HITACHI

GE Hitachi Nuclear Energy

James C. Kinsey
Vice President, ESBWR Licensing

PO Box 780 M/C A-55
Wilmington, NC 28402-0780
USA

T 910 675 5057
F 910 362 5057
jim.kinsey@ge.com

MFN 08-172

Docket No. 52-010

April 16, 2008

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

Subject: **Response to Portion of NRC Request for Additional Information Letter Nos. 129 and 153 Related to ESBWR Design Certification Application – Human Factors Engineering - RAI Numbers 18.9-2 S01, 18.11-7 S01, 18.11-19 S01, 18.11-23 S01, 18.11-24 S01, 18.11-26 S01, and 18.11-29 S01**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) responses to the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI) Requests for Additional Information (RAI) NRC letters No. 129 (Reference 1) dated December 19, 2007, and No. 153, dated February 12, 2008 (Reference 2).

The GEH response to RAIs 18.9-2, 18.11-7, 18.11-19, 18.11-23, 18.11-24, 18.11-26, and 18.11-29 were submitted via References 4 and 5 in partial response to NRC Letter 74 (Reference 3).

GEH's response to RAIs 18.9-2 S01, 18.11-7 S01, 18.11-19 S01, 18.11-23 S01, 18.11-24 S01, 18.11-26 S01, and 18.11-29 S01 are addressed in Enclosure 1.

Also note that these RAI responses correspond to, and answer several open items listed in Reference 6. Please consider these open items to be addressed by this letter.

D068
NRO

If you have any questions or require additional information, please contact me.

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

References:

1. MFN 07-701 - Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, Request For Additional Information Letter No. 129 Related To ESBWR Design Certification Application, dated December 19, 2007
2. MFN 08-130 - Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 153 Related To ESBWR Design Certification Application*, dated February 12, 2008
3. MFN 06-386, Request for Additional Information Letter No.74 Related to ESBWR Design Certification Application, dated October 11, 2006
4. MFN 06-446, *Response to Portion of NRC Request for Additional Information Letter No. 74 – ESBWR Human Factors Engineering, NEDO-33276, Rev. 0 HFE Verification and Validation Implementation Plan – RAI Numbers 18.11-1 through 18.11-33*, dated November 22, 2006
5. MFN 06-444, *Response to Portion of NRC Request for Additional Information Letter No. 74 Related to ESBWR Design Certification Application – ESBWR Human Factors Engineering NEDO-33274 Rev. 0, Procedures Development Implementation Plan – RAI Numbers 18.9-1 through 18.9-10*, dated November 22, 2006
6. MFN 08-194 - Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Economic Simplified Boiling Water Reactor (ESBWR) Chapter 18 Open Items*, dated February 28 2008

Enclosure:

1. Response to Portion of NRC Request for Additional Information Letter Nos. 129 and 153 Related to ESBWR Design Certification Application – Human Factors Engineering - RAI Numbers 18.9-2 S01, 18.11-7 S01, 18.11-19 S01, 18.11-23 S01, 18.11-24 S01, 18.11-26 S01, and 18.11-29 S01

cc:	AE Cubbage	USNRC (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	GB Stramback	GEH/San Jose (with enclosure)
	eDRF	0000-0083-4390, Revision 0

Enclosure 1

MFN 08-172

Response to Portion of NRC Request for Additional Information Letter Nos. 129 and 153 Related to ESBWR Design Certification Application

Human Factors Engineering

RAI Numbers
18.9-2 S01, 18.11-7 S01, 18.11-19 S01, 18.11-23 S01, 18.11-24 S01, 18.11-26 S01, and 18.11-29 S01

For historical purposes, the original text of RAIs 18.9-2, 18.11-7, 18.11-19, 18.11-21, 18.11-23, 18.11-24, 18.11-26, and 18.11-29 and any previous supplemental text and GE responses are included preceding each supplemental response. Any original attachments or DCD mark-ups are not included to prevent confusion.

NRC RAI 18.9-2

A. *DCD Chapter 13.5 and this plan discuss the scope of the procedure program for the ESBWR. Ch. 13.5 commits to ANS 3.2 (no revision provided). However, it does not commit to RG 1.33 (which endorses ANSI/ANS 3.2 but also provides additional guidance). The most current version of ANSI/ANS 3.2 is 1994 (Reaffirmed 1999).Please address.*

B. *DCD Section 13.5.3.4 lists procedures to be covered by the Procedure Development Plan. These are all addressed in NEDO-33274 except for Radiation Control, Calibration, and Inspection procedures. Please address.*

GE Response

A. DCD Tier 2 Chapter 13 will *be* revised to show commitment to Regulatory Guide 1.33 Revision 2, February 1978 as well as ANSI/ANS-3.2 1994: R1999 (R=Reaffirmed), Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants.

B. NEDO-33274 will be revised to address procedures for Radiation Control, Calibration, and Inspection as identified in DCD Tier 2, Section 13.5.3.4.

DCD/LTR Impact

DCD Tier # 2, Section 13.5.3.4 will be revised as noted in the attached markup in Revision 3.

Sections 1.2, 3, and 4 of LTR NEDO-33274 Rev. 0, will be revised as described above.

NRC RAI 18.9-2 S01

Supplemental RAI for Part A of original RAI only.

DCD Tier 2, Chapter 13.5 shows the commitment to ANSI/ANS-3.2 1994: R1999 (R=Reaffirmed), Administrative Controls and Quality Assurance for the Operational Phase of Nuclear Power Plants, as endorsed by Regulatory Guide 1.33 Revision 2, February 1978. However it is not clear whether all aspects of procedure development addressed in RG 1.33 will be met, for example procedures in Appendix A of RG 1.33.

GEH Response

A statement of explicit commitment to the applicable portions of Regulatory Guide 1.33 Rev. 2 concerning plant procedures, which includes the use of Appendix A as specified, will be added to Tier 2 DCD Chapter 13.5.

DCD Impact

DCD Tier # 2, Section 13.5 will be revised as noted in the attached markup. These changes will be made with Revision 5 of DCD Tier # 2.

13.5 PLANT PROCEDURES

Plant procedures are developed to provide control for activities that are important for safe operation of the facility. The applicable portions of Regulatory Guide 1.33 Rev. 2 (Reference 13.5-5) concerning plant procedures shall be followed.

13.5.1 Administrative Procedures

An Administrative Procedures Plan shall be generated and describe administrative procedures that provide administrative control over activities that are important to safety for operation of the facility. These procedures include those, which provide the administrative controls in respect to procedures, and those, which define and provide controls for operational activities of the plant staff.

The COL Applicant shall develop the Administrative Procedures (COL 13.5-1-A).

13.5.2 Operating and Maintenance Procedures

The development of Operating Procedures is generally described in Section 18.9 Procedure Development.

A Plant Operating Procedures Development Plan shall be generated and have the following attributes:

- That the scope encompassed by the procedures development process includes those operating procedures defined in Subsection 13.5.2, which direct operator actions during normal, abnormal and emergency operations. The procedure development process will also include consideration of plant operations during periods when plant systems/equipment are undergoing test, maintenance or inspection.
- The procedure development process will address methods and criteria for the development, verification and validation, implementation, maintenance and revision of procedures. The methods and criteria shall be in accordance with TMI I.C.1, NUREG-0737 (Reference 13.5-3).

The development of Operating and Maintenance Procedures is the responsibility of the COL Applicant (COL 13.5-2-A).

Implementation of the Plant Operating Procedures Development Plan shall establish:

- Procedures that are consistent with the requirements of 10 CFR Part 50 and the TMI requirements described in NUREG-0737 (Reference 13.5-3) and Supplement 1 to NUREG-0737 (Reference 13.5-7).
- Requirements that the procedures developed shall include, as necessary, the elements described in American National Standards Institute (ANSI)/American Nuclear Society (ANS)-3.2-1994:R1999, (Reference 13.5-2), as endorsed by Regulatory Guide 1.33 Rev. 2 (Reference 13.5-5).
- That the operator basis for plant operating procedures shall use actions identified in the operational task analysis and Probabilistic Risk Assessment (PRA) efforts in support of the Standardized Design certification, Standardized Plant Design Emergency Procedure

NRC RAI 18.11-7

NEDO-33276, Section 4.3.2.4 discusses the methods and procedures for conducting task support verification. This section states "Task performance requirements (e.g., HSI Design Implementation Plan, Style Guide for Graphical User Interfaces, and Display Primitives Design Specification) are imposed on the various HSI hardware and software components. These requirements are included (directly or by reference) in hardware and software specifications (e.g., DCIS Hardware/Software Specification)." (p. 33) The documents listed as performance requirements seem to be HSI requirements rather than task driven-requirements. However, on the same page, the plan indicates that HSIs and their characteristics will be compared to the personnel task requirements identified in the task analyses. Please clarify the criteria to be used in task support verification.

GE Response

See response to RAI 18.11-5. This section will be revised to link the tasks to be addressed in the verification stage to the operational analysis as shown in Enclosure 2 of MFN 06-401. A process diagram will be added to replace the first two figures in NEDO-33276.

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 0 will be revised as described above at the next revision.

NRC RAI 18.11-7 S01

In the original RAI, the staff requested clarification as to what criteria were to be used in task support verification. GEH's response referred to their response to RAI 18.11-5. The staff followed up indicating that RAI response addresses the criteria for selecting tasks. This original RAI requested clarification of the criteria to be used to evaluate the Human-Systems Interfaces (HSIs) that support tasks. However, the material is unchanged in NEDO-33226, Rev. 1. Thus the RAI remains open. Please provide such clarification.

GEH Response

To reflect the level of detail required for an Implementation plan, both the text and document organization in NEDO–33276 will be revised. The final organization is incomplete, but the revision will include a section that details what criteria are used to evaluate HSIs during task support verification.

The text below will be inserted in the HSI Inventory and Task Support Verification section.

As can be seen in NEDO-33276, Figure 2, the HFE design verification receives input from task analysis, HSI design, software design, Regulation (such as NUREG-0700), the ESBWR style guide, and the HFEITS resolution process. The design verification develops and characterizes the ESBWR HSI inventory. This characterized inventory is then verified to meet the applicable regulatory, style guide, software, and design requirements. Any HSI that is not verified to meet requirements is entered into HFEITS for resolution. The output of the HFE design verification process is a list of categorized and verified HSIs.

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

HSI criteria identified in task analysis that are verified include:

Task Level

- HSIs that indicate that the task objective is available to be placed in service
- HSIs that indicate that the end state of the task has been accomplished
- HSIs that indicate that the end state of the task has achieved the desired results
- HSIs that indicate that the end state of the task is no longer needed and can be terminated
- HSIs identified as part of the task prerequisites

<u>Steps Within a Task</u>

Any HSIs identified during analysis of:

- Decisions imbedded in the task
- Each human step during the task analysis
- Each step in automation sequences during task analysis
- Step success criteria during task analysis
- Auto logic break points during task analysis
- Communication requirements during task analysis

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

Additionally, task support verification compares the HSIs identified during the detailed analysis of a task to the list of characterized and verified HSIs to ensure that all HSIs meet HFE task requirements.

General Design Principles For HSI Resources

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

1. Human-centered design
2. Minimize change to operator responsibilities
3. Take advantage of technology to improve support for the operators
4. Uniformity of design

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

Human-Centered Design

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

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

- Detection and monitoring/situation awareness
- Interpretation and planning
- Control
- Feedback

Detection and Monitoring/Situation Awareness

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

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

- Where is the mass in the system?
- Where is the energy in the system?
- What is the reactivity?
- What critical safety functions have been violated?

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

Interpretation and Planning

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

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

Control

Control involves decisions in the initiation, tuning, and termination of plant processes. Control is simpler for operators when they control the pace of an event. Control becomes more difficult when multiple individuals or autonomous systems must be coordinated to execute a task. While the control area of the HSI model does not explicitly call out the process of locating the controls, it is considered a part of the HSI task support requirements.

Feedback

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

Minimize Change to Operator Responsibilities

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

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

By minimizing the change to operator roles, except where a specific change is desired, changes to other aspects of the plant (both inside and outside the control room) are controlled.

Taking Advantage of Technology to Support Operators

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

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

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

Uniformity of Design

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

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

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

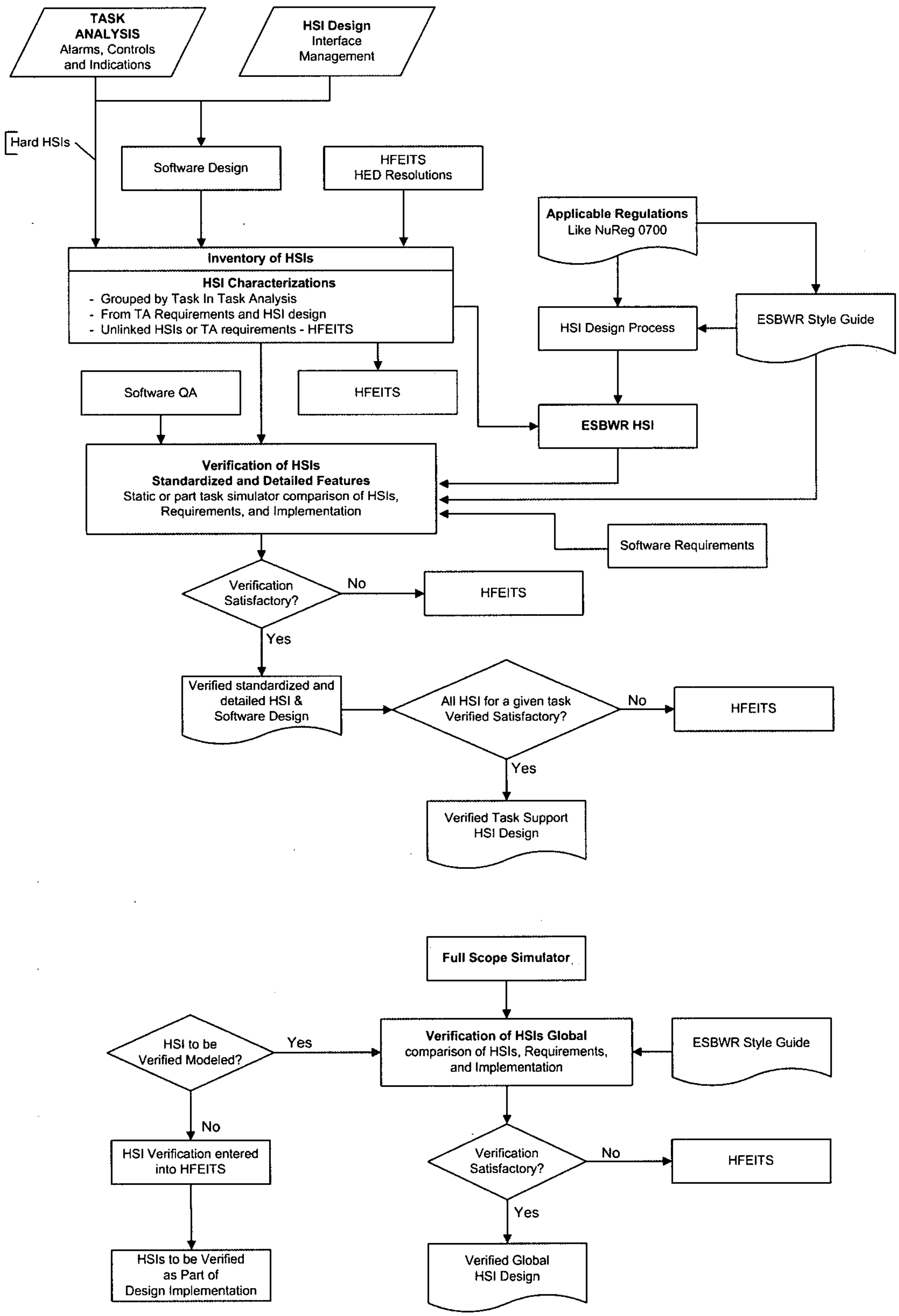
Uniformity of design criteria also extends to implementation features of the HSI design. Maintenance and system engineers and technicians are not expected to develop exceptional knowledge for specific instances of an HSI resource. As the system matures in its design life, there is a risk that such exceptions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

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 1 will be revised with the inserted text provided above. The attached Figure 1 will also be inserted.

Figure 1


TASK ANALYSIS
Alarms, Controls and Indications
HSI Design
Interface Management
Hard HSIs
Software Design
HFEITS
HED Resolutions
Applicable Regulations
Like NuReg 0700
Inventory of HSIs
HSI Characterizations
- Grouped by Task In Task Analysis
- From TA Requirements and HSI design
- Unlinked HSIs or TA requirements - HFEITS
HSI Design Process
ESBWR Style Guide
Software QA
HFEITS
ESBWR HSI
Verification of HSIs
Standardized and Detailed Features
Static or part task simulator comparison of HSIs, Requirements, and Implementation
Software Requirements
Verification Satisfactory?
No
HFEITS
Yes
Verified standardized and detailed HSI & Software Design
All HSI for a given task Verified Satisfactory?
No
HFEITS
Yes
Verified Task Support HSI Design
Full Scope Simulator
HSI to be Verified Modeled?
Yes
Verification of HSIs Global
comparison of HSIs, Requirements, and Implementation
ESBWR Style Guide
No
HSI Verification entered into HFEITS
Verification Satisfactory?
No
HFEITS
Yes
HSIs to be Verified as Part of Design Implementation
Verified Global HSI Design

NRC RAI 18.11-19

NEDO-33276 does not address how important actions at complex HSIs remote from the main control room will be addressed in validation. Specific operational conditions and scenarios to be used in validation have not yet been identified, it is not possible to know what important actions remote from the control room should be represented. Please provide information as to how it will be determined which actions outside the control room should be included in validation scenarios and how these actions will be modeled.

GE Response

The part task simulations and full scope test scenarios will be developed to address actions that are defined in four categories. The first set comes from the operational analysis as shown in Figure 2 of NEDO-33276. The second set comes from PRA/HRA identified risk important actions that involve multiple actions in the same scenario from different locations. The third set comes from specific actions identified in the procedures for systems or integrated plant actions.

The fourth set of actions are based on events and experience. The design of the ESBWR attempts to minimize complex actions by providing a large time interval to take the action, by using natural circulation for cooling and maintaining a passive heat removal system for decay heat. The validation of actions begins with the part task simulator which provides an accurate control room interface for each system. In this case outside actions at local system control stations are estimated using drawings or mockup panels. The validation of integrated actions begins with the full scope simulator (which may use electronic versions of back panels and the RSS).

If some complex actions could not be fully validated during full scope simulation the process can be extended to the plant itself to verify that complex coordinated actions between the control room and local stations can be carried out using the plant procedures and MMIS.

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 0 will be revised as described above at the next revision.

NRC RAI 18.11-19 S01

NRC Summary Text:

Validation Testbeds: Validation Simulator and Simulation of remote actions

NRC Full Text:

This follow-up RAI on testbeds has two parts:

1. *Regarding the testbed to be used for integrated system validation, Section 3.4 of NEDO-33276 states that integrated system validation is performed using dynamic HSI prototypes and high-fidelity simulators. Section 4.3.4 describes a variety of test beds that are to be used to address the different objectives of the validation program. Three of the main simulation facilities to be used in this program are the GEH Test System, Baseline Simulator (BS), and the Full Scope Simulator (FSS), described in Sections 4.3.5.2, 4.3.5.3, and 4.3.5.4, respectively. These simulators provide incremental levels of fidelity, and the BS and FSS models are ANSI/ANS-3.5 compatible. While ANSI/ANS 3.5 compatibility provides an acceptable basis for an integrated system validation testbed as described in NUREG-0711, the BS does not provide the full control room HSI. Thus, based on the staff's validation testbed criteria in NUREG-0711, Section 11.4.3.2.2, only the FSS is suitable for implementing integrated system validation. While the other simulators can provide valuable information to GE during their test and evaluation program, the final validation addressed in NUREG-0711 should be performed using the FSS. GEH should clarify the role of the FSS in the final validation. In addition, in response to RAI 18.10-1 GEH submitted the Attachment to MFN 07-625 in which simulation capabilities are defined, including a Part Task Simulator, Full-Scope Simulator, and Site Specific Training Simulator. The BS is not included in this response. Please describe how these descriptions correspond to those provided in NEDO-33276 and provide any changes to descriptions in NEDO-33276 that may be necessary to reconcile the two documents.*

2. *Regarding the simulation of remote actions, Section 4.3.4.1 indicates that actions at local system control stations are evaluated using drawings or mockup panels, but no information as to what evaluations are performed or how the actions will be analyzed. This statement is in the HFE Design Verification section rather than an integrated system validation section. Beyond this statement, no information about the treatment of local actions is provided. Please identify what remote actions are needed for the scenarios to be used in validation testing and provide information as to how these actions will be modeled and evaluated for validation.*

GEH Response

To reflect the level of detail required for an Implementation plan, both the text and document organization in NEDO–33276 will be revised. The final organization is incomplete, but the revision will include a section that defines testbeds and how they are used in the HFE V&V process. In the same section, the information on how the Remote Shutdown Panel and risk significant local control panels are evaluated will be addressed.

1) GEH clarified the types of simulators used in the ESBWR design development in changes made to NEDO-33275, Rev 1, ESBWR HFE Training Development Implementation plan in response to RAI 18.10-1 S02. In that RAI, GEH defines part task, full scope, and site specific training simulators and removed references to GEH Test System and Baseline Simulators.

Simulators used in HFE V&V activities are described below using the above conventions.

The text below will be inserted in the Integrated System Validation section.

Part Task Simulator

Purpose

The Part Task Simulator (PTS) is a tool used by the Human Factors Engineering group for the development and testing of Human System Interface display screens, initial development and testing of the plant normal, abnormal, and emergency operating procedures, and the initial development of operations training material.

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

On a case by case basis, for the systems they model with the required fidelity, part task simulators can be shown to be high fidelity (in accordance with ANSI 3.5 and Reg Guide 1.149).

Properties

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

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

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

Scope

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

The PTS contains the initial Human System Interface for the plant systems, including VDUs and input devices.

Full Scope Simulator

Purpose

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

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

Properties

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

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

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

Scope

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

The FSS contains the ESBWR Human System Interface for the plant systems, including VDUs and input devices.

Site Specific Training Simulator

Purpose

The Site Specific Training Simulator provides a full scope simulation tool for conducting licensed operator training activities, completing control manipulations for operator license applicants, and conducting license operator operating tests.

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

Properties

The simulation software for the Site Specific Training Simulator provides the plant operational functionality and fidelity required by ANSI 3.5 certification and Reg Guide 1.149. The software for the systems simulates the detailed system design. The remaining systems are modeled either statically or using simplified models.

The hardware for the Site Specific Training Simulator is developed using the same control room design, and the same materials and manufacturing techniques as the actual ESBWR control room hardware.

The Site Specific Training Simulator has an instructor station providing the full functionality required for ANSI 3.5 certified training simulators.

Scope

The Site Specific Training Simulator is an ANSI 3.5 certified and Reg Guide 1.149 compliant full scope simulator for operator training and testing.

The Site Specific Training Simulator contains consoles and panels with the same form, fit, and feel as the ESBWR main control room.

Use of Simulators in Integrated System Validation

Part task and full scope simulators that have not been shown to be high fidelity (by meeting the requirements of ANSI 3.5 and Reg Guide 1.149) for the systems to be tested cannot be used for formal integrated system validation. Such simulators are used for other testing or data gathering activities that do not require a high fidelity simulator.

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

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

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

1) Remote actions will be addressed in the ESBWR V&V process as outlined below.

The text below will be inserted in the Integrated System Validation section.

Remote Shutdown System

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

Risk Significant Local Control Panels

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

DCD Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 1 will be revised with the inserted text provided above.

NRC RAI 18.11-23

NEDO-33276 does not discuss the measurement characteristics, such as reliability and validity. For measures that are new or unique to the ESBWR V&V, please provide information on measurement characteristics that are relevant to that type of measure.

GE Response

The level of detail in the implementation plan was not intended to discuss issues about the characteristics of measurement process, because a high degree of engineering judgment is required to evaluate the acceptability of the MMIS. As a minimum, a range of qualitative and quantitative measures can be used to verify that the MMIS is acceptable. Validity of the measure is the degree to which the accuracy of the assessment based on both objective and qualitative measures in the context of simulated events.

Examples of quantitative measures are:

- Are there sufficient cues to ensure an operator can successfully maintain steady operation after single failures?
- Can the operator perform manual trip if it is required?
- Is the time line for cues and actions suitable for avoiding core damage?

Examples of qualitative measures are:

- Is the interface consistent for different screens?
- Do the operators feel comfortable using the MMIS?
- Is the presentation of information suitable for a wide range of people?

These measures need to be sufficiently accurate for the purpose of validation. Since "operators" will be exercising the interfaces during different phases of the V&V and observers different from the operators will be evaluating the measures and observations, several types of measures are considered during the validation process. The MMIS can be validated on the basis of convergence of the assessments (e.g., reliability of observers) where many people agree that the MMIS operation is successful. The MMIS can be validated on the basis of face validity where knowledgeable people with real world experience agree that the operation meets requirements for the actions tested (judgment basis validity). The MMIS can also be validated on the basis of predictive validity where the observations in the test case can be used to support HRA assessments of the probability of error that are within the assessments in the PRA. Each of these measures will be considered when appropriate for the validation test being conducted. If the observers diverge, knowledgeable people disagree or note that the operation is not successful, or the HEP value is to high for the PRA study, then an HED would be written for the HFEITS.

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

No LTR changes will be made in response to this RAI.

NRC RAI 18.11-23 S01

In the original RAI, the staff requested information on measurement characteristics. GEH's response to the RAI indicated that the level of detail in the implementation plan was not intended to discuss measurement characteristics. GEH should provide this information on applicable measurement characteristics, such as reliability and validity, for all performance measures identified in response to RAI 18.11-24 so the staff is able to conduct an Implementation Plan level review (consistent with NUREG-0711, Section 11.4.3.2.5.1).

GEH Response

To reflect the level of detail required for an Implementation plan, both the text and document organization in NEDO–33276 will be revised. The final organization is incomplete, but the revision will include a section that establishes a hierarchal set of performance measures (as defined in GEH's response to RAI 18.11-24 S01). The measurement characteristics of these performance measures are defined below.

(Note: as RAI 18.11-23 S01, RAI 18.11-24 S01, and RAI 18.11-26 S01 are related areas, GEH recommends that the responses to these RAIs be evaluated together).

The text below will be inserted in the Integrated System Validation section.

The performance measures selected to validate the integrated plant design and the HFE design of plant controls are verified to meet documented measurement characteristics. This verification provides assurance that the selected performance measures are of good quality:

A. Plant – Core Thermal-Hydraulic Condition

- **Construct Validity** – Plant design is driven by the ability to control and determine core thermal-hydraulic condition. The selected performance measures represent the ability of the plant to complete that function, and thus demonstrate construct validity.
- **Impartiality** – Achieved by using a performance measure that provides an equally well measure of successful or unsuccessful performance.
- **Objectivity** – Operator actions can easily be observed and timed; likewise, the outcome of a scenario is easily observed through the use of simulator technology.

- **Reliability** – This measure is repeatable, because any event resulting in the core thermal-hydraulic parameters exceeding defined limits produces the same result.
- **Unintrusiveness** – Achieved by using a performance measure that is monitored with no input required from the test conductors or participants.

B. Plant – PRA/HRA

- **Construct Validity** – Scenario critical tasks that measure the change in complexity of actions needed to attain the desired plant condition provide this data (i.e., an operator or plant response to an event that increases the complexity of parameter interpretation or the tasks required to mitigate the event result in performance measure failure).
- **Reliability** – Achieved by measuring time and value data, which is easily replicated, and by using scenario guides to ensure that the scenario initial conditions, inserted malfunctions and required actions are equivalent for each test.
- **Sensitivity** – The data collection of operator actions and plant responses provide the required detail for analysis of the failure and the contributing factors resulting in the failure.

C. Personnel Tasks

- **Construct Validity** – The change in system state and resulting plant response provide the required information to determine successful completion of the performance measure.
- **Objectivity** – Successful completion of the performance measure is easily verified using available data.
- **Simplicity** – The tests required to complete the performance measure are completed using standard procedures and processes familiar to the test conductors and participants. Successful completion of the performance measure is verified from final system status.

D. Supplemental

1. Crew Coordination and Communications

- **Construct Validity** – Operator performance evaluation using tested evaluation techniques provide the desired information.
- **Diagnosticity** – The evaluation techniques provide the data necessary to determine the cause/source of performance measure failure.

- **Reliability** – Scenario guides ensuring scenarios are conducted in a consistent manner and detailed evaluation guides provide assurance the performance measure is consistently evaluated.

2. Situation Awareness (SA)

The approach used to measure situation awareness draws from the SAGAT approach. The SAGAT technique has thus far been shown to have a high degree of validity, sensitivity, and reliability for measuring SA (Endsley, 2000).

- **Sensitivity** - Previous research has indicated that the SAGAT method for measuring situation awareness has good sensitivity to system manipulations, automatic manipulations, expertise differences and operational concepts in a variety of system domains (Endsley, 2000)
- **Criterion Validity** - The SAGAT approach has been shown to have predictive validity, with SAGAT results being indicative of pilot performance in a combat simulation (Endsley, 1990). This study found that fighter pilots who were able to report on an enemy aircraft's existence during a SAGAT test were three times more likely to later kill that target in a simulation than pilots who were not able to report an enemy aircraft's existence during SAGAT testing.
- **Construct Validity** - Two concerns regarding the SAGAT testing methodology are the perceived intrusiveness of freezes in a simulation to collect SAGAT data, and the degree to which SAGAT results reflect memory and the ability to recall information.

While it is never possible to "prove" a null hypothesis, that administration of the SAGAT does not affect performance, many studies have been done that indicate that the SAGAT approach does not appear to significantly affect performance (Bolstad & Endsley, 1990; Endsley, 2000; 1995; 1990; 1989; Northrop, 1988). Hogg, Folleso, Torralba and Volden (1993) also reported that power plant operators in their study subjectively reported no effect from the freezes and considered it similar to their training exercises.

The second issue with the SAGAT approach is whether it provides a good representation of the operator's SA or whether it is hindered by being dependant on memory. Because the SAGAT approach obtains information immediately after that information has been perceived, SAGAT taps into working memory (Baddeley, 1986), not retrospective memory. By testing measurements immediately after a freeze, memory decay should not be an issue.

- **Reliability** - Measurement reliability has been demonstrated in a study that found high reliability (test-retest scores of .98, .99, .99, and .92) of mean SAGAT scores for four fighter pilots who participated in two sets of simulation trials (Endsley & Bolstad, 1994). Collier and Folleso (1995) also reported good reliability for the measure involving two experienced nuclear power plant operators.

Supplemental Situation Awareness

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

3. Workload

A. Physical Workload

- **Construct Validity** – Achieved by using measures adapted from an established source (State of Washington Department of Labor and Industries)
- **Diagnosticity** – Achieved by documenting the context in which high workload occurs, cause can be identified
- **Impartiality** – Achieved by having observers use a checklist to document occurrences, and by comparing observations to videotapes
- **Objectivity** – Achieved by having observers use a checklist to document observable, physical occurrences
- **Reliability** – Achieved by using a specific, well-defined checklist to document occurrences, and by using videotapes to supplement observer reports
- **Resolution** – Achieved by using a specific, well-defined checklist
- **Simplicity** – Achieved by selected easily measured, easily interpreted measures
- **Unintrusiveness** – Achieved by using videotapes and observers trained in unintrusive data collection techniques, and by measuring environmental elements such as object weight while a testing scenario is not being run

B. Cognitive Workload

- **Construct Validity** – In comparison with other workload assessment methods, subjective ratings have been determined to come the closest to tapping the essence of mental workload and provide the most generally valid and sensitive indicator (Hart & Staveland, 1988; Sanders & McCormick, 1993)
- **Diagnosticity** – Addressed by including the task during which data was collected
- **Impartiality** – The NASA-TLX measures both high, low, and moderate workload
- **Reliability** – The NASA-TLX has been subjected to a number of independent evaluations in which its reliability, sensitivity, and utility were assessed and found to be acceptable (Hart, 2006)
- **Resolution** – Addressed by using a 6-dimension, subjectively weighted measure, and by including the task during which data collection occurred
- **Sensitivity** – In comparison with other workload assessment methods, subjective ratings have been determined to be one of the most sensitive indicators (Hart & Staveland, 1988)
- **Simplicity** – Addressed by choosing an automated, digitally administrated, recorded, and calculated performance measure
- **Unintrusiveness** – Addressed by using a digital collection technique, intrusiveness is minimized

4. Anthropometrics

- **Construct Validity** – Achieved by measuring and evaluating constructs that have been established as valid in the field of Ergonomics and Anthropometry
- **Diagnosticity** – Achieved by instructing observers to include task as a context for the observed behaviors being recorded, and by linking observations and questionnaire results to individual physical measurements
- **Impartiality** – Achieved by using neutral wording and by using a scale that reflects both positive and negative attributes
- **Objectivity** – Achieved by using measurements and easily observed, overt behaviors during observations
- **Reliability** – Achieved by using trained observers and videotaped scenarios

    - **Resolution** – Achieved by using observed and self-report data, with sections dedicated to additional observations and comments to allow greater detail
    - **Simplicity** – Achieved by using easily observed behaviors and pre-established rating scales
- **Unintrusiveness** – Achieved by taking measurements before the onset of simulation, and by using videotapes and observers trained in unintrusive data collection techniques

DCD Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 1 will be revised with the inserted text provided above.

NRC RAI 18.11-24

NEDO-33276, Section 4.3.4.4 does describe in varying levels of detail, the types of performance measures that will be used. These measures include some of the types of measures identified in the criterion. However, it is not clear that a full range of measures will be included. Please provide additional information on the performance measures to be used in validation. Specific questions are identified below:

A. *Plant/system level measures - measures of plant and system performance were not addressed. Please, justify.*

B. *Operator task measures - NEDO-33276, p. 14 lists the performance measures used to determine the validity of the MCR, RSS, and LCS designs. Operator task performance is not included in the list, yet it is included in list of measures on page 45. However, while the term "task performance" is included in the title of Section 4.3.4.4.1, it does not address what measures will be taken and how they will be determined. Section 4.3.4.7.1 identifies a list of task related measures; however, the tasks for which these measures will be taken are not identified. Please identify the tasks that will be evaluated during integrated system validation.*

C. *Situation awareness - Section 4.3.4.4.3 describes the evaluation of situation awareness. The section indicates that the Situation Awareness Control Room Inventory (SACRI) method will be used. However, in Section 4.3.4.7.3, the measurement of situation awareness is discussed. This section indicates that situation awareness is subjectively evaluated on the basis of correctness to test subject responses to questions asked during the test scenarios. Is this statement referring to SACRI method identified in the earlier section? The latter section also describes many other indications of situation awareness. How will all these methods be combined to assess overall situation awareness? If the SACRI method is used, additional details about its implementation should be provided. Please indicate how questions will be developed for each scenario used in the evaluation and what criteria will be used to judge whether or not, the level of situational awareness is acceptable?*

D. *Operator workload - Section 4.3.4.4.4 discusses the assessment of operator workload. This section provides a cross reference to the task analysis implementation plan for a discussion of workload assessment methods. In Section 4.3.4.7.4 performance measures for workload are discussed. It indicates that workload will be assessed using a rating scale method and actual operator performance during test scenarios. The rating scale method identified is the NASA TLX. In addition, a list of activities to evaluate is provided. The list includes evaluating navigation, evaluating* *information gathering, evaluating plant conditions, alarm interaction, analyzing information needed to assess plant situation, and analyzing the memory demands to perform operational tasks. How will each of these be evaluated? And how will they be integrated, along with rating scale evaluations, to determine the acceptability of workload?*

E. *Crew communication and coordination - Section 4.3.4.4.5 indicates that crew, communication and coordination will be subjectively evaluated on the basis of the crew's demonstrated performance during training exercises. Please explain why training exercises are being used for this evaluation and not integrated system validation trials? In Section 4.3.4.7.5, it states that crew communication and coordination are subjectively evaluated on the basis of how well crews exhibited a number of characteristics related to teamwork, such as effective leadership, well defined roles and responsibilities, teamwork, open dialogue, etc. Please indicate how the nine items listed in this section will be measured and how they will be evaluated?*

GE Response

A. In the case of plant/system level measures the impact of transients such as loss of electrical power have little impact on the ESBWR core damage frequency because of the natural circulation and passive cooling features of the plant. Thus temperature changes to the core are calculated to be very slow for all but a very few hypothetical accidents. The main issue for operators' use of the MMIS is to monitor the plant state and backup automatic actions if necessary. The MMIS should permit the operators to control key plant parameters and maintain them within allowed conditions. Such parameters include power level (neutron flux), turbine generator status, isolation, relief and safety valve positions, control rod positions, pump states, feedwater flow, core flow rates and isolation condenser heat transfer.

B. The scope listed in 3.1.1 and 4.3.4.1 will be reconciled. The first sentence in Section 4.3.4.1 will be modified to "Simulations will be used by plant personnel to demonstrate successful task performance on operational events to validate the ability of operators to use the MMIS to support safe plant operations."

The operator tasks that will be evaluated during integrated system validation are those that are defined through the operational analysis, through the PRA/HRA as risk important actions, and those directly called out in the procedures.

C. The first paragraph in Section 4.3.4.7.3, will be changed to:
"The ability of the MMIS to support situational awareness is subjectively evaluated by analysis of one or more of the following measures at different phases of the V&V.

- Timing of operator cues and operator actions,
- Appropriateness of operator actions
- Consequence (good or bad) of operator actions,
- Observation of operator actions, procedure use and communications,
- Freezing the simulator after an operator cue has been simulated and querying the operator about plant status, and/or
- Post scenario video reviews and interviews."

If more than one operator with suitable training cannot take appropriate corrective actions within an appropriate time window, the observation will be considered for documentation as an HED on the MMIS.

D. The workload rating scales will be used to qualitatively assess high or low or not applicable ratings in each area. The ratings will be integrated by converting the workload ratings to a fraction of the time involved over the simulated event time. Then the workload formula in section 4.3.4.6.4 will be applied.

E. The objective here is to verify that the MMIS promotes good communication and coordination of the crew as part of the integrated system evaluation. Of the nine good communication principles five relate to the MMIS. Section 4.3.4.4.5 will be modified to indicate how the five items listed in this section will be measured and evaluated as follows:

"MMIS support for crew communication and coordination are subjectively evaluated on the basis of how well crews exhibit the following:

1. MMIS supports well-defined roles and responsibilities are executable from the assigned station (simulated transients require infrequent movement from the control station).
2. MMIS supports crew teamwork by providing information needed by the individual team members working as a team.
3. MMIS permits two operators to use the same information (e.g., displays, alarms, procedures) at the same time so that operators are able to identify, analyze, plan and implement responses based on information from the workstation displays.

4. MMIS permits proactive monitoring and observation (to enhance situation awareness and progress assessment monitoring is from the local workstation).
5. MMIS is organized for efficient movement between information pages, panels and control screens at workstations (only use several screen maneuvering actions to adjust screens to find information during a simulated event)."

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 0 will be revised as described above at the next revision.

NRC RAI 18.11-24 S01

In the original RAI, the staff requested information on the selection of performance measures. For the staff to perform an implementation plan review,

GEH should identify the hierarchal set of performance measures (including plant/system level performance, operator task performance, situation awareness, operator workload, and anthropometric/physiological factors) that will be used in validation tests. The response should provide a clear picture of the range of measures to be used (consistent with NUREG-0711, Section 11.4.3.2.5.2). GEH's response to this RAI should consider the specific issues identified in the original RAI in RAI Letter 74.

GEH Response

To reflect the level of detail required for an Implementation plan, both the text and document organization in NEDO–33276 will be revised. The final organization is incomplete, but the revision will include a section that establishes a hierarchal set of performance measures, as described below.

(Note: as RAI 18.11-23 S01, RAI 18.11-24 S01, and RAI 18.11-26 S01 are related areas, GEH recommends that the responses to these RAIs be evaluated together).

The text below will be inserted in the Integrated System Validation section.

The plant/system performance measures selected for integrated validation are represented by a tiered system, based on the prevention or mitigation of transients and accidents, as described in DCD Tier 2, Chapter 15 - Transient Analysis. Tasks and events with high PRA/HRA risk significance are selected for measurement.

A. Plant – Core Thermal-Hydraulic Condition

The ability of the crew to maintain core thermal-hydraulic condition within acceptable limits is used as a plant-level performance measure during integrated system validation testing.

TRACG analyses are used to establish thermal-hydraulic parameters that must be kept within a defined limit to prevent core damage. Event analyses are used to determine the specific amount of time allowed to initiate an automatic or manual action in order to maintain these parameters within that calculated limit. Thus, plant level performance is measured in terms of the time required to complete these actions.

To measure performance, the time taken by the crew or automation to initiate the established required actions during a simulated scenario is compared to the calculated time requirements.

B. Plant – PRA/HRA

The response of the integrated plant to abnormal conditions and transients is tested to validate that system manipulations produce the expected or predicted plant responses.

To test PRA/HRA assumptions, scenario events are selected that contain PRA risk significant tasks. The responses of the integrated plant and systems (including operator actions) to the selected events are recorded and evaluated in terms of the times and values assumed in the PRA/HRA.

Average times and values are established across crews for each scenario.

C. Personnel Tasks

HFE task analysis of required system manipulations and monitoring during normal, transient, abnormal, and emergency conditions provides the necessary basis for the procedures directing operator actions in response to the aforementioned conditions. Thus, task criteria are created that can be used to evaluate the ability of the operators to monitor system parameters and system responses to actions and/or operator manipulations.

Personnel task measures are established from the parameters indicated during task analysis as being used to determine a successful sequence change for the integrated system (i.e., the parameters used during task analysis to verify stable system operation in the desired sequence).

The average number calculated from the total number of successful system sequence changes is used as one method of evaluating crew task performance. Other task performance measures include time to complete task, errors observed during task performance, frequency of task performance and any additional items the task analysis team may deem necessary to validate integrated plant and HSI design.

To measure personnel task performance, observations, performed by trained observers using evaluation checklists, and videotaped sessions are compared against saved simulator data. Data is also gathered from crew questionnaire responses pertaining to manipulations that require a more fine-grained analysis. The following are representative of questions appearing on the checklists/questionnaires:

- **Understanding of Plant and System Responses**
  - o Did the crew locate and interpret control room indicators correctly and efficiently to ascertain and verify the status/operation of plant systems?
    - 3 = Each crewmember located and interpreted instruments accurately and efficiently.
    - 2 = Some crewmembers committed minor errors in locating or interpreting instruments or displays. Some crewmembers required assistance.
    - 1 = The crewmembers made serious omissions, delays, or errors in interpreting safety-related parameters.
  - o Did the crew demonstrate an understanding of the manner in which the plant, systems, and components operate, including setpoints, interlocks, and automatic actions?
    - 3 = Crewmembers demonstrated thorough understanding of how systems and components operate.
    - 2 = The crew committed minor errors because of incomplete knowledge of the operation of the system or component. Some crewmembers required assistance.
    - 1 = Inadequate knowledge of safety system or component operation resulted in serious mistakes or plant degradation.
  - o Did the crew demonstrate an understanding of how their actions (or inaction) affected systems and plant conditions?
    - 3 = All members understood the effect that actions or directives had on the plant and systems.
    - 2 = Actions or directives indicated minor inaccuracies in individuals' understanding, but the crew corrected the actions.
    - 1 = The crew appeared to act without knowledge of or with disregard for the effects on plant safety.
- **Diagnosis of Events and Conditions Based on Signals or Readings**
  - o Did the crew recognize off-normal trends and status?
    - 3 = Recognized status and trends quickly and accurately.
    - 2 = Recognized status and trends at the time of, but not before, exceeding established limits.

- 1 = Did not recognize adverse status and trends, even after alarms and annunciators sounded.

- Did the crew use information and reference material (prints, books, charts, emergency plan, implementation procedures) to aid in diagnosing and classifying events and conditions?
  - 3 = Made accurate diagnosis by using information and reference material correctly and in a timely manner.
  - 2 = Committed minor errors in using or interpreting information and reference material.
  - 1 = Failed to use, or misused, or misinterpreted information or reference material that resulted in improper diagnosis.

- Did the crew correctly diagnose plant conditions based on control room indications?
  - 3 = Performed timely and accurate diagnosis.
  - 2 = Committed minor errors or had minor difficulties in making diagnosis.
  - 1 = Made incorrect diagnosis, which resulted in incorrect manipulation of any safety control.

- **Control Board Operations**
  - Did the crew locate controls efficiently and accurately?
    - 3 = Individual operators located controls and indicators without hesitation.
    - 2 = One or more operators hesitated or had difficulty in locating controls.
    - 1 = The crew failed to locate control(s), which jeopardized system(s) important to safety.
  - Did the crew manipulate controls in an accurate and timely manner?
    - 3 = The crew manipulated plant controls smoothly and maintained parameters within specified bounds.
    - 2 = The crew demonstrated minor shortcomings in manipulating controls, but recovered from errors without causing problems
    - 1 = The crew made mistakes manipulating control(s) that caused safety system transients and related problems.

- Did the crew take manual control of automatic functions, when appropriate?
  - 3 = All operators took control and smoothly operated automatic systems manually, without assistance, thereby averting adverse events.
  - 2 = Some operators delayed or required prompting before overriding or operating automatic functions, but avoided plant transients where possible.
  - 1 = The crew failed to manually control automatic systems important to safety, even when ample time and indications existed.

A. Supplemental

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

1. Crew Communications and Coordination

Crew communication and coordination are subjectively evaluated with rating scales, using trained observers and videotaped testing sessions, to determine how well crews exhibit the following (Rated on a 3-point rating scale, where 1 = Poor, 2 = Average, and 3 = Good):

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

- Correct, accurate, concise, and relevant information exchange
- Efficient movement of crew members between panels and workstations

Observers supplement this data, using behaviorally anchored rating scale checklist questions:

- Did the crew exchange complete and relevant information in a clear, accurate, and attentive manner?
  - 3 = Crew members provided relevant and accurate information to each other.
  - 2 = Crew communications were generally complete and accurate, but sometimes needed prompting, or the crew failed to acknowledge the completion of evolutions, or to respond to information from others.
  - 1 = Crew members did not inform each other of abnormal indication(s) or action(s). Crew members were inattentive when important information was requested.
- Did the crew keep key personnel outside the control room informed of plant status?
  - 3 = Crewmembers provided key personnel outside the control room with accurate, relevant information throughout the scenarios.
  - 2 = In minor instances, the crew needed to be prompted for information and/or provided some incomplete/inaccurate information.
  - 1 = The crew failed to provide needed information.
- Did the crew ensure receipt of clear, easily understood communications from the crew and others?
  - 3 = The crew requested information/clarification when necessary and understood communications from others.
  - 2 = In minor instances, the crew failed to request or acknowledge information from others.
  - 1 = The crew failed to request needed information, or was inattentive when information was provided; serious misunderstandings occurred among crewmembers.

2. Situation Awareness

Situation Awareness represents the ability of operators to understand and communicate past and present events or states and to predict future ones. An objective measure of situation awareness is obtained by directly comparing operators' reported SA to reality. With this technique, a human-in-the-loop simulation is frozen at randomly selected times and the system displays are blanked while the operators quickly answer questions about their current understanding of the situation. After a testing session, operators' perceptions about a situation are compared to the reality of the situation (as determined by information recorded on the simulation computers). Comparing the data in this manner provides an objective, unbiased assessment of SA (Endsley, 1995).

Procedure

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

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

Selecting Freeze Points

Using the established list and sequence of events occurring during each scenario, points before or after an event are identified. Selection of time points that occur during a significant event should be avoided, due to the fact that operators could use freeze time to consider what event is occurring and may devise plans of actions that would not occur if operators had not been given extra time to think and plan.

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

Freezes should generally last less than two minutes, and regardless of the number of questions presented, at least 5 seconds should be given before a scenario is resumed after a freeze. Operators should not be aware of when exact freeze points are going to occur.

Selecting Questions

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

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

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

Performance Measures

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

Situation awareness should be measured in terms of:

1. Perception of data:
   - The proportion of correct answers relative to the total amount of data requested by the freeze point questions for each scenario
     - The proportion of unanswered data questions relative to the total number of data questions
     - The proportion of incorrect answers relative to the total number of data questions

2. Comprehension of meaning:
   - Awareness is adequate to correctly comprehend the meaning of the data attended to (Yes/No)

- Accurate or inaccurate judgment of plant/ plant system status
- Accurate or inaccurate selection of procedure in response to data.

3. Projection of the near future:
   - Awareness is adequate to correctly predict events occurring in the plant in the near future (based on data attended to and conclusions drawn from that data) (Yes/No)
     - Accurate or inaccurate selection of procedure in response to data.
     - Accurate or inaccurate prediction of plant/ plant system status in the near future.

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

Supplemental Situation Awareness Information

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

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

During scenario events, trained observers should observe and rate operator behaviors during task performance. Ratings should be conducted using a five point behaviorally anchored rating scale (1= very poor, 5= very good) to rate the degree to which individuals are carrying out actions and exhibiting behaviors that would be expected to promote the achievement of higher levels of SA. The list of SA indicative behaviors should be developed using information from task analysis, training, and established operating procedures.

2. Workload

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

A. Physical Workload

Because of the digital nature of the ESBWR control room, physical workload is not expected to be a significant contributing factor to operator performance. However, to ensure that physical workload does not negatively impact crew performance, physical workload evaluations should be conducted during validation testing.

Performance Measures

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

Force

A. Heavy, frequent, or awkward lifting:

- Any lift of 75 pounds or more
- Lifting 55 pounds or more 10 times per day
- Lifting 10 pounds or more 2 times per minute over 2 hours total per day
- Lifting 25 pounds or more 25 times per day and lift is
  - above the shoulders
  - below the knees
  - at arms length

B. High hand force:

- Task results in any of the following for more than 2 hours per day:
  - Pinching an unsupported object(s) weighing 2 or more pounds per hand, or pinching with force of 4 or more pounds per hand
- Gripping an unsupported object(s) weighing 10 or more pounds per hand, or gripping with a force of 10 pounds or more per hand

C. Repeated impact:

- Using the hand or knees as a hammer more than 10 times per hour for more than 2 hours total per day

Posture

D. Awkward posture - tasks that results in any of the following postures for more than 2 hours per day:

- Working with the hand(s) above the head or the elbow(s) above the shoulder(s)
- Repetitively raising the hand(s) above the head or the elbow(s) above the shoulder(s) more than once per minute
- Working with the neck bent more than 45° (without support or the ability to vary posture
- Working with the back bent forward more than 30° (without support, or the ability to vary posture)
- Squatting, Kneeling

Repetitiveness

E. Highly repetitive motion:

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

Vibration

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

The type, frequency, and context of high physical workload occurrences are documented on a checklist. To determine weight, vibration, and other environmental characteristics that impact workload, measurements may be taken by trained observers before of after a scenario. Measurements should be conducted in a manner that does not interfere with simulator testing activities.

A. Cognitive Workload

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

Selecting Tasks

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

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

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

Performance Measures

Cognitive workload for each of the selected tasks is measured by the NASA-TLX. The NASA-TLX is a subjective measurement of workload. It consists of a multidimensional scale with 6 dimensions of factors related to mental workload (Hart, 2006). To measure cognitive workload within the integrated system, a digital version of the NASA-TLX is used in which individual, task, and overall cognitive workload are recorded:

- At the end of each selected task, a screen in a central location at each operator workstation appears that displays the six NASA-TLX questions (see Figure 2). For each question, the operator clicks the area on the scale that he/she thinks most accurately describes his or her experience on the task that was just completed.
- Since the term mental workload can be interpreted somewhat differently among respondents, personal opinion on what mental workload means for them is taken into the final calculation of the NASA-TLX score, by deriving an overall workload score for each task based on a weighted average of ratings within each participant on the six subscales.
- To obtain weights for each of the 6 workload dimensions per operator, per task, pair wise comparisons are made between each of the dimensions. This is accomplished using follow-up screens in which two dimensions are both displayed, and the operator is asked to choose which of the 2 dimensions contributed more to workload for that task.

- When the weights are applied to the results of the initial operator ratings for each of the six dimensions, a measure of overall cognitive workload is derived.

3. Anthropometrics

HSI anthropometrics are evaluated as part of HSI development (see NEDO-33268, ESBWR Human System Interface Design Implementation Plan) and HFE design verification to ensure compliance to the anthropometric guidelines contained in the ESBWR HFE Style guide.

System-specific and integrated validation testing confirms during simulation the adequacy of the HSI anthropometric design for the population of operators participating in all phases of verification and validation activities.

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

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

Procedure

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

Physical Measurements are selected from the following:

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

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

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

Performance Measures

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

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

- Number of times the operator has to reposition to accomplish task (lateral, leaning, or standing/stooping)
    - Changing posture in order to see displays
    - Changing posture in order to move between controls or between displays and controls
- Operator posture during tasks (using 5-point rating scale where 1 = Very poor and 5 = Very good)
    - Brief description of type of posture problem(s)
- Written description of any additional significant anthropometric problems as identified by trained observers, such as:
    - Visibility of displays being obstructed by operators reaching across displays to engage controls. (This is especially important when working with fine motion controls and feedback from control input is provided through the obstructed display.)
    - Interference with controls created by reaching for other controls. (i.e., inadvertent pressing of keys on a keyboard when reaching for a control switch on panel)

Observer data is supplemented with post-scenario operator questionnaires:

- Operators are asked to rate each anthropometric element using a 5-point rating scale (1 = Very poor, 5 = Very good). Questionnaire items include:

  - Reach and accessibility of control devices
  - Visibility of indications
  - Distance
  - Seating comfort
    - Work surface height
    - Chair adjustability
    - Overall level of comfort
  - Ease of control
  - Ease of device manipulation
  - Overall perception of system usability
  - Overall satisfaction with workspace layout
- Additional comments

References

Baddeley, A. D. (1986). Human Memory. Oxford: Clarendon Press

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

Collier, S. G. & Folleso, K. (1995). SACRI: A measure of situation awareness for nuclear power plant control rooms. Proceedings of an International Conference: Experimental Analysis and Measurement of Situation Awareness (pp. 115-122). Daytona Beach, FL

Endsley, M. R. (1989). Final report: Situation awareness in an advanced strategic mission (No. NOR DOC 89-32). Hawthorne, CA: Northrop Corporation

Endsley, M. R. (1990). Predictive utility of an objective measure of situation awareness. Proceedings of the Human Factors Society 34th Annual Meeting (pp. 41-45). Santa Monica, CA: Human Factors Society

Endsley, M. R. (1995). Measurement of situation awareness in dynamic systems. Human Factors, 37(1), 65-84

Endsley, M. R. & Garland, D. J. (Eds.) (2000). Situation awareness analysis and measurement. Mahwah, NJ: Lawrence Erlbaum Associates

Endsley, M. R. & Bolstad, C. A. (1994). Individual differences in pilot situation awareness. International Journal of Aviation Psychology, 4(3), 241-264

Hart, S.G. (2006) NASA-Task Load Index (NASA-TLX); 20 Years Later. http://humansystems.arc.nasa.gov/groups/TLX/downloads/HFES_2006_Paper.pdf

Hart, S.G. & Staveland, L.E. (1988). Development of NASA-TLX (Task Load Index): results of empirical and theoretical research. In P.A. Hancock & N. Meshkati (Eds.), Human Mental Workload (pp 139-183). Amsterdam: North-Holland

Hogg, D.N., Torralba, B., & Volden, F. S. (1993). A situation awareness methodology for the evaluation of process control systems: Studies of feasibility and implication of use (1993-03-05). Storefjell, Norway: OECD Halden Reactor Project

Northrop Corporation. (1998). Tactical simulation 2 test report: Addendum 1 situation awareness test results. Hawthorne, CA: Author

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

Figure 2

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

DCD Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 1 will be revised with the inserted text provided above. The included Figure 2 will also be inserted.

NRC RAI 18.11-26

Acceptance criteria for performance measures are discussed in NEDO-33276, Section 4.3.4.6. However, the statements contained in this section for each of the performance measures, do not provide actual criteria for acceptability. For example, Section 4.3.4.6.1 provides the following acceptance criteria for operational safety and task performance: "Acceptable human performance is based, in part, on success with the measures for operational safety and task performance." Such a statement would not provide clear criteria for determining the acceptability of observed task performance. And without clear performance criteria, how will HEDs be identified. Please provide specific criteria for the proposed measures and indicate which are to be used in deciding that the design is validated.

GE Response

Section 4.3.4.6.1 of NEDO-33276 will be replaced with the following:

"Human performance during simulated event scenarios provides a framework for demonstrating acceptable margin based on the face validity determined by the knowledgeable observers. The qualitative factors that support the observations are:

- High degree of situational awareness from the MMIS
- Effective use of procedures to guide actions
- Effective use of time during the simulated event
- Consistency of actions between different operators and crews on repeated simulations
- The overall integrated response results in an acceptable plant state (e.g., passive cooling of decay heat load)."

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 0 will be revised as described above at the next revision.

NRC RAI 18.11-26 S01

In the original RAI, the staff requested information on specific acceptance criteria for performance measures. For the staff to perform an implementation plan review, GEH should identify the criteria to be used for performance measures (consistent with NUREG-0711, Section 11.4.3.2.5.3). 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. In addition, GEH should identify the basis for the criteria established. Note that the question of acceptance criteria is related to the discussion in RAI 18.11-29.

GEH Response

To reflect the level of detail required for an Implementation plan, both the text and document organization in NEDO–33276 will be revised. The final organization is incomplete, but the revision will include a section that establishes a hierarchal set of performance measures (as defined in GEH's response to RAI 18.11-24 S01). The performance measure acceptance criteria is described below.

(Note: as RAI 18.11-23 S01, RAI 18.11-24 S01, and RAI 18.11-26 S01 are related areas, GEH recommends that the responses to these RAIs be evaluated together).

The text below will be inserted in the Integrated System Validation section.

A. Plant – Core Thermal-Hydraulic Condition

All crews that participate in scenarios where core thermal-hydraulic limits are challenged must complete the required actions within the required time, and must monitor and maintain all necessary parameters. Scenarios that result in core thermal-hydraulic conditions outside of the allowable calculated conditions result in failure of this performance measure.

Scenarios that result in exceeding thermal-hydraulic limits as calculated by TRACG analyses result in integrated system validation failure.

These criteria are created based on established requirements.

B. Plant – PRA/HRA

Acceptable plant performance is determined through an evaluation of the times and values calculated by PRA/HRA analysis. Events that challenge PRA assumptions for time and parameter values during a scenario are monitored for required operator and plant response times. For each selected scenario, average operator actions/system performance must fall within an acceptable range of time and parameter values. Performance is acceptable if all assumptions for plant and operator response, including time required for completion of the action are within the values allowed by the PRA/HRA calculations.

Critical parameters affecting the validity of the PRA are also collected, to allow verification that operator actions were effective in mitigating the transient.

These normative-referenced criteria are established based on PRA/HRA, and are used as a basis for valid plant design.

C. Personnel Tasks

Integrated system design is validated when the required sequence change of the system is complete as indicated by the value of system parameters at steady state operation. The HSI design is validated when operators successfully monitor and control the system to achieve desired status. These criteria are normative-referenced and used as a basis for design validation.

Observer evaluations are used to determine the ability of the operators to interface with the HSI and communicate necessary parameters. Operator ability to perform required actions in response to parameter changes are also observed. These criteria are benchmark and expert-judgment referenced and are used to increase the understanding of systems or operator performance that resulted in successful or unsuccessful task completion.

Beyond this, additional sources of information are evaluated as supplemental information to better understand the results of other performance measures or are used to identify areas for improvement observed in the other performance measures.

D. Supplemental

Supplemental performance measures are primarily used to provide additional information regarding the results of other performance measures, however significant problems in these areas should be evaluated and addressed as well.

1. Crew Communications and Coordination

Acceptability for crew coordination and communication in terms of validation is decided based on the crew's ability to effectively and correctly perform the appropriate operating procedures for a situation.

Any incidence where unclear communication or interference prevents an operating procedure from being correctly executed is documented as an HED in the HFEITS.

Subjective ratings are evaluated in terms of subject area expert judgment regarding what levels of communication and coordination are deemed acceptable.

2. Situation Awareness

Acceptability of performance is determined by assessing the level of situation awareness in the following way:

1. Perception of data:
   - Operators are able to provide a minimum of half the data requested. For any scenario in which this criteria cannot be met, a HED is entered into the HFEITS.

2. Comprehension of meaning and projection of the near future:
   - Operator answers accurately reflect the current state of the plant, based on the information available. Large discrepancies between the perceived state of the plant or plant systems and the actual state of the plant or plant systems are documented as a HED in the HFEITS.
   - Operator situation awareness levels are high enough to obtain the information required to determine correct operating procedures. If SA is not sufficient to select correct operating procedures, validation cannot occur, and a HED should be entered into the HFEITS.

Supplemental Situation Awareness

An average crew SA rating of 3.5, using the 5 point observation scale, should be attained to determine if a crew is displaying adequate situation awareness.

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

3. Workload

A. Physical Workload

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

Due to the digital nature of the ESBWR control room, significant heavy lifting, high hand force, repeated impact, or high hand/ whole body vibration aspects of physical workload should not have significant impact or should not be applicable. Other aspects of physical workload, such as posture and repetitive motion, may be significant factors in a digital control room. Beyond this, physical workload data is used to better understand the results of other performance measures. For example, data from posture workload measures should be evaluated in conjunction with anthropometric data to better understand the results of both performance measures.

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

B. Cognitive Workload

Levels of mental workload occur along a spectrum. A zone of acceptability exists at the center of the spectrum along a figurative line with conditions of unacceptable levels of mental workload being at either end of the spectrum (high and low).

The zone of acceptability is guided by nuclear industry standards, operator' perceptions of acceptability, and the theories and principles associated with mental workload. Judging workload in terms of the acceptability of a particular scenario is not a new idea (Brabazon & Conlin, 2001, Rouse et al, 1993,) and seems to be the most pragmatic way to approach the measurement of such a dynamic concept with a vast number of variables.

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

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

If any workload issues are identified, the identified concern is entered into the HFEITS for tracking and resolution.

4. Anthropometrics

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

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

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

DCD Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 1 will be revised with the inserted text provided above.

NRC RAI 18.11-29

NEDO-33276 provides little detailed information on data analysis and interpretation. Please describe:

- *what methods will be used to analyze data and to assess performance criteria*
- *how HEDs will be identified*
- *how consistency across different measures will be evaluated*
- *how data analysis will be verified for correctness*

GE Response

The following paragraphs and reference will be added to NEDO-33276.

"The methods for analyzing the simulation results will draw from experience in EPRI OER program as summarized in EPRI NP-6560L, which provides estimates of the median response time and the standard deviation associated with different types of cue response as measures of consistency between crews and individuals.

Acceptability of the MMIS clarity is that standard deviation falls within the ranges of responses demonstrated in existing plant simulations for multiple crews. For larger deviations between crews an examination of the MMIS for improvement is documented in an HED.

The analysis inputs will be verified by comparing observer inputs and comparison with the computer generated event logs. The observer inputs include qualitative assessments of influencing factors such as lighting level, noise level, communication clarity, MMIS information clarity, and other factors that influence detection, analysis, planning and implementation of actions. EPRI NP-6560-L. "A Human Reliability Analysis Approach Using Measurements for Individual Plant Examination," 1990."

DCD/LTR Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 0 will be revised as described above at the next revision.

NRC RAI 18.11-29 S01

To support the staff's review of the implementation plan, please describe (consistent with NUREG-0711, Section 11.4.3.2.7):

- *what methods will be used to analyze data and to assess performance criteria*
- *how HEDs will be identified*
- *how consistency across different measures will be evaluated*
- *how data analysis will be verified for correctness*

NEDO-33276, Rev. 1, Section 4.4.8, contains high-level information about data analysis. Please clarify the following information in Section 4.4.8:

The methods for analyzing the simulation results will draw from experience in EPRI OER program as summarized in EPRI NP-6560L, which provides estimates of the median response time and the standard deviation associated with different types of cue response as measures of consistency between crews and individuals. Acceptability of the MMIS clarity is that standard deviation falls within the ranges of responses demonstrated in existing plant simulations for multiple crews. For larger deviations between crews an examination of the MMIS for improvement is documented in an HED.

This does not seem to be an appropriate means of analyzing validation data. Assuming there will sufficient data to generate reliable statistics; the analysis is based on response variability and a comparison of that variability to the range of responses demonstrated in existing plant simulations. The approach seems to focus on variability alone, and not the acceptability of performance, e.g., are required tasks performed within an acceptable time for plant safety.

It would seem the approach to analyzing data should focus on whether observed integrated system performance (as defined by the set of performance measures selected for use in validation) is acceptable (as defined by the acceptance criteria for each of the performance measures). Please provide an explanation of the approach to data analysis in light of the staff's concern.

Note that the question of acceptance criteria is related to the discussion in RAI 18.11-26.

GEH Response

To reflect the level of detail required for an Implementation plan, both the text and document organization in NEDO–33276 will be revised. The final organization is incomplete, but the revision will include a section that describes the GEH approach to data analysis.

(Note: as RAI 18.11-4 SO1, SO1, RAI 18.11-24 SO1, and RAI 18.11-26 SO1 are related areas GEH recommends that the responses to these RAIs be evaluated together).

The text below will be inserted in the Integrated System Validation section. The reference below to RAI responses will be replaced with appropriate reference to text in the plan.

The response to RAI 18.11-24 SO1 presents the hierarchical four-tier set of performance measures used to evaluate performance during integrated system validation scenarios. Listed in order of significance they are:

- Plant level - Core thermal-hydraulic condition analyses results as compared to performance during observed integrated system validation scenarios
- Plant level – PRA/HRA analysis results as compared to performance during observed integrated system validation scenarios
- Task Level – Task analysis results as compared to performance during observed integrated system validation scenarios
- Supplemental Criteria – Observed or measured performance as compared to set criteria, expectations, or subject matter expert opinion in areas including:
    1. Crew coordination and communications
    2. Situational awareness
    3. Workload
    4. Anthropometrics

The response to RAI 18.11-26 SO1 presents amplifying detail regarding performance criteria associated with the selected performance measures. From these responses it can be seen that the tiered performance measures and their associated criteria range from pass/fail quantitative analysis at the highest significance level (core thermal-hydraulic condition) to a qualitative analysis at the supplemental criteria level.

General analysis type is as shown below:

- Plant level – Quantitative analysis comparing observed performance to pre-determined acceptance criteria derived from the plant's thermal-hydraulic analysis
- Plant level – Quantitative analysis comparing the average observed crew performance to PRA/HRA analysis results with qualitative analysis of any

individual crew's performance that falls between PRA/HRA criteria and corresponding criteria from the plant's thermal-hydraulic analysis

- Task Level – Quantitative and qualitative analysis comparing task analysis results to performance during observed integrated system validation scenarios; largely supplemental in nature except where task performance impacts ability of operators to perform the above criteria
- Supplemental Criteria – Quantitative analysis comparing quantified performance to objective and subjective acceptability analysis; qualitative analysis using objective and subjective observations and ratings compared to subject matter expert judgment; largely supplemental in nature except where task performance impacts ability of operators to perform the above criteria

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

The professionals on the ESBWR HFE evaluation team, are controlling bias through a number of means. These include:

- Pilot studies to ferret out possible bias
- Selection of subjects to balance evaluation groups
- Appropriate statistical analysis
- Appropriate selection of tests and measures for evaluation
- Controls for the effects of data collection and measurement
- Optimization of study (interview and questionnaire) elements
- Control of variables
- Identification of possible validity problems and subsequent control of them
- Carefully designed evaluations that are both qualitative (explicit acknowledgement of bias) and quantitative (attempts to eliminate bias)
- Inclusion of both subjective and objective measures
- Balanced subject pool and diverse subject matter experts

DCD Impact

No DCD changes will be made in response to this RAI.

LTR NEDO-33276, Rev 1 will be revised with the inserted text provided above.