency Core Cooling System
EOF	Emergency Operations Facility
EOL	End of Life
EOP	Emergency Operating Procedures
EPG/SAG	Emergency Procedure Guideline / Severe Accident Guideline
ESF	Engineered Safety Features
FRA	Functional Requirement Analysis
FSS	Full Scope Simulator
HED	Human Engineering Discrepancy
HFE	Human Factors Engineering
HFEITS	Human Factors Engineering Issue Tracking System
HRA	Human Reliability Analysis/Assessment
HSI	Human System Interface
I&C	Instrumentation and Control
K/A	Knowledge and Abilities
LCS	Local Control Station

Acronym	Description
LCO	Limiting Condition of Operation
MCR	Main Control Room
MMIS	Man Machine Interface System
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N-DCIS	Nonsafety-Related Distributed Control and Information System
OER	Operating Experience Review
OATC	Operator at the Controls
PRA	Probabilistic Risk Assessment
PFRA	Plant Functional Requirements Analysis
PTS	Part-task Simulator
QA	Quality Assurance
Q-DCIS	Safety-Related Distributed Control and Information System
REP	Radiological Emergency Plan
RSS	Remote Shutdown System
RSR	Results Summary Report
S&Q	Staffing and Qualifications
SA	Situation Awareness
SAGAT	Situation Awareness Global Assessment Technique
SAMG	Severe Accident Management Guidelines
SDS	System Design Specifications
SFRA	System Functional Requirements Analysis
SRO	Senior Reactor Operator
SSC	Structures, Systems, and Components
STA	Shift Technical Advisor
TA	Task Analysis
TRACG	A GE proprietary version of the Transient Reactor Analysis Code (TRAC)
TSC	Technical Support Center
V&V	Verification and Validation

Acronym	Description
VDU	Video Display Unit

2. APPLICABLE DOCUMENTS

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

2.1 SUPPORTING AND SUPPLEMENTAL DOCUMENTS

2.1.1 Supporting Documents

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

(7) ESBWR DCD, Chapter 15, Rev 5 (26A6642BP).

(8) ESBWR Design Document Control, Chapter 18, Rev 5 (26A6642BX).

(9) NEDE-33217P and NEDO-33217, Rev 4, ESWBR Man-Machine Interface System and Human Factors Engineering Implementation Plan.

2.1.2 Supplemental Documents

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

(1) NEDO-33219, Rev 2, ESBWR HFE Functional Requirements Analysis Implementation Plan.

(2) NEDO-33220, Rev 2, ESBWR HFE Allocation of Function Implementation Plan.

(3) NEDO-33221, Rev 2, ESBWR HFE Task Analysis Implementation Plan.

(4) NEDE-33226, Rev 3, ESBWR I&C Software Management Plan Manual.

(5) NEDO-33245, Rev 3, ESBWR I&C Software Quality Assurance Plan Manual.

(6) NEDO-33262, Rev 2, ESBWR HFE Operating Experience Review Implementation Plan.

(7) NEDO-33266, Rev 2, ESBWR HFE Staffing and Qualifications Implementation Plan.

(8) NEDO-33267, Rev 3, ESBWR HFE Human Reliability Analysis Implementation Plan.

(9) NEDO 33274, Rev 3, ESBWR HFE Procedures Development Implementation Plan.

(10) NEDO 33275, Rev 2, ESBWR HFE Training Development Implementation Plan.

(11) NEDO 33268, Rev 3, ESBWR HFE Human-System Interface Implementation Plan.

(12) NEDO 33277, Rev 3, ESBWR HFE Human Performance Monitoring Implementation Plan.

(13) NEDO 33278, Rev 3, ESBWR HFE Design Implementation Plan.

2.2 CODES AND STANDARDS

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

(1) ANSI/AIAA G-035, American National Standard: Guide to Human Performance Measurements, 1992.

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

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

(4) IEEE Std.1023, Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations, 2004.

2.3 REGULATORY GUIDELINES

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

(2) NUREG/CR-6393, Integrated System Validation: Methodology and Review Criteria, 1997.

(3) NUREG/IA-0137, Study of Control Room Staffing Levels for Advanced Reactors, 2000.

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

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

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(7) Regulatory Guide 1.149, Rev. 3, Nuclear Power Plant Simulation Facilities for Use in Operator Training and License Examinations, 2001.

(8) Regulatory Guide 1.33, Rev 2, Quality Assurance Program Requirements, 1978.

2.4 DOD AND DOE DOCUMENTS

None.

2.5 INDUSTRY/OTHER DOCUMENTS

(1) Bolstad, C.A., & Endsley, M.R. (1990). Single versus dual scale range display investigation (NOR DOC 90-90). Hawthorne, CA; Northrop Corporation.

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(3) Endsley, M. R. (1988). Situation awareness global assessment technique (SAGAT). Proceedings of the National Aerospace and Electronics Conference (NAECON), 789-795. New York: IEEE.

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(16) Nullmeyer, R. T., Stella, D., Montijo, G. A., & Harden, S. W. (2005). Human factors in Air Force flight mishaps: Implications for change. Proceedings of the 27th Annual Interservice/Industry Training, Simulation, and Education Conference (paper no. 2260). Arlington, VA: National Training Systems Association.

(17) Sanders, M. S. & McCormick, E. J. (1993). Human Factors in Engineering and Design (7th Ed.) McGraw-Hill, Inc.

3. DESIGN VERIFICATION

3.1 HSI INVENTORY AND CHARACTERIZATION

The HSI inventory and characterization is created using inputs from Task Analysis, HSI Design, Software Design, and HFEITS HED resolutions. This inventory provides a listing of all HSIs and HSI characterizations. The information developed during this process is used as input to subsequent verification and validation activities.

3.1.1 Scope

All HSI components associated with the personnel tasks selected based upon the operational condition sampling process are within the scope of design verification. In addition to HSIs dedicated to control of the plant, HSIs used for interface management, navigation, and information retrieval are included in the characterized listing of HSIs to be verified.

3.1.2 Objectives

The objective of creating a characterized HSI inventory is to thoroughly and accurately describe all HSI displays, controls, and related equipment that support identified operational conditions. This characterized listing of HSIs is subsequently used to verify that installed HSIs meet their design requirements.

3.1.3 Inputs

Input from the following areas is used to create the HSI inventory:

- Task Analysis – An inventory is created containing the HSIs and HSI characteristic requirements regarding the alarms, controls, and indications needed to support tasks. Along with the stated task requirements, this inventory also contains the HSIs and characteristics that fulfill these requirements.
- HSI Design – The HSI design process develops HSI and HSI characteristics to fulfill the requirements established during TA. In addition, the HSI design process also develops the interface management characteristics of the HSI. These characteristics are added to create a comprehensive inventory.
- Software Design – The software design process develops computer software and code to fulfill the requirements established during TA and HSI design. In addition, the software design process also develops the software implementing the interface management characteristics of the HSI. The Software itself is validated in accordance with the requirements of the software quality assurance process.
- Design Engineering Documents – Input from design engineering documents consists of prints, panel drawings, system design specifications, and any other design documentation that specifies HSI design characteristics, layout, or design of the structure housing the integrated HSI.
- HFEITS – HED resolutions may require design changes, which alter the HSI and HSI characteristics. Therefore, input from relevant HFEITS HEDs is also used to ensure the creation of a complete HSI inventory.

3.1.4 Method

Inputs into the HSI inventory process are used to create a comprehensive inventory and characterization of ESBWR HSIs. The descriptions in the HSI inventory are compared to directly observed components, both hardwired and computer-generated, to verify that the inventory accurately reflects the current state of the HSIs.

The HSI inventory describes the characteristics of each HSI component within the scope of the review, including information such as:

(1) HSI unique identifier.

(2) Associated plant system and subsystem.

(3) Associated personnel functions and tasks.

(4) Type of HSI component:

  a. Computer-based control.

  b. Hardwired control.

  c. Computer-based display.

  d. Hardwired display.

(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 (identification code for information display screen).

(9) Physical location in the HSI, if applicable.

Photographs, copies of VDU screens, and/or similar samples of HSI components are included in the HSI inventory and characterization. These graphic examples of HSIs that exist only in software are used to document the displayed presence of HSIs that do not have a physical presence. The graphics are used in subsequent V&V activities to ensure that the current state of the HSI inventory forms the basis for concluding acceptability or unacceptability of the HSI design.

The characterized inventory of ESBWR HSIs is developed as shown in Figure 2, HFE Design and Task Support Verification, and uses the steps outlined below:

- <u>Task Analysis</u> – Analyzes the allocated functions generated as outputs from functional requirements analysis and allocation of function. Task analysis also specifies the required alarms, controls, and indications that must be present for the safe and efficient performance of operator tasks associated with transitioning between and monitoring the performance of functions. Where applicable, equipment characteristics such as alarm points, indication ranges, and control device capabilities are specified.

- HSI Design – Produces HSI design solutions that satisfy design engineering and task analysis requirements. HSI design solutions are developed in accordance with the HSI design process style guide and applicable regulations. As part of the HSI design process, equipment characteristics associated with the physical or software implementation of task analysis HSI requirements are defined.
- Software Design – Implements soft-control, indication, alarm, and HSI interface requirements and regulations in the computer code that operates the HSI electronics. Additional HSI characteristics defined include software code locations in the data management system and specific parameters contained in the code structure that govern the associated HSI's capabilities and display characteristics.
- HED Resolutions – Are implemented in the appropriate HFE design process shown in Figure 1, HFE process, and are analyzed as appropriate by each of the downstream HFE design processes. Final HSI design solutions resulting from HED resolutions are incorporated into the characterized inventory of HSIs.

3.1.5 Outputs and Results Documentation

The output from the HSI inventory and characterization process is a complete, comprehensive listing of all of the ESBWR HSIs and their characteristics.

3.2 TASK SUPPORT VERIFICATION

Task support verification is a process that ensures that the HSIs and their characteristics meet all of the operator task requirements as defined by the HFE task analysis process. This process also identifies any HSIs or HSI characteristics that exist but do not support tasks.

3.2.1 Scope

The scope of the task support verification applies to all of the ESBWR HSIs associated with the personnel tasks selected based upon the operational condition sampling process, and associated HSI characteristics and tasks analyzed in task analysis.

3.2.2 Objectives

The objectives of task support verification verify that:

- The HSI inventory and characterization are consistent with the HFE analyses.
- Each HSI component meets the requirements associated with a given task.
- The overall HSIs provide all alarms, information, and control capabilities required for operator tasks.
- No unnecessary components are present in the HSI design.
- Any human engineering discrepancies identified during the verification are documented and entered into the HFEITS as an HED.

3.2.3 Inputs

Input from the following areas is used to perform task support verification:

- Task Analysis – An inventory is created containing the HSIs and HSI characteristic requirements regarding the alarms, controls, and indications needed to support tasks. Task analysis develops each task inventory of HSIs in the context of a sequential process that shifts the system being manipulated from one function to another. HSIs are grouped by task in task analysis and are an input to the task support verification.
- List of categorized HSIs – Individual HSIs that have been verified to individually meet design requirements, regulatory requirements, and the ESBWR style guide input into the task support verification process. These individual HSIs are then verified as a task based group.
- Style guide – Provides a standard for implementing HSI design requirements that ensures consistency across different aspects of the ESBWR alarm, indication, and control system. The HFE design requirements for task based grouping and presentation of HSIs inputs to the task support verification.

3.2.4 Method

Task support verification compares the HSIs identified during the detailed analysis of a task to the list of characterized and verified HSIs to ensure that all HSIs needed to safely and efficiently complete the task are present in the final design.

3.2.4.1 Task Support Verification Criteria

HSI criteria identified in task analysis that are verified include:

3.2.4.1.1 Task Level

HSIs identified as part of the task prerequisites and that include:

- Task objective is available to be placed in service.
- End state of the task has been accomplished.
- End state of the task has achieved the desired results.
- End state of the task is no longer needed and can be terminated.

3.2.4.1.2 Steps within a Task

HSIs identified during analysis of:

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- Each human step.
- Each step in automation sequences.
- Step success criteria.

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- Communication requirements.

Task support verification performers verify that all of the HSIs identified in task analysis for a given task are present in the design and have been verified in HFE design verification to meet all applicable HFE, task analysis, style guide, regulatory and other requirements.

3.2.4.1.3 General Design Principles for HSI Resources

General HFE principles are established to guide the design of the HSI resources and their interrelationships and to serve as HSI task support verification criteria. These principles are:

- Human-centered design
- Minimize change to operator responsibilities
- Technology optimization to improve operator support
- Uniformity of design

These four principles serve as the HFE task support verification criteria for the HSIs that support tasks. Each principle has varied effects on the design of the individual HSI resources. Also, each principle has an important role in the design of each resource, and provides a foundation for the design basis of that resource.

Human-Centered Design

Control room resources are designed to support the operator. Support of the operator to control and monitor the plant is the primary objective of each resource. All aspects of the design basis of the HSI resources are derived from this need to support the operators.

To provide adequate task support, the HSI must support four major cognitive activities:

- Detection and Monitoring/Situation Awareness - Operators monitor plant parameters to understand the plant state. This includes active monitoring guided by procedures or a supervisor, and passive monitoring, such as board or display scanning. It also includes monitoring to support awareness of the goals and activities of other agents, both people and machines.

  In abnormal or emergency situations, operators are alerted to a disturbance that leads to monitoring of plant parameters to identify what is abnormal. Detection and monitoring are initially driven by a cue that something is abnormal. In an attempt to understand the proper context for an abnormality, operators assess the overall status of the plant, addressing questions such as:

  – Where is the mass in the system?

  – Where is the energy in the system?

  – What is the reactivity?

  – What critical safety functions have been violated?

  Based on the results of these monitoring activities (active, passive, and abnormal/emergency situations), operators develop an awareness of plant state.

- Interpretation and Planning - The most critical components of decision-making are correct situation assessment and identification of the most appropriate response plan (procedure), given the current state of the plant. In some cases, identification and procedure selection are straightforward. In other cases, operators may have to integrate multiple information sources for correct situation assessment and make tradeoffs among operational goals. The ESBWR HSI is designed to support both rule-based and knowledge-based performance.

  The process of initial allocation of functions to human and automated sources, and later coordination of tasks (goals to be addressed) is included in the interpretation and planning area of the model. The HSI model makes explicit the monitoring of goal achievement, which is a means to assess how well each operator or automated system is progressing.

- Control - Control involves decisions in the initiation, tuning, and termination of plant processes. Control is simpler for operators when they control the pace of an event. Control becomes more difficult when multiple individuals or autonomous systems must be coordinated to execute a task. With these considerations taken into account, the ability of the operators to effectively control the plant through the use of the designed HSI is considered to be a part of the HSI task support requirements.

- Feedback - Feedback occurs at several levels. Initially, operators need to verify that the control is executed by verifying that the plant components have changed state as expected. Second, operators need to monitor the state of plant parameters and processes to determine whether the actions are having the intended effect. The final, and most critical, level of feedback is determining if the operational goal is achieved.

Minimize Change to Operator Responsibilities

Thorough operational analysis ensures that the responsibilities of each member of the operations crew are well established. These responsibilities have been defined in the context of the plant's administrative protocols and technological limitations. There are two concerns related to this principle:

- Because the MCR is a focal point for day-to-day activities, changing the role of the operators can have unintended impacts on activities inside and outside the MCR.
- Changing the role of an operator within the crew can have unintended impacts on operating procedures and communication protocols during all plant activities.

By keeping the role of each operator the same, these two potential impacts can be controlled.

Taking Advantage of Technology to Support Operators

Technological advancements adopted for the ESBWR are significant and are a primary driving force for design of ESBWR HSIs. The advancements are used in a way that improves the support of each operator. The additional burden on the operator to manage the technology in the course of performing normal responsibilities is considered with the advantages provided by the technology to ensure that the resulting design is as good as or better than predecessor control room design.

New technologies require new skills, and it is important that an operator not be distracted from his/her responsibilities of operating the plant by overly complex data access or non-intuitive data organization. This important aspect of the ESBWR design ensures that full advantage of the new technologies can be realized. The following criteria are used to ensure well-organized, easily accessible data:

- The plant itself is used as a model for the organization of the data.
- Ergonomic principles are applied as an integral part of the design.
- A uniform HSI design is applied to the extent possible within the technologies and products used.

Uniformity of Design

HSI resources appear in common forms throughout the ESBWR control centers – main control room, local control stations, remote shutdown, technical support center, and the emergency operating facility. This principle ensures that an operator's expectations for use of a resource are consistent and that he/she does not need to develop special knowledge for non-standard designs.

The design of an HSI resource is consistent from workplace to workplace across the MCR and ESBWR plant facilities. Between HSI resources, the design is consistent to the extent possible within the bounds of the technology and products used and to the extent that the individual functions of the HSI resources are similar.

One example of the uniformity of design principle is the use of coding like colors across the HSI resources and within a given resource. Guidelines and specifications defining the use of colors are provided to ensure a consistent application.

Uniformity of design criteria also extends to implementation features of the HSI design. Maintenance and system engineers and technicians are not expected to develop exceptional knowledge for specific instances of an HSI resource. As the system matures in its design life, there is a risk that such exceptions can be a source of errors by systems and maintenance personnel that result in the degradation of the HSI resource's performance. Uniformity in the equipment design ensures that the plant maintenance personnel can maintain familiarity with the equipment.

3.2.4.2 Evaluation

The HSIs and their characteristics (as defined in the HSI inventory and characterization) are compared to the personnel task requirements identified in the TA. For each task, the requirements of the HSI are compared to the characteristics of that HSI.

The HFE design team utilizes one or more of the following methods to evaluate the task support capabilities of the HSI:

High-Fidelity Part-task and Full Scope Simulators

High-fidelity part-task and full scope simulators are used to verify that the HSIs required for the task being evaluated are present and grouped in keeping with HFE, regulatory, and style guide requirements. Simulators that meet ANSI 3.5 fidelity requirements for the HSIs being evaluated and any adjacent equipment or features that might impact the usability of the HSIs being verified are used.

ESBWR Control Room/Panel Design Drawings

ESBWR control room/panel design drawings are used to verify that the HSIs required for the task being evaluated are depicted on the design drawings and that the design and grouping align with HFE, regulatory, and style guide requirements.

Computer Generated Displays

Computer generated displays are used to verify that HSIs required for the task being evaluated are present on HSI screens and that the design and grouping align with HFE, regulatory, and style guide requirements.

3.2.5 Outputs and Results Documentation

The primary output of the task support verification process is groups of HSIs that have been verified to support the tasks they were designed to implement in accordance with HFE principles, regulations, and the style guide.

Additional outputs include deficiencies and unnecessary components identified and documented as HEDs. Documentation includes the HSIs involved, the task criteria, and the basis for any identified deficiencies. A HED is logged into the HFEITS if any of the following exist:

HSI Component Deficiencies

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

- Unsupported tasks: a required control, display, or alarm needed for task performance is not available.
- Partially supported tasks: HSI characteristics do not fully meet requirements (e.g., poor real-time response and feedback when using a manual/auto controller or inadequate pushbutton tactile feedback).
- HSI characteristics that 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).

Unnecessary HSI Components

Unnecessary HSIs introduce clutter and can distract personnel for the selection of appropriate HSIs. An HSI component is considered unnecessary if it is determined not to be required for any personnel tasks.

3.3 HFE DESIGN VERIFICATION

HFE design verification evaluates implemented HSI designs using the criteria and requirements contained in the ESBWR HSI style guide and the characterized list of HSIs. This verification ensures that the implemented design complies with HFE design principles.

3.3.1 Scope

HFE design verification applies to:

- HSI features:
  a. Detailed (individual HSI not addressed by general HFE guideline).
  b. Standardized (display screen organization, display format conventions, coding, etc.).
  c. Global (layout, workstation configuration, lighting, noise, etc.).
- Panel anthropometrics.
- Interface management features such as navigation and data retrieval.

3.3.2 Objectives

The objective of HFE design verification is to verify that the implemented HSI component design and environment conform to the HFE guidelines, standards, and principles reflected in the ESBWR HFE style guide.

3.3.3 Inputs

Input from the following areas is used to perform HFE design verification:

- Implemented ESBWR HSI – Implemented HSI designs as represented in part-task or full scope simulators. If available, the as-built control room or site-specific training simulator may be used.
- List of categorized HSIs – Individual HSIs that have been verified to individually meet task requirements, design requirements, regulatory requirements, and the ESBWR style guide.
- Style guide – Provides a standard for implementation of HSI design requirements that ensure consistency across different aspects of the ESBWR alarm, indication, and control system. The HFE design requirements contained in applicable regulations are met through compliance with ESBWR HSI style guide criteria.

3.3.4 Method

Implemented HSI designs are compared to applicable criteria to verify compliance. Any instances of noncompliance are documented as HEDs.

3.3.4.1 Criteria

The applicable NUREG-0700, Rev 2 criteria for HSI design are contained in the ESBWR HFE style guide. ESBWR design specific criteria are contained in the characterized list of ESBWR HSIs. HFE design verification criteria covers the following design aspects:

- Individual HSI meet design requirements and criteria.
- HSI characteristics meet requirements for overall plant consistency.

- HSI consistently incorporate HFE design requirements in displays containing plant level, system level, and other information. Integrated design features result in an intuitive process for maneuvering on and between screens for operator tasks.
- Room layouts and panel configurations meet HFE requirements.
- MCR, RSS, and risk significant LCS areas meet environmental requirements needed to accomplish tasks identified through the HFE process.
- The HSI designs account for human factors characteristics and capabilities.

3.3.4.2 Evaluation

The designed HSIs and their characteristics (as defined in the HSI inventory and characterization) are compared to the installed HSIs. For each HSI feature, requirements are compared to the characteristics of the installed HSI.

High fidelity part-task and full scope simulators are used to verify that the HSIs required for the task being evaluated are present, correctly implemented, and grouped in keeping with HFE, regulatory, and style guide requirements. Simulators that meet ANSI 3.5 fidelity requirements for the HSIs being evaluated and any adjacent equipment or features that might impact the usability of the HSIs being verified are used.

HSI Components

Installed HSIs and their characteristics are compared to designed HSIs and characteristics (as defined in the HSI inventory and characterization) to verify that installed HSIs comply with design requirements, which in turn comply with regulation and style guide requirements.

Part-task and full scope simulators are used to compare increasingly complex and integrated HSI characteristics against the characterized HSI inventory list and style guide requirements. Most standardized and detailed HSI features are verified in this way.

Integrated HSI and Local Environment

Installed groups of HSIs, panels, and the control room layout and environment are compared to design requirements to verify that installed integrated HSIs comply with the design, which in turn complies with regulation and style guide requirements.

Part-task and full scope simulators are also used to verify that physical control room layout conforms to HFE guidelines by demonstrating sight lines, workspace arrangement, and operator activity patterns during procedure and event walk/talk-throughs. In this way, global features and some standardized HSI features are verified.

The verification of global HSI features, such as environmental aspects (lighting, noise, heating, ventilation), MCR layout, and general workstation configuration, is accomplished by comparing style guide criteria to the global attributes of the full scope simulator. Some global features may require construction of an actual ESBWR control room before they can be verified.

Static anthropometric evaluation verifies the adequacy of the HSI anthropometric design features and documents any identified HEDs in HFEITS for tracking and resolution. Verification uses simulator versions of the MCR and RSS panels to verify that control room anthropometric conditions are suitable for the intended population of operators.

Anthropometrics

Full anthropometric evaluation is performed on the panels and workstations during HFE design verification to ensure compliance to anthropometric guidelines contained in the ESBWR HFE style guide and NUREG-0700, Rev 2. This includes the following evaluation areas:

- Reach and accessibility of control devices
  - Control position
  - Control grouping
- Visibility of indications
  - Visibility during control manipulation
  - VDU viewing distance
- Seating comfort
  - The relationship of working surface height and area, knee room, and chair height allows users to work comfortably
  - Seat adjustability

Measurements are taken using tape measures, electronic distance measuring devices and/or calibrated anthropometric tools to verify that the measurements and physical characteristics of the panels and workstations conform to the applicable regulatory and HFE style guide dimension criteria and can accommodate the 5th percentile female and the 95th percentile male, as defined in Table 11.1 of NUREG 0700, Rev 2.

For example, to verify display height and orientation, all displays, including alarm indicators, should be within the upper limit of the visual field of the 5th percentile female and the lower limit of the 95th percentile male.

3.3.5 Outputs and Results Documentation – HEDs

The primary output of the HFE design verification process is installed HSIs that have been verified to properly implement the ESBWR design in accordance with HFE principles, regulations, and the style guide.

Additional outputs include any instances of noncompliance, full or partial, from accepted HFE guidelines documented as HEDs. HEDs involving standardized features are evaluated further to identify potential discrepancies across HSIs with similarities in the standardized characteristics. For example, identifying an inappropriate format for presenting data on an individual display could be a sign that other display formats could be incorrectly used or that the observed format is inappropriately used elsewhere.

If some HSI characteristics or anthropometrics cannot be fully verified during HFE V&V, the process is extended to the plant itself, and accomplished during design implementation, as described in NEDO-33278, Rev 2, ESBWR Design Implementation Plan. For these instances, the V&V team describes the verification to be performed, indicates the style guide and regulation criteria, and documents the requirement in the V&V results summary report and in the HFEITS.

4. OPERATIONAL CONDITIONS SAMPLING

The purpose of the operational condition sampling process is to ensure that a broad and representative range of operating conditions is included in the sample population of integrated system validation scenarios. To ensure a representative sample that emphasizes safety significance, risk, and challenges to the operating crew, a weighted list of operational conditions is developed.

4.1 SCOPE

The scope of the operational condition sampling process is the full range of conditions that are representative of the events that could be encountered during operation of the ESBWR. Using the structured and risk informed process described below, a representative sample set of operation conditions is selected and then used as the basis for integrated system validation scenarios.

4.2 OBJECTIVES

The objective of the operational conditions sampling process is to identify a sample of operational conditions that includes conditions from a representative range of events. These conditions reflect characteristics expected to contribute to performance variation and take into account the safety significance of HSI components.

4.3 INPUTS

Input from a variety of different areas is used to perform operational conditions sampling. Areas of input for include:

- HRA/PRA – Used to determine risk significant scenarios and risk significant human actions and also to weight scenario selection criteria.
- Task Analysis – Indicates areas of high workload, high stress, or the presence of a critical task.
- Normal, abnormal, and emergency procedures and SAMGs.
- ANSI/ANS-3.5 Nuclear Power Plant Simulators for Use in Operator Training and Examination – Provides operational conditions used for simulator fidelity verification that also merit consideration for inclusion in integrated system validation scenarios.

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- HED resolutions that warrant inclusion in or re-performance of integrated system validation scenarios.

4.4 METHOD

4.4.1 Establish Sampling Dimension Criteria

The ESBWR operational condition sampling process occurs in four major phases:

- Define the weighting factors used in integrated system validation scenario selection.

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- Develop a representative population of operational conditions and tasks used in the selection integrated system validation scenarios.
- Perform weighted selection of scenarios from the defined population used to validate the integrated ESBWR systems and their controls.

4.4.1.1 Weighting Factors

The scenario selection process uses multidimensional selection criteria to identify integrated system validation scenarios that maximize relevance and significance while ensuring all operational condition diversity is met. To accomplish this, the following weighting factors are used to sort scenarios (list presented in order of lowering weight):

- HRA/PRA significance of the event scenario.
- Presence of HRA/PRA risk significant human actions.
- Presence of D3 credited human actions.
- Task analysis results indicating high workload, high stress, [[
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These factors are used later in the process to select the most significant and relevant scenario when analysts encounter situations where more than one scenario can be used to validate the same operational conditions.

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4.4.1.3 Representative Population of Operational Conditions and Tasks

In order to develop a satisfactory multidimensional sampling of conditions resulting in the selection of integrated system scenarios that thoroughly evaluate the ESBWR design, one or more operational conditions or tasks representing each of the following are identified:

Plant control

- Design basis accidents identified in the ESBWR DCD.
- Additional risk important scenarios within the scope of the EOPs and SAMGs.
- License basis document abnormal operational occurrences.
- Additional risk important abnormal events and transients within the scope of AOPs.
- Additional risk important equipment degradations and failures within the scope of ARPs.
- Normal plant operating manipulations ranging from cold shutdown/refueling to full power operations.

Personnel tasks

- Human actions identified in the HRA/PRA, DCD, and the NRC safety evaluation report as being risk significant.
- Historically problematic tasks as identified in the operating experience reports generated using the ESBWR operating experience process.
- Procedures from each class used in the operation of the plant including administrative, emergency, abnormal, alarm response, general operating, system operating, surveillance and testing, maintenance, chemistry control, and radiation control (those portions involving the MCR, RSS, or risk significant LCS).

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- Tasks representing a broad range of human cognitive activities. Tasks in this population are those that analysts identified as containing the following attributes as in the response requirements portion of detailed task analysis.
  - Detection and monitoring.
  - Diagnosis and situation assessment.
  - Decision making and planning.
  - Plant manipulation.
  - Monitoring plant response.
- Tasks involving a range of human interactions and communications as identified in the ESBWR task analysis. Tasks in this population are those that analysts identified as containing communication interactions between the primary task performer and other personnel.
- Tasks performed with high frequency as identified in the ESBWR task analysis. [[

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Situational factors

- Operationally difficult tasks as identified in the operating experience reports generated using the ESBWR operating experience process.
- Scenarios specifically designed to generate human errors. This allows evaluation of error tolerance and error recovery.
- Scenarios performed with varying crew sizes. Variance between minimum and nominal crew size as discussed elsewhere in this document.
- Instances of high workload as identified in the ESBWR task analysis. Tasks in this population are those that analysis identified as high workload in the workload determination portion of the detailed task analysis.
- Instances of varying workload. Tasks in this area can vary by their nature (e.g., a scram during normal operations, or the cessation of work following the shutdown of a system the crew is controlling), or may vary due to sequencing high and low workload tasks.
- Fatigue and circadian factors. Tasks in this population are those performed with crews that are fatigued and off their normal circadian sleep cycles.
- Environmental factors such as poor lighting, high noise, radiological contamination, or other factors such as operator physical position identified in the ESBWR task analysis. [[

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4.4.1.4 Weighted Selection of Integrated System Validation Scenarios

Scenarios are selected from the representative population that together fulfills all of the minimum condition and task requirements. When more than one scenario can be used to validate an operational condition or task, the scenario with the highest multidimensional weight is selected.

The scenario selection process uses multidimensional selection criteria to identify integrated system validation scenarios that maximize relevance and significance while ensuring all operational condition diversity is met. To accomplish this, the following weighting factors are used to sort scenarios (list presented in order of lowering weight):

- HRA/PRA significance of the event scenario.
- Presence of HRA/PRA risk significant actions.
- Presence of defense-in-depth and diversity (D3) credited human actions.
- Task analysis results indicating high workload, high stress, or the presence of a critical task.

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4.4.2 Scenario Identification and Development

Integrated system validation scenarios that exercise the selected operational conditions are developed using a structured process to ensure consistency, quality, and the minimization of bias. Procedures governing the performance of the integrated system validation process contain guidance regarding the requirements for development and documentation of all scenario attributes including:

- Objectives.
- Initial conditions.
- Selecting and documenting events.
- Scenario attributes, both qualitative and quantitative.
- Determining scenario endpoint.
- Validation of the scenario itself.
- Critical task determination.

Each of the major activities that contribute to dynamic simulator scenario development is completed in accordance with the ESBWR simulator scenario development guide and is summarized below.

4.4.2.1 Identifying Scenario Objectives

Scenarios are assigned a predetermined set of specific objectives based upon the events that take place during the scenario and the attributes, abilities, procedures, and training to be validated. The basic objective of the scenarios is to evaluate the operators' ability to effectively use the ESBWR HSI to respond to the event being simulated. Specifically, each scenario validates the attributes of the associated HSIs and procedures, and the operators' training experiences with them, through observations of:

- Operator knowledge of integrated plant operations (gained through training).
- Operator ability to use the integrated HSI to gather and validate indication and plant performance data.
- Operator ability to diagnose abnormal plant conditions.
- Operator ability to formulate mitigation strategies.
- Operator ability to locate and use the appropriate procedures.
- Operator ability to use the integrated HSI to implement the chosen mitigation actions.
- Operator ability to effectively communicate within the control room environment.

Additionally, each scenario contains objectives specific to the operational conditions and events that are contained in it, including:

- Validation of the ability to meet event and scenario acceptance criteria.
- Validation of the ability to meet supplemental event and scenario criteria.

4.4.2.2 Initial Conditions

Scenarios are assigned a predetermined set of initial conditions established to allow the simulated scenario to commence realistically. The initial conditions are representative of typical plant status that would exist in the ESWBR at the time in the plant operating cycle in which the scenario is to take place. Additional initial conditions are included for realism and may include tagged out components or systems, in-progress maintenance, or testing. To eliminate predictability, some initial conditions that have no bearing on subsequent scenario events are included. Specific initial conditions that are to be covered in the scenario shift turnover are identified.

4.4.2.3 Selecting and Documenting Events

After initial conditions are established, a sequence of events designed to achieve the scenario's objectives is developed. Each event either directly supports or contributes to the support of one or more objectives. Scenarios are developed so that various systems are affected by each type of event, such as:

- Degradation or failure of instruments, controls and components.
- Major plant transients and accidents.
- Normal plant maneuvering.

Realistic conditions limit the predictability, recognizability, and potential bias from operator expectations of scenario event timelines. Some scenarios incorporate equipment failures that cause or exacerbate problems in other systems. This practice allows validation of the operators' understanding of system and component interactions, integrated system operations, and the integrated HSI performance across a broad range of conditions.

Scenarios are not a series of totally unrelated events. Integrated system validation scenarios are designed to flow from event to event, giving operators sufficient time to:

- Analyze what has happened.
- Evaluate consequences of action options.
- Evaluate consequences of inaction.
- Assign priorities to the event based upon current plant conditions.
- Determine a course of action.
- Implement the actions.
- Observe and evaluate the plant's response.

Scenario designers pre-determine each planned operation, malfunction, and transient and document them as a scenario timeline.

Scenario documentation includes:

- Event descriptions.
- How and when the event is initiated.
- A listing of the event cues, indications, and symptoms that are available to operators.
- Expected actions to be taken.
- Expected communications.
- Procedures to be used.

- Scenario endpoint.
- Required operator actions to be observed, including any critical tasks contained within the scenario.
- Other variable actions and behaviors that provide useful basis for evaluating operator and integrated HSI performance.

4.4.2.4 Scenario Attributes, both Qualitative and Quantitative

Integrated system validation scenarios are constructed to accurately test:

- Each individual operator's abilities and skills.
- Crewmember's team dependent abilities and skills.
- The integrated HSIs support of safe and efficient operation.
- Procedures.
- Staffing and qualification criteria.

Each scenario is of sufficient length, scope, and complexity to allow differentiation between acceptable and unacceptable performance. Scenario attributes consist of both qualitative and quantitative elements. Experienced scenario developers use scenario attributes to both construct and assess the quality of ESBWR integrated system validation scenarios. This assessment, combined with scenario validation, ensures the scenario is an acceptable tool to validate the integrated HSI and crew operating it. The following attributes used to develop and assess scenario acceptability are described in greater detail in the ESBWR Scenario development procedures:

Scenario Qualitative Attributes

- <u>Realism/Credibility</u> – Initial conditions, external communications, plant response, and other similar scenario details are sufficiently similar to actual plant performance that the crew performance observed is representative of what is expected in an operating ESBWR.
- <u>Event Sequencing</u> – Event sequencing supports the scenario objectives. The order of events can affect complexity and some events build upon the aftermath of others. Additionally, some scenario objectives may seek to validate the crew's ability to respond to simultaneous events.
- <u>Simulator Modeling</u> – The simulator model used in the scenario retains its ANS-3.5 fidelity and is not altered simply to derive the desired scenario results.
- <u>Evaluating Competencies</u> – Scenarios are of sufficient duration, complexity, and diversity that the competencies and attributes validated during the scenario can be adequately assessed.
- <u>Level of Difficulty</u> – Scenarios are sufficiently difficult to adequately validate that the integrated HSI and the crew's ability to safely and efficiently meet the scenario objectives. Scenarios that are too easy or too difficult are not effective discriminators.

Scenario Quantitative Attributes

- Normal Evolutions – To meet the objective of validating the integrated HSI and its use, a sufficient number of normal system manipulations are incorporated in the scenario.
- Number and Sequence of Malfunctions – The number of equipment malfunctions incorporated into the scenario and the sequence in which they are presented varies between scenarios and validates response to both minor inconveniences and loss of significant safety equipment and indications.
- Abnormal Events and Major Transients – The number, severity, and sequence of abnormal and major events adequately exercises the areas contained in the scenario validation objectives. The abnormal and major transients contained in the scenario meet the objective of validating the integrated HSI and its use.
- EOPs and Contingencies Used – The scenario is constructed to fully exercise any EOPs or contingencies designated as validation objectives for the scenario. The EOP exercises contained in the scenario meet the objective of validating the integrated HSI and its use.
- Total Run Time – Typical scenario run time is approximately 60-90 minutes though some scenarios may require either more or less time based upon their content. The scenario duration is sufficient to meet the objective of validating the integrated HSI and its use.
- Critical Tasks – The number of critical tasks contained in a scenario and scenario difficulty varies. The scenarios are adjusted to ensure that they are neither so easy nor so difficult that they are not valid measures of performance. Scenario critical tasks and difficulty are sufficient to meet the objective of validating the integrated HSI and its use.

4.4.2.5 Determining Scenario Endpoint

A scenario endpoint is selected and documented. The endpoint specified identifies a particular plant condition, procedural step, plant parameter, or other clearly recognizable condition. The endpoint parameter is specifically selected to allow completion of all scenario objectives prior to scenario termination.

4.4.2.6 Validation of the Scenario

The structure, timeline, flow, and all other aspects of integrated system validation scenarios are validated prior to use of the scenario in ESBWR V&V. Scenario validation ensures that the scenario runs as intended and that supporting scenario development and execution materials are accurate.

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4.4.3 Measures Taken to Eliminate or Control Bias

Bias represents any influence, condition, or set of conditions that singly or together distort the data. Bias can produce systematic (but unexpected) variation in a research finding, and can invalidate any conclusions made based on a biased sample. Therefore, when selecting operational conditions and developing scenarios, care must be taken to avoid creating a biased sample.

Qualified test personnel control scenario bias through a number of means. These include:

- Procedurally controlled scenario development and validation process.
- Ensuring validation tests are performed using scenarios that are developed by selecting from the full range of operational conditions, and that cover a representative range of conditions.
- Scenario validation, which includes an evaluation of scenario attributes and their distribution.
- Pilot studies to identify possible sources for scenario bias and for developing controls.
- "Backcasting"- Part of the scenario identification and development process that involves identifying a future state (both desirable and undesirable) as identified in SAMGs, EOPs, AOPs, ARPs, and normal operating conditions. It also involves constructing paths that connect the specified end condition to the conditions and actions required to achieve or avoid it.

  This approach reduces the risks of hidden bias in construction of scenarios. By selecting both desirable and undesirable outcomes, and by developing scenarios with conditions and events that vary the likelihood of reaching the outcome, a representative and balanced set of scenarios is identified.

After scenario development is complete, the resulting set of scenarios is evaluated to identify selection bias in any of the following areas:

- Scenarios for which only positive outcomes are expected – This is avoided in part by selecting operating conditions for use in scenarios that are identified in the HRA/PRA as risk important, risk important accident scenarios within the scope of EOPs and SAMGs, and conditions known to challenge human performance. This type of bias is also avoided by following the "backcasting" methodology.

- Scenarios that are relatively easy to conduct administratively (scenarios that place high demands, data collection or analysis are avoided) – Scenarios are developed that best accommodate all of the selected tasks and conditions and not just those scenarios that are the easiest to conduct.
- Scenarios that are familiar and well structured (e.g., those which address familiar systems and failure modes that are highly compatible with plant procedures such as "textbook" design-basis accidents) – Because scenarios are developed from selected operational conditions, and because event sequencing is built in as part of scenario definition, it is not expected that scenarios will follow highly familiar sequences.

If development bias is detected, scenarios are analyzed for alternatives to create a more fair and representative range of events. Any occurrences of significant sampling bias are logged as HEDs in the HFEITS for tracking and resolution.

4.5 OUTPUTS AND RESULTS DOCUMENTATION

The output of the operational condition sampling process is a group of simulator scenarios that thoroughly evaluates the ESBWR design.

5. INTEGRATED SYSTEM VALIDATION

Integrated system validation is the performance-based evaluation of the integrated HSI design. Simulations are used by plant personnel to demonstrate successful task performance during operational events to validate the ability of operators to use the integrated HSI to support safe plant operations. Validation is intended to evaluate the acceptability of those aspects of the design that cannot be evaluated through analytical means (e.g., task support or HFE design verification activities). Integrated system validation is performed using high-fidelity simulators.

Discrepancies identified during previous verification activities are corrected prior to integrated system validation to prevent unwanted impact on the integrated validation results.

5.1 SCOPE

Validation activities apply to the integrated systems and use the selected tasks, conditions, and scenarios in a simulator to test crew performance. Performance is measured in terms of the plant, personnel tasks, crew communications and coordination, situation awareness, workload (both cognitive and physical), and anthropometric and physiological factors.

5.2 OBJECTIVES

The objectives of the validation activities are to validate:

- The role of plant personnel.
- Adequacy of procedures.
- Shift staffing, assignment of tasks to crewmembers, and crew coordination (both within the control room as well as among the control room and local control stations and support centers) are acceptable. This includes validation of nominal shift levels, minimal shift levels, and shift turnover.
- Automation functions (allocation of functions and the degree of task dependence on procedures).
- Adequacy of the integrated HSI configuration for achieving HFE program goals consistent with HFE guidelines, principles, and methods.
- Adequacy of the HSI to support the crew in accomplishing critical functions and tasks. For each task, the design provides adequate alerting, information, control, and feedback capability for human functions performed under normal plant evolutions, transients, design-bases accidents, and selected, risk-significant events that are beyond-design basis.
- The effect of HSI characteristics on operator workload.
- The crew is able to make effective transitions between the HSIs and procedures during accomplishment of their tasks and that interface management tasks such as display configuration and navigation are not a distraction or undo burden.
- The HSI facilitates efficient search and retrieval of information and controls.

- Specific personnel tasks are accomplished within time and performance criteria, with a high degree of operating crew situation awareness, and with acceptable workload levels that provide a balance between a minimum level of vigilance and operator burden.
- HSIs minimize operator error and provide for error detection and recovery capability when errors occur.
- The integrated system is tolerant of human error, system faults, and failures of individual HSI features.
- Human performance assumptions in HRA/PRA.

In addition to these objectives, integrated system validation is also used to identify any additional aspects of the integrated system that may negatively impact integrated system performance.

5.3 INPUTS

Input from the following areas is used to develop and implement integrated system validation tests:

- Operational Conditions Sampling – This process selects the set of testing scenarios employed during integrated system validation. The scenario selection process uses multidimensional criteria to identify integrated system validation scenarios that maximize relevance and significance while ensuring operational condition diversity.
- HSI Inventory and Characterization – The inventory of HSIs and HSI characteristics is used as input when developing validation testbeds. The inventory is also used to verify that the HSIs in validation testbeds are complete and have the appropriate fidelity for the scope of the integrated system test being performed.
- Procedures – Procedures define how a crew should respond to the conditions and events presented during integrated validation testing scenarios. The ability of the crew to select and successfully carry out the correct procedures within the integrated system plays an integral role in the validation of that system.
- Training – Training provides an input to integrated validation by determining the level of knowledge and skills that the operating crews possess during validation testing.
- HFEITS – HED resolutions are implemented in the appropriate HFE design process shown in Figure 1, HFE Process and are analyzed as appropriate by each of the downstream HFE design processes. Final HED resolutions are validated within the scope of the integrated system, and therefore provide input as to what beyond the specified tasks and conditions must be tested.

5.4 METHOD

During integrated system validation testing, test participants are subjected to a set of scenarios run on a simulator with the appropriate fidelity for the scope of testing. [[

]] Test participants are not told what particular scenario will be simulated. Test personnel observe the simulated exercise and document crew performance. Debriefings, structured interviews, and questionnaires are administered after the simulated scenarios. Post-scenario information is used to supplement video recordings and visual observations.

5.4.1 Testbeds

Use of Simulators in Integrated System Validation

Part-task simulators (PTS) and full scope simulators (FSS) lacking in high fidelity (failing to meet the requirements of ANSI 3.5 and Reg Guide 1.149 for the systems tested) cannot be used for formal integrated system validation. Such simulators are used for other testing or data gathering activities that do not require a high fidelity simulator.

The simulator testbeds used to perform integrated system validation must provide the fidelity required for the validation being conducted to be meaningful and valid. Demonstrating that a testbed meets the requirements of ANSI 3.5 and Reg Guide 1.149 provides assurance of high fidelity in accordance with common industry and regulatory standards and definitions.

Integrated system validations of limited scope (e.g., testing the integrated system controlling control rod movement) may be performed on a part-task simulator that meets ANSI 3.5 and Reg Guide 1.149 fidelity requirements for the systems that affect the validation scenario.

Integrated system validations whose scope is the complete integrated HSI are performed on a high fidelity full scope simulator that meets the requirements of ANSI 3.5 and Reg Guide 1.149

Validation Testbed Requirements

The following testbed fidelity requirements must be met for the scope of the integrated validation activity being conducted:

- Interface Completeness – The testbed completely represents the integrated system being tested, including HSIs and procedures not specifically required in scenarios.
- Interface Physical Fidelity –The testbed represents a high degree of physical fidelity in the HSIs and procedures. This includes the presentation of alarms, displays, controls, job aids, procedures, communications, interface management tools, layout, and spatial relationships.
- Interface Functional Fidelity – The testbed represents a high degree of functional fidelity in the HSIs and procedures. All HSI functions are available within the integrated system being tested, including HSI component modes of operation.
- Environment Fidelity – The testbed represents a high degree of environment fidelity. The lighting, noise, temperature, and humidity characteristics reflect the expected plant environment to the extent practicable.
- Data Completeness Fidelity – The information and data provided to test participants completely represents the plant systems monitored and controlled from that facility.
- Data Content Fidelity – The testbed represents a high degree of data content fidelity. The information and controls presented during testing scenarios are based on an underlying model that accurately reflects the predecessor plant. This model provides input to the HSI in a manner such that the information presented during the scenario accurately depicts information that would actually be presented in a real plant.

- Data Dynamics Fidelity – The testbed represents a high degree of data dynamics fidelity. The process model is capable of providing input to the HSI in a manner such that information flow and control responses occur accurately and in a correct response time (for example, information is provided to personnel with the same delays as would occur in the plant).

Testbed Verification

To ensure that fidelity requirements are met, the testbeds are verified as matching the plant at each phase of validation testing by noting that the same software and computers used for development of the part-task simulators and full scope simulator match what is to be installed the plant. Testbed verification is accomplished during pilot tests conducted prior to validation.

To make sure testbeds accurately reflect the current design, the HSI is adjusted as the system is developed so that by the time the full scope simulator is developed the HSI design is stabilized. The software system for simulating plant behavior is upgraded as improved data becomes available for the plant sensors, controllers, and other components.

The simulators used during HFE V&V activities are described below:

5.4.1.1 Part-task Simulator

Purpose

The PTS is a tool used by the HFE group for the development and testing of HSI display screens, initial development and testing of the plant normal, abnormal, and emergency operating procedures, and the initial development of operations training material.

The PTS has the plant and system fidelity deemed necessary to allow for simulating normal plant operation, including plant heat up and startup, maneuvering at power, and plant shutdown and cool down. Additionally, the PTS simulates plant responses to design basis Abnormal Operational Occurrences (AOOs) and accidents.

On a case-by-case basis, for the systems modeled with the required fidelity, PTS can be shown to be high fidelity (in accordance with ANSI 3.5 and Reg Guide 1.149)

Properties

The simulation software contains the simulation models resulting from the initial system design of the systems deemed necessary for the PTS, and generic or simplified models of the remainder of the plant systems.

The hardware for the PTS consists of enough table/desk space and VDUs to simulate one console section of the preliminary ESBWR control room design and the required input devices and computers.

The PTS has an instructor station providing the required basic functions (establishing desired initial conditions, backtracking, snap-shot storage, and trending) as determined by the HFE group.

Scope

The PTS software contains the initial system design simulation models for the systems deemed necessary for normal plant operations and generic or simplified models as required for the remaining systems. The systems selected as necessary for the PTS include the normal BWR heat cycle and required auxiliaries, control and protection systems, and ECCS systems.

The PTS contains the initial HSIs for the plant systems and includes VDUs and input devices.

5.4.1.2 Full Scope Simulator

Purpose

The FSS is a high fidelity (in accordance with ANSI 3.5 and Reg Guide 1.149) ESBWR simulation tool used by the HFE group for the validation of the control room design, the validation of plant normal, abnormal, and emergency operating procedures, and the validation of operations training material.

The FSS is able to perform normal, abnormal, and emergency plant operations, and is ANSI 3.5 certified. Those full scope simulators that are used for training are also Regulatory Guide 1.149 compliant.

Properties

The simulation software for the FSS contains the simulation models for the ESBWR plant systems included in the detailed system design along with generic or simplified models of the remainder of the plant systems.

The hardware for the FSS consists of a full-scale mockup of the ESBWR control room.

The FSS has an instructor station providing the full functionality required for ANSI 3.5 certified training simulators.

Scope

The FSS contains the simulation models for the ESBWR plant systems.

The FSS contains the ESBWR HSI for the plant systems, including VDUs and input devices.

5.4.1.3 Site-Specific Training Simulator

Purpose

The site-specific training simulator provides a full scope simulation tool for conducting licensed operator training activities, completing control manipulations for operator license applicants, and conducting license operator operating tests.

In addition to the systems contained in the ESBWR design, the site-specific training simulator simulates site support systems and infrastructure necessary for the operation of the ESBWR. The site-specific training simulator is ANSI 3.5 certified and Reg Guide 1.149 compliant.

Properties

The simulation software for the site-specific training simulator provides the plant operational functionality and fidelity required by ANSI 3.5 certified and Reg Guide 1.149. The software for the systems simulates the detailed system design. The remaining systems are modeled either statically or using simplified models.

The hardware for the site-specific training simulator is developed using the same control room design, and the same materials and manufacturing techniques as the actual ESBWR control room hardware.

The site-specific training simulator has an instructor station providing the full functionality required for ANSI 3.5 certified training simulators.

Scope

The site-specific training simulator is an ANSI 3.5 certified and Reg Guide 1.149 compliant full scope simulator for operator training and testing.

The site-specific training simulator contains consoles and panels with the same form, fit, and feel as the ESBWR main control room.

5.4.1.4 Remote Shutdown System

The remote shutdown panel is verified in accordance with the task support verification and HFE design verification processes. Additionally, integrated system validation of the remote shutdown panel is performed utilizing a high fidelity remote shutdown panel simulator meeting the requirements of ANSI 3.5 and Reg Guide 1.149

The remote shutdown station (RSS) and its HSIs are verified in accordance with the task support verification and HFE design verification processes. All of the factors associated with RSS operations incorporated into a scenario are specified, in detail, in the scenario guide written to govern performance of the simulation. The scenario validation process verifies that cues, indications, communications, and feedback built into the scenario guide are accurate and timely. In this way, scenarios containing RSS actions are accurately rendered and support validation of the integrated system HSI.

5.4.1.5 Risk Significant Local Control Panels

Risk significant local control stations and their HSIs are verified in accordance with the task support verification and HFE design verification processes. Additionally, integrated system validations that require actions to be performed at local control stations are performed utilizing action durations, simulated feedback indications in the HSI, and communication mechanisms used in the plant. Validation of risk important local control operations is performed using simulations and mockups as needed. All of the factors associated with local operations incorporated into a scenario are specified, in detail, in the scenario guide written to govern performance of the simulation. The scenario validation process verifies that remote manual action cues, indications, communications, and feedback built into the scenario guide are accurate and timely. Thus, scenarios that contain remote actions are accurately rendered and support validation of the integrated system HSI.

5.4.2 Participant Selection

The participants selected for early validation activities using PTS can include trainers, licensed SROs, licensed operators from other BWRs, start up engineers, I&C engineers, HRA/PRA engineers and human factors engineers. The crews used during the later integrated system validation activities include people trained to become ESBWR operators and SROs. The sample of participants used in testing reflects the characteristics of the population from which the sample is drawn.

5.4.2.1 Sampling Criteria

The characteristics contributing to task performance variation are identified and taken into account during sampling to ensure that variation along those dimensions is included in integrated system validation. These characteristics are determined from operator experience and Task Analysis and include:

- License, qualifications, and shift staffing – There must be at least one SRO and one or two operators in each crew.
- Skill and experience – A range of skill and plant operating experience is included to represent the experience levels of potential population users. Operational personnel selected to participate in operational tests exhibit a mix of high and low skill levels to approximate the range of capability found in operational personnel.
- Age – The distribution of user population age is represented in the participant group.
- Population demographics – The participant subject pool is drawn from a randomly selected sample of operators representing the population demographics of operators (age, gender, ability, etc.).

5.4.2.2 Minimal and Normal Crew Configurations

During full scope simulator HSI testing, a minimum number of three crews and a minimum crew configuration of two and a normal crew configuration of three are tested. Additionally, some scenarios are conducted with the addition of a shift manager and/or a shift technical advisor.

In the full scope simulator, a normal crew of three is used to test the HSI, as determined in NEDO-33266. This crew consists of: two licensed operators and one SRO. The first operator is assigned to normal control actions at the MCR HSI. The second operator performs plant control duties as directed and is assigned to control of testing, surveillance, and maintenance activities. This crew operates the ESBWR during all phases of normal plant operation, abnormal events, and emergency conditions.

A minimal crew of two is used to test HSI capabilities in a condition in which one of the normal crew operators has become incapable of performing operating procedures due to accident, illness, etc. This crew consists of one SRO and one operator.

5.4.2.3 Prevention of Sampling Bias

Randomized sampling is used to select participants from a population representative of the plant personnel who interact with the HSI. To prevent sampling bias, the following personnel are ineligible for participation:

- Participants who are part of the design organization.
- Participants who were involved in prior design evaluations. However, participants may perform a training evaluation following ESBWR operator training.
- Participants who were selected for some specific characteristic (selecting only good or experienced crews).

5.4.3 Scenario Definition and Documentation

The integrated system validation scenarios selected during the operational conditions sampling and scenario development process are defined so that they can be performed on a simulator. Scenario definition is used to provide a consistent, objective, and high fidelity environment in which to validate performance of the integrated systems. The defined scenarios involve major plant evolutions or transients, reinforce team concepts, and identify the role each individual plays within the team.

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5.4.3.13 *Staffing Objectives*

Staffing for the performance of integrated system validation testing scenarios uses licensed personnel for crewmembers or participants enrolled in training classes for the purpose of ESBWR licensing. Crews are selected to ensure that both experienced and new operators are evaluated and provide input regarding the HSI. Test participants are not allowed to act as a crewmember in a given scenario more than once.

Scenario events and tasks that result in common problems for test participants are documented as HEDs in HFEITS to track the HFE or HSI factors that are changed to resolve the problem.

Tasks that result in the failure of the plant or crew to meet established acceptance criteria are also added as HEDs and tracked to resolution in HFEITS.

5.4.4 Performance Measures

A hierarchal set of performance measures are selected to assess the adequacy of the integrated system. The plant/system performance measures selected for integrated validation are selected based on the prevention or mitigation of transients and accidents, as described in DCD Tier 2, Chapter 15 - Transient Analysis. Tasks and events with high HRA/PRA risk significance are selected for measurement. [[ ]]

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Supplemental performance measures are developed to provide additional dimensions of information. A multidimensional approach to integrated system validation allows test personnel to view data outcomes in a richer context. This creates a greater understanding of crew performance in the varying scenario conditions, leading to more valid, well-informed conclusions and to an increased ability to diagnose and fix performance problems.

Supplemental performance measures are primarily used to provide additional information regarding the results of other performance measures. Significant problems in these areas are evaluated and addressed as well. Potential performance concerns identified in supplemental measurement areas are evaluated in the context of overall scenario performance and HEDs are written if needed. Supplemental measures include:

- Crew communication and coordination.
- Situation awareness.
- Workload (both physical and cognitive).
- Anthropometrics and physiological factors.

Satisfactory completion of integrated system validation and its associated performance measures, and criteria validates the ESBWR HSI and the context in which it is used. This includes automation, training, procedures, and staffing and qualifications.

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Procedure

During testing, crews should attend to tasks as during all other simulations, with SA questions being considered secondary. No displays or visual aids should be visible while participants are answering questions (therefore screens should be blank during testing, or test participants should be asked to turn away from screens). If participants do not know or are uncertain about the answer to a question, they are encouraged to make their best guess. If participants are not comfortable enough to make a guess, they are permitted to skip that question and go to the next question. Talking or sharing of information between participants is not permitted. All participants are queried at the same time.

During a freeze point, all screens should go blank except for one screen in a central location at each workstation. On this screen a series of situation awareness questions are presented, and the operator's type in/ select their responses.

Selecting Freeze Points

Using the established list and sequence of events occurring during each scenario, points before or after an event are identified. Selection of time points that occur during a significant event should be avoided because freezes disrupt the scenario. During a significant event, many inputs and actions occur during a short period of time. Stopping operators during busy, face-paced events changes the context of a test, thereby compromising test fidelity for other measures.

If it is determined that SA needs to be measured during a significant event, this will be done during isolated testing in which only SA is measured or using methods that do not involve freezing the scenario.

Out of the population of time points that meet the aforementioned criteria, a number of time points should be randomly selected. The number of freeze points should be proportional to the length of the scenario. No greater than two stops should be performed during a 15-minute interval. The total number of stops should be kept to the minimum needed to achieve an adequate range of situation awareness data samples. Excessive scenario freezing should be avoided in order to maintain low testing impact on operator performance and to maintain test environment fidelity.

Freezes should generally last less than two minutes, and regardless of the number of questions presented, at least five seconds should be given before a scenario is resumed after a freeze. Operators should not be aware of when exact freeze points are going to occur.

Selecting Questions

Questions given during a freeze point are relevant to the information that is available to operators prior to that freeze point. Questions should be constructed in terms of operating procedures and phrased using language standard to the nuclear industry.

Questions during each freeze point cover three different levels of situation awareness: perception of data, comprehension of meaning, and projection of the near future. Questions include how the system is functioning and system status.

Situation awareness questions reflect requirements that are developed based on information provided by TA, training, and operating procedures. These requirements indicate what information an operator needs to be aware of in order to successfully complete all of the required tasks in a scenario.

Performance Measures

The operators' situation awareness, as determined by answers to freeze point questions, are compared to situation information recorded on the simulation computers just prior to, and at the same point in time as the freeze.

Situation awareness should be measured in terms of:

- Perception of data:
  - The proportion of correct answers relative to the total amount of data requested by the freeze point questions for each scenario
    - The proportion of unanswered data questions relative to the total number of data questions
    - The proportion of incorrect answers relative to the total number of data questions
- Comprehension of meaning:
  - Awareness is adequate to correctly comprehend the meaning of the data attended to. (Yes/No)
    - Accurate or inaccurate judgment of plant/ plant system status
    - Accurate or inaccurate selection of procedure in response to data.
- Projection of the near future:
  - Awareness is adequate to correctly predict events occurring in the plant in the near future (based on data attended to and conclusions drawn from that data). (Yes/No)
    - Accurate or inaccurate selection of procedure in response to data.
    - Accurate or inaccurate prediction of plant/ plant system status in the near future.

Perceived operator information, as determined by the above analysis, should be compared to the information requirements needed to select the appropriate procedures to follow, and to successfully complete required tasks, as determined by the TA and operating procedures.

Supplemental Situation Awareness Information

Because situation awareness data using freeze points is not used during significant events, supplemental data is used to measure operator situation awareness during events.

During events, subjective SA data is gathered by test personnel using behavioral measures. Observers infer SA from the actions that operators chose to take, based on the assumption that good actions (following the correct procedure) follow from good SA and vice-versa.

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To establish reliability, each participant should be rated by more than one observer, and test personnel observations should be compared. Observed ratings can also be compared to videotapes of the test session, to confirm accuracy of observations. Observations should be recorded from locations that are unobtrusive.

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In addition, operator situation awareness levels must be high enough to obtain the information required to determine correct operating procedures. If SA is not sufficient to select correct operating procedures, validation cannot occur, and a HED is entered into the HFEITS.

For supplemental situation awareness measures, an average crew SA rating of at least 3.5 should be attained to determine that a crew is displaying adequate situation awareness. For ratings less that 3.5, a HED is entered into the HFEITS.

Beyond the aforementioned criteria, situation awareness performance is used as a supplement to better understand the results of other performance measures.

5.4.4.6 Workload

Workload represents the cost incurred by an operator to achieve a particular level of performance. Workload can be divided into two elements: physical workload and cognitive workload.

5.4.4.6.1 Physical Workload

Because of the digital nature of the ESBWR control room, physical workload is not expected to have an impact on control room operator performance. However, to ensure that physical workload does not negatively impact crew performance, physical workload evaluations are conducted during validation testing.

To evaluate physical workload impact on operator performance, video recordings and observations by test personnel are used to identify conditions that represent any of the following (number of occurrences per day are predicted using the sample of occurrences during the time frame of a scenario):

Force

- Heavy, frequent, or awkward lifting:
  - Any lift of 75 pounds or more.
  - Lifting 55 pounds or more 10 times per day.
  - Lifting 10 pounds or more 2 times per minute over 2 hours total per day.
  - Lifting 25 pounds or more 25 times per day and lift is above the shoulders, below the knees, and/or at arm's length.
- High hand force:

  - Task results in any of the following for more than 2 hours per day: pinching an unsupported object(s) weighing 2 or more pounds per hand, or pinching with force of 4 or more pounds per hand.
  - Gripping an unsupported object(s) weighing 10 or more pounds per hand, or gripping with a force of 10 pounds or more per hand.
- Repeated impact:
  - Using the hand or knees as a hammer more than 10 times per hour for more than 2 hours total per day.

Posture

- Awkward posture - tasks that results in any of the following postures for more than 2 hours per day:
  - Working with the hand(s) above the head or the elbow(s) above the shoulder(s).
  - Repetitively raising the hand(s) above the head or the elbow(s) above the shoulder(s) more than once per minute.
  - Working with the neck bent more than 45° (without support or the ability to vary posture.
  - Working with the back bent forward more than 30° (without support, or the ability to vary posture).
  - Squatting, kneeling.

Repetitiveness

- Highly repetitive motion:
  - Using the same motion with little or no variation every few seconds (excluding keying activities) for more than 2 hours total per day.
  - Intensive keying or use of mouse for more than 4 hours total per day.

Vibration

- High hand or whole body vibration:
  - Using hand tools that typically have high vibration levels more than 30 minutes total per day.
  - Using hand tools that typically have moderate vibration levels more than 2 hours total per day.

Test personnel document the type, frequency, and context of high physical workload occurrences. To determine weight, vibration, and other environmental characteristics that impact workload, measurements may be taken by test personnel before or after a scenario. Measurements are conducted in a manner that does not interfere with simulator testing activities.

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5.4.4.6.1.2 Acceptance Criteria

Ergonomics rules established by the State of Washington Department of Labor and Industries provide the basis for determining acceptable workload.

Due to the digital nature of the ESBWR control room, significant heavy lifting, high hand force, repeated impact, or high hand/ whole body vibration aspects of physical workload should not have significant impact or should not be applicable. Other aspects of physical workload, such as posture and repetitive motion, may be significant factors in a digital control room.

Any observations of physical workload occurrences that exceed the aforementioned criteria are documented as HEDs in the HFEITS.

5.4.4.6.2 Cognitive Workload

Mental or cognitive workload refers to the information processing resources required of an operator in achieving task goals. Because excessive cognitive workload is associated with decreased situation awareness and decreased ability to perform safety significant tasks, knowledge of an operator's mental workload is required to ensure that it is within acceptable limits. Because of the relationship between cognitive workload and situation awareness, both measures are evaluated in the context of one another.

Selecting Tasks

TA is an important component of workload measurement. TA is used to determine the critical tasks requiring workload assessment. As such, the results of the operational analysis, including TA is used as a screening mechanism by which tasks, scenarios, and situations can be meaningfully selected for cognitive workload assessment.

Tasks known to be free from time pressure, complicated evolutions, and/or considered failsafe, along with other predetermined parameters are screened and eliminated from cognitive workload assessment.

Then, tasks are chosen that may have the possibility of error, burden the operator, have associated time pressures or other constraints and are those that are most meaningful relative to garnering information relative to mental loading.

Performance Measures

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5.4.4.6.2.2 Acceptance Criteria

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Additionally, cognitive workload can be used to understand other integrated validation results. For example:

- Cognitive workload should be used when evaluating situation awareness (and vice-versa) because the two measures have been found to have a significant inverse correlation with one another.
- During a scenario or task, operators could not perform procedures correctly and within established time constraints, and that task was recorded as having high/low cognitive workload for one or more of the operators. If this occurs, it may be determined that high/low cognitive workload contributed to the unacceptable performance.

If any workload concerns are identified, the identified concern is entered as a HED into the HFEITS for tracking and resolution.

5.4.4.7 Anthropometric and Physiological Factors

Control room ergonomics using anthropometric data are evaluated as part of HSI development (See NEDO-33268, ESBWR HFE Human System Interface Design Implementation Plan) and HFE design verification to ensure compliance to the anthropometric guidelines contained in the ESBWR HFE style guide.

System-specific and integrated validation testing confirms during simulation the adequacy of the HSI anthropometric design for the population of operators in a real plant.

Validation tests to ensure that no significant negative impact on crew performance occurs within the context of the integrated system. Validation tests also ensure that no problems arise during HSI use that may not have been evident when HSI components were verified without reference to specific tasks.

Review of anthropometric data should be done in conjunction with physical workload posture data.

Procedure

After test participants have been selected for integrated system validation activities, physical measurements are taken of each participant using tape measures and/ or calibrated anthropometric tools.

Physical Measurements are selected from the following:

Stature	Thigh Thickness	Shoulder Grip Length
Eye Height	Upper Leg Length	Hand Length
Shoulder Height	Seat Length	Hand Breadth
Elbow Height	Knee Height	Foot Length
Hip Height	Seat Height	Foot Breadth
Knuckle Height	Shoulder Breadth	Span
Sitting Height	Hip Breadth	Elbow Span
Sitting Eye Height	Upper Arm Length	Vertical Grip Reach (standing)
Sitting Shoulder Height	Elbow-Fingertip Length	Vertical Grip Reach (sitting)
Sitting Elbow Height	Upper Limb Length	

Measurements for each participant are entered into an electronic database along with a unique participant tracking number.

Physical measurements for each participant are used to supplement anthropometric observations and self-report questionnaires are used to validate the anthropometrics of the integrated system. If anthropometric issues arise for a test participant, that participant's physical measurements are referenced to better understand the problem.

Performance Measures

Integrated validation testing focuses on the aspects of anthropometrics as they apply to the integrated system of displays and controls. This is measured by how effectively operators can use the integrated system. Effectiveness is measured using a combination of quantitative and qualitative measurements.

The following are recorded (along with time and task) by test personnel during simulation and/or using videotaped simulations:

- Number of times the operator has to reposition to accomplish task (lateral, leaning, or standing/stooping).
  - Changing posture in order to see displays.
  - Changing posture in order to move between controls or between displays and controls.

- Operator posture during tasks (using 5-point rating scale where 1 = Very poor and 5 = Very good).
  - Brief description of type of posture problem(s).
- Written description of any additional significant anthropometric problems as identified by test personnel, such as:
  - Visibility of displays being obstructed by operators reaching across displays to engage controls. This is especially important when working with fine motion controls and feedback from control input is provided through the obstructed display.
  - Interference with controls created by reaching for other controls. (e.g., inadvertently pressing the keys on a keyboard when reaching for a control switch on panel).

Observation data is supplemented with post-scenario operator questionnaires:

- Operators are asked to rate each anthropometric element using a 5-point rating scale (1 = Very poor, 5 = Very good). Questionnaire items include:
  - Reach and accessibility of control devices.
  - Visibility of indications.
  - Distance.
  - Seating comfort: Work surface height, chair adjustability, and/or overall level of comfort.
  - Ease of control.
  - Ease of device manipulation.
  - Overall perception of system usability.
  - Overall satisfaction with workspace layout.
- Additional comments.

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5.4.4.7.2 Acceptance Criteria

If anthropometric design of the physical panels and layout of elements in the control room degrade crew performance such that procedures could not be accomplished correctly and within time constraints by operators representing the range of physical measurements, the integrated design fails validation. This criteria is based on established operating procedures and timelines.

If anthropometric design of the HSI represents a risk to operator safety or well-being, a HED is entered into the HFEITS. This determination is based on established anthropometric guidelines and subject matter expert judgments. This should be done in conjunction with workload analysis.

Beyond this, anthropometric data is used to better understand the results of other performance measures. Evaluation of this data should be based on established anthropometric guidelines, expert judgment, and the ESBWR HFE style guide.

5.4.5 Test Design

Test design is the process of developing the integrated validation test such that the required attributes for scenario assignment and the qualifications of the test personnel and participants permit the observation of integrated system performance in a manner that avoids or minimizes bias, confounds, and noise (error variance).

5.4.5.1 Coupling Crews and Scenarios

The coupling of crews and scenarios determines how the test participants experience the test scenarios.

Scenario Assignment

Scenario assignment to crews is made prior to the initiation of the integrated test sequence. Depending upon the number of available crews during testing, some crews may not participate in all scenarios. The set of scenarios, selected by test personnel and presented to a crew, should be carefully balanced to ensure that each crew receives a similar and representative range of scenarios (difficult scenarios are not only assigned to above average crews). To establish adequate test data reliability, each validation scenario should be performed by a minimum of three crews.

Scenario balance among crews is maintained by providing test personnel with a checklist for making assignments. This checklist requires scenario selection to be based on scenario complexity, operating conditions, and expectations during the scenario (each crew receives scenarios that test their abilities and plant responses during normal, abnormal and emergency plant conditions). The checklist also ensures that the crews do not repeat scenarios.

Presentation of the same scenario to the same crew for a second time may not occur in the context of integrated system validation.

Scenario Sequencing

Test personnel should balance the order in which scenarios are presented to crews. The same type of scenario is not presented in the same linear position (avoiding always presenting the easy scenarios first) and the scenario sets do not always occur in the same sequence. Control of scenario sequencing also serves to minimize any bias resulting from crew expectations of scenario type.

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5.4.5.3 Training

Test Personnel

Test personnel receive training, similar to the training required by ACAD97-014 for simulator instructors/evaluators, prior to initiation of the integrated validation tests. Some components of this training include:

- Planning and coordinating simulator sessions
- Observing operator performance
- Evaluating operator performance
- The use and importance of test procedures
- Experimenter bias and the types of errors that may be introduced into test data through the failure of test personnel to accurately follow test procedures or interact properly with participants.
- The importance of accurately documenting problems that arise in the course of testing, even if due to test personnel oversight or error.
- Test personnel conducting the scenario and operating the simulator should be qualified as simulator operators and familiar with the capabilities of the applicable PTS or FSS.

Also included in training are protocols such as when and how to interact with the crew during the simulation, non-intrusive locations, use of recording devices, and the development and use of observation tools for taking notes during the scenario. Additionally training presents how to focus on the HSIs, procedures, or tasks of importance for the specific scenario.

Test Participants

Integrated system testing requires comprehensive knowledge of the systems included in the test. This knowledge is attained through formal classroom and simulator training. After training is complete, a comprehensive examination covering the training received and job performance measures for system manipulations on the simulator are conducted to prove the success of the training. Test participants selected have completed sufficient ESBWR specific training to exhibit an acceptably stable level of performance across trials.

Test participants used during the full scope simulator integrated validation tests are trained as follows:

- Test participants that were licensed on previous generation BWRs are required to receive ESBWR systems training, procedure training and simulator training for familiarization with the controls for the specific ESBWR systems. This training is similar to existing BWR license training in content.
- Test participants with no previous BWR operating experience are required to receive additional training for BWR general fundamentals. The ESBWR systems and procedure training required for these personnel is similar to existing BWR initial license training. The formerly licensed personnel should attend integrated plant simulator training with the new trainees to promote teamwork and allow the new trainees to benefit from their experience.
- All personnel receive a comprehensive operating test in the full scope simulator before participating in the full scope simulator V&V testing.

5.4.6 Pilot Testing

A pilot study is performed prior to the initiation of the V&V process in the simulator. This study is used to test the process for determining adequate design, determining the correct data collection techniques, and verifying appropriate testbed completeness and fidelity.

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Personnel used during pilot testing differ from those used as test participants during integrated validation tests. If a pilot testing participant is used in integrated system validation, the scenario sets must be different from those developed for pilot testing. Participant exposure to the data collection process is minimized.

5.4.7 Data Analysis and Interpretation

Data analysis is conducted in accordance to the established four-tier hierarchical set of performance measures with the greatest weight placed on data coming from the highest performance measure tiers. Analysis is dependent on the type and quality of data that can be acquired. Actual data collection and analysis may be subject to variation during the course of testing.

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For each tier, it can be seen that the performance measures and their associated criteria range from pass/fail quantitative analysis at the highest significance level ([[ ]]) to a qualitative analysis at the supplemental criteria level. [[ ]]

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To provide additional information, timelines and movement pattern diagrams (when applicable) for each crew are constructed for each simulated scenario using video recordings and visual observation records. Test participants may provide assistance by interpreting videotaped sessions and interrelating recorded events with test data.

The resulting timelines and movement pattern diagrams are evaluated by qualified test personnel to assess the correctness, timeliness, and completeness of responses to scenarios. The information gathered from these evaluations is used to better understand the results of higher tier performance measures.

Additional information collected by test personnel observations regarding qualitative assessments of influencing factors such as lighting level, noise level, communication clarity, HSI information clarity, and other factors that influence detection, analysis, planning and implementation of actions may also be used to better understand results and data.

For performance measures used as pass/fail indicators, failed indicators must be resolved before the design can be validated. Where performance does not meet criteria for supplemental performance measures, the results are evaluated using the HED resolution process.

When making inferences from observed performance to estimated real-world performance, test personnel allow for a margin of error (some allowances are made to reflect the fact that actual performance may be slightly more variable than observed validation test performance).

Verification

Analysis inputs are verified by comparing test personnel observations to each other and by comparing personnel observations to the computer-generated event logs. Data analysis and the conclusions drawn are independently verified.

Establishing Convergent Validity

During data evaluation and analysis, convergent validity can be established by comparing data from performance measures that are intended to measure the same or closely related aspects of performance. For instance, SA ratings from test participants should have moderate to high association with SA ratings from test personnel. Likewise, posture data obtained from physical workload performance measures should have moderate to high association with related anthropometric data.

If instances occur in which two performance measures that are intended to measure the same thing have no apparent association, a HED is entered into the HFEITS.

Controlling Bias

ESBWR subject matter experts and human factors specialists control bias during evaluation stages of design and during validation and verification. The intent is to eliminate sources of bias. When that is not possible, sources of bias are measured, and are included as additional predictors in statistical analysis to statistically control for bias.

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5.5 OUTPUTS AND RESULTS DOCUMENTATION

The output from integrated system testing is validation of the following:

- Integrated procedures.
- Integrated HSIs.
- Integrated training.
- Integrated software design.
- Personnel roles.
- Staffing and qualifications.
- Transition capability between HSIs and procedures.
- Integrated system tolerance of individual HSI failures.

The results of validation activities also provide input for revision to procedures, HSI, training, software design, personnel roles, staffing and qualifications, etc.

Validation conclusions are documented, including the bases for acceptable performance. Deficiencies and discrepancies identified throughout the V&V process by test personnel are documented and logged into the HFEITS. Design specifications, procedures, training, etc., are revised (if necessary) using inputs from V&V activities.

The limitations of validation testing are documented, along with considerations regarding the potential effects of these limitations on validation conclusions and design implementation. These include problems such as:

- Aspects of the tests that were not well controlled.
- Potential differences between the test situation and actual operations, such as absence of productivity-safety conflicts.
- Potential differences between the validated design and plant as-built.

If an integrated system validation item cannot be fully validated during HFE V&V due to testing limitations or other complications, the process is extended to the plant itself, and accomplished during design implementation, as described in NEDO-33278, ESBWR Design Implementation Plan. For these instances, the V&V team describes the validation to be performed, indicates the acceptance criteria, and documents the requirement in the V&V results summary report and in the HFEITS.

6. V&V HED IDENTIFICATION AND RESOLUTION

HED identification and resolution is discrepancy tracking and resolution process that functions concurrently and iteratively with the V&V process (Figure 2, HFE Design and Task Support Verification and Figure 3, Operational Condition Sampling and Integrated System Validation). HEDs and are documented, evaluated, resolved, and the results are verified to address the HED in a satisfactory manner as shown in Figure 4, HED Resolution Process. HEDs that affect specific V&V activities are resolved prior to performance of the V&V activities they affect.

The HFEITS is a software database tool that is used by the ESBWR design team to record, evaluate, and track HEDs and their resolution. The tool facilitates four key activities associated with processing HEDs. These are:

- Evaluation of HEDs to determine their significance and whether or not the HED warrants correction when evaluated in the context of the full ESBWR design.
- Identification of appropriate solutions to address HEDs including, as appropriate, changes to design, procedure, software, S&Q, or training.
- Verification that solution options implemented to address HEDs resolves the identified discrepancy without generating additional HEDs.
- Documentation of all aspects of the HED resolution process.

HFE discrepancies identified during V&V, are tracked in the ESBWR HFEITS, which is maintained throughout the ESBWR project.

HED documentation, tracking, evaluation, and resolution activities are conducted in accordance with regulatory and QA requirements, the requirements of NUREG-0711, Rev 2.

6.1 SCOPE

V&V HED identification and resolution applies to discrepancies identified during all HFE activities that require V&V resolution, or HEDs identified during V&V activities.

6.2 OBJECTIVES

The objective of V&V HED identification and resolution is to ensure that HEDs are acceptably resolved and that any changes made to the design, procedure, software, S&Q, or training are implemented and verified to have resolved the HED.

The V&V HED identification and resolution process presents a systematic framework for identifying, evaluating, and dispositioning discrepancies by outlining:

- Criteria for HED identification.
- Methodology for HED justification.
- Process to consistently analyze HED impact on plant safety, task performance, HSI design, and personnel performance.
- Systematic approach to prioritizing HEDs.
- Process for developing HED solutions.

- Process for evaluating the effectiveness of HED resolutions.

6.3 INPUTS

HEDs are identified throughout the ESBWR HFE design process, as illustrated in Figure 1, HFE Process. Identified discrepancies that cannot be satisfactorily resolved within the normal HFE design process are entered into the HFEITS database for documentation, evaluation, and resolution. Inputs to the HED identification and resolution process therefore include HEDs documented in:

- Operational analysis including PFRA, SFRA, AOF, and TA.
- Staffing and Qualifications.
- HSI design.
- Software design.
- Training development.
- Procedures development.
- Verification and validation.

When the ESBWR project enters construction and operation, two additional processes provide HED inputs for resolution:

- Design implementation.
- Human performance monitoring

HEDs noted in the processes listed above that are documented in HFEITS and resolved via the HED identification and resolution process include:

- A discrepancy or set of discrepancies that adversely impacts plant safety.
- A discrepancy issue or set of discrepancies that adversely impacts personnel performance of plant related functions or tasks (increases the likelihood of human error).
- Deviations from HFE guidelines, principles, and methods.
- Deviations from the ESBWR style guide.

6.4 METHOD

The HED identification and resolution process uses a structured approach that ensures methodical and consistent treatment of identified discrepancies, analysis and development of resolutions, verification of discrepancy resolution, and thorough documentation. All HEDs are entered into the HFEITS database, which then guides the HED identification and resolution process.

The major HED identification and resolution process steps, as shown in Figure 4, HED Resolution Process, include:

- HED identification.
- Entry into HFEITS and determination if the discrepancy can justifiably be accepted as-is.

- Initial analysis and prioritization of HED based upon impact on plant safety, task performance, HSI design, and personnel performance.
- Cause determinations appropriate for HED priority.
- Developing HED solutions.
- Implementing HED resolutions.
- Evaluating the effectiveness of HED resolutions.
- Documenting the HED resolution.

GEH, as custodian of the HFEITS, performs verification for the discrepancies that are resolved prior to plant startup. Thereafter, the COL applicant performs verification of any discrepancies.

6.4.1 HED Identification

HEDs are identified throughout the ESBWR HFE design process and can range from minute details needing resolution to significant safety issues. Because the ESBWR design team documents both individual HEDs and monitors HED trends for programmatic problems, all HEDs are entered into the HFEITS database for tracking and resolution.

A discrepancy is a HED if it constitutes a departure from some benchmark of system design suitability for the roles and capabilities of the human operator. This may include a deviation from a standard or convention of human engineering practice, an operator preference or need, or an instrument/equipment characteristic that is implicitly or explicitly required for an operator's task but is not provided to the operator (NUREG 0700, Rev 2).

6.4.2 Entry into HFEITS and HED Justification

HEDs are entered into HFEITS for tracking and resolution.

The first step in the HED identification and resolution process is determining whether or not the discrepancy can or should be justifiably accepted as-is. If sufficient justification exists, a deviation from established HFE guidelines may not constitute a HED. The technical basis for determining if a HED is justifiable should include an analysis of recent literature or current practices, tradeoff studies, and/or HFE or design engineering evaluations and data.

No HEDS constituting safety concerns (either direct or indirect) or performance problems (either plant or personnel) can be justified. HEDs deviating from HFE principles or the ESBWR style guide but are shown to have inconsequential impact on task support or integrated system operations can be accepted as-is and documented. If a HED is justified, its associated HFEITS entry is closed after documentation is complete. An example of this might be a HED that, while it deviates from a HFE principle, does not have an adverse impact on safe and efficient plant operation when evaluated in the context of the fully integrated design.

6.4.3 Initial Analysis and Prioritization of HEDs

An initial analysis of the HED is performed to provide analysts a general overall perspective of the discrepancy. The scope and impact of the HED both alone and in the context of any other open HEDs against the system are taken into consideration. If the HED addresses a global or standard design feature and therefore potentially affects more than one system, the full impact of the HED must be investigated and understood so as to accurately determine the HED's impact, and priority. The perspective gained during this initial analysis is then used to identify similar or related discrepancies that may indicate cross cutting or programmatic problems. If any such discrepancies are noted during trend analysis, the potential adverse trend is entered into HFEITS for resolution.

Specific information considered during analysis includes:

- Discovery method – what activity identified the HED.
- System or systems affected.
- Scope – whether the HED affects global, standardized, or detailed design features and therefore how far reaching its consequences or effects may be.
- HSIs affected.
- Personnel functions or tasks affected.
- Procedures or training affected.
- Cumulative impact of HED in the context of other open HEDs affecting the same design features, functions, or processes.

The perspective gained during initial analysis is also used to prioritize the HED and thereby determine the depth and breadth of its resolution requirements. HEDs are prioritized to ensure that resources are applied in a risk informed manner. Prioritization levels and criteria are as follows:

Priority 1 - Safety Consequences (either direct or indirect)

A condition (equipment, HSI, procedure, training, or staffing deviation, deficiency, or nonconformance) or adverse trend that has the potential to impact plant risk or safety or safety-related systems, structures, or components. Examples include:

- Equipment or HSI design deficiencies or discrepancies that could lead to safety system, train, or component inoperability, unavailability, or unexpected operation.
- A HED that impacts a system, component, or human action determined in HRA/PRA as risk significant and drives risk importance above cutoff.
- A HED that reduces the plant margin of safety below an acceptable level, as indicated by such conditions as violations of operating limits, or tech spec limits, or limiting conditions of operation (NUREG 0711, Rev 2).
- Adverse HED trends, that if found to be present in safety related systems could lead to safety system, train, or component inoperability, unavailability, or unexpected operation.
- Procedure deficiencies or discrepancies in documents relied upon to mitigate transients and design basis accidents.
- Training deficiencies or discrepancies that could cause or contribute to the conditions noted above.
- Staffing and qualification deficiencies or discrepancies that could cause or contribute to the conditions noted above.

- A group of HEDs that when considered together could cause or contribute to the conditions noted above.

Priority 2 - Plant or Personnel Performance Impact

A condition (equipment, HSI, procedure, training, or staffing deviation, deficiency, or nonconformance) or adverse trend that does not have significant safety consequences, but does have potential consequences to plant or personnel performance or efficiency. Examples include:

- Equipment or HSI design deficiencies or discrepancies that deviate from personnel information requirements or HFE guidelines for tasks associated with plant productivity, availability, or protection of investment.
- Equipment or HSI design deficiencies or discrepancies that could lead to significant non-safety system, train, or component inoperability, unavailability, or unexpected operation.
- The HED impacts a system, component, or human action determined in HRA/PRA as risk significant but does not drive risk importance above cutoff.
- Adverse HED trends, that if found to be present in significant non-safety systems could lead to system, train, or component inoperability, unavailability, or unexpected operation.
- Procedure deficiencies or discrepancies in documents relied upon to mitigate transients, abnormal events, and failures involving significant non-safety equipment.
- Training deficiencies or discrepancies that could cause or contribute to the conditions noted above.
- Staffing and qualification deficiencies or discrepancies that could cause or contribute to the conditions noted above.
- A group of HEDs that when considered together could cause or contribute to the conditions noted above.

Priority 3 - Enhancement (Neither safety consequential or impacting performance)

A condition (equipment, HSI, procedure, training, or staffing deviation, deficiency, or nonconformance) or adverse trend that deviates from the style guide or HFE principles that has neither significant safety nor plant or personnel performance consequences.

Priority 4 - Other (Not a safety, performance or enhancement)

A condition or adverse trend that does not deviate from the style guide or HFE principles and that has neither significant safety nor plant or personnel performance consequences.

6.4.4 Cause Determinations

Determining the factor or factors that are causing the observed HED is important in developing effective corrective actions. The cause determination and extent of condition determination processes can, however, be time consuming and divert resources from more risk significant activities. The HED identification and resolution process therefore uses a risk informed approach based upon the HED's previously determined priority. Cause determination and extent of condition determination requirements are as follows:

Priority 1

- Root or apparent cause performed based upon the significance of the HED and whether or not the causal factor is self-revealing or not.
- Extent of condition determination performed.

Priority 2

- Apparent cause performed.
- Extent of condition determination performed.

Priority 3 & 4

Cause and extent of condition determinations are not required prior to development of corrective actions but may be performed at the discretion of the person developing the HED resolution.

6.4.5 Developing HED Solutions

Using all of the information gathered during analysis and cause determinations (if required) solutions to the identified discrepancies are developed. Actions are developed for each aspect of the HED that represents a correction opportunity. Actions are developed to address the HED symptoms and causes identified and to prevent recurrence of the deviation or limit the effects of recurrence.

HED resolution corrective actions are developed taking into account the aggregate affect of all open HEDs impacting the system, components, HSIs, procedures, or processes they are developed to address. Design solutions are analyzed using industry operating experience and the appropriate HFE design processes including, where appropriate:

- Functional Requirements Analysis.
- Allocation of Function.
- Task Analysis.
- Procedures Development.
- Training development.
- HSI Design.
- Staffing and Qualification.

Where a variety of possible corrective actions exist, corrective actions are chosen that strike a balance among the safety significance of the HED, the resources required for implementation, and the effectiveness of the corrective action.

Solutions selected may include:

- Design change to the system or component.
- Software change.
- Reevaluation in the operations analysis process resulting in reallocation or task redesign.
- Procedure change.
- Training change.

- HSI design change.
- Staffing and qualification change.
- Other actions resulting from analysis of the HED.

6.4.6 Implementing HED Resolutions

HED resolution corrective actions are implemented using the appropriate HFE design process as illustrated in Figure 1, HFE Process. Corrective actions are input into the appropriate HFE design process for implementation and proceed normally through the remainder of the HFE design process as shown in Figure 1, HFE Process. If, for example, a HED resolution corrective action is input into allocation of function and changes an allocation, this change may require additional action in downstream processes such as task analysis, HSI design, software design, procedures, training, staffing and qualifications, and V&V.

HED resolution corrective actions are tracked until completed. Their completion is scheduled commensurate with the HED significance and its impact upon other scheduled activities. For example, corrective actions for priority 1 and 2 HEDs should be completed prior to performance of integrated system validations involving the HSIs, systems, or tasks they impact. HED corrective actions not resolved prior to related integrated system validations may require additional integrated system validation test performances.

HED resolutions that require the "as built" control room to complete are implemented as part of the design implementation process. V&V requirements that must be met as part of the verification of the effectiveness of the HED corrective actions are identified and are completed after the design is implemented.

6.4.7 Evaluating the Effectiveness of HED Resolutions

All HED resolution corrective action design solutions are evaluated to verify the effectiveness of corrective actions. If all corrective actions for a HED are completed prior to the performance of the HFE design verification, task support verification, or integrated system validation the HED may be closed in HFEITS because the normal V&V process evaluates the design solution effectiveness.

If any HED corrective action is completed after the start of V&V activities then assessors must determine if it is appropriate to perform additional verifications or validations to document the efficacy of the actions taken.

Portions of the V&V process impacted by the HED are repeated to provide assurance that the HED is resolved and that the corrective actions taken did not inadvertently generate new HEDs or deviations from HFE design principles. Depending upon what the HED and its corrective actions impact, portions or all of the HFE design verification, task support verification, or integrated system validation are redone.

If V&V activities reveal that corrective actions taken do not fully and satisfactorily address all issues related to the HED or they generate new issues, the HED remains open in HFEITS until satisfactorily resolved or justified and documented as previously discussed.

6.5 OUTPUTS AND RESULTS DOCUMENTATION

The HFEITS database contains traceable references to issues, resolutions, and implementation of corrective actions. V&V HEDs are justified, resolved, or maintained in HFEITS until they can be resolved.

Records within the database include documentation of the performance of each step in the HED identification and resolution process shown in Figure 4, HED Resolution Process. Some of the information documented in the HFEITS database associated with each HED resolution includes:

- HED identification information
- Accept as-is analysis, determination, and justification (if acceptance is justified)
- Initial analysis, including:
  - System affected
  - Scope – whether the HED affects global, standardized, or detailed design features and therefore how far reaching its consequences or effects may be
  - HSIs affected
  - Personnel functions or tasks affected
  - Procedures or training affected
  - Cumulative impact of HED in the context of other open HEDs affecting the same design features, functions, or processes.
- Prioritization of HED based upon impact on plant safety, task performance, HSI design, and personnel performance
- Cause determinations appropriate for HED priority
- HED solutions developed
- HED resolutions implemented
- HED resolution effectiveness evaluation (if required)

7. RESULTS

7.1 RESULTS SUMMARY REPORT

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

- The scope of V&V.
- Major conclusions reached during V&V and their basis.
- A description of the process for documenting and retaining the detailed V&V results.
- A summary of the following activities:
  - HSI inventory and characterization.
  - HSI task support verification.
  - HFE design verification.
  - Operational conditions used for the V&V.
  - Integrated system validation.
  - HED resolution.

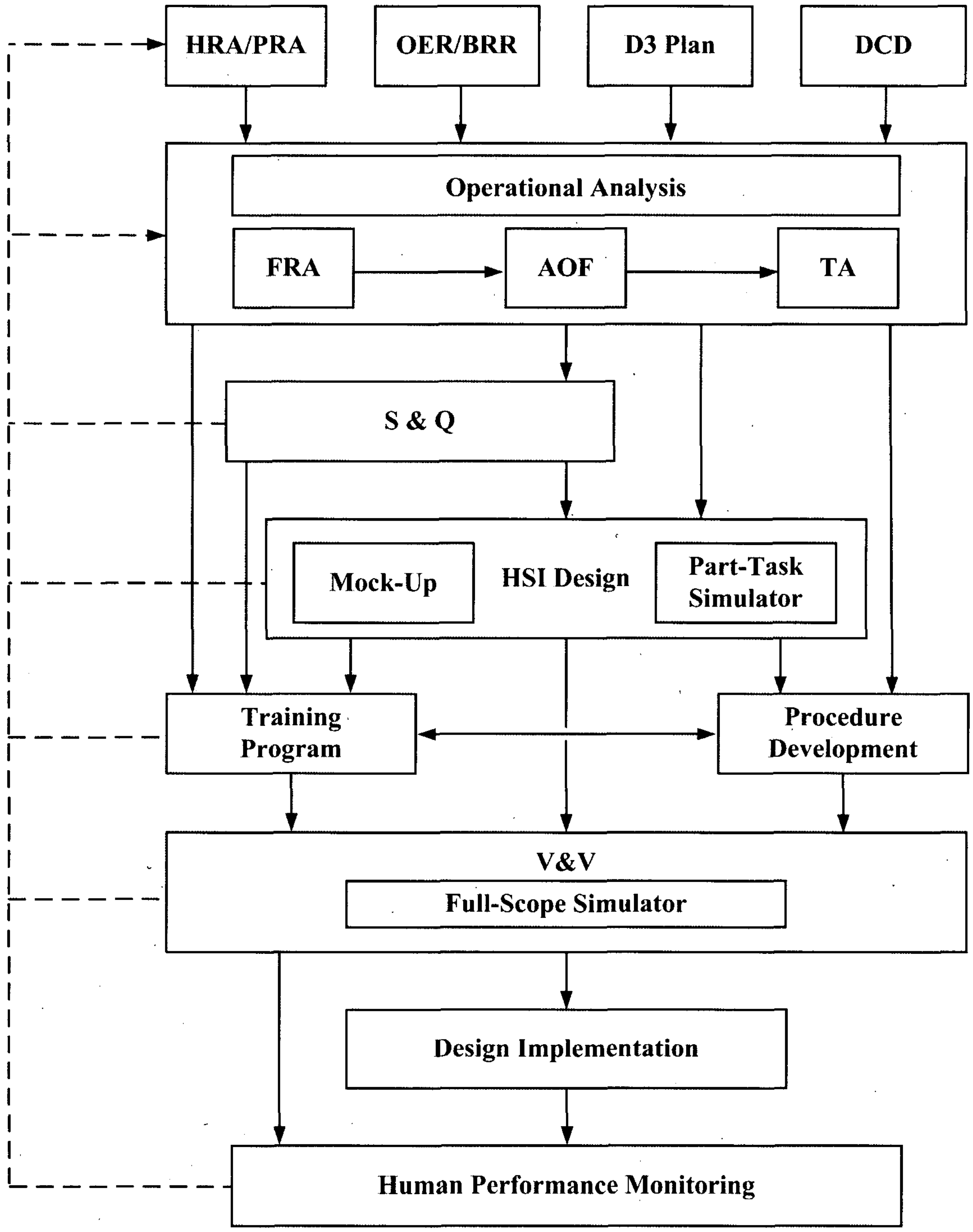

Figure 1 HFE Implementation Process

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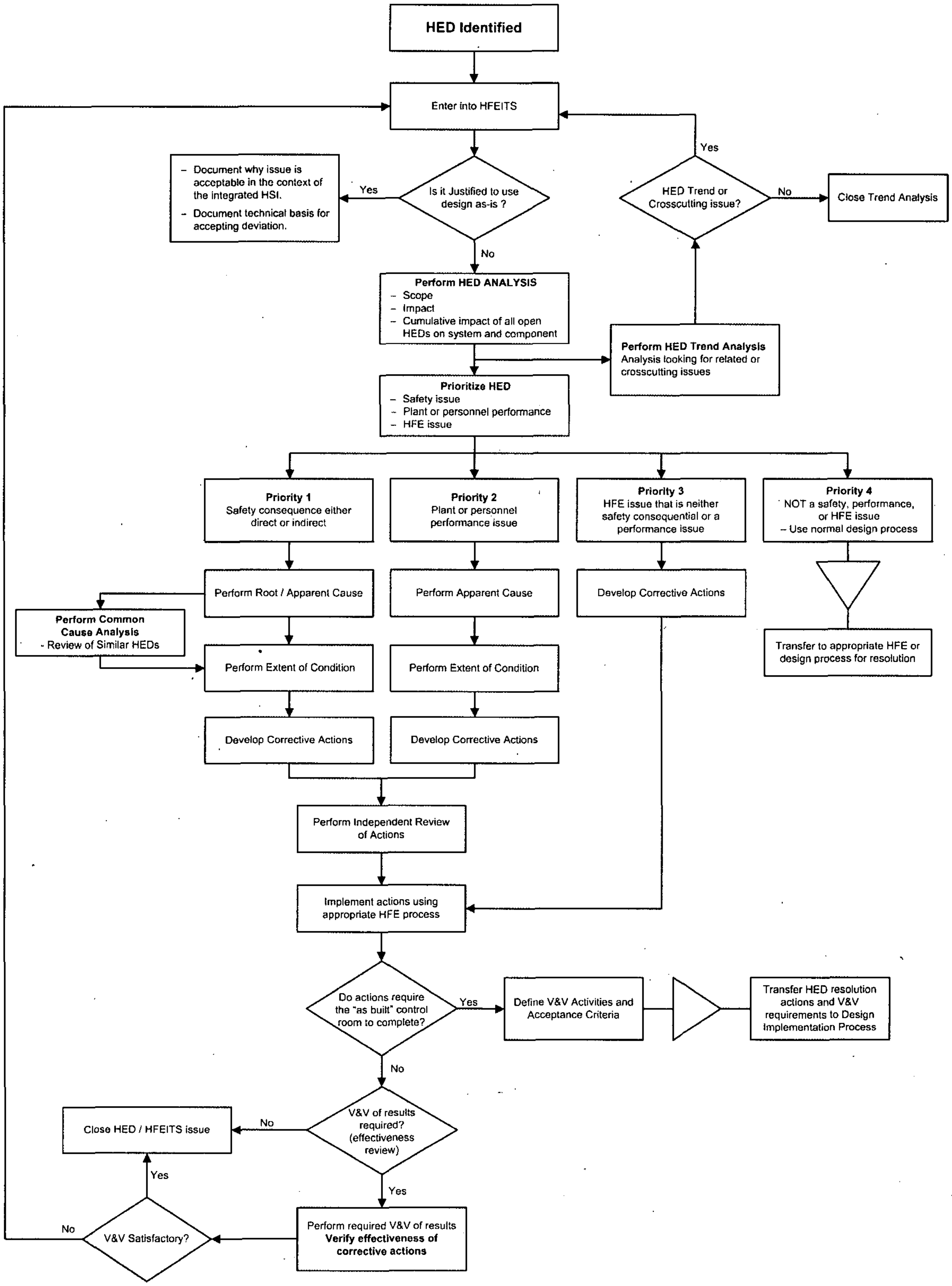

Figure 4 HED Resolution Process

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Title	Endpoints	Descriptions
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MFN 08-264

Enclosure 3

Affidavit

GE Hitachi Nuclear Energy

AFFIDAVIT

I, David H. Hinds, state as follows:

(1) I am the Manager, New Units Engineering, GE Hitachi Nuclear Energy ("GEH"), and have been delegated the function of reviewing the information described in paragraph (2) which is sought to be withheld, and have been authorized to apply for its withholding.

(2) The information sought to be withheld is contained in Enclosure 1 of GEH letter MFN 08-264, Mr. James C. Kinsey to U.S. Nuclear Regulatory Commission, entitled *Transmittal of Licensing Topical Report NED-33276P, "ESBWR Human Factors Engineering Verification and Validation Implementation Plan," May 2008,* dated June 25, 2008. The GEH proprietary information in Enclosure 1, which is entitled *Licensing Topical Report NEDE-33276P, "ESBWR Human Factors Engineering Verification and Validation Implementation Plan," May 2008 - GEH Proprietary Information,* is delineated by a [[dotted underline inside double square brackets.{3}]]. Figures and large equation objects are identified with double square brackets before and after the object. In each case, the superscript notation {3} refers to Paragraph (3) of this affidavit, which provides the basis for the proprietary determination. A non-proprietary version of this information is provided in Enclosure 2, *Licensing Topical Report NEDO-33276, "ESBWR Human Factors Engineering Verification and Validation Implementation Plan," May 2008 - Non-Proprietary Version.*

(3) In making this application for withholding of proprietary information of which it is the owner, GEH relies upon the exemption from disclosure set forth in the Freedom of Information Act ("FOIA"), 5 USC Sec. 552(b)(4), and the Trade Secrets Act, 18 USC Sec. 1905, and NRC regulations 10 CFR 9.17(a)(4), and 2.390(a)(4) for "trade secrets" (Exemption 4). The material for which exemption from disclosure is here sought also qualify under the narrower definition of "trade secret," within the meanings assigned to those terms for purposes of FOIA Exemption 4 in, respectively, Critical Mass Energy Project v. Nuclear Regulatory Commission, 975F2d871 (DC Cir. 1992), and Public Citizen Health Research Group v. FDA, 704F2d1280 (DC Cir. 1983).

(4) Some examples of categories of information which fit into the definition of proprietary information are:

a. Information that discloses a process, method, or apparatus, including supporting data and analyses, where prevention of its use by GEH competitors without license from GEH constitutes a competitive economic advantage over other companies;

b. Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product, including unique or first time use of information in the context of the specific application;

c. Information which reveals aspects of past, present, or future GEH customer-funded development plans and programs, resulting in potential products to GEH;

d. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs (4) a. and (4) b., above.

(5) To address 10 CFR 2.390(b)(4), the information sought to be withheld is being submitted to NRC in confidence. The information is of a sort customarily held in confidence by GEH, and is in fact so held. The information sought to be withheld has, to the best of my knowledge and belief, consistently been held in confidence by GEH, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties including any required transmittals to NRC, have been made, or must be made, pursuant to regulatory provisions or proprietary agreements which provide for maintenance of the information in confidence. Its initial designation as proprietary information, and the subsequent steps taken to prevent its unauthorized disclosure, are as set forth in paragraphs (6) and (7) following.

(6) Initial approval of proprietary treatment of a document is made by the manager of the originating component, the person most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge, or subject to the terms under which it was licensed to GEH. Access to such documents within GEH is limited on a "need to know" basis.

(7) The procedure for approval of external release of such a document typically requires review by the staff manager, project manager, principal scientist or other equivalent authority, by the manager of the cognizant marketing function (or his delegate), and by the Legal Operation, for technical content, competitive effect, and determination of the accuracy of the proprietary designation. Disclosures outside GEH are limited to regulatory bodies, customers, and potential customers, and their agents, suppliers, and licensees, and others with a legitimate need for the information, and then only in accordance with appropriate regulatory provisions or proprietary agreements.

(8) The information identified in paragraph (2), above, is classified as proprietary because it identifies detailed GE ESBWR process methodology for the Design Verification and Validation process. GE utilized prior design information and experience from its fleet with significant resource allocation in developing the process methodology over several years at a substantial cost.

The development of the evaluation process along with the interpretation and application of the analytical results is derived from the extensive experience database that constitutes a major GEH asset.

(9) Public disclosure of the information sought to be withheld is likely to cause substantial harm to GEH's competitive position and foreclose or reduce the availability of profit-making opportunities. The information is part of GEH's comprehensive BWR safety and technology base, and its commercial value extends beyond the original development cost. The value of the technology base goes beyond the extensive physical database and analytical methodology and includes development of the expertise to determine and apply the appropriate evaluation process. In addition, the technology base includes the value derived from providing analyses done with NRC-approved methods.

The research, development, engineering, analytical and NRC review costs comprise a substantial investment of time and money by GEH.

The precise value of the expertise to devise an evaluation process and apply the correct analytical methodology is difficult to quantify, but it clearly is substantial.

GEH's competitive advantage will be lost if its competitors are able to use the results of the GEH experience to normalize or verify their own process or if they are able to claim an equivalent understanding by demonstrating that they can arrive at the same or similar conclusions.

The value of this information to GEH would be lost if the information were disclosed to the public. Making such information available to competitors without their having been required to undertake a similar expenditure of resources would unfairly provide competitors with a windfall, and deprive GEH of the opportunity to exercise its competitive advantage to seek an adequate return on its large investment in developing these very valuable analytical tools.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to the best of my knowledge, information, and belief.

Executed on this 25th day of June 2008.

David H. Hinds
GE Hitachi Nuclear Energy