US-APWR
Human Factors Verification and Validation Implementation Plan

May 2014

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## Revision History

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Abstract

This document provides the human factors verification and validation (V&V) implementation plan (IP) for the US-APWR human-system interface (HSI) system (HSIS). The IP was prepared using the guidance of NUREG-0711, Revision 2, “Human Factors Engineering Program Review Model,” issued February 2004, and follows the methodology developed for and applied to the design testing program described in Chapter 18 of the US-APWR Design Control Document (DCD) (Reference 8-1) and MUAP-07007, “Human-System Interface System Description” (Reference 8-2).

The V&V program uses the output from the operating experience review (OER), task analysis (TA), human reliability analysis (HRA) (consisting of the deterministically important human actions (DIHAs) defined in the US-APWR transient and accident analysis (TAA) (Reference 8-23) and defense-in-depth and diversity coping analysis (D3CA) (Reference 8-27), and the risk-important human actions (RIHAs) defined in the probabilistic risk assessment (PRA) (Reference 8-33), staffing and qualifications (S&Q), and HSI design (HD), as well as the procedure and training program development effort.

The V&V process confirms that the design conforms to human factors engineering (HFE) design principles and that plant personnel are able to perform their tasks to achieve plant safety and operational goals. By applying a checklist approach, design verification evaluates the HSI design’s conformance to good HFE practices, including the US-APWR HSI Design Style Guide, and to the task requirements, including HSI inventory determined by the TA. The validation uses performance-based testing.

The verification process involves two types of design verification: HSI task support verification and HFE design verification. The HSI task support verification assesses the HSI design as it supports the tasks identified in the TA. The HFE design verification is done to assess whether the HSI is designed to accommodate human capabilities per the HSI Design Style Guide (Reference 8-5).

Verification is conducted early in the V&V process to allow for HSI modifications based on a rigorous processing and resolution of issues identified. The human engineering discrepancies (HEDs) program is initiated at the design phase and continues through the design implementation (DI). The verification relies on the use of interface photographs and drawings, a personal computer (PC) part-task representation of the displays designed specifically for the verification, mockups, and a full-scope dynamic simulator.

The integrated system validation (ISV) confirms proper operational performance of the US-APWR HSIS by use of a set of selected test scenarios. The scenarios are selected to represent a comprehensive sample of operating conditions with clearly defined evaluation criteria. The scenarios are performed on a full-scope dynamic main control room (MCR) simulator and other mockups and analyses representative of actual plant operations. These scenarios include a set of operating conditions that include RIHAs and deterministically important human actions (IHAs).

The ISV program specifically uses a full-scope dynamic simulator developed for operator training in compliance with American National Standards Institute/American Nuclear Society...
(ANSI/ANS) 3.5-2009 (Reference 8-6) requirements for activities conducted in the MCR. The validation tests rely on a set of US-APWR operating procedures and include the incorporation of staffing design assumptions, including minimum staffing. The validation of the MCR includes communication interfaces with personnel outside of the MCR at local control stations (LCSs) that fall into the categories identified in DCD Sections 18.1 and 18.7 (Reference 8-1), the technical support center (TSC), and the central alarm station/secondary alarm station (CAS/SAS).

Validation of the HSI for activities outside of the MCR (LCSs used by operators and the TSC) is also included in the ISV and uses mockups and part-task approaches. For cases in which analysis shows that the supportive activities have no impact on plant safety, analytical approaches are used to validate the HSI design.

Proper performance of the HSI is judged based on measurement methods including subjective data collected through test personnel and participant questionnaires, structured interviews, observations, and video and audio recording and objective plant data automatically collected via the simulator computer for each scenario for plant performance and personnel performance. These performance measures are evaluated against acceptance criteria. A converging perspectives analysis approach is applied to the data analysis and conclusions about the HSIS interface performance. HEDs identified by the ISV pass/fail criteria and fail determination results are resolved prior to completion of the V&V program element as outlined in Section 4.4 of this report and the overall HFE program’s HED identification, resolution, closure, and tracking process described in the HFE program management plan (Reference 8-4).

The V&V is conducted in accordance with a set of three procedures (task support verification procedure, HFE design verification procedure, and ISV procedure) using qualified personnel for verification, test management, administration and observation, and post-test data analysis in the validation.

This IP also describes the requirements for documenting the completion of the V&V program element in the V&V results summary report (ReSR). The ReSR serves to demonstrate that the V&V program was conducted in accordance with this IP, which is a requirement for inspections, tests, analyses, and acceptance criteria (ITAAC) closure.
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</tr>
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<td>AAC</td>
<td>alternate alternating current</td>
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<td>alternating current</td>
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<td>ANSI/ANS</td>
<td>American National Standards Institute/American Nuclear Society</td>
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<td>AO</td>
<td>auxiliary operator</td>
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<td>abnormal operating procedure</td>
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1.0 PURPOSE

This document provides the human factors verification and validation (V&V) implementation plan (IP) for the US-APWR human-system interface (HSI) system (HSIS). The purpose of the V&V program is to provide a logical and comprehensive confirmation that the US-APWR HSIS conforms to human factors design principles and that it adequately supports plant personnel in the safe and efficient operation of the plant. This human factors engineering (HFE) program element conforms to the guidance and satisfies the acceptance criteria of NUREG-0711, “Human Factors Program Review Model,” Revision 2, Section 11, issued February 2004 (Reference 8-7).

The V&V program assures that the integrated HSI design:

- Meets the design specified by Mitsubishi Heavy Industries, Ltd. (MHI)
- Remains within acceptable performance limits under a broad set of operating modes and conditions
- Provides the alarms, information, and controls needed to support the personnel tasks as identified in the task analysis (TA)
- Meets the guidance of JEJC-1763-1001, “HSI Design Style Guide,” (hereafter referred to as the “HSI Design Style Guide”) (Reference 8-5)

The V&V takes input from the operating experience review (OER), TA, important human actions (IHA), staffing and qualifications (S&Q), and HSI design (HD) elements of NUREG-0711 (Reference 8-7). The US-APWR HSIS V&V is performed using a dynamic simulator whose plant model reflects the final, as-built, US-APWR plant design. The V&V employs the operator staffing levels for the modes of operation defined by S&Q. The HSI confirmed by the V&V program is to be implemented to accurately reflect the design of the site-specific US-APWR HD in the design implementation (DI) program element.

The results from the V&V program are reported in a results summary report (ReSR). The ReSR serves to demonstrate that the V&V program was conducted in accordance with this IP, which is a requirement for inspections, tests, analyses, and acceptance criteria (ITAAC) closure.
2.0 SCOPE

The V&V IP fully meets the review criteria as outlined in NUREG-0711, Section 11 (Reference 8-7). The V&V program uses the results from other HFE program elements and has a feedback path in the design process as described in MUAP-09019, “Human Factors Engineering Program Management Plan” (hereafter referred to as the “HFE PMP”) (Reference 8-4). This IP describes the methodology for conducting V&V, including:

- The inventory development methodology use to characterize the HSIs
- The criteria to be used for task support verification and HFE design verification
- The validation test objectives
- The test bed for the validation performance-based tests
- Selection and training of plant personnel used as test crews
- Scenario selection and definition for the validation
- The performance measures to be used in the validation
- The pass/fail criteria
- Data analysis methods applied to validation data
- Detailed examples of scenarios for integrated system validation (ISV) (and how they were identified through the sampling of operational conditions), performance measures, and acceptance criteria
- Validation questionnaires
- The methods by which human engineering discrepancies (HEDs) are evaluated as specific to the V&V program element

The V&V implementation program, using guidance from NUREG/CR-6393, “Integrated System Validation: Methodology and Review Criteria,” issued January 1997 (Reference 8-8), validates the integrated HSIS through performance-based tests. The tests include:

- Important human actions (IHAs)
- Selected beyond-design-basis events
- Dominant accident sequences
- Events including dominant systems as identified in the probabilistic risk assessment (PRA)
- Full range of plant operating conditions, including:
  - Startup/ shutdown/ refueling
  - Normal operations
  - Abnormal and emergency operations
  - Transient conditions

The V&V IP addresses the US-APWR HSIS, which is employed in the main control room (MCR). The V&V also includes the US-APWR HSIS that is employed in the remote shutdown room (RSR). The V&V includes voice communication between the MCR/RSR and other plant locations that can influence the MCR/RSR crew’s performance. This includes communication with the technical support center (TSC), the emergency operations facility (EOF), other off-site
entities (e.g., emergency officials), selected remote locations (local control stations (LCSs), and the central alarm station/secondary alarm station (CAS/SAS). The V&V also confirms communications between the TSC and these other entities.

The V&V IP also provides for evaluation of the HSI outside of the MCR for LCSs used by operators. Since the local HSIs and TSC are not fully simulated during US-APWR V&V, they require additional V&V during the DI. The validation of the local HSIs and the TSC relies on mockups and part-task simulations. Analytical approaches, in lieu of validation testing, are applied to facilities that have been determined not to impact plant safety.

The scope of MCR staff size evaluated by the V&V program is as follows:

- Minimum MCR staff of one senior reactor operator (SRO) and one reactor operator (RO) for MODES 1 and 2
- Minimum crew size for all other MODES, which is defined by TA and S&Q
- Adequacy of the MCR for the maximum staffing design assumption in S&Q

The validation exercises the integrated system (including the HSI, plant personnel, and procedures) for situations in which communications and coordination with plant personnel outside of the MCR is required and when additional plant personnel are performing work in the control room. This includes operator communication with local HSIs and the shift manager’s implementation of the emergency plan. The goal of the V&V program is to verify and test the HSI in real-world conditions resulting in assurance that expected situations have been enveloped by the V&V process. Therefore, implementation of the V&V program provides high confidence that the US-APWR HSIS meets safety and performance objectives.

The V&V program covers the HSI that is in the scope of the US-APWR HFE program, as described in the US-APWR Design Control Document (DCD) Section 18.1 (Reference 8-1). The process of identification, resolution, closure, and tracking of HEDs, as discussed in Section 4.4 of this report and in the HFE PMP (Reference 8-4), is applied to the HSIS V&V. HEDs not related to acceptance criteria are resolved outside V&V, prior to completion of DI program element. The V&V results are reported in the ReSR as described in Section 6 of this report.
3.0 METHODOLOGY OVERVIEW
4.0 METHODOLOGY

4.1 Operational Conditions Sampling

4.1.1 Sampling Dimensions
Table 4-1  Example of HSI Features in Verification and Validation Table
4.1.2 Identification of Scenarios

4.2 Design Verification

4.2.1 HSI Inventory and Characterization
4.2.2 HSI Task Support Verification
4.2.3 HFE Design Verification
4.3 Integrated System Validation
4.3.1 Test Objectives
4.3.2 Validation Test bed
4.3.3 Plant Personnel
4.3.4 Scenario Definition
4.3.5 Performance Measurement
4.3.5.1 Measurement Characteristics

4.3.5.2 Performance Measure Selection
4.3.5.3 Plant Performance Measurement

4.3.5.4 Personnel Task Measurement
4.3.5.5 Situation Awareness
4.3.5.6 Cognitive Workload

4.3.5.7 Anthropometric and Physiological Factors
4.3.5.8 Performance Criteria

4.3.5.9 Criteria Used

4.3.5.10 Criteria Basis
4.3.5.11 Data Collection Process
4.3.6 Test Design
4.3.6.1 Coupling Crews and Scenarios

4.3.6.2 Test Procedures
4.3.6.3 Test Personnel Training
4.3.6.4 Operating crew, Test Participant Training

4.3.6.5 Pilot ISV Testing

4.3.7 Data Analysis and Interpretation

4.3.7.1 Data Analysis
4.3.7.2 Interpretation of Results
4.3.7.3 Use of Convergent Validity
4.3.7.4 Independent Review

4.3.7.5 Margin of Error Estimation

4.3.8 Validation Conclusions
4.4 Human Engineering Discrepancy Resolution
5.0 IMPLEMENTATION TEAM

The SMEs who conduct the human factors V&V program element are described in Section 4 above and summarized in Table 5-1, below.

Table 5-1 V&V Implementation Summary

<table>
<thead>
<tr>
<th>Implementation Activity</th>
<th>Section</th>
<th>Subject Matter Experts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Conditions Identification of Scenarios</td>
<td>4.1.1</td>
<td>HFE/HSI</td>
</tr>
<tr>
<td>Scenario Definition</td>
<td>4.1.2</td>
<td>Plant operations</td>
</tr>
<tr>
<td>Coupling Crews and Scenarios</td>
<td>4.3.4</td>
<td>Plant procedure development</td>
</tr>
<tr>
<td></td>
<td>4.3.6.1</td>
<td>Computer systems engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Systems engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nuclear engineering</td>
</tr>
<tr>
<td>HSI Task Support Verification</td>
<td>4.2.2</td>
<td>HFE/HSI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plant operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Task analysis</td>
</tr>
<tr>
<td>HFE Design Verification</td>
<td>4.2.3</td>
<td>HFE/HSI</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plant operations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>I&amp;C engineering</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Working knowledge of the US-APWR HSI Design Style Guide</td>
</tr>
<tr>
<td>Independent Review of Scenario</td>
<td>4.3.4</td>
<td>HFE/HSI</td>
</tr>
<tr>
<td>Independent Review of HSI Task Support</td>
<td>4.2.2</td>
<td>Systems engineering</td>
</tr>
<tr>
<td>Verification</td>
<td></td>
<td>I&amp;C engineering</td>
</tr>
<tr>
<td>Independent Review of HFE Design Specification</td>
<td>4.2.3</td>
<td>Plant operations, including RO/SRO licensed individuals for operating crews</td>
</tr>
<tr>
<td>Independent Review of Coupling Crews and</td>
<td>4.3.6</td>
<td>Plant procedure development</td>
</tr>
<tr>
<td>Scenarios</td>
<td></td>
<td>Personnel training</td>
</tr>
<tr>
<td>Data Analysis and Interpretation</td>
<td>4.3.7</td>
<td>Systems engineering</td>
</tr>
<tr>
<td></td>
<td>4.4</td>
<td>Nuclear engineering</td>
</tr>
</tbody>
</table>

The SME qualifications are defined in Table 3-1 of the HFE PMP (Reference 8-4). The required qualifications and roles of the V&V team, V&V team manager, and HD team are also described in the HFE PMP.

Independent review is performed by members of the Expert Panel as described in Section 3.3.1 of the HFE PMP (Reference 8-4).

The other personnel’s roles and qualifications are described below.
5.1 Test Personnel (Observers/Administrators)

The observers/administrators use a multidisciplinary team composed of three members having the following combined qualifications:

- HFE/HSI
- Plant operations
- Personnel training
- Plant systems engineering
- Human performance testing
- HRA

The observers/administrators are responsible for daily management of the ISV tests in accordance with this IP, controlling each scenario in accordance with the test procedure and the scenario description, acting in scripted positions during the scenario, conducting data collection, administering questionnaires, conducting post-scenario debriefings, documenting observations for each scenario, developing post-scenario consensus on performance, and generating HEDs.

5.2 Operating Crews/Test Participants (Operators)

All operating crew personnel are plant personnel and have the same qualifications and licenses for their positions in the validation test as those required by the NRC for currently operating NPPs. The operating crew test participants have qualifications in plant operations.

Operating crews are responsible for performing the functions of the plant operating crew as called out for each scenario.

5.3 Simulator Engineers

The simulator engineer is a qualified computer systems engineer.

The simulator engineer is responsible for maintaining the test simulator, setting up the simulator for each scenario, managing the simulator for each scenario, and assuring the collection and archiving of plant data from the simulator records for each scenario.

5.4 Specific Qualifications

The V&V ReSR, Section 6, includes the specific names and qualifications of all personnel supporting the V&V program.
6.0 RESULTS SUMMARY REPORT CONTENT

The results of the V&V program element are compiled in a ReSR. This report is used to demonstrate that the V&V program was conducted in accordance with this IP. Demonstrating conformance to this IP, as documented through this ReSR, is a requirement of the ITAAC closure defined in the US-APWR DCD Tier 1.

The V&V ReSR contains the following information:

- Each implementation team member’s name and the SME position that they fulfill
- The V&V results overview, which includes the principal findings of the HFE program element
- The V&V execution results, which include all details that demonstrate compliance with the methodology section of this IP. This includes the following:
  - Verification
    - A description of the application of this IP in conducting the verification program
    - Verification results based on the TA
    - Verification results based on the HSI Design Style Guide (Reference 8-5) per the HFE PMP (Reference 8-4)
    - A discussion of the HEDs that resulted from the verification, their extent across the HD, their resolution, and any subsequent HD changes made prior to the validation
    - A copy of the verification test procedures
    - A copy of the verification procedure and any analysis tools used to draw conclusions, such as tables or checklists
  - Validation
    - A description of the application of this IP in conducting the validation program
    - A copy of the validation test procedures
    - A copy of the ISV procedure, including the ISV scenarios
    - A detailed description of the specific scenario sets used in the testing as illustrated in Appendix A, including: test instructions, data collection instruments, OCS versus scenario comparison table, and the scenario identification summary table
    - Data analysis results and validation conclusions, as compared to the minimum set of test objectives
    - A discussion of the pass/fail HEDs that resulted from the validation, their extent across the HD, their resolution, and any subsequent HSI changes and analysis or retest
    - A discussion of the performance improvement measures
A clear discussion of the validation results and conclusion that the pass/fail criteria set forth in the IP have been met
Identification of HEDs that were evaluated for further HSI improvements

A conclusion that the V&V program element has been conducted in accordance with the V&V IP, and that the US-APWR HSIS and US-APWR local HSIs have been verified, and that the US-APWR HSIS has been validated, and that both represent HSI designs that comply with regulatory requirements and guidance for plant safety.
7.0 NUREG-0711 COMPLIANCE EVALUATION

This V&V IP is in full compliance with NUREG-0711, Revision 2 (Reference 8-7). Table 7-1 indicates where each NUREG-0711 criterion is met in this IP.

<table>
<thead>
<tr>
<th>Review Criteria Stated in NUREG-0711, Rev. 2</th>
<th>V&amp;V IP Section No. and Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>11.4.1.2.1 Sampling Dimensions</strong></td>
<td></td>
</tr>
<tr>
<td>(1) The following plant conditions should be included:</td>
<td></td>
</tr>
<tr>
<td>• normal operational events including plant startup, plant shutdown or refueling, and significant changes in operating power</td>
<td>Section 4.1.1, item (1), bullet 1</td>
</tr>
<tr>
<td>• failure events, e.g.,</td>
<td></td>
</tr>
<tr>
<td>- instrument failures [e.g., safety-related system logic and control unit, fault tolerant controller, local “field unit” for multiplexer (MUX) system, MUX controller, and break in MUX line] including I&amp;C failures that exceed the design basis, such as a common mode I&amp;C failure during an accident</td>
<td>Section 4.1.1, item (1), bullet 2 and its sub-bullets</td>
</tr>
<tr>
<td>- HSI failures (e.g., loss of processing and/or display capabilities for alarms, displays, controls, and computer-based procedures)</td>
<td></td>
</tr>
<tr>
<td>• transients and accidents, e.g.,</td>
<td></td>
</tr>
<tr>
<td>- transients (e.g., turbine trip, loss of off-site power, station blackout, loss of all feedwater, loss of service water, loss of power to selected buses or main control room (MCR) power supplies, and safety and relief valve transients)</td>
<td>Section 4.1.1, item (1), bullet 3 and its sub-bullets</td>
</tr>
<tr>
<td>- accidents (e.g., main steam line break, positive reactivity addition, control rod insertion at power, anticipated transient without scram, and various-sized loss-of-coolant accidents)</td>
<td></td>
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<tr>
<td>- reactor shutdown and cooldown using the remote shutdown system</td>
<td></td>
</tr>
<tr>
<td>• reasonable, risk-significant, beyond-design-basis events, which should be determined from the plant specific PRA</td>
<td>Section 4.1.1, item (1), bullet 5</td>
</tr>
<tr>
<td>• consideration of the role of the equipment in achieving plant safety functions [as described in the plant safety analysis report (SAR)] and the degree of interconnection with other plant systems. A system that is interconnected with other systems could cause the failure of other systems because the initial failure could propagate over the connections. This consideration is especially important when assessing non-class 1E electrical systems.</td>
<td>Section 4.1.1, item (1)</td>
</tr>
<tr>
<td>(2) The following types of personnel tasks should be included:</td>
<td></td>
</tr>
<tr>
<td>• Risk-significant HAs, systems, and accident sequences - All risk-important HAs should be included in the sample. These include identified in the PRA and those identified as risk-important in the SAR and NRC's safety evaluation report (SER) should be included. Situations where human monitoring of an automatic system is risk-important should be considered. Additional factors should be sampled that contribute highly to risk, as defined by the PRA, including:</td>
<td>Section 4.1.1, item (2), bullet 1</td>
</tr>
<tr>
<td>- dominant human actions (selected via sensitivity analyses)</td>
<td></td>
</tr>
<tr>
<td>- dominant accident sequences</td>
<td></td>
</tr>
<tr>
<td>- dominant systems (selected via PRA importance measures such as Risk Achievement Worth or Risk Reduction Worth)</td>
<td></td>
</tr>
<tr>
<td>• OER-identified difficult tasks- The sample should include all personnel tasks identified as problematic during the applicant's review of operating experience.</td>
<td>Section 4.1.1, item (2), bullet 2</td>
</tr>
</tbody>
</table>
**Review Criteria Stated in NUREG-0711, Rev. 2**

<table>
<thead>
<tr>
<th>V&amp;V IP Section No. and Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Range of procedure guided tasks</strong> - These are tasks that are well defined by normal, abnormal, emergency, alarm response, and test procedures. The operator should be able to, as part of rule-based decision-making, understand and execute the specified steps. Regulatory Guide 1.33, Appendix A, contains several categories of &quot;typical safety-related activities that should be covered by written procedures.&quot; The sample should include appropriate procedures in each relevant category:</td>
</tr>
<tr>
<td>Section 4.1.1, item (2), bullet 3 and its sub-bullets</td>
</tr>
<tr>
<td>- administrative procedures</td>
</tr>
<tr>
<td>- general plant operating procedures</td>
</tr>
<tr>
<td>- procedures for startup, operation, and shutdown of safety-related systems</td>
</tr>
<tr>
<td>- procedures for abnormal, off normal, and alarm conditions</td>
</tr>
<tr>
<td>- procedures for combating emergencies and other significant events</td>
</tr>
<tr>
<td>- procedures for control of radioactivity</td>
</tr>
<tr>
<td>- procedures for control of measuring and test equipment and for surveillance tests, procedures, and calibration</td>
</tr>
<tr>
<td>- procedures for performing maintenance</td>
</tr>
<tr>
<td>- chemistry and radiochemical control procedures</td>
</tr>
<tr>
<td><strong>Range of human cognitive activities</strong> - The sample should include the range of cognitive activities performed by personnel, including:</td>
</tr>
<tr>
<td>Section 4.1.1, item (2), bullet 5 and its sub-bullets</td>
</tr>
<tr>
<td>- detection and monitoring (e.g., of critical safety-function threats)</td>
</tr>
<tr>
<td>- situation assessment (e.g., interpretation of alarms and displays for diagnosis of faults in plant processes and automated control and safety systems)</td>
</tr>
<tr>
<td>- response planning (e.g., evaluating alternatives for recovery from plant failures)</td>
</tr>
<tr>
<td>- response implementation (e.g., in-the-loop control of plant systems, assuming manual control from automatic control systems, and carrying out complicated control actions)</td>
</tr>
<tr>
<td>- obtaining feedback (e.g., of the success of actions taken)</td>
</tr>
<tr>
<td><strong>Range of human interactions</strong> - The sample should reflect the range of interactions among plant personnel, including tasks that are performed independently by individual crew members and tasks that are performed by crew members acting as a team. These interactions among plant personnel should include interactions between:</td>
</tr>
<tr>
<td>Section 4.1.1, item (2), bullet 6 and its sub-bullets</td>
</tr>
<tr>
<td>- main control room operators (e.g., operations, shift turnover walkdowns)</td>
</tr>
<tr>
<td>- main control room operators and auxiliary operators</td>
</tr>
<tr>
<td>- main control room operators and support centers (e.g., the technical support center and the emergency offsite facility)</td>
</tr>
<tr>
<td>- main control room operators with plant management, NRC, and other outside organizations</td>
</tr>
<tr>
<td><strong>Tasks that are performed with high frequency.</strong></td>
</tr>
<tr>
<td>Section 4.1.1, item (2), bullet 6, sub-bullet 3</td>
</tr>
<tr>
<td>(3) The sample should reflect a range of situational factors that are known to challenge human performance, such as:</td>
</tr>
<tr>
<td><strong>Operationally difficult tasks</strong> - The sample should address tasks that have been found to be problematic in the operation of NPPs, e.g., procedure versus situation assessment conflicts. The specific tasks selected should reflect the operating history of the type of plant being validated (or the plant's predecessor).</td>
</tr>
<tr>
<td>Section 4.1.1, item (2), bullet 2</td>
</tr>
<tr>
<td><strong>Error-forcing contexts</strong> - Situations specifically designed to create human errors should be included to assess the error tolerance of the system and the capability of operators to recover from errors should they occur.</td>
</tr>
<tr>
<td>Section 4.1.1, item (3), bullet 1</td>
</tr>
<tr>
<td><strong>High-workload conditions</strong> - The sample should include situations where human performance variation due to high workload and multitasking situations can be assessed.</td>
</tr>
<tr>
<td>Section 4.1.1, item (3), bullet 2</td>
</tr>
<tr>
<td><strong>Varying-workload situations</strong> - The sample should include situations where human performance variation due to workload transitions can be assessed. These include conditions that exhibit (1) a sudden increase in the number of signals that must be detected and processed following a period in which signals were infrequent and (2) a rapid reduction in signal detection and processing demands following a period of sustained high task demand.</td>
</tr>
<tr>
<td>Section 4.1.1, item (3), bullet 3</td>
</tr>
<tr>
<td>Review Criteria Stated in NUREG-0711, Rev. 2</td>
</tr>
<tr>
<td>---------------------------------------------</td>
</tr>
<tr>
<td>• <em>Fatigue and circadian factors</em> - The sample should include situations where human performance variation due to personnel fatigue and circadian factors can be assessed.</td>
</tr>
<tr>
<td>• <em>Environmental factors</em> - The sample should include situations where human performance variation due to environmental conditions such as poor lighting, extreme temperatures, high noise, and simulated radiological contamination can be assessed.</td>
</tr>
</tbody>
</table>

11.4.1.2.2 Identification of Scenarios

1. The results of the sampling should be combined to identify a set of scenarios to guide subsequent analyses. A given scenario may combine many of the characteristics identified by the operational event sampling.

2. The scenarios should not be biased in the direction of over representation of the following:
   - scenarios for which only positive outcomes can be expected
   - scenarios that for integrated system validation are relatively easy to conduct administratively (scenarios that place high demands, data collection or analysis are avoided)
   - scenarios that for integrated system validation are familiar and well structured (e.g., which address familiar systems and failure modes that are highly compatible with plant procedures such as “textbook” design-basis accidents)

11.4.1.2.3 Special Considerations for Plant Modernization Programs

When evaluating plant modifications, the following factors should be addressed when identifying operational conditions:

11.4.2.1.2 Inventory and Characterization Review Criteria

1. Scope - The applicant should develop an inventory of all HSI components associated with the personnel tasks based on the identified operational conditions. The inventory should include aspects of the HSI that are used for interface management such as navigation and display retrieval in addition to those that control the plant.

2. HSI Characterization - The inventory should describe the characteristics of each HSI component within the scope of the review. The following is a minimal set of information for the characterization:
   - a unique identification code number or name
   - associated plant system and subsystem
   - associated personnel functions/subfunction
   - type of HSI component
     - computer-based control (e.g., touch screen or cursor-operated button and keyboard input)
     - hardwired control (e.g., J-handle controller, button, and automatic controller)
     - computer-based display (e.g., digital value and analog representation)
     - hardwired display (e.g., dial, gauge, and strip chart recorder)
   - display characteristics and functionality [e.g., plant variables/parameters, units of measure, accuracy of variable/parameter, precision of display, dynamic response, and display format (bar chart, and trend plot)]
   - control characteristics and functionality [e.g., continuous versus discrete settings, number and type of control modes, accuracy, precision, dynamic response, and control format (method of input)]
   - user-system interaction and dialog types (e.g., navigation aids and menus)
   - location in data management system (e.g., identification code for information display screen)
   - physical location in the HSI (e.g., control panel section), if applicable Photographs, copies of VDU screens, and similar samples of HSI components should be included in the HSI inventory and characterization.

3. Information Sources - The inventory should be based on the best available information sources. Equipment lists, design specifications, and drawings describe HSI components. These descriptions should be compared by directly observing the components, both hardwired and computer-generated, to verify that the inventory accurately reflects their current state.
### 11.4.2.2.2 HSI Task Support Verification Review Criteria

<table>
<thead>
<tr>
<th><strong>Review Criteria Stated in NUREG-0711, Rev. 2</strong></th>
<th><strong>V&amp;V IP Section No. and Paragraph</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Criteria Identification</strong> - The criteria for Task Support Verification come from task analyses of HSI requirements for performance of personnel tasks that are selected operational conditions should be defined.</td>
<td>Section 4.2.2, paragraph 2, bullet 1 &amp; sub-bullets</td>
</tr>
<tr>
<td><strong>General Methodology</strong> - The HSIs and their characteristics (as defined in the HSI inventory and characterization) should be compared to the personnel task requirements identified in the task analysis.</td>
<td>Section 4.2.2, paragraph 2, bullet 2 &amp; sub-bullets</td>
</tr>
<tr>
<td><strong>Task Requirements Deficiencies</strong> - HEDs should be identified when:</td>
<td>Section 4.2.2, paragraph 2, bullet 3</td>
</tr>
<tr>
<td>• an HSI needed for task performance (e.g., a required control or display) is not available</td>
<td></td>
</tr>
<tr>
<td>• HSI characteristics do not match the personnel task requirements, e.g., a display shows the necessary plant parameter but not the range or precision needed for the task</td>
<td></td>
</tr>
<tr>
<td><strong>Unnecessary HSI Components</strong> - An HED should be identified for HSIs that are available in the HSI but are not needed for any task. Unnecessary HSIs introduce clutter and can distract personnel for the selection of appropriate HSIs. It is important to verify that the HSI is actually unnecessary. Appropriate HSI components may not appear to be associated with personnel tasks for the following reasons:</td>
<td>Section 4.2.2, paragraph 2, bullets 3 &amp; 5, bullet 5, sub-bullet 1</td>
</tr>
<tr>
<td>• The HSI component is needed for a task that was not addressed by the task analysis (e.g., it was not within the scope of the design review).</td>
<td></td>
</tr>
<tr>
<td>• The task analysis was incomplete, and thus overlooked the need for the HSI component.</td>
<td>Section 4.2.2, paragraph 2, bullet 5, sub-bullet 2</td>
</tr>
<tr>
<td>• The HSI component only partially meets the personnel task requirements that were established.</td>
<td>Section 4.2.2, paragraph 2, bullet 5, sub-bullet 3</td>
</tr>
<tr>
<td>If an HSI component has no associated personnel tasks because the function and task analysis was incomplete, then the applicant should identify and resolve any shortcomings in that analysis.</td>
<td>Section 4.2.2, paragraph 3</td>
</tr>
<tr>
<td><strong>Additional Methodology Considerations for Plant Modifications</strong> - the following considerations should be addressed:...</td>
<td>N/A (see Section 6.4 of HFE PMP, Reference 8-4)</td>
</tr>
<tr>
<td><strong>HED Documentation</strong> - HEDs should be documented to identify the HSI, the relevant task criterion, and basis for the deficiency (what aspect of the HSI has been identified as not meeting task requirements).</td>
<td>Section 4.2.2, paragraph 5</td>
</tr>
</tbody>
</table>

### 11.4.2.3.2 HFE Design Verification Review Criteria

<table>
<thead>
<tr>
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<th><strong>V&amp;V IP Section No. and Paragraph</strong></th>
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<tbody>
<tr>
<td><strong>Criteria Identification</strong> - The criteria for this verification are the HFE guidelines. The selection of guidelines used in the review depends upon the characteristics of the HSI components included in the scope of the review, as defined in the HSI characterization. It also depends upon whether the applicant has developed a style guide (design-specific HFE guideline document). When a style guide is used by the applicant, its acceptability should be reviewed by the staff. The procedures involved are described in Section 8.4.5. The HFE guidelines contained in NUREG-0700 may be used to support the staff's review of the guidance contained in an applicant's style guide. When an NRC reviewed style guide has been used, it can provide the criteria for HFE design verification. When no style guide is available, the guidelines in NUREG-0700 can be used for the HFE design verification. However, since not all of these guidelines will be applicable to each review, the selection of guidelines should be based on the characteristics of the HSI components being evaluated. A subset of guidelines appropriate to the specific design implementation should be identified based on the HSI characterization.</td>
<td>Section 4.2.3, paragraph 2</td>
</tr>
</tbody>
</table>
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<tr>
<th>Review Criteria</th>
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</thead>
<tbody>
<tr>
<td><strong>(2) General Methodology</strong> - The characteristics of the HSI components should be compared with HFE guidelines. These guidelines are applicable to different aspects of the design: task-independent features (e.g., font size), task-specific features (e.g., scale units), and task-integration features (e.g., proximity of control-display).</td>
<td>Section 4.2.3, paragraph 3, bullet 1</td>
</tr>
<tr>
<td>A single guideline may apply to many identical HSI components, especially in the case of significant HSI modifications and HSIs for new plants. In addition, some environmental considerations (e.g., lighting) may be applicable. To simplify the application of guidelines and reduce redundancy when reporting findings, the guidelines may be applied to features of the HSI as follows:</td>
<td></td>
</tr>
<tr>
<td>• Global features - global HSI features are those relating to the configurational and environmental aspects of the HSI, such as MCR layout, general workstation configuration, lighting, noise, heating, and ventilation. These aspects of the review, e.g., MCR lighting, tend to be evaluated only once.</td>
<td></td>
</tr>
<tr>
<td>• <strong>Standard features</strong> - standardized features are those that were designed using HFE guidelines applied across individual controls and displays (e.g., display screen organization, display format conventions, and coding conventions). Therefore, their implementation should be more consistent across the interface than features that were not designed with guidelines. Thus, for example, if display labeling is standardized by the applicant's HFE guidelines (style guide), which have been accepted by the NRC, then display labels can be spot-checked rather than being verified individually.</td>
<td>Section 4.2.3, paragraph 3, bullet 2</td>
</tr>
<tr>
<td>• <strong>Detailed features</strong> - detailed features are the aspects of individual HSIs that are not addressed by general HFE guidelines. The latter can be expected to be more variable than the standardized design features.</td>
<td>Section 4.2.3, paragraph 3, bullet 3</td>
</tr>
<tr>
<td>For each guideline, it should be determined whether the HSI is &quot;acceptable&quot; or &quot;discrepant&quot; from the guideline (therefore, potentially unacceptable), an HED. &quot;Acceptable&quot; should be indicated only if there is total compliance, i.e., only if every instance of the item is fully consistent with the criteria established by the HFE guidelines. If there is any instance of noncompliance, full or partial, then an evaluation of discrepant should be given, and a notation made as to where noncompliance occurs. Discrepancies should be evaluated as potential indicators of additional issues. For example, identifying an inappropriate format for presenting data on an individual display should be considered a potential sign that other display formats could be incorrectly used or that the observed format is inappropriately used elsewhere. As a result, the sampling strategy could be modified to encompass other display formats. In some cases, discovering these discrepancies could warrant further review in the identified areas of concern.</td>
<td>Section 4.2.3 in whole paragraph 10</td>
</tr>
<tr>
<td><strong>(3) Additional Methodology Considerations for Plant Modifications</strong> - the following considerations should be addressed:…</td>
<td>N/A (see Section 6.4 of HFE PMP, Reference 8-4)</td>
</tr>
<tr>
<td><strong>(4) HED Documentation</strong> - HEDs, should be documented by the applicant in terms of the HSI component involved and how its characteristics depart from a particular guideline.</td>
<td>Section 4.3.3, paragraph 10</td>
</tr>
</tbody>
</table>

#### 11.4.3.2.1 Test Objectives

(1) Detailed objectives should be developed to provide evidence that the integrated system adequately supports plant personnel in the safe operation of the plant. The test objectives and scenarios should be developed to address aspects of performance that are affected by the modification design, including personnel functions and tasks affected by the modification. The objectives should be to:

- Validate the role of plant personnel.

- Validate that the shift staffing, assignment of tasks to crew members, and crew coordination (both within the control room as well as between the control room and local control stations and support centers) is acceptable. This should include validation of the nominal shift levels, minimal shift levels, and shift turnover.
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<tr>
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<tbody>
<tr>
<td>• Validate that for each human function, the design provides adequate alerting, information, control, and feedback capability for human functions to be performed under normal plant evolutions, transients, design-basis accidents, and selected, risk-significant events that are beyond-design basis.</td>
<td>Section 4.3.1, bullet 3</td>
</tr>
<tr>
<td>• Validate that specific personnel tasks can be accomplished within time and performance criteria, with a high degree of operating crew situation awareness, and with acceptable workload levels that provide a balance between a minimum level of vigilance and operator burden. Validate that the operator interfaces minimize operator error and provide for error detection and recovery capability when errors occur.</td>
<td>Section 4.3.1, bullet 4 and 5 and 7</td>
</tr>
<tr>
<td>• Validate that the crew can make effective transitions between the HSIs and procedures in the accomplishment of their tasks and that interface management tasks such as display configuration and navigation are not a distraction or undue burden.</td>
<td>Section 4.3.1, bullet 9</td>
</tr>
<tr>
<td>• Validate that the integrated system performance is tolerant of failures of individual HSI features.</td>
<td>Section 4.3.1, bullet 10</td>
</tr>
<tr>
<td>• Identify aspects of the integrated system that may negatively affect integrated system performance.</td>
<td>Section 4.3.1, bullet 15</td>
</tr>
<tr>
<td>• For modifications that change plant systems but do not modify the HSI, validation can provide evidence about the adequacy of the existing HSIs, procedures, and training for supporting personnel performance. The staff should verify that the applicant validates that the functions and tasks allocated to plant personnel can be accomplished effectively when the integrated design is implemented.</td>
<td>N/A (see Section 6.4 of HFE PMP, Reference 8-4)</td>
</tr>
</tbody>
</table>

#### 11.4.3.2.2 Validation test beds

A test bed is the HSI representation used to perform validation evaluations. One approach to identifying a validation test bed that is consistent with the following review criteria, is to use the American National Standard "Nuclear power plant simulators for use in operator training," (ANSI/ANS 3.5-1998) as a guide.

<table>
<thead>
<tr>
<th>Validation Test Bed Criteria</th>
<th>V&amp;V IP Section No. and Paragraph</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) <strong>Interface Completeness</strong> - The test bed should completely represent the integrated system. This should include HSIs and procedures not specifically required in the test scenarios. For example, adjacent controls and displays may affect the ways in which personnel use those that are addressed by a particular validation scenario.</td>
<td>Section 4.3.2, paragraph 6, bullet 1</td>
</tr>
<tr>
<td>(2) <strong>Interface Physical Fidelity</strong> - A high degree of physical fidelity in the HSIs and procedures should be represented, including presentation of alarms, displays, controls, job aids, procedures, communications, interface management tools, layout and spatial relationships.</td>
<td>Section 4.3.2, paragraph 6, bullet 2</td>
</tr>
<tr>
<td>(3) <strong>Interface Functional Fidelity</strong> - A high degree of functional fidelity in the HSIs and procedures should be represented. All HSI functions should be available. High functional fidelity includes HSI component modes of operation, i.e., the changes in functionality that can be invoked on the basis of personnel selection and/or plant states.</td>
<td>Section 4.3.2, paragraph 6, bullet 3</td>
</tr>
<tr>
<td>(4) <strong>Environment Fidelity</strong> - A high degree of environment fidelity should be represented. The lighting, noise, temperature, and humidity characteristics should reasonably reflect that expected. Thus, noise contributed by equipment, such as air handling units and computers, should be represented in validation tests.</td>
<td>Section 4.3.2, paragraph 6, bullet 4</td>
</tr>
<tr>
<td>(5) <strong>Data Completeness Fidelity</strong> - Information and data provided to personnel should completely represent the plant systems monitored and controlled from that facility.</td>
<td>Section 4.3.2, paragraph 6, bullet 5</td>
</tr>
<tr>
<td>(6) <strong>Data Content Fidelity</strong> - A high degree of data content fidelity should be represented. The information and controls presented should be based on an underlying model that accurately reflects the reference plant. The model should provide input to the HSI in a manner such that information accurately matches that which will actually be presented.</td>
<td>Section 4.3.2, paragraph 6, bullet 6</td>
</tr>
<tr>
<td>(7) <strong>Data Dynamics Fidelity</strong> - A high degree of data dynamics fidelity should be represented. The process model should be capable of providing input to the HSI in a manner such that information flow and control responses occur accurately and in a correct response time; e.g., information should be provided to personnel with the same delays as would occur in the plant.</td>
<td>Section 4.3.2, paragraph 6, bullet 7</td>
</tr>
<tr>
<td>(8) For important actions at complex HSIs remote from the main control room, where timely and prescient human actions are required, the use of a simulation or mockup should be considered to verify that human performance requirements can be achieved. (For less risk–important HAs or where the HSIs are not complex, human performance may be assessed based on analysis such as task analysis rather than simulation.)</td>
<td>Section 4.3.2, paragraph 6, bullet 8</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>(9) The test beds should be verified for conformance to the test bed characteristics identified above before validations are conducted.</th>
<th>Section 4.3.2, paragraph 6, bullet 9</th>
</tr>
</thead>
</table>
| **11.4.3.2.3 Plant Personnel**  
(1) Participants in the validation tests should be representative of actual plant personnel who will interact with the HSI, e.g., licensed operators rather than training or engineering personnel. | Section 4.3.3, paragraph 1 |
| (2) To properly account for human variability, a sample of participants should be used. The sample should reflect the characteristics of the population from which the sample is drawn. Those characteristics that are expected to contribute to system performance variation should be specifically identified and the sampling process should provide reasonable assurance that variation along that dimension is included in the validation. Several factors that should be considered in determining representativeness include: license and qualifications, skill/experience, age, and general demographics. | Section 4.3.3, paragraph 2, bullets 1–4 |
| (3) In selection of personnel, consideration should be given to the assembly of minimum and normal crew configurations, including shift supervisors, reactor operators, shift technical advisors, etc., that will participate in the tests. | Section 4.3.3, paragraph 4 |
| (4) To prevent bias in the sample, the following participant characteristics and selection practices should be avoided:  
• participants who are part of the design organization  
• participants in prior evaluations  
• participants who are selected for some specific characteristic, such as using crews that are identified as good or experienced. | Section 4.3.3, paragraph 3, bullets 1–3 |
| **11.4.3.2.4 Scenario Definition**  
(1) The operational conditions selected for inclusion in the validation tests should be developed in detail so they can be performed on a simulator. The following information should be defined to provide reasonable assurance that important performance dimensions are addressed and to allow scenarios to be accurately and consistently presented for repeated trials:  
• description of the scenario and any pertinent "prior history" necessary for personnel to understand the state of the plant upon scenario start-up  
• specific initial conditions (precise definition provided for plant functions, processes, systems, component conditions and performance parameters, e.g., similar to plant shift turnover)  
• events (e.g., failures) to occur and their initiating conditions, e.g., time, parameter values, or events  
• precise definition of workplace factors, such as environmental conditions  
• task support needs (e.g., procedures and technical specifications)  
• staffing objectives  
• communication requirements with remote personnel (e.g., load dispatcher via telephone)  
• the precise specification of what, when and how data are to be collected and stored (including videotaping requirements, questionnaire and rating scale administrations)  
• specific criteria for terminating the scenario. | Section 4.3.4, paragraph 9, item (1) paragraph 1, paragraph 2, bullets 1–11 |
| (2) Scenarios should have appropriate task fidelity so that realistic task performance will be observed in the tests and so that test results can be generalized to actual operation of the real plant. | Section 4.3.4, paragraph 9, item (2) |
| (3) When evaluating performance associated with operations remote from the main control room, the effects on crew performance due to potentially harsh environments (i.e., high radiation) should be realistically simulated (i.e., additional time to don protective clothing and access radiologically controlled areas). | Section 4.3.4, paragraph 9, item (3) |
### Review Criteria Stated in NUREG-0711, Rev. 2

#### 11.4.3.2.5 Performance Measurement

(1) **Performance Measurement Characteristics** - Performance measures should acceptably exhibit the following measurement characteristics to provide reasonable assurance that the measures are of good quality (it should be noted that some of the characteristics identified below may not apply to every performance measure):

- **Construct Validity** - A measure should accurately represent the aspect of performance to be measured.
- **Diagnosticity** - A measure should provide information that can be used to identify the cause of acceptable or unacceptable performance.
- **Impartiality** - A measure should be equally capable of reflecting good as well as bad performance.
- **Objectivity** - A measure should be based on phenomena that are easily observed.
- **Reliability** - A measure should be repeatable; i.e., if the same behavior is measured in exactly the same way under identical circumstances, the same measurement result should be obtained.
- **Resolution** - A measure should reflect the performance at an appropriate level of resolution, i.e., with sufficient detail to permit a meaningful analysis.
- **Sensitivity** - A measure's range (scale) and the frequency of measurement (how often data are collected) should be appropriate to the aspect of performance being assessed.
- **Simplicity** - A measure should be simple both from the standpoint of executing the tests and from the standpoint of communicating and comprehending the meaning of the measures.
- **Unintrusiveness** - A measure should not significantly alter the psychological or physical processes that are being investigated.

#### 11.4.3.2.5.2 Performance Measure Selection

(1) A hierarchal set of performance measures should be used which includes measures of the performance of the plant and personnel (i.e., personnel tasks, situation awareness, cognitive workload, and anthropometric/physiological factors). Some of these measures could be used as "pass/fail" criteria for validation and the others to better understand personnel performance and to facilitate the analysis of performance errors. The applicant should identify which are in each category.

(2) **Plant Performance Measurement** - Plant performance measures representing functions, systems, components, and HSI use should be obtained.

(3) **Personnel Task Measurement** - For each specific scenario, the tasks that personnel are required to perform should be identified and assessed. Two types of personnel tasks should be measured: primary (e.g., start a pump), and secondary (e.g., access the pump status display). Primary tasks are those involved in performing the functional role of the operator to supervise the plant; i.e., monitoring, detection, situation assessment, response planning, and response implementation. Secondary tasks are those personnel must perform when interfacing with the plant, but which are not directed to the primary task, such as navigation and HSI configuration. This analysis should be used for the identification of potential errors of omission.

- Primary tasks should be assessed at a level of detail appropriate to the task demands. For example, for some simple scenarios, measuring the time to complete a task may be sufficient. For more complicated tasks, especially those that may be described as knowledge-based, it may be appropriate to perform a more fine-grained analysis such as identifying task components: seeking specific data, making decisions, taking actions, and obtaining feedback. Tasks that are important to successful integrated system performance and are knowledge-based should be measured in a more fine-grained approach.

- The measurement of secondary tasks should reflect the demands of the detailed HSI implementation, e.g., time to configure a workstation, navigate between displays, and manipulate displays (e.g., changing display type and setting scale).

- The tasks that are actually performed by personnel during simulated scenarios should be identified and quantified. (Note that the actual tasks may be somewhat different from those that should be performed). Analysis of tasks performed should be used for the identification of errors of commission.
Review Criteria Stated in NUREG-0711, Rev. 2 | V&V IP Section No. and Paragraph
--- | ---
- The measures used to quantify tasks should be chosen to reflect the important aspects of the task with respect to system performance, such as: - time - accuracy - frequency - errors (omission and commission) - amount achieved or accomplished - consumption or quantity used - subjective reports of participants - behavior categorization by observers | Section 4.3.5.4, paragraph 4 and all of the bullets that follow it

(4) **Situation Awareness** - Personnel situation awareness should be assessed. The approach to situation awareness measurement should reflect the current state-of-the-art. | Section 4.3.5.5

(5) **Cognitive Workload** - Personnel workload should be assessed. The approach to workload measurement should reflect the current state-of-the-art. | Section 4.3.5.6

(6) **Anthropometric and Physiological Factors** - Anthropometric and physiological factors include such concerns as visibility of indications, accessibility of control devices, and ease of control device manipulation that should be measured where appropriate. Attention should be focused on those aspects of the design that can only be addressed during testing of the integrated system, e.g., the ability of personnel to effectively use the various controls, displays, workstations, or consoles in an integrated manner. | Section 4.3.5.7

### 11.4.3.2.5.3 Performance Criteria

(1) Criteria should be established for the performance measures used in the evaluations. The specific criteria that are used for decisions as to whether the design is validated or not should be specified and distinguished from those being used to better understand the results. | Sections 4.3.5.8 and 4.3.5.9; Table C-1

(2) The basis for criteria should be defined, e.g., requirement-referenced, benchmark referenced, normative referenced, and expert-judgment referenced. | Section 4.3.5.10; Table C-1

### 11.4.3.2.6.1 Coupling Crews and Scenarios

(1) **Scenario Assignment** - Important characteristics of scenarios should be balanced across crews. Random assignment of scenarios to crews is not recommended. The value of using random assignment to control bias is only effective when the number of crews is quite large. Instead, the validation team should attempt to provide each crew with a similar and representative range of scenarios. | Section 4.3.6.1

(2) **Scenario Sequencing** - The order of presentation of scenario types to crews should be carefully balanced to provide reasonable assurance that the same types of scenarios are not always being presented in the same linear position, e.g., the easy scenarios are not always presented first. | Section 4.3.6.1, paragraph 1

### 11.4.3.2.6.2 Test Procedures

(1) Detailed, clear, and objective procedures should be available to govern the conduct of the tests. These procedures should include:

- The identification of which crews receive which scenarios and the order that the scenarios should be presented. | Section 4.3.6.2, paragraph 2, bullet 1

- Detailed and standardized instructions for briefing the participants. The type of instructions given to participants can affect their performance on a task. This source of bias can be minimized by developing standard instructions. | Section 4.3.6.2, paragraph 2, bullet 2

- Specific criteria for the conduct of specific scenarios, such as when to start and stop scenarios, when events such as faults are introduced, and other information discussed in Section 11.4.3.2.4, Scenario Definition. | Section 4.3.6.2, paragraph 2, bullet 3

- Scripted responses for test personnel who will be acting as plant personnel during test scenarios. To the greatest extent possible, responses to communications from operator participants to test personnel (serving as surrogate for personnel outside the control room personnel) should be prepared. There are limits to the ability to preplan communications since personnel may ask questions or make requests that were not anticipated. However, efforts should be made to detail what information personnel outside the control room can provide, and script the responses to likely questions. | Section 4.3.6.2, paragraph 2, bullets 4 and 5
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<tr>
<td><strong>• Guidance on when and how to interact with participants when simulator or testing difficulties occur.</strong> Even when a high-fidelity simulator is used, the participants may encounter artifacts of the test environment that detract from the performance for tasks that are the focus of the evaluation. Guidance should be available to the test conductors to help resolve such conditions.</td>
</tr>
<tr>
<td>Section 4.3.6.2, paragraph 2, bullet 6</td>
</tr>
<tr>
<td><strong>• Instructions regarding when and how to collect and store data. These instructions should identify which data are to be recorded by:</strong></td>
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<tr>
<td>- simulation computers</td>
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<tr>
<td>- special purpose data collection devices (such as situation awareness data collection, workload measurement, or physiological measures)</td>
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<td>- video recorders (locations and views)</td>
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<td>- test personnel (such as observation checklists)</td>
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<td>- subjective rating scales and questionnaires.</td>
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<tr>
<td>Section 4.3.6.2, paragraph 2, bullet 14; Section 4.3.5; Table C-1</td>
</tr>
<tr>
<td><strong>• Procedures for documentation, i.e., identifying and maintaining test record files including crew and scenario details, data collected, and test conductor logs. These instructions should detail the types of information that should be logged (e.g., when tests were performed, deviations from test procedures, and any unusual events that may be of importance to understanding how a test was run or interpreting test results) and when it should be recorded.</strong></td>
</tr>
<tr>
<td>Section 4.3.6.2, paragraph 2, bullet 18</td>
</tr>
<tr>
<td><strong>(2) Where possible, test procedures should minimize the opportunity of tester expectancy bias or participant response bias.</strong></td>
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<tr>
<td>Section 4.3.6.2, paragraph 4</td>
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<tr>
<td><strong>11.4.3.2.6.3 Test Personnel Training</strong></td>
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<tr>
<td><strong>(1) Test administration personnel should receive training on:</strong></td>
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<tr>
<td>- the use and importance of test procedures</td>
</tr>
<tr>
<td>- experimenter bias and the types of errors that may be introduced into test data through the failure of test conductors to accurately follow test procedures or interact properly with participants</td>
</tr>
<tr>
<td>- the importance of accurately documenting problems that arise in the course of testing, even if due to test conductor oversight or error.</td>
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<tr>
<td>Section 4.3.6.3, paragraph 1</td>
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<td>Section 4.3.6.3, paragraph 1</td>
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<tr>
<td><strong>11.4.3.2.6.4 Participant Training</strong></td>
</tr>
<tr>
<td><strong>(1) Participant training should be of high fidelity; i.e., highly similar to that which plant personnel will receive in an actual plant. The participants should be trained to provide reasonable assurance that their knowledge of plant design, plant operations, and use of the HSI's and procedures is representative of experienced plant personnel. Participants should not be trained specifically to perform the validation scenarios.</strong></td>
</tr>
<tr>
<td>Section 4.3.6.4, paragraph 1, item (1)</td>
</tr>
<tr>
<td><strong>(2) Participants should be trained to near asymptotic performance (i.e., stable, not significantly changing from trial to trial) and tested prior to conducting actual validation trials. Performance criteria should be similar to that which will be applied to actual plant personnel.</strong></td>
</tr>
<tr>
<td>Section 4.3.6.4, paragraph 1, item (2)</td>
</tr>
<tr>
<td><strong>11.4.3.2.6.5 Pilot Testing</strong></td>
</tr>
<tr>
<td><strong>(1) A pilot study should be conducted prior to conducting the integrated validation tests to provide an opportunity to assess the adequacy of the test design, performance measures, and data collection methods.</strong></td>
</tr>
<tr>
<td>Section 4.3.6.5, bullet 2</td>
</tr>
<tr>
<td><strong>(2) If possible, participants who will operate the integrated system in the validation tests should not be used in the pilot study. If the pilot study must be conducted using the validation test participants, then:</strong></td>
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<tr>
<td>- the scenarios used for the pilot study should be different from those used in the validation tests, and</td>
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<tr>
<td>- care should be given to provide reasonable assurance that the participants do not become so familiar with the data collection process that it may result in response bias.</td>
</tr>
<tr>
<td>Section 4.3.6.5, bullet 1</td>
</tr>
<tr>
<td><strong>11.4.3.2.7 Data Analysis and Interpretation</strong></td>
</tr>
<tr>
<td><strong>(1) Validation test data should be analyzed through a combination of quantitative and qualitative methods. The relationship between observed performance data and the established performance criteria should be clearly established and justified based upon the analyses performed.</strong></td>
</tr>
<tr>
<td>Section 4.3.7.1, paragraph 3</td>
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</table>
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<tr>
<td>(2) For performance measures used as pass/fail indicators, failed indicators must be resolved before the design can be validated. Where performance does not meet criteria for the other performance measures, the results should be evaluated using the HED evaluation process.</td>
<td>Section 4.3.7.2, paragraph 1</td>
</tr>
<tr>
<td>(3) The degree of convergent validity should be evaluated, i.e., the convergence or consistency of the measures of performance.</td>
<td>Section 4.3.7.3</td>
</tr>
<tr>
<td>(4) The data analyses should be independently verified for correctness of analysis.</td>
<td>Section 4.3.7.4</td>
</tr>
<tr>
<td>(5) The inference from observed performance to estimated real-world performance should allow for margin of error; i.e., some allowance should be made to reflect the fact that actual performance may be slightly more variable than observed validation test performance.</td>
<td>Section 4.3.7.5</td>
</tr>
</tbody>
</table>

#### 11.4.3.2.8 Validation Conclusions

1. The statistical and logical bases for determining that performance of the integrated system is and will be acceptable should be clearly documented.

2. Validation limitations should be considered in terms of identifying their possible effects on validation conclusions and impact on design implementation. These include:
   - aspects of the tests that were not well controlled
   - potential differences between the test situation and actual operations, such as absence of productivity-safety conflicts
   - potential differences between the validated design and plant as built (if validation is directed to an actual plant under construction where such information is available or a new design using validation results of a predecessor)

#### 11.4.4.2 Human Engineering Discrepancy Resolution Review Criteria

1. **HED Justification** - Discrepancies could be acceptable within the context of the fully integrated design. If sufficient justification exists, a deviation from the guidelines may not constitute an HED. The technical basis for such a determination could include an analysis of recent literature or current practices, tradeoff studies, or design engineering evaluations and data. Unjustified discrepancies should be identified as HEDs to be addressed by the HED resolution.

2. **HED Analysis** - The following should be included in the HED evaluations:
   - Plant system - the potential effects of all HEDs relevant to a single plant system should be evaluated. The potential effects of these HEDs on plant safety and personnel performance should be determined, in part, by the safety significance of the plant system(s), their effect on SAR accident analyses, and their relationship to risk significant sequences in the plant PRA.
     - HED scope
     - Global features HEDs - these are HEDs that relate to configurational and environmental aspects of the design such as lighting, ventilation, and traffic flow. They relate to general human performance issues.
     - Standardized features HEDs - these are HEDs that relate to design features that are governed by the applicant's design guidelines used across various controls and displays of the HSI (e.g., display screen organization and conventions for format, coding, and labeling). Because a single guideline may be used across many aspects of the design, a single HED could be applicable to many personnel tasks and plant systems.
     - Detailed features HEDs - these are HEDs that relate to design features that are not standardized, thus there generality has to be assessed.
     - Other - this subcategory specifically pertains to HEDs identified from integrated system validation that cannot be easily assigned to any of the three preceding categories.
   - Individual HSI or procedure HEDs should be analyzed with respect to individual HSIs and procedures. The potential effects of these HEDs on plant safety and personnel performance are determined, in part, by the safety significance of the plant system(s) that are related to the particular component

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Mitsubishi Heavy Industries, Ltd.

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### Review Criteria Stated in NUREG-0711, Rev. 2

<table>
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<tr>
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<tbody>
<tr>
<td><strong>Personnel function - HEDs</strong> should be analyzed with respect to individual personnel functions. The potential effects of these HEDs is determined, in part, by the importance of the personnel function to plant safety (e.g., consequences of failure) and their cumulative effect on personnel performance (e.g., degree of impairment and types of potential errors). Section 4.4, paragraph 6, item (4), item (f)</td>
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</table>

HEDs should also be analyzed with respect to the cumulative effects of multiple HEDs on plant safety and personnel performance. While an individual HED might not be considered sufficiently severe to require correction, the combined effect of several HEDs upon the single aspect of the design could have significant consequences to plant safety and, therefore, necessitate corrective action. Likewise, when a single plant system is associated with multiple HEDs that affect a number of HSI components, then their possible combined effect on the operation of that plant system should be considered. Section 4.4, paragraph 6, item (5) |

In addition to addressing the specific HEDs, the analysis should treat the HEDs as indications of potentially broader problems. For example, identifying multiple HEDs associated with one particular aspect of the HSI design, such as the remote shutdown panel, could also indicate that there are other problems with that aspect of the design, such as inconsistent use of procedures and standards. In some cases, the evaluation of HEDs could warrant further review in the identified areas of concern. Section 4.4, paragraph 6, item (5) |

**HED Prioritization - Identification of HEDs for correction** should be based upon a systematic evaluation, such as that illustrated in Figure 11.2. Priority 1 HEDs should be those with direct safety consequences and those with indirect or potential safety consequences. HEDs with significant safety consequences are those that affect personnel performance where the consequences of error could reduce the margin of plant safety below an acceptable level, as indicated by such conditions as violations of Technical Specification safety limits, operating limits, or limiting conditions for operations. They include deviations from personnel information requirements or HFE guidelines for personnel tasks that are related to plant safety. These could include the following: Section 4.4, paragraph 6, item (6), item (a) |

- are required by personnel tasks but are not provided by the HSI Section 4.4 |
- do not satisfy all personnel information needs (e.g., information not presented with the proper range or precision) Section 4.4 |
- contain deviations from HFE guidelines that are likely to lead to errors that would prevent personnel from performing the task. Section 4.4 |

HEDs with indirect safety consequences include deviations from HFE guidelines that would seriously affect the ability of personnel to perform the task. The severity of an HFE guideline deviation should be assessed in terms of the degree to which it contributes to human performance problems, such as workload and information overload. Section 4.4 |

Priority 2 HEDs should be those that do not have significant safety consequences, but do have potential consequences to plant performance/operability, non-safety-related personnel performance/efficiency, or other factors affecting overall plant operability. These include deviations from personnel information requirements and HFE guidelines for tasks associated with plant productivity, availability, and protection of investment. These HEDs should be considered for correction. Section 4.4, paragraph 6, item (6), item (b) |

The remaining HEDs are those that do not satisfy the criteria associated with the first and second priorities. Resolution of these HEDs is not an NRC safety concern but may be resolved at the discretion of the applicant. Section 4.4, paragraph 6, item (c) |

**HED Evaluation Documentation - Each HED** should be fully documented including assessment category (priority for correction), associated plant system, associated personnel function, and associated HSI or procedure. The documentation should clearly show whether the HED was dismissed or identified as needing design modification and the basis for this determination in terms of consequence to plant safety or operation should be clearly described. Section 4.4 |

HED documentation is described in the HFE PMP (Reference 8-4) |
### Review Criteria Stated in NUREG-0711, Rev. 2

<table>
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<tr>
<th>Section 4.4</th>
<th>The HED resolution process is described in the HFE PMP (Reference 8-4)</th>
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<th>V&amp;V IP Section No. and Paragraph</th>
<th>Review Criteria Stated in NUREG-0711, Rev. 2</th>
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<tr>
<td><strong>(5) Development of Design Solutions</strong></td>
<td>Design solutions to correct HEDs should be identified. The design solutions should be consistent with system and personnel requirements identified in the Preparatory Analysis (i.e., Operating Experience Review, Function and Task Analysis, and HSI Characterization). Inter-relationships of individual HEDs should be evaluated. For example, if a single HSI component is associated with multiple HEDs, then design solutions should be considered to address these HEDs together. If a single plant system is associated with multiple HSI components that are associated with HEDs, then the design of the individual solutions should be coordinated so that their combined effect enhances rather than detracts from that system's operation.</td>
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<td><strong>(6) Design Solution Evaluation</strong></td>
<td>Designs should be evaluated by repeating the appropriate analyses of the verification and validation. For example, the HSI Task Support Verification should be conducted to provide reasonable assurance that the design satisfies personnel task requirements. Portions of the HFE design verification analysis should be conducted to provide reasonable assurance that the design is consistent with HFE guidelines, and integrated system validation could be conducted to evaluate its usability. When the problems identified by an HED cannot be fully corrected, justification should be given.</td>
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<tr>
<td><strong>(7) Design Modification</strong></td>
<td>There should be an implementation schedule for activities associated with installing, testing, and HFE evaluation of the design solutions. All design solutions for Priority 1 HEDs should be scheduled for prompt implementation. The schedule should be developed to minimize demands and disruptions for personnel. For operating plants, the schedule should distinguish between solutions that can be implemented without interfering with the operation of the plant, and improvements that can only be made when the plant is not operating. Installing large groups of design solutions at discrete intervals should be considered to avoid subjecting operating crews to a continually changing HSI. Procedures should be established to provide reasonable assurance that information related to the design of the HSI such as plant procedures, drawings, and training programs is updated to reflect the changes.</td>
</tr>
</tbody>
</table>
8.0 REFERENCES

8-1 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP-DC018, Revision 4, MHI, August 2013

8-2 Human-System Interface System Description, MUAP-07007-P and MUAP-07007-NP, Revision 6, MHI, May 2014

8-3 Deleted

8-4 Human Factors Engineering Program Management Plan, MUAP-09019, Revision 4, MHI, May 2014


8-6 Nuclear Power Plant Simulators for Use in Operator Training and Examination, ANSI/ANS 3.5-2009, American National Standards Institute

8-7 Human Factors Engineering Program Review Model, NUREG-0711, Revision 2, U.S. Nuclear Regulatory Commission, February 2004


8-9 Human-System Interface Design Review Guidelines, NUREG-0700, Revision 2, U.S. Nuclear Regulatory Commission, May 2002


<p>| 8-16 | Operator Licensing Examination Standard for Power Reactors, NUREG-1021, Revision 9, U.S. Nuclear Regulatory Commission, July 2004 |
| 8-18 | Task Analysis Implementation Plan, MUAP-13009, Revision 1, MHI, May 2014 |
| 8-19 | Human Reliability Analysis Implementation Plan, MUAP-13014, Revision 1, MHI, May 2014 |
| 8-20 | Operating Experience Review Implementation Plan, MUAP-13005, Revision 1, MHI, May 2014 |
| 8-21 | Staffing and Qualifications Implementation Plan, MUAP-10008, Revision 4, MHI, May 2014 |
| 8-23 | Design Control Document for the US-APWR, Chapter 15, Transient and Accident Analyses, MUAP-DC015, Revision 4, MHI, August 2013 |
| 8-24 | Design Control Document for the US-APWR, Chapter 19, Probabilistic Risk Assessment and Severe Accident Evaluation, MUAP-DC019, Revision 4, MHI, August 2013 |
| 8-25 | Quality Assurance Program Requirements (Operation), Regulatory Guide 1.33, Revision 6, U.S. Nuclear Regulatory Commission, June 2013 |
| 8-26 | Design Implementation Implementation Plan, MUAP-10013, Revision 4, MHI, March 2014 |
| 8-27 | Defense-in-Depth and Diversity Coping Analysis, MUAP-07014, Revision 6, MHI, September 2013 |</p>
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<td>US-APWR Probabilistic Risk Assessment, MUAP-07030, Revision 3, MHI, June 2011</td>
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<td>Functional Requirements Analysis and Function Allocation Implementation Plan, MUAP-13007, Revision 1, MHI, May 2014</td>
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DEFINITIONS

Situation Awareness Global Assessment Technique (SAGAT) – “Situation awareness is the continuous extraction of environmental information, the integration of this information with previous knowledge to form a coherent mental picture, and the use of that picture in directing further perception and anticipating future events” (Reference 8-29). The SAGAT is a query technique. SAGAT is based on information-processing theory and considers situation awareness as an internal model that is derived from the environment prior to decision-making and performance. SAGAT is the best publicized and most widely known measure of situation awareness.

NASA Task Load Index (NASA-TLX) – NASA-TLX is a subjective, post-hoc workload assessment tool. NASA-TLX allows users to perform subjective workload assessments on operator(s) working with various human-machine systems. NASA-TLX is a multidimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six subscales. The subscales include Mental Demands, Physical Demands, Temporal Demands, Own Performance, Effort, and Frustration (Reference 8-28).
## Scenario Format Template

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Note
Throughout this template:
- Normal fonts indicate standard language to be included in each scenario
- *Italic fonts indicate explanatory or directive material to be replace with scenario specific material or delete, as appropriate*
- [Bracketed language indicates suggested or expected information to be replaced with plant or design specific values or descriptions]
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**Approximate Duration:** 90 Minutes
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4.3 Dropped Control Rod
5.0 POST-SCENARIO REVIEW
Example Scenario 2

ISV Id: SO2

Title: Small-Break LOCA (SB-LOCA) with Violation of Critical Safety Function

Signature/Printed Name
Preparer
Validator
HFE
Approver

Date

Approximate Duration: 2.0 hours
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5.0 POST-SCENARIO REVIEW
Example Scenario 3

ISV Id: SO3

Title: SGTR with Common Cause Failure (CCF) of all Digital I&C

Signature/Printed Name          Date
Preparer                        
Validator                      
HFE                            
Approver                       

Approximate Duration: 2.0 hours
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