Enclosure 3
HFE Technical Report MPWR-TECR-005010 (Redacted)

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babcock & wilcox mPower

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a progressive energy solution

B&W mPower™ Reactor Program
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ABSTRACT

This technical report describes the human factors engineering verification and validation process. The verification and validation process evaluates the completed human-system interface design and ensures that human factors engineering principles have been successfully integrated into the plant instrumentation and control system, process system, and control facility designs. Verification and validation is conducted as two major activities: design and task support verification, and integrated system validation. Both of these activities, as well as the operational condition sampling, inventory and characterization, and human engineering discrepancy resolution processes that support them, are presented in detail in this document. Ultimately, the verification and validation process confirms that the Babcock & Wilcox mPower™ design enables plant personnel to safely and successfully perform the tasks necessary to meet the plant safety and operational goals through all human-system interfaces.

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RECORD OF REVISION

Revision No.	Date	Preparer	Description of Changes
000		Daniel Laughman	Initial issue

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1. INTRODUCTION

1.1 Applicability

This document is applicable to all design activities for the Babcock & Wilcox (B&W) mPower™ reactor systems within the scope of the human factors engineering (HFE) program as defined in *Human Factors Engineering Program Management Plan*, MPWR-TECR-005002 (Reference 6.3.1). This includes all B&W employees and contractors assigned to design activities of the B&W mPower reactor.

1.2 Scope and Objectives

[

] [CCI per Affidavit 4(a)-(d)]

This report provides the processes, methods, and criteria for performing the HFE V&V process. The V&V process evaluates a representative sample of plant conditions, tasks, and situational factors affecting human performance (and the associated HSIs) and ensures that HFE principles have been successfully integrated into the design. This report also provides a methodology for performing HFE design and task support verification, ensuring that the HSIs are designed in accordance with the accepted HFE criteria and meet their individual and task-based grouping design and functionality requirements. HFE design verification analyzes the completed plant control system design to evaluate whether or not HSI design features meet design, regulatory, style guide, and HFE requirements. Task support verification analyzes the completed plant control system design to evaluate whether or not the HSI requirements identified in the task analysis for a given task are present in the design and possess the required characteristics.

Additionally, this report presents the processes, methods, and criteria for performing the integrated system validation (ISV), which ensures that the operating staff is able to perform the assigned tasks within the integrated control room environment. MCR hardware, software, communication devices, procedures, workstation placement, and HSI configurations used by the control room operators during the performance of their assigned tasks are evaluated during the ISV. ISV uses a sampling of dynamically simulated scenarios to evaluate whether or not the integrated HSI adequately uses human capabilities and accommodates human limitations.

Performance during validation scenarios is evaluated to ensure that the integrated system design meets the performance requirements and criteria that support the safe and efficient operation of the plant.

In support of these activities, this report provides the processes, methods, and criteria for performing operational condition sampling and human engineering discrepancy (HED) identification and resolution. The operational condition sampling process ensures that a broad and representative range of operating conditions is included in the sample population used to select HSIs, tasks, and ISV scenarios to be examined. The HED resolution process documents, evaluates, resolves and closes discrepancies identified during HFE V&V.

[

] **[CCI per Affidavit 4(a)-(d)]**

1.3 Responsibilities

Work performed within the scope of this technical report is under the direction of the Unit Manager of the Operations/Integration Design Process which includes Human Factors Engineering Program activities. The individuals performing V&V evaluation activities are selected from the HFE design team. [

] **[CCI per Affidavit 4(a)-(d)]**

Staffing for the performance of ISV testing scenarios uses participant personnel with previous license experience or enrolled in training classes for the purpose of obtaining a B&W mPower operating license. Crews are selected to ensure that they are representative of actual plant personnel including both experience and a range of general demographics . Participants are selected to support both minimum and normal crew configurations.

2. BACKGROUND

Title 10 of the Code of Federal Regulations (CFR) Part 50, Appendix A, general design criteria 19 (References 6.1.1 and 6.1.2), requires that a control room be provided from which actions can be taken to operate a nuclear power plant safely under normal, abnormal, and emergency conditions. Other U.S. Nuclear Regulatory Commission (NRC) documents such as NUREG-0711 (Reference 6.2.1) and NUREG-0700 (Reference 6.2.2) specify that human-system interfaces for the nuclear control system be developed in accordance with an HFE program. This guidance states that both MCR HSIs and equipment at appropriate locations outside the control room be provided with a capability for hot shutdown of the reactor and potential subsequent cold shutdown of the reactor through suitable procedures. In order to design these HSIs and to provide input to the development of training and procedures, the HFE process integrates human engineering principles into the design process. The HFE design process ensures that a human-centric approach to control system design results in an efficient and user-friendly integration of plant systems as appropriate. The systems integration for HFE matches the plant operator (as well as testing and maintenance personnel) with the technology to be used within the environment in which it is used. The entire process is guided by a systems engineering controlled process.

The purpose for performing V&V at the conclusion of the systems engineering design process (of which the HFE design process is a part) is to sample the completed control system design and to ensure that HSIs (both individually and collectively) meet requirements and design criteria. Verification ensures that individual HSIs meet component specific design criteria and that the grouping of components supports task performance as defined by HFE task analysis. Validation ensures that the integrated control room environment including HSIs, procedures, training, room layout, and environmental conditions collectively supports the safe and efficient operation of the plant through dynamic testing. The V&V process provides either confirmation that the HSI meets HFE principles and design requirements or documentation of identified deficiencies in the form of HEDs. The HED resolution process ensures that discrepancies are resolved in a manner that meets HFE principles and design requirements. The HEDs found during the V&V process are resolved to the extent practicable before continuing with the V&V process to minimize possible masked problems. The HFE V&V process results in a B&W mPower HSI and associated control environment that supports the safe and efficient operation of the plant.

3. METHODOLOGY

3.1 Approach Overview

The HFE V&V process confirms that the integrated control room design conforms to HFE design principles and that the design facilitates the successful performance of tasks allocated to control room personnel.[

[CCI per Affidavit 4(a)-(d)]

]The HSI listing is derived from task analysis results (see task analysis topical report, Reference 6.3.4) for the selected operational tasks and scenarios. The characterization of each HSI is derived from the instrumentation and controls (I&C) and plant system engineering design documents associated with the HSI.

The HSI task support verification process ensures that the inventory of HSIs, which HFE task analysis determined are required for successful completion of the tasks or scenarios being examined, are included in the design. This process compares the characterized listing of the HSIs to requirements contained in task analysis results. Additionally, task support verification evaluates the grouping of these HSIs in accordance with the task whose completion they support.

Design verification confirms that each individual HSI is designed in accordance with the specifications and requirements defined in the HFE and systems engineering design processes. This process verifies the availability of the correct alarm, information, and control capabilities and that they are designed in accordance with plant engineering criteria, human engineering criteria, style guides, and operating and functional requirements. Verification ensures that the HSI design is implemented appropriately.

ISV is the evaluation of operator interface with procedures, HSI, hardware, and software during real-time task performance using full-scope simulation. The validation process measures the ability of the users to perform tasks using the HSI in the complete control room environment. Validation is the process of determining and documenting that the design effectively serves its intended purpose. Validation ensures that the appropriate design has been implemented.

In support of the processes described above, this report presents the following elements of HFE V&V:

- Requirements and objectives
- HFE V&V team make-up
- Methods and procedures
- Test conditions, data collection, and analysis
- Acceptance criteria and performance measures
- Documenting and reporting of results

The following design features are verified and validated in accordance with the V &V process:

- HSIs (both software- and hardware-based alarms, controls and indications, and displays)
- Workstation configuration and anthropometrics
- Automation features
- Display navigation

- Crew communications
- Procedure usage in the context of ISV scenarios
- Operator work environment (e.g., lighting, temperature, humidity, vibration, floor design, and noise levels)
- Provisions for routine HSI tests and maintenance

The HFE design and task support verification processes are completed using part-task or full-scope simulators of sufficient completeness and fidelity for the task verification to be performed as determined by the V&V administrators. The ISV is completed using a full-scope simulator prior to the performance of ANSI Standard 3.5 (Reference 6.3.2) conformance testing. HFE V&V confirms that HFE principles and criteria have been applied to the design of work environments, work stations, facilities, and HSIs which affect human performance under normal, abnormal and emergency conditions. These elements of the design are evaluated to ensure they have adequately addressed:

[

] **[CCI per Affidavit 4(a)-(d)]**

Elements listed above that cannot be verified or validated during HFE V&V are addressed in accordance with HFE design implementation process as defined in *Human Factors Engineering Design Implementation*, MPWR-TECR-005014 (Reference 6.3.3).

Any deficiencies noted during the HFE V&V process are documented as HEDs. The HED resolution process documents, evaluates, resolves and closes discrepancies identified during HFE V&V. HSI attributes that do not meet HFE V&V criteria and requirements and are determined to warrant further consideration, are documented as HEDs. HSI components that are shown to be not needed to support any task in the design are entered as HEDs for removal. Missing HSIs (i.e., HSIs that are shown to be needed but not included as demonstrated through the V&V process) are analyzed through the HED process and added for continuation in the V&V process.

Ultimately, the HFE V&V process confirms that the HSI enables plant personnel to safely and successfully perform the tasks necessary to meet the plant safety and operational goals. The HFE V&V process is depicted in Figure 1.

[

] **[CCI per Affidavit 4(a)-(d)]**

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3.2 Operational Condition Sampling Process

The OCS process identifies a sample population within a representative range of plant operating conditions[ ]The sample reflects characteristics expected to contribute to performance variation and takes into account the safety significance and risk associated with the tasks' HSI components. **[CCI per Affidavit 4(a)-(d)]**

The B&W mPower reactor and its I&C system are an evolutionary design that incorporates the operating experience from highly similar plants, plant systems, and plant functions. Because it is impractical and unnecessary to review every HSI, the HFE V&V process employs a sample of plant conditions, tasks, and factors influencing Human Performance to select the HSIs to be verified and validated.

The sampled operational conditions included in the V&V activities are as follows:

- Conditions that are representative of the range of events that are encountered during plant operation
- Conditions that reflect the characteristics that are expected to contribute to human/system performance variation and challenges
- Safety-significant events that are reasonable, risk-significant, and/or exercise the EOPs

These sampling techniques ensure full representation of the conditions, tasks, plant systems, functions, and situational factors that are encountered during the operation of a nuclear power plant.

Potential plant operating conditions and the range of personnel tasks expected to be encountered make up the two major criteria used to select the representative sample of HSIs, tasks, and scenarios. These sampling criteria are combined in a set of control room operator tasks and scenarios used to evaluate the performance of the HSI and plant operator interface with the HSI. The operational conditions sampled represent numerous operating conditions that are typical of an operating plant as well as variables that have the potential to impact operator performance.

[

] **[CCI per Affidavit 4(a)-(d)]**

To develop a multidimensional sampling of conditions that results in the selection of HSI design elements, tasks, and integrated system scenarios that evaluate the HSI design, one or more operational conditions or tasks representing plant conditions, personnel tasks, and situational factors known to challenge human performance are identified. The plant conditions, personnel tasks, and the situational factors considered are discussed in Subsections 3.2.1 through 3.2.3. The task and scenario selection criteria and the process of selecting risk-informed scenario sample are discussed in Subsections 3.2.4 and 3.2.5.

3.2.1 Plant Conditions

All plant modes are considered during the scenario selection process. Realistic and feasible scenarios are selected based on the list provided in NUREG-0711 (Reference 6.2.1).

As described in NUREG-0711 (Reference 6.2.1), the following plant conditions sampling criteria are addressed:

- Normal operational events including plant startup, plant shutdown or refueling, and significant changes in operating power
- Failure events:
  - Instrument failures including I&C failures that exceed the design basis, such as a common mode I&C failure during an accident.
  - HSI failures
- Transients and accidents:
  - Transients
  - Accidents
  - Reactor shutdown and cool down using the remote shutdown station
- Risk-significant, beyond-design-basis events, which are determined from the PRA/HRA
- The role of the equipment in achieving plant safety functions and the degree of interconnection with other plant systems is also considered.

3.2.2 Personnel Tasks

A variety of personnel tasks are considered when selecting sampling criteria, tasks to be evaluated, and scenarios.

As described in NUREG-0711 (Reference 6.2.1), the following types of personnel tasks are sampled:

- Human actions identified in the PRA/HRA as being risk-important
- Historically problematic tasks as identified in the HFE operating experience review process (see Reference 6.3.5)

- Procedures used in the operation of the plant including administrative, emergency, abnormal, alarm response, general operating, plant system operating, surveillance and testing, and maintenance (those portions associated with the operator interface in the MCR, RSS, or risk-significant LCSs)
- Tasks that are not well-defined by detailed procedures. Tasks of this type may require knowledge-based decision-making that involves greater reasoning about safety and operating goals and the various means of achieving them.
- Tasks representing a broad range of human cognitive activities. Tasks in this population are those that contain the following attributes as identified during task analysis:
  - Detection and monitoring
  - Diagnosis and situational assessment
  - Decision making and planning
  - Plant manipulation
  - Plant response monitoring
- Tasks representing a broad range of human interactions and communications as identified in the HFE task analysis. Tasks in this population are those that contain communication interactions among the primary task performer and other plant personnel.
- Tasks performed with high frequency as identified in the HFE task analysis. Tasks in this population are those that have high repetition as identified during task analysis.

Details for each of these types of personnel tasks for sampling are provided below.

3.2.2.1 Risk-Important Tasks

Risk-significant human actions, plant systems, and accident sequences are included in the sample. Additionally, the sampling process considers factors that contribute to risk as identified by the PRA, including:

- Dominant human actions (selected via HRA sensitivity analyses).
- Dominant accident sequences.
- Dominant plant systems (selected via PRA important measures such as risk achievement worth or risk reduction worth).

3.2.2.2 Operating Experience Review-Identified Difficult Tasks

These are tasks or actions determined by the operating experience review process as being problematic (see Reference 6.3.5).

3.2.2.3 Procedure Guided Tasks

Plant procedure guided tasks are considered during the scenario selection process. As described in Regulatory Guide 1.33, Appendix A (Reference 6.2.3), the following written procedures are part of the sample population:

- Administrative procedures
  - Security and visitor control
  - Authorities and responsibilities for safe operation and shutdown
  - Equipment control (lockout/ tagout)
  - Procedure adherence and temporary change methods
  - Procedure review and approval
  - Schedule for surveillance test and calibration
  - Shift and relief turnover
  - Log entries, record retention, and review procedures
  - Access to containment
  - Bypass of safety functions and jumping control
  - Maintenance of minimum shift complement and call-in of personnel
  - Plant fire protection program
  - Plant communication system procedures
- General operating procedures
  - Cold shutdown to hot standby
  - Hot standby to minimum load
  - Recovery from reactor trip
  - Operation at hot standby
  - Turbine startup and synchronization of generator
  - Changing load and load following
  - Power operation and process monitoring
  - Power operation with less than full reactor coolant flow
  - Plant shutdown to hot standby
  - Hot standby to cold shutdown
  - Preparation for refueling and refueling equipment operation
  - Refueling and core alterations
- Emergency operating procedures

- Abnormal operating procedures
- Alarm response procedures
- Normal operating procedures
- Surveillance tests, inspections, and calibrations performed by plant operators from the MCR, RSS, or risk-significant LCSs.
- Procedures for plant, system, and component maneuvering and alignment to support repair or replacement of equipment

3.2.2.4 Knowledge-Based Tasks

Knowledge-based decision-making involves greater reasoning concerning safety and operating goals and the various ways of achieving them. A situation requires knowledge-based decision-making if the rules and procedures do not fully address the observed plant conditions, or if the selection of the appropriate rule or procedure is not clear.

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.2.5 Human Cognitive Activities

The sample population of tasks to be evaluated incorporates a range of cognitive activities including:

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.2.6 Range of Human Interactions

The sample population of tasks to be evaluated includes a range of interactions among plant personnel, including tasks performed independently and tasks performed by a team.[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.2.7 High Frequency Tasks

Tasks in this population are those that have high repetition as identified during task analysis.

3.2.3 Situational Factors Known to Challenge Human Performance

The task and scenario selection process ensures that the risk-informed representative sample to be evaluated by HFE V&V reflects the range of situational factors known to challenge human performance presented in NUREG-0711 (Reference 6.2.1). These situational factors include:

- Operationally difficult tasks identified in the operating experience review process
- Scenarios specifically designed to generate human errors. This allows evaluation of error tolerance and error recovery.
- Instances of high workload identified in the HFE task analysis. Tasks in this population are those identified as high workload conditions during task analysis.
- Instances of varying workload identified in the HFE task analysis. Tasks in this area can vary by their nature, or can vary due to the sequencing of high and low workload tasks.
- Environmental factors such as poor lighting, high noise, radiological contamination, or other factors such as operator physical position. Tasks in this population are those identified as having environmental factors of interest during task analysis.

[

] **[CCI per Affidavit 4(a)-(d)]**

3.2.4 Task and Scenario Selection Criteria

The V&V operational condition sampling process uses multidimensional selection criteria to identify tasks and scenarios to be evaluated. This diversity maximizes the relevance and significance of the resulting sample while ensuring that a broad range of HSIs, tasks, and scenarios are evaluated in HFE V&V. [

] **[CCI per Affidavit 4(a)-(d)]**

These factors are used in the scenario selection process to ensure that the most significant and relevant scenario is selected when analysts encounter situations where more than one scenario can be used to validate the same operational conditions.

3.2.5 Selection of Risk-Informed Sample of Scenarios

HFE design team members assigned to perform HFE V&V develop the risk-informed representative sample of tasks and scenarios[

] **[CCI per Affidavit 4(a)-(d)]**

3) For each of the operational conditions contained in the list of the operational conditions, identify if any of the following situational factors known to challenge human performance are associated with the operational condition being considered:

- **Operationally difficult task** – A task's operational difficulty is determined by examining the following aspects of task complexity:

[

] **[CCI per Affidavit 4(a)-(d)]**

- **Error-forcing contexts** – A task or scenario presents the opportunity to force errors through the removal of safeguards, limiting knowledge, unclear communications, and faulty procedures. In the course of the V&V activities, scenarios, functions, or tasks that may likely lead to errors are presented to operators. For example, the operators may be presented with inaccurate data, contrived trends, or no feedback. Error-forcing tasks or scenarios provide the opportunity to evaluate operator decision-making, error tolerance of the system, and the crew's ability to identify and recover from error.
- **Task analysis results indicating high workload** – Task analysis results are reviewed and those that indicate the presence of high task workload are identified including:
  - High cognitive workload – tasks involving extensive analysis and decision-making
  - High physical workload – tasks requiring the exertion of high physical force, awkward positioning, extensive repetition, or similarly stressful physical working conditions.
- **High and varying workload** – Task analysis results are reviewed and those that indicate the presence of high workload task segment(s) either preceded or followed (or both) by low workload tasks segments are identified. Situations exhibiting varying workload provide the opportunity to evaluate transitions between high and low workload.
- **Environmental factors** – Regulatory requirements and industry guidance specify that environmental conditions in the MCR are maintained within ranges that support long-term habitability. Due to limitations in the environmental variability of the simulator environment, external environmental V&V variables are assessed in the operating plant environment and are accounted for during HFE design implementation and are described in the *Human Factors Engineering Design Implementation*, MPWR-TECR-005014.(Reference 6.3.3).

  The effects of environmental factors on completion of tasks performed in the field that support control room operations are estimated. Where possible, field tasks to be included in V&V scenarios are timed using real-time walkdowns of actual plant equipment to be operated, taking into account the effects of environmental conditions that may vary as a result of a given scenario. Examples of how the V&V scenarios in the scenario guides reflect field environmental factors include:

  - Predetermined delay times added to field task completion times reported to control room operators due to the time it takes to don protective anti-contamination clothing

- Scenarios with local tasks that require the site emergency director to make a decision about whether or not to exceed NRC dose limits to save a life or significant plant equipment

4) Select the risk-informed representative sample of tasks and scenarios to be evaluated by HFE V&V. The priorities and situational factors known to challenge human performance are used by the HFE design team as the basis for an unbiased, risk-informed method to select a representative sample of operational conditions having the most significance to the B&W mPower reactor.

[

[CCI per Affidavit 4(a)-(d)]

]All risk-significant human actions are represented within the group of tasks and scenarios selected. Additionally, the selection process ensures that each of the situational factors known to challenge human performance is included in at least one task or scenario. Based upon analysis of the selected operational conditions and situational factors matrix, HFE V&V team members select a sufficient number of tasks and scenarios to ensure a broad and representative sample of the highest significance.

5) The risk-informed representative sample of tasks and scenarios to be evaluated by HFE V&V is peer-reviewed by an HFE V&V team member independent from the person(s) that developed the sample. The reviewer ensures that risk-informed representative sample is:

- Representative of the range of events that are encountered during plant operation
- A reflection of the characteristics that are expected to contribute to plant system performance variation
- Reflective of the safety-significance of HSI components

If the reviewer identifies any selection issues, the reviewer works with the other member(s) of the task and scenario selection team to ensure that the sample and the matrix of all of the operational conditions are analyzed for alternative scenario selections that would create an acceptable risk-informed representative sample. Any significant changes to the sample (greater than 10 percent) are documented as HEDs for tracking and resolution.

Additionally, the reviewer ensures that the resulting set of scenarios is evaluated for selection bias in any of the following areas:

- Tasks or scenarios for which only positive outcomes are expected – this is avoided by selecting operating conditions for use in scenarios identified in the PRA/HRA as risk-important and conditions known to challenge human performance.

- Tasks or scenarios that are relatively easy to conduct administratively – tasks or scenarios are selected that best accommodate the selected tasks and conditions, not which are the easiest to conduct.
- Tasks or scenarios that are familiar and well-structured – tasks and scenarios are selected that allow scenario development writers to introduce sufficient variation into the task or scenario sequence.

If development bias is detected, the reviewer works with the other member(s) of the task and scenario selection team to ensure that the sample and the matrix of all plant operational conditions are analyzed for alternative scenario selections that would create a risk-informed representative sample. Any occurrences of significant sampling bias (greater than 10 percent) are documented as HEDs for tracking and resolution.

6) The risk-informed representative sample of tasks and scenarios to be evaluated by HFE V&V identified above is documented for use throughout the HFE V&V process and for audit/review.

[

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[CCI per Affidavit 4(a)-(d)]

3.3 Human-System Interface Inventory and Characterization

The HSI inventory and characterization process provides a comprehensive listing of HSIs and their design attributes associated with the list of conditions developed by the OCS. This characterized listing is used throughout the HFE V&V process to ensure:

- Inventory and individual HSI design capabilities and features are consistent with HFE analysis and HSI design results
- Individual HSIs and their grouping support the safe and efficient performance of operator tasks
- The integrated HSI provides all alarm, information, and control capabilities required for the safe and efficient performance of operator tasks and scenarios

The HSI inventory and characterization process documents the design characteristics, descriptions, and requirements of the HSI components required to perform the tasks and scenarios selected to be verified and validated. The inventory is created from the HSI task support requirements determined during task analysis for the selected tasks and scenarios. Design details and requirements for the HSIs needed to complete a task are gathered from I&C and plant design documents such as system description documents, design specifications, and plant design and instrumentation drawings. The inventory includes aspects of the HSI that are used for interface management such as navigation and display retrieval in addition to those that control the plant.

The characterized inventory of HSIs is developed using the steps outlined below:

- Obtain the risk-informed representative sampling of tasks and scenarios selected in the operational condition sampling process.
- Identify the HSIs required for successful task completion of the tasks and scenarios in the risk-informed representative sample and gather design attribute data for each of these HSIs.
- Document the HSI characteristics for verification in the other elements of HFE V&V. The HSI characteristics include:
  - Individual HSI functionality
  - Coding and labeling
  - Design conventions (use of color, font size, spacing, etc.)
  - HSI input devices (keyboard, mouse, trackball, etc.)
  - Soft display navigation
- Document functional capabilities, performance, and ease of use of plant communication systems
- Document room layouts and panel configurations (anthropometrics, ergonomics, organization, and labeling)

- Document work environment (lighting, space, air conditions, floor design, and noise mitigation)

- Document physical screen layouts and the placement of those screens within the navigation hierarchy.

3.4 Human-System Interface Task Support Verification

The task support verification process ensures that HSIs (alarms, controls, and displays):

- Are designed and grouped with capabilities and features consistent with task analyses and HFE design requirements
- Collectively support the safe and efficient performance of plant operator tasks for which they are being evaluated
- Provide all alarms, information, and control capabilities required for the safe and efficient performance of plant operator tasks

Task support verification process also assures that the HSIs required to perform the task being validated are present in the design and meet the requirements defined during task analysis. This process also identifies any missing HSIs (i.e., those HSIs required for task performance but are not included) or HSIs and HSI characteristics that exist, but do not support tasks.

Task support verification evaluates the completeness of the HSI inventory in relation to the tasks being verified and the HSI design's conformance to HFE requirements. The bases for the task support verification process are task analysis results, HSI style guide task-based grouping guidelines, and related guidelines and requirements.

The process of verifying task support capabilities consists of two main activities:

- Verify the presence (or absence) of instruments and equipment that provide the information and control capabilities necessary to implement each step required to complete the task or scenario being considered. This activity verifies the availability of the required HSIs.
- Determine whether the HSIs are effectively designed to support task accomplishment. This activity verifies human engineering suitability and compliance with HFE guidelines and requirements.

The HFE design team utilizes the following resources to complete the activities described above:

- 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 high-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.

- Control room/panel design drawings and mockups

  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 groupings are in keeping with HFE, regulatory, and style guide requirements.

  Mockups may be used for task support verification in lieu of panel and room layout drawings.

- Computer-generated displays

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

  Computer screen printouts may be used for task support verification in lieu of active HSI screen displays. Computer screen printouts portray the soft-HSI components on a screen-by-screen basis and, if used, are saved as part of the task support verification data package.

The task support verification is conducted using a process of preparation, evaluation, and documentation. These steps are discussed below.

1) Preparation

   Preparation for the verification process includes identifying source documents and evaluation criteria, assigning an evaluation team, developing a detailed evaluation plan, briefing the evaluation team, and scheduling the evaluation.

   - The source documents used include:
     - Task analysis results
     - The list of characterized HSIs from the operational condition sampling process
     - The HSI style guide task grouping criteria
     - Design basis documents such as panel layout drawings or soft-HSI screenshots
   - Preparation activities include:
     - Identifying the system tasks and scenarios to be evaluated, and the evaluation criteria
     - Preparing task grouping data-gathering tools based upon HSI task grouping design criteria
     - Identifying the task support verification evaluation team
     - Scheduling the evaluation

2) Evaluation

The purpose of evaluation is to ensure that all the HSIs required to complete the tasks and scenarios evaluated by the V&V process are present in the design and are engineered in a manner that supports successful task performance. This process is completed by comparing the HSI design with task support-based verification criteria.

HSI task support verification results are documented in a traceable manner and in accordance with applicable document control procedures.

The task support verification evaluates whether or not plant operators can perform safely and efficiently complete tasks with the available HSI.

Task support verification ensures that:

- Information required for successful task or scenario completion is available to the operator
- The design and capabilities of the HSIs provided support successful task or scenario completion
- The arrangement and layout of the integrated HSI and operator workstations support successful task or scenario completion

The task support verification evaluation team verifies that both the hard- and soft-HSIs required for the task being evaluated are present and grouped in keeping with HFE, regulatory, and HSI design style guide requirements. The verification process includes verification of the HSI availability and suitability.

- Verification of Availability

  In this portion of the task support verification process, the task support verification evaluation team verifies that the necessary HSIs are present. This activity compares the information and control component requirements identified in the task analysis with the HSI inventory to ensure that all HSIs needed to complete a task are present.

  HEDs are written if the HSIs either do not meet the requirements as identified in the task analysis, or if they exist when no requirements for them have been identified.

- Verification of Suitability

  In this portion of the task support verification process, the task support verification evaluation team verifies that the HSI design supports safe and efficient operator task performance. This activity compares the HSI functionality and usability requirements identified in the task analysis and the HSI style guide with the HSI inventory to ensure that HSI functionality needed to complete a task is present.

  HEDs are written if the HSIs do not function as needed or do not conform to style guide requirements.

3) Documentation

The output of the task support verification process is a listing of HSIs that have been verified to meet HFE, regulatory, and style guide task grouping/support design requirements.

HEDs are entered into the HED database for deficiencies associated with HSIs that support task completion and unnecessary components identified during the verification process. Documentation includes the HSIs involved, the task support criteria impacted, and the basis for identified deficiencies.

HSI task support verification documentation provides a traceable record of the verification process and identifies:

- Evaluators who performed the task support verification
- Date of the task support verification
- Tasks and HSIs evaluated
- Acceptance criteria used for the evaluation including task analysis results and requirements, as well as HSI style guide requirements.
- HEDs written to document and resolve HFE issues identified during the HSI task support verification

3.5 Human Factors Engineering Design Verification

The HFE design verification process ensures that HSIs:

- Are individually designed with capabilities and features consistent with task analyses results and HFE design and style guide requirements
- Individually support the safe and efficient performance of the operator tasks for which they are being evaluated
- Individually provide the alarm, information, or control capabilities for which they are designed

HFE design verification evaluates the conformance of each HSI component design with HFE guidelines, standards, and principles presented in the HSI design style guide and applicable regulatory requirements. Design verification evaluates the following HSI component design details:

- HSI characteristics:
  - Individual HSI functionality
  - Coding and labeling
  - Design conventions (e.g., use of color, font size, spacing, etc.)

- HSI input devices (e.g., keyboard, mouse, trackball, etc.)
- Soft display navigation

- Functional capabilities, performance, and ease of use of plant communication systems
- Room layouts and panel configurations (e.g., anthropometrics, ergonomics, organization, and labeling)
- Work environment (e.g., lighting, space, air conditions, floor design, and noise mitigation)

HSI component designs are compared to the HSI style guide and HFE guidelines to ensure that their designs incorporate features intended to:

- Provide consistency among the controls of the plant systems
- Limit paradigm shifts to that ensure that HSI arrangement reflects consistent use of style guides and HFE guidelines
- Take advantage of human strengths and compensate for human weaknesses
- Ensure that individual HSI designs accommodate human characteristics and capabilities

Deviations from the HSI style guide or HFE guidelines, standards, and principles are documented as HEDs for resolution in the HED resolution process.

The HFE design verification process evaluates the hard controls, soft controls, and information display HSIs used to complete the tasks and scenarios being evaluated. In addition to the plant alarms, controls, and displays, HSIs used for interface management, navigation, and information retrieval are verified.

The HFE design verification evaluates the design of the control room, control panels, and individual hardware- and software-based HSIs to ensure compliance with HFE design requirements and HSI style guide requirements. The bases for design verification are the HSI style guide, HSI design requirements, guidelines, and related criteria. The design verification process examines the HSI components required to complete the risk-informed sample of tasks and scenarios to ensure that they individually meet HFE design requirements, and therefore support the safe and efficient performance of operator tasks.

The HFE design verification includes:

- Verification that the design of features relating to the configuration and environmental aspects of the HSI meet the guidelines and requirements of the HSI style guide. This activity verifies the design of the room and environment within which plant operator's interface with plant alarms, control, and displays. These configuration and environmental aspects are evaluated once per design attribute.
- Verification that the design of standardized HSI features meets the HFE guidelines and requirements of the HSI style guide. Alarm, control, and display designs are verified to meet the HFE guidelines and requirements of the HSI style guide applicable to their

specific design. Standardized features are evaluated once during the design of each specific type of HSI component and spot-checked thereafter.

- Verification that the design of detailed HSI features not addressed by general HFE guidelines meets HSI style guide requirements or good engineering design practices, and meets the spirit of HFE principles for similar design attributes. Detailed features are evaluated on a case-by-case basis.

Design verification is a process that ensures that individual HSIs (alarms, controls, and displays) required to perform the task being validated are present in the design and meet the requirements defined during task analysis. This process also identifies any HSIs or HSI characteristics that exist, but do not support tasks. The bases for the design verification process are task analysis results, HSI style guide component guidelines, HSI design documentation, and related guidelines and requirements.

The process of verifying HSI design attributes consists of two main activities:

- Verify the presence (or absence) of the individual alarms, controls, and displays documented in the inventory and characterization process. This activity verifies the availability of the required HSIs.

- Determine whether the HSIs are designed in accordance with all applicable requirements, guidance, and accepted HFE principles. This activity verifies human engineering suitability and compliance with HFE guidelines and requirements.

The HFE design team utilizes the following resources to complete the activities described above:

- 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 are designed in keeping with HFE, regulatory, and style guide requirements. Simulators that meet high-fidelity requirements for the HSIs being verified are used.

- Control room/panel design drawings and mockups

  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 is in keeping with HFE, regulatory, and style guide requirements.

  Mockups may be used for design verification in lieu of panel and room layout drawings.

- 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 is in keeping with HFE, regulatory, and style guide requirements.

Computer screen printouts may be used for design verification in lieu of active HSI screen displays. Computer screen printouts portray the soft-HSI components on a screen-by-screen basis and, if used, are saved as part of the design verification data package.

The design verification is conducted using a process of preparation, evaluation, and documentation. These steps are discussed below.

1) Preparation

   Preparation includes identifying source documents, identifying evaluation criteria, assigning an evaluation team, developing a detailed evaluation plan, briefing the evaluation team, and scheduling the evaluation.

   - The source documents used include:
     - The list of characterized HSIs determined to be within the scope of HFE V&V
     - The HSI style guide
     - Design basis documents such as system design documents that include HSIs, instrumentation and control drawings, panel layout drawings, or computer-based HSI screenshots.
   - Preparation activities include:
     - Obtaining the list of characterized HSIs associated with the tasks and scenarios selected in the operational condition sampling process
     - Identifying the HSI design verification evaluation team
     - Scheduling the evaluation

2) Evaluation

   The purpose of evaluation is to ensure that all the HSIs identified in the V&V inventory and characterization process are present in the design and are designed in a manner that meets engineering design requirements and HSI style guide requirements. Deviations are identified by comparing the HSIs and their design attributes with the verification criteria.

   Design verification results are documented in a traceable manner and in accordance with applicable document control procedures.

   The design verification evaluates whether or not individual HSI components and the environment in which they are used conform to engineering design requirements and HFE guidelines.

   The design verification evaluation is accomplished by comparing the characterized HSI inventory with HFE guidelines. The design verification evaluation team ensures that HSI components, environmental features, design document characterizations, simulator features, and computer-generated displays conform to design requirements and HFE guidelines. The design verification is completed and documented for all HSIs in the inventory and characterization listing and includes:

- Work environment
- Workplace layout
- Panel anthropometrics
- Individual alarm, control, and display components
- Control room support equipment such as communication devices (support equipment is evaluated primarily for usability and placement as it is generally procured as a completed product)

HSI components determined to be discrepant during design verification are recorded as HEDs and resolved using the HED process. Should the HED resolution process require retesting using the design verification process, the process described in this section is re-performed for the applicable HSIs.

3) Documentation

The output of the design verification process is a listing of HSIs that have been verified to meet HFE, regulatory, and style guide design requirements. Because the HSI design style guide used in the evaluation of HSIs is written in compliance with HFE principles, regulations, and guidance, compliance with the style guide demonstrates that the evaluated HSIs or environmental features conform to HFE guidelines.

HEDs are entered into the HED database for deficiencies associated with HSIs that are needed but do not meet all design requirements and unnecessary components identified during the verification process. Documentation includes the HSIs involved, the design criteria impacted, and the basis for identified deficiencies.

HSI design verification documentation provides a traceable record of the verification process and identifies:

- Evaluators who performed the design verification
- Date of the design verification
- HSIs, environmental features, and other design features evaluated
- Acceptance criteria used for the evaluation including task analysis results and requirements, as well as HSI style guide requirements.
- HEDs written to document and resolve HFE issues identified during the HSI task support verification

3.6 Integrated System Validation

The ISV evaluates the HSI, the environment in which it is used, and plant operators in the context of completion of personnel tasks and scenarios selected in the operational condition sampling process. The ISV evaluates the ability of plant operators to use the integrated HSI to safely and efficiently operate the plant. This validation ensures that the integrated HSI and operator interface with it meets HFE guidelines, standards, and principles reflected in the HSI design style guide.

The ISV is a performance-based evaluation of the integrated HSI design during human task performance to ensure the HSI meets all performance requirements, and that it supports safe operation of the plant. It evaluates the acceptability of those aspects of the design that cannot be evaluated by the task support or design verification processes. The ISV is performed using a dynamic high-fidelity full-scope simulator which evaluates plant operator ability to efficiently and effectively use the integrated HSI to successfully complete controlled dynamic scenarios.

ISV performance is compared to HFE guidelines, PRA/HRA assumptions and risk-significant human actions, design criteria, and HFE analysis results to determine whether the integrated HSI supports successful task completion. Deviations from task performance requirements or accepted HFE guidelines, standards, and principles are documented as HEDs for resolution in accordance with the HED resolution process.

ISV confirms the adequacy of the following:

- Integrated HSI support for safe and efficient task and scenario performance
- Allocation of functions to human, automation, or shared performance and associated role of plant personnel alignment with operational analysis results, the concept of operation, and HFE guidelines and requirements
- Task completion within the limitations and performance assumptions documented in the PRA/HRA
- Integrated HSI support of tasks accomplishment within the time and performance criteria established through task analysis
- Integrated HSI support for efficient search and retrieval of information and controls
- Integrated HSI configuration support for achieving HFE program goals and compliance with HFE practices and principles
- Integrated HSI support for transitions between plant and system modes, safety and non-safety HSIs, and between the HSI interface and other operator tasks such as reading procedures and communication devices
- Integrated HSI design minimization of the chance for operator error, tolerance of human error and system faults, and crew ability to detect these issues
- Operator workload associated with using the integrated HSI design during task and scenario performance

- HSI support of high situational awareness to minimize operator errors
- Both minimum and normal staffing levels and qualification for appropriate roles

The ISV process develops scenarios that incorporate the tasks and scenarios selected in the operational condition sampling process. These tasks and scenarios, and the validation test objectives are developed in detail and documented to facilitate their performance on a high-fidelity full-scope simulator.

The ISV scenarios are presented to test participants by members of the HFE design team specifically selected to support the delivery and evaluation of a given scenario. Most scenarios require similar skills to be present in the team administering them. When required to support specific scenario requirements, additional skill sets are added to the scenario administration team.

Administrative packages are produced that govern the presentation and evaluation of each ISV scenario. Included in these scenario packages are detailed HFE measures applicable to the specific scenario to be administered, and acceptance criteria customized for applicability to the specific scenario.

The scenario packages describe the initial conditions, the proper sequence of plant responses and applicable symptoms. Sequences of events expected to be followed by the crew when responding to the scenario are documented in the scenario package in order to allow for the evaluation criteria development. After crews complete a given evaluation scenario, the expected crew response is compared to the actual path that the crews take to complete each scenario. Additionally, the ISV process provides the administrative procedures governing the presentation of scenarios to test participants and the documentation of results.

After scenario administration packages for all ISV scenarios are developed, the scenarios are organized into the order in which they are to be administered and presented to the assigned test crews. Scenarios are presented to test crews in accordance with their administrative scenario packages and their crew assignments. During scenario performance, crew ability to safely and efficiently utilize the HSI to successfully complete scenarios is observed, documented, and evaluated. The primary emphasis of the ISV is upon human interaction with the HSI and design aspects of the integrated HSI. Issues relating to procedures, training, or performance of the operators are documented as HEDs for resolution. Any human engineering discrepancies noted during the ISV process are also documented as HEDs for tracking, evaluation, and resolution.

3.6.1 Validation by Simulation

The full-scope simulator is a high-fidelity simulation tool used by the HFE design team to validate the integrated control room design. The hardware and software configuration is a high-fidelity replication of the layout, look, and functionality of the control room and the integrated HSIs it contains.

The ISV is performed prior to the formal high-fidelity proof-testing of the simulator in accordance with ANSI Standard 3.5 (Reference 6.3.2) and Regulatory Guide 1.149

(Reference 6.2.5). The HFE design team, I&C engineering, and simulator engineers collectively make the determination when the full-scope simulator is of sufficiently high-fidelity to support validation testing of the integrated HSI. The basis for this determination is documented prior to testing.

The basis for determining when the full-scope simulator is of sufficiently high-fidelity to support validation testing of the integrated HSI includes the following elements of simulator fidelity:

- Interface completeness – The full-scope simulator accurately represents the integrated system and includes alarms, controls, displays, and other control room features in close proximity to the HSIs being evaluated. This includes HSIs and procedures not specifically required for the test scenario.
- Interface physical fidelity – The full-scope simulator accurately represents the physical layout and content of the integrated control room including room, panel, and HSI layouts, shapes, colors, and contents as well as other control room features such as operator aids, procedures, and communications equipment.
- Interface functional fidelity – The full-scope simulator hard and soft control functionality accurately represents the functionality of control room HSIs including modes of operation, feedback, design capabilities, and limitations along with all necessary procedures.
- Environmental fidelity – The environment in which the full-scope simulator is housed accurately represents the plant control room environment including ambient lighting, noise, humidity, and temperature.
- Data completeness fidelity – The simulated plant and HSI data presented by the full-scope simulator accurately represents the data that is presented in the control room with no pertinent data missing and no extra data available.
- Data content fidelity – The full-scope simulator accurately represents plant responses as observed through the HSI including plant and plant system responses to simulated transients, accidents, and system perturbations or control device input.
- Data dynamics fidelity – The full-scope simulator plant modeling and the simulation computers simulating and stimulating integrated HSIs are of sufficient capability to accurately represent the manner in which control room hard and soft HSIs provide information and feedback to operators. Response times are consistent with actual plant responses.

3.6.2 Integrated System Validation Presentation Team and Participant Population

- ISV Scenario Presentation Team

  The ISV presentation team develops sets of scenarios for validation tests and presentation documentation. The team is made up of personnel meeting the required HFE design team qualifications. The presentation team size and skill set diversity are expanded as needed to meet the development, presentation, observation, measurement, and evaluation needs of specific scenarios.

The names and qualifications of presentation team personnel involved in the development, presentation, observation, measurement, and evaluation of specific scenarios are documented and retained.

- Participant Population

  The participant population from which the ISV test crews are drawn includes previously licensed personnel or personnel enrolled in training classes for the purpose of licensing. Crews are selected that are representative of actual plant personnel including both experienced and new operators, and a range of ages and general demographics. Information regarding each participant's age, experience, work history/skill, and biometric information is gathered and documented.

  Participant personnel are selected to support both minimum and normal crew configurations including Shift Managers (SMs), Senior Reactor Operators (SROs), Shift Technical Advisors (STAs), and Reactor Operators (ROs).

  To prevent participant sample bias:

  - Members of the HSI design team are not allowed to act as crew members.
  - Test participants do not act as a crew member in a given scenario more than once.
  - Criteria specifically targeting individual characteristics are not used in the participant selection process.

3.6.3 Scenario Definition

The scenarios used in the validation evaluation are written to incorporate one or more of the tasks and scenarios selected in the OCS process. The presentation team develops a set of scenarios that collectively evaluates every task or scenario selected in the operational condition sampling process. Because of the diversity of the sample, V&V scenarios cover a wide range of plant conditions, and plant system- and component-level malfunctions.

Scenarios are verified on the simulator prior to testing to ensure that they can be conducted by the presentation team and that they do not impose requirements that exceed the capabilities of the simulator.

Scenarios selected for inclusion in the validation tests have presentation documentation developed in sufficient detail to support consistent presentation on a simulator. To ensure scenario presentation accuracy, consistency and repeatability, these documentation packages include the following:

- Description of the scenario and any pertinent information necessary for personnel to understand the state of the plant upon scenario initiation

- Specific initial conditions similar to an operations crew shift turnover
- Events (failures) to occur and initiating conditions (e.g., parameter values, or events)
- Definition of workplace factors (e.g., environmental conditions)
- Task support needs (e.g., operating procedures, technical specifications, test equipment and procedures)
- Staffing objectives
- Communication requirements with remote personnel
- The specification of what, when, and how data is to be recorded
- Criteria for scenario termination

Scenario packages are developed to ensure that scenario presentation incorporates appropriate task fidelity so that realistic task performance is observed in the tests and so that test results can be generalized to actual operation of the real plant.

When evaluating performance associated with operations remote from the main control room, the effects on crew performance due to potentially harsh environments such as high radiation areas are simulated (e.g., additional time to don protective clothing and access radiologically controlled areas). Appropriate time delays, feedback alarms and displays within the HSI, and verbal cues are included in the scenario package.

3.6.4 Performance Measurement

The ISV evaluation criteria are consistent with all applicable regulations, standards, and guidelines. Criteria are defined for the evaluation of the integrated HSI and for interactions between the HSI and participant crews. The ISV scenario measurement characteristics, performance measures, and performance criteria confirm the incorporation of HFE design principles in the integrated HSI and the ability of the crew to interact with it.

3.6.4.1 Performance Measurement Characteristics

The quality of each performance measure is evaluated in terms of the following characteristics (not all of which apply to every measure):

- Construct Validity – A determination of the extent to which a performance measure accurately represents the performance aspect to be measured. While some performance attributes such as physical actions are directly measurable, others such as situational awareness and cognitive workload are not. These attributes are not directly observed but rather are inferred based on observation of behavior. Performance measures that most accurately infer the aspect of performance being considered have the greatest construct validity.
- Diagnosticity – A determination of the extent to which a performance measure provides the information necessary to determine the cause of acceptable or unacceptable performance. Supplemental measures such as situational awareness

and cognitive workload provide diagnostic support to the set of performance measures because they measure characteristics of human performance that provides contextual information. This contextual information is used to identify the underlying causes of acceptable and unacceptable performance.

- Impartiality – A determination of the ability of a performance measure to reflect good as well as poor performance. Impartiality is indicative of a lack of bias in the performance measure.
- Objectivity – A determination of the extent to which a performance measure is based on phenomena that are easily observed. An objective performance measure utilizes direct observation/measurement and minimizes interpretation.
- Reliability – A determination of the extent to which a performance measure can yield consistent results across repeated tests of the same subject under identical conditions. A measure has high reliability if repeated measurements produce the same results. A reliable performance measure yields the same measurement distribution with repeated tests.
- Resolution – A determination of the extent to which the detail captured by a performance measure supports detailed analysis of results. A performance measure with adequate resolution provides sufficient detail to permit meaningful analysis of results leading to a supportable conclusion regarding the performance measured.
- Sensitivity – A determination of the extent to which a measure's data gathering parameters are appropriate for the performance being evaluated. A performance measure with adequate resolution provides sufficient scale and frequency of measurement to permit meaningful analysis of results leading to a supportable conclusion regarding the performance measured. Scale refers to the level of detail a performance measure is able to discriminate. More sensitive measures have the ability to capture smaller performance variations but in turn may provide excessive detail making the identification of relevant data more difficult. Frequency refers to the rate at which a performance measure samples the performance parameters it monitors.
- Simplicity – A determination of the extent to which a performance measure is relatively easy to test, measure, and interpret. A simple performance measure lends itself to ease of use and interpretation but does so without sacrificing reliability or validity.
- Unintrusiveness – A determination of the extent to which a performance measure can be tested without affecting the psychological or physical processes being measured. An unintrusive performance measure disturbs test subjects so little that behaviors are not altered due to observation and measurement.

Performance measures considered for use in the ISV are considered in light of these characteristics. The performance measures presented below are a hierarchical set of performance measures selected to maximize these characteristics while providing the objectivity, accuracy, and level of detail required to judge the acceptability of the HSI and human interface with it. Additionally, the hierarchy of performance measures provides sufficient supplemental/amplifying detail to understand the reasons/causes for observed performance or performance issues.

3.6.4.2 Performance Measures

A hierarchical set of performance measures is used to assess the adequacy of the integrated HSI and human interface with it. This hierarchy contains "Pass/Fail" measures that must be satisfied for successful scenario completion and supplemental measures that facilitate analysis of performance errors and their underlying causes.

The ISV performance measures and associated criteria evaluate the performance of plant personnel interfacing with the integrated HSI. Ultimately, these measures provide the basis for determining whether or not the integrated HSI satisfies HFE requirements, goals, and design criteria. This hierarchical set of performance measures and associated criteria applicable to each ISV scenario are different and are a function of the events that are presented during the scenario. Criteria applicable to each scenario event are documented in the scenario package developed to guide the presentation and evaluation of each scenario.

Both high-level pass/fail and supplemental measures are appropriate for performance measurement because successful plant and plant system performance requires that supporting components and HSIs be effectively utilized by plant operators.

1) High-Level Pass/Fail Performance Measures

   The pass/fail performance measures selected for the ISV are based on predetermined plant design basis critical safety function criteria. The relationship between progressively higher tier criteria and associated plant states can be seen in Figure 2. [

   ] **[CCI per Affidavit 4(a)-(d)]**

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[CCI per Affidavit 4(a)-(d)]

Figure 2. Scenario Criteria Hierarchy and Plant State

- Thermal-Hydraulic Analysis Results

  The ability of the crew to maintain core thermal-hydraulic conditions within acceptable limits as defined by design basis analysis results is a pass/fail performance measure during ISV scenarios.

  Thermal-hydraulic models are used to establish parameters that must be kept within defined limits in order to prevent core damage. Pass/fail performance is determined by whether or not plant thermal-hydraulic parameters are maintained within design basis limits. To measure performance, thermal-hydraulic parameter extremes that occur during scenario are compared to the expected values and limits determined during design basis analyses.

  Core thermo-hydraulic design basis criteria are established and documented as part of the B&W mPower engineering design process. For the design basis accidents and events analyzed, the B&W mPower design has been shown to be safe with critical parameter peaks documented for each analysis (Reference 6.3.7).

The design basis thermal-hydraulic limits and associated criteria form pass/fail criteria for ISV scenarios that contain one or more design basis events. The crews that participate in scenarios where design basis thermal-hydraulic limits are challenged must use the integrated HSI to respond to events without exceeding design basis thermal-hydraulic limits or supporting licensing analyses. If a validation scenario contains a design basis event within its sequence of events, the design basis thermal-hydraulic limits for that event contained in B&W mPower licensing documents are included in the HFE ISV scenario package as scenario pass/fail criteria.

The events contained in an ISV scenario determine the design basis thermal-hydraulic limits that are challenged and whose limits then become acceptance criteria for the scenario.

- PRA/HRA Analysis Results

  The ability of the crew to maintain plant and containment conditions within acceptable limits as defined by PRA/HRA results is a pass/fail performance measure during ISV scenarios. The ability of test participants to respond to events using the integrated HSI is tested to validate that system manipulations produce plant responses in keeping with analysis results.

  To test PRA/HRA assumptions and risk-important human actions, scenarios are developed that contain risk-important actions. The extent to which the integrated HSI can be effectively utilized by plant operators to respond to events is recorded and evaluated with respect to the completion times and peak parameter values determined during PRA/HRA analysis.

  For the design basis accidents and abnormal operational occurrences examined during the PRA/HRA analysis, the B&W mPower design has been shown to have acceptable risk (Reference 6.3.8). For each PRA/HRA scenario analyzed the results document both the level of risk and the critical plant parameter limits and human action completion times associated with the risk determination. It is unacceptable for design basis PRA/HRA parameter limits or response times to be exceeded by average test participant crew response to a respective PRA/HRA-analyzed event.

  For each ISV scenario containing PRA/HRA-analyzed events, average plant operator performance must fall within the acceptable range of parameters and time limits defined by PRA/HRA analyses.

2) Supplemental Performance Measures

   Supplemental performance measures provide additional information regarding the results of other performance measures. This supplemental information is used to understand the basis for observed performance. Understanding the basis for crew actions results in more accurate and credible conclusions regarding observed performance. Primary operator tasks are those involved in the performance of the task. Secondary tasks are those involved with HSI utilization such as navigation and screen configuration.

Supplemental measures include personnel task performance, situation awareness, physical and cognitive workload, anthropometric and physiological factors, and crew coordination and communication.

- Personnel Task Performance

  For each ISV scenario, the primary tasks that personnel perform during the scenario are identified. Tasks identified during scenario development are assessed during scenario performance to validate that the integrated HSI adequately supports task performance.

  The results of the task analysis process include task performance criteria that can be used to evaluate the ability of the operators to complete plant system manipulations, control equipment, and to monitor plant system parameters and plant system responses to automatic actions and manual manipulations.

  Other task performance measures include time to complete tasks, errors observed during task performance, frequency of task performance and any additional task performance parameters identified during task analysis. These task performance parameters include (as applicable):

  - Task completion time requirements
  - Accuracy requirements
  - Frequency requirements
  - Quantity of materials used in task performance
  - Quantity of task end product produced

[

] **[CCI per Affidavit 4(a)-(d)]**

  Observations performed by test personnel are used to determine participant task performance. These observations are verified by comparison with videotaped recordings of the session and saved simulator data. Data is also gathered from crew questionnaire responses pertaining to manipulations that require in-depth analysis.

- Situation Awareness

  Situation awareness is monitored and assessed during ISV scenarios because inadequate situation awareness has been identified as one of the primary factors in accidents attributed to human error. Situation awareness is of particular importance in scenarios where information flow is high and poor decisions may lead to serious consequences. Even if poor situation awareness is not a primary cause of ISV issues, it is assessed and documented in order to gather additional insights regarding the results of other performance measures.

  An objective measure of situation awareness is obtained by directly comparing operators' reported situation awareness to reality. To use this technique, ISV scenarios are frozen at randomly selected times to allow operators to be questioned regarding their current understanding of plant and plant system statuses. During data analysis after ISV scenario completion, operators' perceptions about a situation are compared to the reality of the situation at the time the situation awareness questions are asked. Comparing actual scenario status to the status perceived in this fashion provides an objective, unbiased assessment of situation awareness.

  It should be noted that situation awareness and cognitive workload (discussed below) often affect each other and are therefore evaluated in the context of each other.

- Physical and Cognitive Workload

  Workload represents effort (cognitive, physical, or a combination) expended by an operator to complete a task or series of tasks. The ISV process analyzes two elements of workload: physical and cognitive.

  To evaluate physical workload impact on operator performance, video recordings and scenario presentation team observations are documented that identify any of the following conditions during an ISV scenario:

  - Excessive or prolonged application of force (as defined by scenario performance criteria)
  - Repetitiveness
  - Awkward posture
  - Excessive or prolonged vibration (as defined by scenario performance criteria)

  Scenario presentation team personnel document the type, frequency, and context of instances of high physical workload. Measurements are taken either before or after integrated system validation scenarios to document HSI or control room characteristics that impact workload.

  To evaluate cognitive workload impact on operator performance, the information processing resources required for an operator to complete a task or sequence of tasks must be understood. Operator cognitive workload is evaluated to ensure that it is within acceptable limits because excessive cognitive workload is associated with decreased situation awareness and ability to perform complex tasks.

Cognitive workload for each ISV task or sequence of tasks is measured using the NASA-TLX tool (Reference 6.3.6) The NASA-TLX is a measurement tool that consists of a multidimensional scale comprised of evaluation factors related to mental workload.

- Anthropometrics and Physiological Factors

  Anthropometric and physiological factors include such concerns as visibility of displays, accessibility of control devices, and ease of control device manipulation that should be measured where appropriate. Control room anthropometric data is evaluated as part of the HFE design verification to ensure compliance to the anthropometric guidelines and HSI style guide. ISV testing confirms the adequacy of the combined HSI anthropometric design when operated collectively to respond to simulated plant events. ISV testing ensures that no problems arise during aggregate HSI use that may not have been evident when HSI components are individually verified to comply with anthropometric guidelines.

  Prior to performance of ISV scenarios, physical measurements are obtained from each test participant. These measurements are documented both as a historical record and for use in anthropometric analyses. Should issues related to anthropometric aspects of the design arise during ISV, the measurements of the test participants involved are referenced to better understand the issue and any contributing factors.

  It should be noted that anthropometric factors and physical workload (discussed previously) often affect each other and are therefore evaluated in the context of each other.

- Crew Coordination and Communication

  Communications between control room personnel and between control room personnel and plant staff outside the control room are observed and evaluated.

  Evaluator observations of crew coordination and communication are complemented by audio and video recording of crew performance in this area. It should be noted that crew coordination/communication and situation awareness (discussed above) often affect each other and are therefore evaluated in the context of each other.

3.6.4.3 Performance Criteria

- "Pass/Fail" Performance Measures

  The ISV scenario analyses and associated criteria evaluate the extent to which the integrated HSI meets plant-level goals and HFE design criteria. This integrated plant-level criteria applicable to each scenario is different and is a function of the events that take place within the scenario. Criteria applicable to each scenario are documented in the scenario guide written to facilitate the performance of the scenario.

Successful plant and plant system performance requires that supporting components and HSIs be effectively utilized to respond to events and maintain plant safety. Therefore, plant and plant system performance measures relevant to plant safety are documented and recorded during the performance of ISV scenarios. Simulator data is collected real-time and time-stamped. During analysis, this data is synchronized with the videos recorded during the scenario. Other sources of information such as simulator logs and scenario observer notes provide supplemental crew and HSI performance data that provides amplifying information to better understand and analyze performance.

This performance data is evaluated against plant, plant system, or component performance limits and criteria contained in design basis documents such as thermo-hydraulic analyses, PHR/HRA analyses, technical specifications, and task analysis results. Should observed critical plant or plant system parameters exceed design basis limits or design basis PRA/HRA calculation limits (as documented in the scenario guide for a give scenario), then the scenario is considered to have failed pass/fail criteria. HEDs are written for any pass/fail criteria that is not satisfied during an ISV scenario.

- Supplemental Measures

  In addition to the "Pass/Fail" criteria, subject matter expert and observer judgments are made and documented. These observations and judgments are themselves pass/fail criteria but are instead used to better understand the results of ISV scenarios. Supplemental performance criteria specific to a given scenario are documented in the applicable scenario guides.

  Because the integrated HSI is evaluated in the context of operator task performance, task analysis results establish the performance criteria for required plant system manipulations and monitoring during normal, transient, abnormal, and emergency conditions. Personnel task measurement criteria are established from the parameters identified during task analysis as indicative of successful task of evolution performance. Additionally, task performance criteria relating to the time to complete a task, errors observed during task performance, frequency of task performance, and any additional criteria the ISV scenario developers determine to be relevant are documented in the applicable scenario guides.

  Data related to observed human errors of both omission or commission is collected and analyzed.

  As is the case for pass/fail performance measures, supplemental performance measure data is documented and recorded during the performance of ISV scenarios. Simulator data is collected real-time and time-stamped. During analysis, this data is synchronized with the videos recorded during the scenario. Other sources of information such as simulator logs and scenario observer notes provide supplemental crew and HSI performance data that provides amplifying information to better understand and analyze performance.

Should observed supplemental performance exceed predetermined limits (as documented in the scenario guide for a give scenario), then the scenario is considered to have exhibited discrepant performance and an HED is written. HEDs are also written if supplemental performance is seen to affect more than one scenario though each of the scenarios may be acceptable when individually evaluated.

3.6.5 Test Design and Administration

The ISV process develops detailed documentation controlling the presentation of scenarios that incorporate the tasks and conditions selected in the OCS process. These scenario packages facilitate the presentation of each scenario on a high-fidelity full-scope simulation of the B&W mPower control room and associated HSI. The information presented in this section provides detailed procedures and processes that govern the conduct of ISV testing.

The ISV scenarios are presented to test subjects by members of the HFE design team specifically selected to support the delivery and evaluation of each scenario. Though most scenarios require the same base set of skills to be represented in the team presenting it to test subjects, the evaluation team adds additional team members with specialty skills if required for a given scenario.

Administrative packages are produced that govern the presentation and evaluation of each ISV scenario. The scenario packages describe the initial conditions, the sequence of events and plant responses, and applicable symptoms. The expected paths to be followed by the plant operators to mitigate each event within the scenario are provided to facilitate a comparison of the expected path and the actual path that the crews take to complete each scenario. Additionally, the scenario packages include details regarding performance measures and criteria applicable to the specific scenario for which the package is written.

In addition to defining the administrative processes and documentation associated with the scenario development, the ISV process provides the administrative process governing the presentation of these scenarios to test subjects and the documentation of results.

After the administrative packages for the full array of scenarios to be conducted are developed, the scenarios are organized in the order in which they are to be conducted and presented to the appropriate crews.

Scenarios are presented to test crews in the manner specified by the corresponding administrative scenario packages. The crew ability to effectively utilize the HSI and successfully complete scenarios is observed, documented, and evaluated. Successful performance (in the areas evaluated by both pass/fail and supplemental measures) demonstrates that the integrated HSI and operator interface with it satisfies HFE requirements and supports the safe and efficient operation of the plant. Any discrepancies noted are documented as HEDs and are tracked until resolved.

3.6.5.1 Coupling Crews and Scenarios

[

] **[CCI per Affidavit 4(a)-(d)]**

ISV testing is scheduled to occur after the full-scope simulator is of sufficient completeness and fidelity to support testing but prior to the commencement of ANSI Standard 3.5 (Reference 6.3.2) testing. The ISV testing schedule provides sufficient time for each scenario to be set up, completed, evaluated, and documented.

3.6.5.2 Integrated System Validation Test Procedures

The ISV is governed by a hierarchical system of administrative control documents. The highest tier documents are the ISV process administration documents that apply to the planning, execution, evaluation, and documentation of the aggregate ISV process including scenarios. Subordinate to the overall ISV administrative control documents are the individual scenario document packages. These documents provide working-level details that comply with and implement the processes and requirements contained in this technical report.

- Integrated System Validation Process Administration Documents

  The ISV process administration documents are written to govern relevant aspects of the process and to ensure that scenario preparation, presentation, and evaluation activities are conducted in a consistent, formal, and unbiased manner. These administration documents define the requirements for the following aspects of the ISV process:

  - Training of test administrators and participant crews
  - Scenario development and writing of the scenario document packages
  - Assigning simulation scenarios to crews

- Sequencing scenarios and scheduling their performance
- Simulator setup in support of scenario presentation
- Crew briefing prior to the performance of a scenario. The briefing procedure follows a detailed script that is prepared during scenario development.
- Crew walkdown of the simulator panels and verification of initial conditions.
- Conducting scenarios in accordance with the applicable scenario guides.
- Communication protocols for presenter/crew communications. All communications and cues are pre-scripted to prevent bias.
- Observation methods and the recording of performance results and supporting details
- Evaluation of scenario results and determination of whether or not the integrated HSI and human interface with it meet pass/fail and supplemental performance criteria
- Evaluation of aggregate ISV scenario results after all scenarios are presented to identify any cross-cutting issues
- Identification of HEDs
- Documentation of ISV results for inclusion in the V&V results summary report

- Scenario Document Packages

  Documentation packages are developed for each ISV scenario that provide clear and consistent guidance for the development and execution of ISV scenarios. These packages govern every aspect of preparing, presenting, and documenting of scenario results. These packages ensure unbiased, consistent, and repeatable preparation, presentation, and results evaluation for each scenario. The ISV scenario documentation packages are detailed and standardized groups of documents that include:

  - A coversheet and revision log
  - An administrative information sheet
  - Console operator instructions including timeline and manipulations required for initiation of the scenario events
  - Test personnel information sheet
  - One or more event guides with expected crew and simulator responses
  - Sequence of scenario events timeline specifying when events, faults, or cues are introduced
  - Realistic simulation of remote responses during scenarios
  - Scripting for communications with outside personnel expected to take place during the scenario

- Shift briefing/ transfer of authority information
- Administrative tools for determining where and when an HSI design attribute contributed to a performance problem
- Predetermined pass/fail and supplemental performance criteria specific to the events contained in the scenario
- Termination criteria for completion of the scenario

If the simulator fails to perform as expected during the performance of an ISV scenario, the crew continues participating in the scenario until instructed to stop by test personnel. If the simulator failure cannot be resolved, or if the test personnel feel the failure has invalidated the scenario as an evaluation tool, the scenario is terminated. If an ISV scenario is aborted due to simulator failure, an alternate scenario is selected that evaluates the integrated HSI in a manner that closely replaces the failed scenario (this ensures that the full sample scope is tested as planned even if a scenario cannot be presented as planned).

- Data Collection Methods

  ISV scenario performance data is collected using methods designed to minimize bias in both observers and participants. Automatic collection by videotaping and recording of plant parameters and manual HSI manipulations is used to the maximum extent possible. The videotape system and simulator software record time stamps are synchronized during post-scenario analysis.

  Detailed and standardized instructions for the collection and storage of scenario performance data are provided in ISV process test procedures and in individual scenario documentation packages. Performance data collection techniques include:

[

] **[CCI per Affidavit 4(a)-(d)]**

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- Controlling Bias

  Any influence, condition, or set of conditions that singly or together could distort the ISV scenario performance data represents bias and is minimized. Bias can produce variation in validation findings and can invalidate conclusions. The ISV process administrative control procedures provide a consistent and controlled framework within which the opportunity for bias is minimized. [

  ] **[CCI per Affidavit 4(a)-(d)]**

  HFE design team members participating in the preparation for, and execution of, the ISV minimize bias during the validation process. When bias cannot be eliminated, sources of bias are documented, measured, and are included as additional predictors in the final scenario analysis.

[

] **[CCI per Affidavit 4(a)-(d)]**

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[CCI per Affidavit 4(a)-(d)]

3.6.5.3 Integrated System Validation Administration Team and Participant Training

HFE design team members participating in the preparation, presentation, and evaluation of ISV scenarios receive training prior to initiation of the integrated validation testing. The ISV presentation team training includes:

- Scenario documentation package development
- Planning and scheduling of simulator sessions
- Simulation system training and qualification for simulation "drivers" (those personnel running the software that makes the full-scope simulator function)
- Observing test participant interaction with the HSI (such as, use of recording devices, development and use of observation tools, and taking notes during a scenario)
- Evaluating observations with regard to performance measures
- The use of test procedures
- Tester expectancy bias and the types of errors that are introduced through the failure of test personnel to accurately follow test procedures or interact properly with participants (such as when and how to interact with the crew during the simulation, non-intrusive locations to stand, etc.)
- Documenting problems that occur during ISV

Personnel that make up the ISV test crews receive comprehensive training on plant systems, procedures, and the integrated HSI. Participant crew training is substantially similar to the training presented to actual plant operating crews and includes both plant-specific formal classroom and high-fidelity simulator training. ISV participant crew training includes:

- Test participants who were previously licensed on a PWR receive plant-specific systems, procedure, and simulator training.
- Test participants with no previous PWR operating experience are required to receive PWR fundamentals training in addition to training on plant-specific systems, procedure, and plant-specific HSI. These test participants also receive their simulator training with previously licensed test participants. Performing simulator training in this manner promotes teamwork and allows the new trainees to benefit from the experience of the formerly licensed participants.
- All test participants are tested on both a periodic and comprehensive basis. ISV participant testing is similar to the tests plant personnel receive in actual plant qualification and licensing training. Participant training continues until tests show the following:
  - Satisfactory knowledge, skills, and abilities
  - Stable testing results that do not significantly vary from test to test

3.6.5.4 Pilot Testing

The ISV processes and procedures are pilot tested in conjunction with presentation team training. These pilot tests are used to exercise the processes and procedures for developing and executing test scenarios, gathering and interpreting data, and determining and documenting design adequacy.

Personnel used during pilot testing are not the same personnel used as test participants during integrated validation tests. Pilot testing participant crews are comprised of a combination of the following:

- Simulator maintenance and computer personnel
- ISV scenario presenters, observers, and evaluators
- Training department personnel and instructors

Anyone participating in pilot testing is barred from being part of the ISV test participant population.

3.6.6 Data Analysis and Interpretation

The data analysis process includes transforming the performance data collected during ISV scenarios into dependent variables of interest by grouping related data and placing it in meaningful context. The dependent variable is the variable that is being measured. The data analysis and interpretation process also assesses the extent to which variations of independent variables affect the dependent variables being assessed. The data analysis and interpretation process ultimately determines whether the integrated HSI meets the pass/fail criteria and whether or not supplemental criteria indicate the presence of one or more HEDs. Should a scenario not satisfy pass/fail performance measures, the scenario is considered to have failed and the cause of the failure is corrected by the HED resolution process before the design is considered validated.

Supplemental measurement data recorded during scenario performance supports qualitative assessments (e.g., a Likert scale assessment) of influencing factors such as lighting, noise, communication clarity, HSI information clarity, and other factors. The influence these factors have on the crew's ability to accurately detect, analyze, respond to, and monitor the success of mitigation actions is analyzed in order to better understand scenario results. Where performance does not satisfy supplemental performance measures, the scenario results are evaluated and resolved using the HED resolution process.

- Scenario Results Analysis

  After concluding an ISV scenario, scenario evaluators conduct post-scenario interviews and complete the documentation of their individual scenario observations. Individual conclusions are drawn regarding compliance with pass/fail measures contained in the scenario package. Additionally, individual evaluators draw conclusions regarding their perceptions of the relationship between observed performance and supplemental performance measures. Collective evaluation team results analysis, discussion, and the conclusions are documented after individual documentation is completed.

  Initial team data analysis activities include independent verification of individual evaluator pass/fail performance criteria results. Further group analysis is conducted regarding the relationship between failed pass/fail criteria results and observed supplemental performance criteria results. Group discussion and analysis continue until the team collectively concludes that the cause(s) of failed pass/fail performance criteria and any contributing factors are fully understood and documented. Additionally, group analysis and discussion address performance related solely to supplemental performance measures.

  The evaluation team's observations relating to a given performance measure are collectively reviewed by the team. Supplemental measures (see Section 3.6.4) that contain qualitative elements (i.e., elements that require a non-numerical evaluation) are evaluated in accordance with the criteria established during scenario development. A team analysis is performed and an aggregate team conclusion regarding the acceptability of each performance measure is reached. Integrated HSI features and attributes addressed by supplemental performance measure are acceptable if the analysis team determines that in their expert opinion, integrated system performance is acceptable. Team analysis conclusions and their bases are documented.

- Establishing Convergent Validity

  During data evaluation and analysis, convergent validity is established by comparing data from performance measures that measure the same or closely related aspects of performance. For example, situation awareness results obtained from test participants interviews, questionnaires, and feedback should have moderate to high association with situation awareness results obtained from the scenario evaluation team. Additionally, anthropometric results obtained from physical workload interview responses of test personnel should have moderate to high association with related anthropometric performance observations and measurements obtained from the scenario evaluation team.

In instances where two performance measures that are intended to measure the same performance aspect have no apparent association, an HED is written to document and resolve the issue.

- Margin of Error between Results and Reality

  The central purpose of the ISV process is to provide assurance via testing on a high-fidelity simulator that the HSI installed in the actual plant supports its safe and efficient operation. Because the high-fidelity full-scope simulator (though demonstrably highly similar to the actual plant control room) is not the actual plant control room, some variations between performance observed on the simulator and actual control room performance can be expected. The ISV process as well as the HFE design implementation and human performance monitoring processes are structured to minimize this issue and to detect and correct any significant variances.

  In order to assist the HFE design implementation process in the detection and evaluation of divergence between performance observed during ISV scenarios and real-world performance, validation testing limitations are documented. These limitations are documented, along with considerations regarding the potential effects of these limitations on validation conclusions and design implementation. Documented limitations include:

  - Aspects of the ISV scenarios that are not well controlled. Since the simulation is based on the models for the plant and not actual plant data, there may be some aspects that are not the same and cannot be controlled in the same way as the actual plant. Noted problems are documented.
  - Potential differences between the full-scope simulation used in validation testing and the real main control room such as lighting, vibration, background noise, etc.

  Additionally, the design implementation process ensures that the effects of design changes made to the integrated HSI after validation testing is complete are verified and validated to maintain reasonable assurance that the validity of V&V results is maintained.

- Aggregate Analysis of ISV Scenarios

  In addition to individual scenario analysis, the ISV evaluation team evaluates aggregate scenario results. The aggregate scenario review accomplishes the following:

- Evaluation of the aggregate impact of supplemental performance-related issues that may not have raised concerns when considered in the context of individual scenarios
- Evaluation of the integrated HSI as a whole to ensure its compliance with HFE requirements and guidelines and to identify any cross-cutting issues that may exist

HFE design team members evaluate the results of all ISV scenarios. Additionally, all HEDs generated during the ISV process are considered to determine if there is an aspect of the integrated HSI that warrants the generation of a cross-cutting issue HED due to broad low-level impact upon performance

The HFE design team combines the insights gained from evaluation of individual ISV scenarios and the aggregate analysis of all scenario results to make a final determination of the acceptability of the integrated HSI.

- Independent Verification of ISV Results

  The results and conclusions reached for each scenario as well as the aggregate HFE integrated system analysis are independently verified to ensure that the conclusions reached are accurate. Independent reviews are performed by HFE design team members not involved in the administration or evaluation of ISV scenarios. Should an independent reviewer identify any issues with the analysis or conclusions reached of either individual scenarios or the aggregate, HEDs are written.

3.6.7 Validation Conclusions

Following the completion of all ISV scenarios, a review is conducted of all HEDs, their significance, and their aggregate impact on the acceptability of the integrated HSI. The integrated HSI cannot be found acceptable with any unresolved and retested failed pass/fail performance measures. When all ISV scenarios are completed, all pass/fail performance measures are satisfied, and both the individual and aggregate impact of any remaining HEDs is acceptable pending their ultimate resolution, the following are considered to have been validated:

- Integrated HSIs, their layout, and the environment in which they are housed
- Personnel roles
- Staffing and qualifications
- Transition capability between HSIs
- Integrated system tolerance of individual HSI failures
- Integrated system tolerance of human error
- Integrated system ability to alert operators to failures and errors and provide for their mitigation

Validation conclusions and the bases for these conclusions are documented and summarized in the V&V results summary report. Discrepancies identified during the ISV process are documented as HEDs and resolved using the HED resolution process.

3.7 Human Engineering Discrepancy Resolution

Discrepancies identified during the V&V process are documented in a B&W mPower HFE issue tracking system database through the HED resolution process to ensure that they are tracked and resolved. The HFE design team documents, evaluates, and resolves tracked HEDs until satisfactory re-testing is complete (if required). The following is performed for each identified HED:

- HED is documented in the HFE issue tracking system
- HED is evaluated to determine the need for correction or if it warrants justification to use as-is
- HED resolution is identified including changes to design, procedures, or training (or a combination thereof)
- Evaluation testing (if required) to ensure that resolution actions are effective
- HED is closed when all required testing is satisfactory
- Those HEDs that cannot be closed through the HFE process are entered into the B&W corrective action process for tracking and resolution

The HED resolution process is presented Figure 3.

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[CCI per Affidavit 4(a)-(d)]

Figure 3. HED Resolution Process Flow

3.7.1 Human Engineering Discrepancy Tracking Database

The B&W mPower HFE issue tracking system is used to document, track, evaluate, and resolve HEDs. Each identified HED is documented, evaluated, and resolved either through the HFE design process or through the design change control process. Issues that can be resolved within the HFE design process are resolved in accordance with the provisions of the appropriate HFE design process element through selection of the appropriate solution pathway and process within the overall HFE process. The resolution is documented in the issue tracking system. Issues that cannot be resolved within the HFE design process are documented and resolved in accordance with the B&W mPower design change control process and the resolution is documented in the corrective action process.

The HED documentation and tracking database contain sufficient information to ensure that the status of the HEDs can be determined at any time. The documentation and tracking system identify and prioritize the HEDs and summarize the HED evaluation, resolution actions, and required resolution action adequacy testing (if any).

3.7.2 HED Resolution Process

HEDs are design discrepancies identified during the HFE V&V process associated with regulatory or HFE design guidance. Some examples include:

- Controls are operated contrary to popular and accepted principles: for example, up-arrow for decrease or off, counterclockwise for increase or close
- Displays are difficult to read or require interpretation
- Conflicting color standards: for example, color red used to indicate “open” valve in one plant system but “closed” valve in another plant system
- Labels are confusing or missing, or different labeling standards are used between plant systems
- Manual valves operators are located outside of acceptable ranges for human reach, require too much force, or do not have adequate clearance

A deviation from compliance means that a regulatory or industry guidance applicable to the HSI being verified or validated has not been met.

When an HED is identified, it is recorded in both the HED tracking database and the corrective action system. The person who identifies the HED is encouraged to recommend a resolution if apparent or known. Once the HED is entered into the corrective action process it is assigned to an HFE design team member for resolution. In accordance with the corrective action process, the person assigned to resolve an HED performs the following:

- Performs initial HED evaluation and determines if the condition documented in the HED should be justified as-is

- Analyzes the HED to determine the impact of the discrepancy by itself and in the context of the aggregate HED population
- Assigns HED priority
- Analyzes the HED to determine causal factors, contributing factors, and the understanding needed to develop resolution actions. Resolution actions required to resolve the HED and completion dates for the identified actions are determined
- Determines and documents resolution action effectiveness testing requirements (if any)
- Ensures that resolution actions and testing (if required) are completed
- Closes the HED upon confirmation that the resolution is implemented and no new human factors issues are identified

Each of these HED resolution steps is described below.

1) Initial Human Engineering Discrepancy Evaluation and Justification

Initial evaluation of an HED may reveal that it does not require correction and can therefore be accepted as-is. An example of an HED that might be justified as-is is one that poses no safety or task performance concerns but which deviates from accepted HFE guidelines. For an HED of this kind, HFE design team members may determine from recent industry literature, tradeoff studies, or HFE analyses that the benefits of the deviant design feature outweigh potential drawbacks. The basis for accepting an HFE deviation as-is is documented by the HFE design team member assigned to resolve the HED, and independently reviewed. An HED justification report is then written that documents the technical basis for why no resolution actions are needed. After the justification document for an HED is completed and approved, the HED and associated database entries are closed.

HEDs that document safety concerns or performance problems cannot be accepted as-is and are processed through the corrective action process.

2) Human Engineering Discrepancy Analysis

HEDs that require resolution are analyzed to determine the effect of the HED on plant control systems, plant safety, and personnel performance. Additionally, HED analysis considers the relationship between the HED and operator training or plant procedures. To ensure that similar problems are identified, the HED analysis includes analysis of any possible impacts in other similar areas of the design.

In addition to analysis of the individual impact of the HED, the impact of HED is considered in the context of the entire HED population. Analysis of the aggregate HED population associated with a HSI type or plant system is conducted to determine if other HEDs affect the same plant system or HSI type. Aggregate HED analysis is conducted because the presence of multiple low-level HEDs on a plant system or HSI may warrant corrective action while the impact of just one HED related to the plant system or HSI type may not require resolution. Additionally, aggregate effects of multiple HEDs on a plant system or HSI type may warrant a higher priority HED than would be the case if all HEDs were considered discretely.

3) Human Engineering Discrepancy Prioritization

All HEDs that are not justified and closed are prioritized to ensure that the most significant HEDs are treated appropriately in keeping with their importance to safety (the most effort is expended on HEDs with the greatest safety significance). The priority classification process is shown in Figure 4.

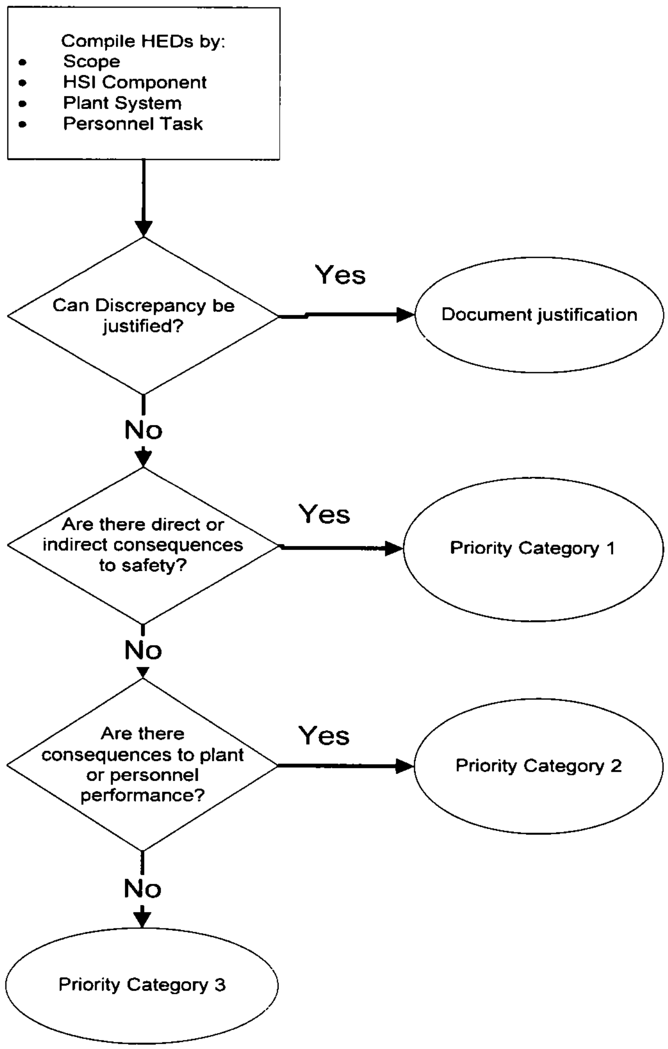

Figure 4: HED Priority Classification

The HED priority categories include:

Priority Category 1 - HEDs with direct, indirect, or potential safety consequences. This priority category includes an HED or a group of HEDs that when considered together have a potential impact on safety. Priority 1 HEDs have significant safety consequences that affect personnel performance where the margin of plant safety is reduced below acceptable levels. This priority category includes HFE or HSI design deficiencies or adverse trends that impact human performance and could affect the following:

- Violations of Technical Specification safety limits, operating limits, or limiting conditions for operation
- The operability or availability of a safety-related structure, system, or component
- Task support requirements for a safety-related task
- Plant Operator physical or mental workload which restricts their ability to perform a safety-related task

Priority Category 2 - HEDs with potential consequences to plant performance or operability, personnel performance or efficiency by using non-safety-related SSCs, or other factors affecting overall plant operability. This priority category includes individual HEDs or a group of HEDs that when considered together fit the priority category 2 criteria. These HEDs are corrected before plant startup. This priority category also includes HFE or HSI design deficiencies or adverse trends that impact human performance and could affect the following:

- Operability or availability of a non-safety system or component
- Non-safety-related task performance or successful task completion by control room operators
- HSI design compliance with HFE guidelines or style guide
- Plant Operator physical or mental workload which restricts their ability to perform a non-safety-related task.

Priority Category 3 - The remaining HEDs that do not meet the criteria for either priority category 1 or priority category 2. These HEDs have no impact to plant safety, plant performance, or personnel performance. These HEDs are recorded and analyzed using the HED process although they may not require correction.

4) Human Engineering Discrepancy Resolution Action Determination

The HFE issue tracking system used to document, track, and resolve HEDs incorporates evaluation and resolution processes used to develop solutions to issues identified in an HED. Additionally, this process determines if an apparent cause or root cause evaluation is required to be performed as part of the HED resolution action development process. The HFE design team, in coordination with other applicable disciplines, identifies the most likely cause of the discrepancy and determines the most appropriate resolution actions.

Actions that resolve the identified discrepancies are developed for each HED that requires resolution. These resolution actions are governed by the same HFE design process requirements imposed on the original HFE design activities. Any changes to the detailed design are evaluated to ensure that they do not introduce new deviations from design requirements or create additional HEDs. The efficacy of resolution actions are considered in the context of both the specific plant system they address as well as the integrated HSI.

Once resolution actions have been selected they are entered into the corrective action program for tracking and completion.

Any design change that is being considered for the plant design must follow the design change process for the project. The design change process includes rigorous cross-disciplinary reviews that evaluate the impact of design changes on all aspects of the design, procedures, or training.

5) Human Engineering Discrepancy Design Solution Evaluation and Documentation

HED resolution actions are evaluated to ensure the following:

- They resolve the discrepancies identified in the HED and address the causes that led to the discrepancy (if root cause or apparent cause determinations are required by the corrective action process)
- They do not adversely impact other aspects of the integrated HSI
- They are consistent with HFE guidelines and applicable regulations
- Any re-testing requirements are identified

The issue tracking system in which HEDs are tracked and resolved provides criteria for development of resolution action testing requirements. If testing is required to verify that resolution actions adequately address the issue documented by the HED without creating other unintended consequences, then the specific testing requirements are identified, documented and tracked until completed. Any V&V testing that must be performed following resolution action completion is also identified, documented, and tracked until completed.

6) Resolution Action and Testing Completion

HEDs are resolved as soon as possible in the V&V process so that the issues identified by the HED do not hide or compound discrepancies as the V&V proceeds. HEDs remain open until resolution actions have been approved, implemented and the HFE V&V retesting (if any) has been completed. HEDs not resolved during HFE V&V remain open in the issue tracking system and are either resolved or evaluated for plant operations impact prior to plant operation. HED resolution action implementation activities are integrated into the project schedule to ensure that they are completed in a timely manner and that they do not conflict with other design activities.

7) HED Closure

HEDs remain open and active in the issue tracking system database until all resolution actions are implemented and any required testing is completed. When all resolution actions have been successfully implemented and tested, the HED is closed.

4. SUMMARY RESULTS AND DOCUMENTATION

The results of the verification and validation (including the HED resolution process) are summarized in a results summary report. This report demonstrates that activities conducted as part of the HFE V&V process meet regulatory requirements and satisfy applicable regulatory review criteria. Additionally, V&V process results document the extent to which the B&W mPower HSI design meets HFE design requirements.

The V&V results summary report summarizes the following:

- The scope of V&V
- A summary of the following activities:
  - Operational condition sampling
  - HSI inventory and characterization
  - HSI task support verification
  - HFE design verification
  - ISV
  - HED resolution
- Major conclusions reached during V&V and their bases

5. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

5.1 Definitions

Term	Definition
Critical Safety Function	Those functions that provide: • Reactivity control • Reactor core cooling and heat removal from the primary system (RCS inventory and secondary heat sink) • Reactor coolant system integrity • Radioactivity control • Containment conditions
Functional Requirements Analysis	The examination of system goals to determine what functions are needed to achieve them.
Human Action	A manual action completed by a person in order to accomplish a task.
Human Engineering Discrepancy	Human performance issues identified in V&V evaluations
Human Error Probability	A measure of the likelihood that various failure modes for plant personnel to obtain the correct, required, or specified action or response in a given situation. The human error probability is the probability of the human failure event.
Human-System Interface	That part of the system through which personnel interact to perform their functions and tasks. This interaction includes the alarms, displays, controls, and job performance aids (e.g., procedures, instructions, etc.).
NASA Task Load Index	A measure of mental workload placed on an operator during and after task performance. It measures six sub-scales: mental, physical, and temporal demand; performance, effort, and frustration levels.
Operating Experience Review	A review of operating experiences from industry operations, maintenance, design, and construction tasks for collection, analysis, and documentation of lessons learned. This also includes interviews with plant staff or design personnel with operations backgrounds.

Term	**Definition**
Probabilistic Risk Assessment	A qualitative and quantitative analysis of the risk associated with plant operation under normal, abnormal, and emergency conditions. This assessment measures frequency of occurrence of adverse outcomes such as core damage or the release of radioactive material and the effects of these adverse outcomes on the health and safety of the public.
Risk-Important Human Actions	Actions that are performed by plant personnel to provide reasonable assurance of plant safety. Actions may be made up of one or more tasks. There are both absolute and relative criteria for defining risk-important actions. From an absolute standpoint, a risk-important action is any action whose successful performance is needed to provide reasonable assurance that probabilistic design objectives are met. From a relative standpoint, the risk-important actions may be defined as those with the greatest risk contribution in comparison to all risk contributors.
Task Analysis	A method for determining and 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.

5.2 Abbreviations and Acronyms

B&W	Babcock and Wilcox
CFR	code of federal regulations
D3	diversity and defense-in-depth
EOF	emergency operations facility
EOP	emergency operating procedure
HED	human engineering discrepancy
HFE	human factors engineering
HFEITS	human factors engineering issue tracking system
HRA	human reliability analysis
HSI	human-system interface
I&C	instrumentation and control
ISV	integrated system validation
LCS	local control station
MCR	main control room
NASA-TLX	NASA task load index
NRC	U.S. Nuclear Regulatory Commission
OCS	operational conditional sampling

OER	operating experience review
PRA	probabilistic risk assessment
PWR	pressurized water reactor
RO	reactor operator
RSS	remote shutdown system
SM	shift manager
SRO	senior reactor operator
SSC	structures, systems, and components
STA	shift technical advisor
TSC	technical support center
V&V	verification and validation

6. REFERENCES

6.1 Code of Federal Regulations

6.1.1 10 CFR 50, Domestic Licensing of Production and Utilization Facilities

6.1.2 10 CFR 50, Appendix A, General Design Criteria 19, Control Room

6.2 U.S. Nuclear Regulatory Guidance

6.2.1 NUREG-0711, Human Factors Engineering Program Review Model

6.2.2 NUREG-0700, Human-System Interface Design Review Guidelines

6.2.3 Regulatory Guide 1.33, Quality Assurance Program Requirements (Operation)

6.2.4 NUREG-1122, Knowledge and Abilities Catalogue for Nuclear Power Plant Operators: Pressurized Water Reactors

6.2.5 Regulatory Guide 1.149, Nuclear Power Plant Simulation Facilities for Use in Operator Training and License Examinations

6.3 Other References

6.3.1 MPWR-TECR-005002, Human Factors Engineering Program Management Plan

6.3.2 ANSI Standard 3.5, Nuclear Power Plant Simulators for Use in Operator Training (2009)

6.3.3 MPWR-TECR-005014, Human Factors Engineering Design Implementation

6.3.4 MPWR-TECR-005005, Task Analysis

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