



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 08-154

Docket No. 52-010

April 1, 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. 125 and 135, Related to ESBWR Design Certification
Application – Human Factors Engineering - RAI Numbers 18.2-19,
18.2-20, 18.4-16 S02, 18.4-21 S01, 18.4-25 S01, 18.7-7 S02, 18.11-32
S01, 18.12-2 S01, 18.12-3 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 (RAIs) sent by NRC letter No. 125, dated December 14, 2007 (Reference 1).

This letter also transmits original RAI response to RAI 18.2-20 as requested by NRC Letter No. 135, dated January 15, 2008 (Reference 13).

RAI 18.4-16 S02 was requested by Reference 1, and was previously responded to in Reference 2. Reference 4 provided the original response as originally requested by NRC in Reference 6.

RAI 18.7-7 S02 was requested by Reference 1, and was previously responded to in Reference 2. Reference 5 provided the original response as originally requested by the NRC in Reference 6.

RAIs 18.4-21 S01 and 18.4-25 S01 were requested by Reference 1, and were originally responded to in Reference 4. Reference 6 originally requested these RAIs.

D068
NEO

RAI 18.11-32 S01 was requested by Reference 1, and was previously responded to by Reference 10. Reference 9 originally requested this RAI by the NRC.

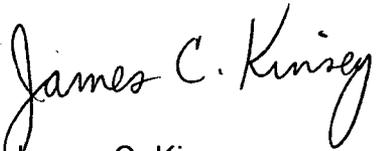
RAIs 18.12-2 S01 and 18.12-3 S01 were requested by Reference 1, and were previously responded to by Reference 11. Reference 9 originally requested these RAIs by NRC.

GEH's responses to RAIs 18.2-19, 18.2-20, 18.4-16 S02, 18.4-21 S01, 18.4-25 S01, 18.7-7, S02, 18.11-32 S01, 18.12-2 S01, 18.12-3 S01 are provided in Enclosure 1.

Also note that these RAI responses correspond to and answer several open items listed in Reference 12. Please consider these open items to be addressed by this letter.

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

Sincerely,

A handwritten signature in cursive script that reads "James C. Kinsey".

James C. Kinsey
Vice President, ESBWR Licensing

References:

1. MFN 07-702 - Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 125 Related To ESBWR Design Certification Application*, dated December 14, 2007
2. MFN 07-334 - Submittal of "*ESBWR DCD Chapter 18, Human Factors Engineering - RAI to DCD Roadmap Document*", dated June 27, 2007
3. Reference Deleted
4. MFN 06-400, *Response to Portion of NRC Request for Additional Information Letter No. 64 – Human Factors Engineering – RAI Numbers 18.4-1 through 18.4-25*, dated November 1, 2006
5. MFN 06-403, *Response to Portion of NRC Request for Additional Information Letter No. 64 – Human Factors Engineering – RAI Numbers 18.7-1 through 18.7-15*, dated October 27, 2006
6. MFN 06-352, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 64 Related to ESBWR Design Certification Application*, dated September 25, 2006
7. Reference Deleted
8. Reference Deleted
9. MFN 06-386, *Request for Additional Information Letter No. 74 Related to ESBWR Design Certification Application*, dated October 11, 2006
10. 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
11. MFN 06-447, *Response to Portion of NRC Request for Additional Information Letter No. 74 Related to ESBWR Design Certification Application – ESBWR Human Factors Engineering NEDO-33278, Rev. 1, ESBWR HFE Design Implementation Plan - RAI Numbers 18.12-1 through 18.12-6*, dated November 18, 2006
12. 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
13. Reference Deleted

Enclosure:

1. MFN 08-154 -Response to Portion of NRC Request for Additional Information Letter Nos. 125 and 135 Related to ESBWR Design Certification Application - Human Factors Engineering - RAI Numbers 18.2-19, 18.2-20, 18.4-16 S02, 18.4-21 S01, 18.4-25 S01, 18.7-7 S02, 18.11-32 S01, 18.12-2 S01, 18.12-3 S01

Attachment:

1. MFN 08-154 - Enclosure 1, Attachment 1- Markups and Added Text for RAIs 18.2-19, 18.4-21 S01, 18.4-25 S01, 18.7-7 S02, 18.11-32 S01, 18.12-3 S01

cc: AE Cabbage USNRC (with enclosure)
RE Brown GEH/Wilmington (with enclosure)
DH Hinds GEH/Wilmington (with enclosure)
GB Stramback GEH/San Jose (with enclosure)

eDRF	0000-0081-2357	RAI 18.2-19, 18.4-25 S01
	0000-0081-2779	RAI 18.11-32 S01
	0000-0081-2772	RAI 18.2-20
	0000-0081-2787	RAI 18.12-2 S01
	0000-0081-8034	RAI 18.4-16 S02, 18.4-21 S01, 18.12-3 S01
	0000-0082-4057	RAI 18.7-7 S02

Enclosure 1

MFN 08-154

**Response to Portion of NRC Request for Additional
Information Letter Nos. 125 and 135 Related to ESBWR**

Design Certification Application

Human Factors Engineering

RAI Numbers

**18.2-19, 18.2-20, 18.4-16 S02, 18.4-21 S01, 18.4-25 S01,
18.7-7 S02, 18.11-32 S01, 18.12-2 S01, and 18.12-3 S01**

For historical purposes, the original text of RAIs 18.4-16, 18.4-21, 18.4-25, 18.7-7, 18.11-32, 18.12-2, and 18.12-3 and any previous supplemental text and GE/GEH responses are included preceding each supplemental response. Any original attachments or DCD mark-ups are not included to prevent confusion.

NRC RAI 18.2-19

The staff has determined that the material contained in NEDO-33217, Rev 3 and in the detailed implementation plans for the HFE activities reviewed in Sections 18.3 through 18.13 provide the basis for the staff's safety determination. This NEDO and the implementation plans should be identified as Tier 2 in the DCD.*

GE Response

GEH will comply with the request for identifying NEDE-33217P and the other HFE implementation plans listed below as Tier 2* in the DCD. A revision to these documents incorporating the responses to staff RAI questions will be issued at the same time, and the new revision numbers will be included in the DCD.

The HFE Tier 2* documents to be identified in the DCD are:

NEDE-33217P Man-Machine Interface System and Human Factors Engineering Implementation Plan
NEDO-33262 ESBWR Operating Experience Review (Human Factors) Implementation Plan.
NEDO-33219 ESBWR Functional Requirements Analysis Implementation Plan.
NEDO-33220 ESBWR Allocation of Functions Implementation Plan.
NEDO-33221 ESBWR Task Analysis Implementation Plan.
NEDO-33266 ESBWR HFE Staffing and Qualifications Implementation Plan.
NEDO-33267 ESBWR HFE Human Reliability Analysis Implementation Plan.
NEDO-33268 ESBWR Human-System Interface Design Implementation Plan.
NEDO-33276 ESBWR HFE Verification and Validation Implementation Plan.
NEDO-33274 ESBWR HFE Procedure Development Implementation Plan.
NEDO-33275 ESBWR Training Development Implementation Plan.
NEDO-33278 ESBWR HFE Design Implementation Plan.
NEDO-33277 ESBWR HFE Human Performance Monitoring Implementation Plan.

DCD/LTR Impact

DCD Tier 2, Corresponding Reference Sections in 18.1 through 18.1-2 will be revised in accordance with the sample in the attached markup.

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

NRC RAI 18.2-20

DCD, Revision 4 references Revision 3 of the ESBWR MMIS and HFE Implementation Plan (NEDE 33217P). It is the staff's understanding that the plan will undergo a significant revision to remove detailed discussions of HFE program elements documented in the individual implementation plans. This reference should be updated to the revised plan.

GEH Response

All of the NEDO/NEDE plans referenced in the DCD chapter 18 will have revisions issued at the same time of the DCD revision 5 with the new revision numbers updated in DCD chapter 18 sections so that the revision numbers of the plans will be up-to-date in the DCD.

This response is for information purposes on the revisions to the subject documents and does not describe or result in a change in the documents themselves.

DCD/LTR Impact

DCD Rev 5 will be updated with the current HFE LTR revision numbers.

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

NRC RAI 18.4-16

NEDO-33220 Section 4.2 addresses the process for allocating functions.

- a) The decision guidelines on page 26 appear to be incomplete. The first bullet addresses allocation to multiple regions in Figure 9. Are decision guidelines needed for allocation to each region of the figure? Clarify second bullet decision guideline.*
- b) This section contains many criteria for allocating functions. Most are stated at a very general level. Are there more specific criteria available for analysts to use as part of the decision making process?*
- c) Figure 17 identified criteria for allocating a function to humans. One is "Objective of Function is Maintain ON/OFF control." Please clarify what this means.*
- d) On page 34 the following criterion is provided: "1. Automated Data Display. Examine each function and function segment and specify points where automated display will simplify the core performance requirements for detecting, monitoring, planning or executing." Clarify the meaning of this statement.*
- e) Figure 21, the second diamond appears to be mislabeled. It should contain a title per the description on page 40.*

GE Response

- (a) The first bullet says "...follow the process for the rest of the function..". The process is covered in Sections 4.2.1 through 4.2.3.
- (b) No "more specific" criteria are available. Specificity typically originates on a case-by-case basis as the system design is developed and detailed, or new requirements come about (e.g., severe accident guidelines).
- (c) Control room operators need to physically perform the ON/OFF action either by hard switch/button or Software/Touch Screen interface.
- (d) Core Performance is described in Section 3.3.3. Core performance is the working categorization for describing the steps to process data from sensors to control signals, whether performed by human or machine. They consist of Detection, Monitoring, "Planning and Decision Making" and Control.
- (e) The wording will be changed to "Man meets human performance requirements" in the next revision of NEDO-33220.

DCD/LTR Impact

LTR NEDO-33220, Rev. 0 will be revised as noted above.

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

NRC RAI 18.4-16 Supplement 1

Subquestion C - The response defined what an ON/OFF control is. To further clarify the question: What does it mean to say the "objective" of a function is to maintain ON/OFF control? An example may help to clarify this aspect.

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/Question	Resolved	Plan	Section	Resolution Description
18.4-16	4	16	N	LTR NEDO-33220	From GE response	33220		Figure 21 deleted
18.4-16	4	16	Y	Function Allocation Process Clarifications	From GE response	33220		The statement has been removed from the revised plan.

NRC RAI 18.4-16 Supplement 2

The staff asked for additional information in RAI 18.4-16. Some parts were addressed, but the following parts of the original RAI are still open:

(b) This is a follow-up to RAI 18.4-16. This section contains many criteria for allocating functions. Most are stated at a very general level. Are more specific criteria available for analysts to use as part of the decision making process?

(f) This is a follow-up to RAI 18.4-16. For non-safety functions for which configuration change is required during normal or emergency operations, the methodology assumes the function will be handled by the Plant Automation System (see Figure 3). It would seem that the same set of human performance considerations should be made here as for safety functions. Please clarify the rationale for using the Plant Automation System as this is not clearly presented in NEDO-33220, Rev 1.

GEH Response

(b) RAI 18.4-16 was originally written against Rev 0 of NEDO-33220. Revision 1 of NEDO-33220 refined the Allocation of Function (AOF) process to support the top-down approach to human factors engineering adopted by the ESBWR design team. As a result of this refinement, the allocation process was clarified and presented in flow chart form with supporting descriptive paragraphs providing amplifying detail for each step in the process.

NEDO-33220, Rev 1, Section 4.1.3 contains descriptions for each decision block in the AOF process that presents the concept being evaluated and, where needed, a listing of specific criteria and technical bases to be considered when making the requisite determinations. Additional criteria and guidance for use during the AOF process is provided in NEDO-33220 Appendix A. Currently this appendix is not referenced in the body of the NEDO. The GEH response to NRC RAI 18.4-21 S01 (provided in this correspondence) (and associated change to NEDO-33220) links these additional criteria and guidance to the AOF process steps.

The criteria and guidance of NEDO-33220 is implemented in a systematic and consistent manner through the use of a work instruction. The HFE Design Team supports this implementation. The design team is a multi-disciplined group of industry personnel with experience in plant operations, human science, engineering, procedure development, and personnel training. The HFE Design Team can also draw from the broader ESBWR and GEH engineering teams when necessary to support allocation decision-making.

Subsequent steps of the HFE top-down HFE process build upon, validate, and can motivate reconsideration of the allocations made in AOF. The detailed analyses performed in Task Analysis re-examine many of the same criteria and considerations

that factor into allocation decisions and provide feedback to the AOF process. Verification and Validation will validate allocation decisions and provide feedback if allocations need to be revised.

(f) NEDO-33220, Rev 1, section 4.1.1 lists as one of the plans assumptions that:

“The control systems for the ESBWR have a high degree of automation. All systems are automated unless regulation or HFE analysis results dictate otherwise.”

It is the ESBWR concept of operations that all non-safety related functions are automated unless precluded as noted above. In the limited number of cases where automation is precluded, the HFE design team documents the basis for deviation from the normal allocation process as shown in NEDO-33220, Rev 1, Figure 3.

Additionally, the detailed analyses performed in Task Analysis examine the task details relating to allocation decisions and provides feedback to the AOF process if revision is warranted. The HFE V&V activity will validate allocation decisions and provide feedback if the allocations require revision.

DCD Impact

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

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

NRC RAI 18.4-21

Section 5 makes reference to Appendix A for the criteria that may be used as a decision basis. Why was this appendix not referenced in the function analysis section where the basis for allocation is presented? And why isn't the basis the analysis that results from the methodology in Section 4.2, Function Allocation?

GE Response

The basis is the analysis that results from the methodology of Section 4.2.

The next revision of NEDO-33220 will include the following change:

In Section 5, remove the 1st sentence of the 2nd paragraph and add the following words to the last sentence of Section 4.2.1: “and Appendix A, Human Capabilities and Limitations.”

DCD/LTR Impact

LTR NEDO-33220, Rev. 0 will be revised as noted above.

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

NRC RAI 18.4-21 Supplement 1

Please clarify the role of NEDO-33220, Rev 1, Appendix A. For example, how does the analyst use HRA significance to conclude that automation is desirable? There is some guidance for several human performance considerations (from NUREG/CR-2623) in Appendix A of NEDO-33220, Rev 1, but the appendix is not referenced in the FRA Implementation Plan and the list of considerations in the Appendix is not the same as those presented in the Implementation Plan description.

GEH Response

Note: The question refers to NEDO-33220, Allocation of Function, but later refers to the plan as the FRA Implementation Plan. GEH response is based on the assumption that the staff intended to refer to the Allocation of Function Implementation Plan instead of the FRA Implementation Plan. NEDO-33220, Rev 1, Appendix A consists of two tables of factors to be considered by analysts when making allocation determinations. The first of these two tables, A1 "Criteria that Limit or Preclude Human Participation in a System Function" provides examples of instances in which human performance of the function may not be appropriate. The second table, A2 "Criteria that Define Unique Human Capabilities" provides examples of instances where human performance of the function is warranted. The information in these tables is used in addition to the other technical bases presented in the plan when making allocation determinations.

NEDO-33220, Rev 1 will be revised as shown in the attached markup to provide specific linkage between the applicable process steps and Appendix A.

Appendix A, Table A1 will be used when considering whether or not to allocate a function to either "Human Only" or "Shared". Should one or more of the criteria in table A1 exist, the analyst will give strong consideration to allocating the function to "Machine Only", allocating "Shared" sub-functions to automation in accordance with paragraph 4.1.3.2 of NEDO-33220, or specifying mitigating requirements. Appendix A, Table A2 will be used when considering whether or not to allocate a function to either "Machine Only" or "Shared". Should one or more of the criteria in table A2 exist, the analyst will give strong consideration to allocating the function to "Human Only", allocating "Shared" sub-functions to humans in accordance with paragraph 4.1.3.2 of NEDO-33220, or specifying mitigating requirements. An example of such a mitigating requirement might be a break point in an automation sequence requiring human input or action prior to continuation of the automation.

In the case of HRA/PRA significance, the criteria contained in Appendix A and in the main body text of NEDO-33220 are to be applied. HRA/PRA significance is an input to the AOF process to ensure that analysts place greater emphasis on the successful completion of HRA/PRA risk significant actions. Examples of how risk significant functions will receive greater emphasis in the allocation process are:

- 1) In step 4.1.3.1-2 “Automatic Actuation Required” decision block: Risk significant functions would be biased toward automation (where possible) to benefit from the reliability of machines.
- 2) In step 4.1.3.1-3 “Human Backup Required” decision block: Risk significant functions would be biased toward requiring human backup (where possible) to ensure performance of the function should the machine fail.
- 3) In step 4.1.3.1-4 “Automatic Backup Required” decision block: Risk significant functions would be biased toward requiring automatic backup (where possible) to ensure performance of the function should the human fail.

The methodology represented above for treatment of risk significant actions, is continued throughout the allocation process. This evaluation focuses the design team to those choices that provide the greatest assurance for successful completion of the function.

DCD Impact

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

LTR NEDO-33220, Rev 1 will be revised as noted in the attached markup (see Attachment).

NRC RAI 18.4-25

Function allocation is addressed in Section 18.4.2.

(a) Item (1) (e) states "[a]nalyzes shall confirm that the personnel can perform tasks allocated to them while maintaining operator situation awareness, acceptable personnel workload, and personnel vigilance." The implementation plan does not clearly address this analysis. Please address.

(b) Item (2)(b) (ii) states "[d]evelopment of alternative function allocations for use in the conduct of comparative evaluations. The implementation plan does not clearly address this analysis. Please address.

(c) Item (2)(b) (v) states "[d]evelopment of test and analysis methods for evaluating function allocation alternatives." The implementation plan does not clearly address this analysis.

Please clarify.

Note: NEDO-33219, NEDO-33220, and DCD Tier 2, Section 18.4, should be updated to reflect the responses to RAIs 18.4-1 through 18.4-24 above.

GE Response

(a) Section 4.2.4 Global Test and Section 4.3 Evaluation of Function Allocation clearly defines the analysis to be performed to maintain operator awareness (Section 4.2.4.2), acceptable personnel workload (Section 4.2.4.1/4.3.2.2) and personal vigilance (Section 4.3.2.5/4.3.2.6).

In addition to the above, the TA will assess the personnel workload issues directly by making a personnel assignment in a scenario context and assessing the workload. In the same way, the decisions and information needs for the operational context will be assessed and this information will become the basis for the operator event training. As regards to vigilance, the planned HSI interface is designed to minimize operator vigilance decrement by involving the plant automation system in the monitoring and tracking of the various procedure steps and actions that may be happening simultaneously. The operator to automation interface will be designed and verified through plant automation simulations, addressed in the task analysis and training and procedure development, and validated in the HFE V&V activity.

(b & c) Section 4.3.3 "Tradeoff Studies" of the FA plan addresses the development, test and analysis of FA alternatives. These include the relevant topics, such as, identify alternatives, selection criteria, weighting criteria, evaluating the alternatives and performing a sensitivity check.

DCD/LTR Impact

No changes to the subject LTRs will be made in response to this RAI.

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

NRC RAI 18.4-25 S01

The content of 18.4.2 is not consistent with NEDO-33220, Rev 1. Please clarify and update DCD Section 18.4.2.

GE Response

In relation to the original RAI 18.4-25, which stated "...The implementation plan does not clearly address this analysis. Please address."

DCD 18.4.2(1)e, Rev. 4, does address an analysis confirming that personnel can perform tasks. This will be changed to address the future aspect of this as a plan and not an actual analysis that has already been completed. The step will be changed to read that this is an analysis plan for confirming that personnel can perform tasks and agrees with the wording specified in LTR NEDO-33220, Rev. 1.

NEDO-33220, Rev 1, was distributed on March 2007 and referred to DCD Chapter 18, Rev. 3. The DCD Chapter 18, section 18.4 was subsequently revised in September 2007. This resulted in inconsistencies between the DCD and NEDO document. Rev. 4 of DCD section 18.4.1(3) provides agreement with the types of Function Requirements Analysis that are described in NEDO-33220 Rev. 1 (see Figure 2).

DCD Section 18.4.1(3) will be revised to delete extraneous information that details and describes the outputs from other RSRs. The intent was to provide information about related outputs. However, this appears to be causing more confusion than clarification as none of this information can be found in NEDO-33220. Therefore, the list describing other outputs will be removed from DCD Section 18.4.1(3).

This extra information will also be removed from DCD Section 18.4.2(3).

DCD/LTR Impact

DCD Tier 2, Section 18.4 will be revised in Revision 5 as noted in the attached markup (see Attachment).

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

RAI Number 18.7-7

NEDO-33267 and DCD Tier 2, Chapter 18.7 state in several places that the PRA/HRA will provide a listing of potentially risk-important human interactions for use in several portions of the HFE program. The initial PRA/HRA for ESBWR has been completed and submitted to NRC along with Chapter 19 of the DCD. Therefore, sufficient information is available to develop the initial list of risk important actions using the methods discussed in this report. The PRA and DCD Chapter 19 provide very informative lists of risk important structures, systems and components (SSCs), however they note in several places that human actions are not included. It is not clear why human actions were excluded from these importance listings and are not in NEDO-33267. Please provide the initial list of risk important human actions.

GE Response

Risk important operator actions developed from the PRA rev. 1 are listed in Tier 2 Chapter 19 Rev 1, September 2006, in Table 19.2-3 on Risk Insights and Assumptions.

The use of the PRA/HRA in human factor engineering (HFE) is an iterative process, and this initial listing will be enhanced with additional actions as the design matures. For example, system level actions that are included within system level reliability models of the design level PRA do not specifically separate the automatic versus manual actions. This use of generic failure rate estimates for the structures, systems and components is adequate for estimating the overall risk in terms of the top down level 1 and 2 PRA. However, an enhanced listing of human actions requires the allocation of manual versus automated actions in each system and modeling within the PRA to expand the initial risk importance listing.

The HRA plan indicates that a process will be established to enhance this listing as an iterative tool to pass between the HFE/HRA assessments and the PRA/HRA risk evaluation. The list will be dynamic as HSI design features are established, and will be upgraded as the design details are established and modeled in the PRA. Listings of risk important actions in Table 19.2-3 will be further enhanced through implementation of the HFE HRA plan.

Reference to Table 19.2-3 in Tier 2 Chapter 19 Rev 1, September 2006 will be provided in the next revision to section 5.2 second paragraph of NEDO-33267.

“The initial baseline ESBWR PRA study which is described in the ESBWR DCD Chapter 19 will be used as the starting point for defining risk important human actions (e.g., Table 19.2-3 in Tier 2 Chapter 19 Rev. 1, September 2006).”

Also the reference for chapter 19 will be updated.

DCD/LTR Impact

LTR NEDO-33267, Rev 0 will be revised as described above.
No DCD changes will be made in response to this RAI.

RAI Number 18.7-7 Supplement 1

The response refers to the updated Chap. 19, Rev. 1 and specifically Table 19.2-3. The initial list of R-I HAs, that was requested in the RAI, was not provided. The updated Chap. 19 and PRA/HRA still appear to have in HA modeling that may limit the ability to correctly identify the R-I HAs. This should be improved, as necessary, so that the R-I HAs can be identified and so that the design process can appropriately address R-I HAs. We did note that Table 18-2 of the PRA includes HAs and contains both RAW and F-V importance values. Examples of issues: 1. From the RAI response "...system level actions that are included within system level reliability models of the design level PRA do not specifically separate the automatic versus manual actions..., an enhanced listing of human actions requires the allocation of manual versus automated actions in each system and modeling within the PRA to expand the initial risk importance listing." Without such separation, how can R-I manual actions (such as manual actuation upon automation failure) be identified. 2. Table 19.1-3, Importance Analysis Results, is not discussed or explained in the text of Ch. 19. Col. 2 of the Table gives the basis for inclusion of items in the Table as RAW, FV, CCF but does not list values or selection criteria. 3. Operator actions are not clearly identified in Table 19.1-3, for example N21, condensate and feedwater valves are listed, but it is not clear if they are auto or manually operated. 4. In justifying the less than complete status of the PRA, Section 19.2.1 states that "...many aspects of assessing human actions cannot be analyzed in absence of a physical, operating plant and operation staff." This is true but other shortcomings, as in example #1 above, do not require an operating staff to model. Section 19 overall discusses the use of PRA insights for design decisions. However, this could be compromised by the limited nature of HA modeling. For example insights related to functional allocation between operators and automation may be lost. 5. In the discussion of Significant CD sequences in Section 19.2.3.1.1, it is not always clear whether actions are automatic or performed by operators (e. g., injection with CRD pumps). 6. The RAI response referred to Table 19.2-3 for important operator actions, but that Table includes all risk insights and assumptions. Thus, it is not clear which items are the risk-important operator actions. And the dispositions for HAs in the Table would not seem to include all activities for these actions that would be called out by the implementation plan. 7. Table 19.2-3 appeared to be incomplete. For example, operator actions noted in Section 19.2.3.1.2 (Significant Large Release Sequences) related to LERF for minimizing water accumulation in lower drywell with core in vessel are not listed in Table 19.2-3. The dominant operator actions for internal shutdown fires from Sec. 18.4.3 of the ESBWR PRA are not included in the Table. 8. The row for Human Actions in Table 19.2-1 states that "No operator actions are required for safety function success in the ESBWR for the first 72 hours of an event." This is a deterministic statement. What does the PRA analysis show? Are the important HAs, as identified in the PRA, from the pre-72 hour regime? 9. For Item 2b in Table 19.2-3 was an error of commission modeled in the PRA?

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/Question	Resolved	Plan	Section	Resolution Description
18.7-7	7	7	N	LTR NEDO-33267	From GE response	33267	4.2	Para change per RAI
18.7-7	7	7.0	Y	Risk-important (R-I) Human Actions (HAs)	From GE response	33267	3.2.1 4.2	The initial list of human actions with a potential for risk contribution will be in the phase 0 HRA summary report. The criteria and approach for determining risk important human actions are provided in section 3.2.1 and the process for identifying additional actions through interaction with the HFE tasks is addressed in the third paragraph of section 4.2.
	7	7.1	Y	Issue 1-manual v. auto actions	From GE response	33267	3.1, 4.2	The allocation of functions activity in the operations analysis will establish the manual actions. In the case of the ESBWR the passive features and automation of the safety-related systems virtually eliminate the need for the safety-related human actions required for design basis events (e.g., manually start a safety system). These design features reduce the CDF to a mean value much lower than the plants used as the basis for the NRC risk regions in RG 1.174. As a result the risk boundaries associated with the risk regions in RG 1.174 are far above the ESBWR baseline risk. Hence, the ESBWR basic events representing HIs do not become important contributors to plant

Chapter 18 Roadmap Document

RAI NO	SEC	#	NRC Supplemental	DocName/Question	Resolved	Plan	Section	Resolution Description
								risk on an absolute basis.
	7	7.2	Y	Issue 2-Table 19.1-3 is not discussed and does not list values or criteria	From GE response	33267	3.2	These will be provided in the HRA initial results summary report for rev 1 of the PRA. Summary: To evaluate the risk impact of the HIs for the beyond design basis events a relative risk approach is used. First, risk sensitive actions that support ESBWR safety for beyond design basis events are identified in both the PRA and through the top down HFE operational analysis. Sensitivity analyses using the FV, RAW and RRW described above on the to basic events related to HIs human action tasks in are used to create a listing of the top risk contributors on a relative basis. This listing is generated in the PRA and is compared with the top down operational analysis to identify gaps and support requantification for the PRA. On a relative scale the HIs with a FV greater than 0.1 and RAW of 2.0 for CDF and LERF are subjected to the greatest detail in the HFE tasks, even though the absolute risk values are far below regions I and II described in NUREG-1764 (NRC, 2004).

Chapter 18 Roadmap Document

RAI NO	SEC	#	NRC Supplemental	DocName/Question	Resolved	Plan	Section	Resolution Description
	7	7.3	Y	Issue 3-operator actions not clearly identified in Table 19.1-3	From GE response	33267	3.2 4.2	The operating assumption is that these will be automated actions with the operator in a monitoring role with manual backup in the case of automation failure. The allocation of function will complete the determination of manual actions. The approach described in issue 2 is followed for these actions
	7	7.4	Y	Issue 4-with justifying incomplete PRA status, insights related to functional allocation may be lost	From GE response	33267	Figure 3 4.2.2 4.2.3 4.2.4	The functional allocation and detailed task information from the operation analysis are key inputs to the refinement of both the HRA and the PRA. After the initial listing of risk-important human actions from the PRA (labeled PRA/HRA probabilistic importance evaluation in Fig 3), the allocation and task details are used to expand the risk important actions (HRA qualitative evaluation for HFE tasks in Fig 3). This re-analysis is used to update the HRA and PRA (iteration loop).
	7	7.5	Y	It is not clear if actions are manual or automatic in CD sequences in 19.2.3.1.1	From GE response	33267	3.2 4.2	See answer to issues 1, 3, and 4.

Chapter 18 Roadmap Document

RAI NO	SEC	#	NRC Supplemental	DocName/Question	Resolved	Plan	Section	Resolution Description
	7	7.6	Y	It is not clear from Table 19.2-3 which items are risk-important Human Actions and it seems not to include all activities called for in the HRA implementation plan	From GE response	33267	4.2	The Risk Important actions modeled in the PRA are listed and screened in the HRA initial results summary report. From the ESBWR PRA model as described in DCD Tier 2 Chapter 19 Rev 1, September 2006, Tables 19.1-3, 19.2-1 and 19.2-3 list important components, systems functions, tasks and event initiators considered in the ESBWR PRA model and PRA models of previous BWR designs. Table 19.1-3 lists hardware elements that are important. The human interactions for these hardware elements including manual operation (if assigned in the allocation of functions), maintenance, repair, and backup to automatic functions are defined during the operational analysis by the HFE team. These results are then employed as described in item 18.7-7(4).
	7	7.7	Y	Table 19.2-3 incomplete	From GE response	33267	4.2	The human actions in these events will be identified in the operations analysis. See response to 18.7-7(4).

Chapter 18 Roadmap Document

RAI NO	SEC	#	NRC Supplemental	DocName/Question	Resolved	Plan	Section	Resolution Description
	7	7.8	Y	No operator actions for first 72 hrs - Is this from PRA? Are human actions in PRA from the pre-72 hrs	From GE response	33267	4.2	The initial baseline ESBWR PRA study is used as the starting point for defining risk-important HA tasks. The ESBWR design objective is to avoid the need for operator actions for the first 72 hours following an initiating event for the design basis events. The types of human actions from the initial PRA are actions such as misposition valve (either latent Type A, or commission type C). These are addressed in initial HRA and are described in the HRA results summary report. The operations analysis will identify and analyze human actions supporting these events. See response for 18.7-7(4).
	7	7.9	Y	Was error of commission modeled in PRA?	From GE response	33267	3.2.3	Errors of commission are addressed as follows: The Risk Important actions modeled in the PRA, are compared with other PRA studies and with important OER events. Data from the OER provide error modes, including potential examples of errors of commission (EOC). The results are listed and screened in the HRA and documented in the HRA results summary report. Errors of commission from the initial results include premature depressurization.

RAI Number 18.7-7 Supplement 2

The staff asked for additional information in RAI 18.7-7 regarding the PRA/HRA which was addressed; however, the following parts of the original RAI are still open:

2. Table 19.1-3, Importance Analysis Results, is not discussed or explained in the text of Ch. 19. Col. 2 of the Table gives the basis for inclusion of items in the Table as RAW, FV, and CCF, but does not list values or selection criteria. Rev. 2 of Plan gives acceptance criteria as FV greater than 0.1 and RAW of 2.0 for both CDF and LERF. However, these criteria are not specifically linked to the RI HAs. This should be clarified.

8. The row for Human Actions in Table 19.2-1 states that “No operator actions are required for safety function success in the ESBWR for the first 72 hours of an event.” This is a deterministic statement. What does the PRA analysis show? Are the important HAs, as identified in the PRA, from the pre-72 hour regime? This RAI was not satisfactorily answered. Please provide a response.

9. For Item 2b in Table 19.2-3 (spurious actuation of GDCS deluge to containment) was an error of commission modeled in the PRA? The Roadmap answer provided a discussion of the EOC method used for the HRA but didn't answer the specific question related to Item 2b.

GEH Response

Table 19.1-3 was removed from the DCD in revision 4 with the pertinent information restructured in Tables 19.2-2 and 19.2-3.

Also, the PRA referenced in Chapter 19 DCD revision 4 demonstrated that no accidents generated early health effects as considered for a large early release frequency (LERF), thus the PRA team uses the term large release frequency (LRF) to address accident sequences that result in containment releases. For this reason the calculation for LRF is used for measuring the importance of human action instead of the calculation for LERF. The PRA/HRA models will continue to search for LERF sequences.

Comment 2 Discussion

Both quantitative and qualitative tools are used by GEH to develop risk insights for the ESBWR. The risk insights are based on the use of the importance measures Risk Achievement Worth (RAW) and Fussell Vesely (FV) to measure the risk importance of basic events and common cause failures that contribute to the CDF for level 1 and LRF for level 2, internal and external events, and other special PRA models. The risk summary information and insights in DCD Chapter 19 rev 2 were significantly revised with additional information added based on results from Rev. 2 of NEDO-33201 PRA Model which accounted for greater understanding of the design features and operator interface design. The ESBWR PRA defines potentially risk-significant structure, system

or component (SSC) and HI events and information using conservative thresholds such as FV greater than 0.01, and a RAW greater than 5.0 for individual basic events and a RAW greater than 50.0 for common cause failures. The resulting listings of SSCs and HIs in NEDO-33201 Rev 2 section 18 are used to generate the risk insights that are qualitatively provided in Table 19.2-3. Some of the insights from the predecessor PRA models have been addressed through design changes and no longer appear, because the risk values are well below the quantitative PRA risk importance identification values. The HFE design examines all HIs required for each system and mode of operation during the operational assessment, task analysis and HRA. Many of these actions are addressed implicitly in the PRA at a functional level until specifically identified as an automatic system or operator control action as determined in the operational assessment. Once incorporated in the PRA models, any potentially risk important human actions are examined and are kept below the threshold risk measures for FV of 0.1 and for RAW of 2.0 through verification that the design clearly provides the means to identify, plan, and carry out the action within the required timing.

In summary:

The ESBWR PRA defines potentially risk-significant SSC and HI events and information that contribute to CDF and LRF using conservative thresholds such as FV greater than 0.01, and a RAW greater than 5.0 for individual basic events and a RAW greater than 50.0 for common cause failure events. The goal of the HRA and HFE operational analysis in DCD Chapter 18 is to verify that the means are provided in the plant design to keep the quantitative risk importance of all potentially risk important human interactions modeled in the PRA below a FV value of 0.1 and RAW of 2.0. The goals are met by ensuring that information for identifying, planning and implementing the needed action within the time permitted is provided in the design or by providing automated support to carry out the needed action. For example, the operator can identify the need for manual actions through the HSI plan through procedures and training and implement with tools as needed.

The revised approach is added to NEDO-33267, section 3.2.1 as provided in the attached markup. The quantitative thresholds for evaluating the risk importance of human actions are added to DCD Tier 2, Section 19.2.2.1 as noted in the attached markup.

Comment 8 Discussion

The deterministic statement in DCD Revision 4, September 2007, Tier 2, "No operator actions are required for safety function success in the ESBWR for the first 72 hours of an event," relates to the design goal of providing passive cooling and automatic systems for responding to the DCD Chapter 15 design basis events. These design basis events provide the means for sizing the systems to respond to an initiating event and a single failure except for special initiators such as fire, which go beyond single failures.

The role of the licensed operators in the ESBWR is to be in control of the plant via monitoring with the potential to override the automatic responses to obtain a better path to shutdown, restart, plant operating points and protection of safety barriers than provided

Enclosure 1

by the automatic system; or as backup to automated system failures that might occur as a result of multiple and common cause failures. Thus, in considering multiple failures in many sequences that go beyond the design basis events, the PRA treats many operator actions combined with failures of the automatic control and protection systems as a basic event. If the sequence becomes important, then the details of the operator interaction during the sequence is explicitly defined and is further evaluated by human factors engineering if identified as risk important. Such specific operator actions occur near the recognition of additional failures and are clearly within the 72 hour regime.

Therefore, by design, operator actions are not required for any safety function success in the ESBWR for the first 72 hours of an event as long as the plant is operated within its design basis. Many important actions can be actuated or inhibited either manually or automatically. Example manual actions in predecessor plants that have automatic initiation in the ESBWR include reactor vessel depressurization, ADS inhibit, actuation of standby liquid control, and equipment alignments for reactor core and suppression pool cooling.

The PRA also addresses cases where the plant is outside the design basis due to hypothetical event sequences that involve multiple failures. In cases where the automatic systems fail, the operators can switch from their normal monitoring functions, to actively control systems that are needed for safe operation of the plant at any time. For rare events in the ESBWR, such as automatic control failures, the operators provide the back up to selected automatic functions. In this way the operator actions can provide another path to shutdown, cooldown, managing the operating point or providing barrier protection than would normally be achieved with reliance only on the automated systems. This use of operators (i.e. manual recovery actions) provides an additional reduction in the frequency of the hypothetical core damage sequences.

The human action section right hand column in Table 19.2-1 will be revised as noted in the attached markup.

Comment 9 Discussion

Table 19.2-3 was revised with additional information added based on results from Rev. 2 of NEDO-33201 PRA Model. The question of explicitly modeling errors of commission (EOC) in the PRA has been replaced with an identification of possible situations, making an assumption for the PRA with regard to the impact and providing the information to human factors engineering for operational assessment including detailed task analysis and identification of HSI features, procedures and training to minimize the potential for an EOC. The results of these HFE/HRA evaluations are returned to the PRA for adjustment of the assumptions. There is no need to adjust format for Table 19.2-3, but the content is updated as the HFE results are completed and human interface systems are developed and tested.

There are no document revisions as a result of this comment response.

DCD Impact

DCD Tier 2, Subsection 19.2.2.1 will be revised as noted in the attached markup (see Attachment).

DCD Tier 2, Table 19.2-1 will be revised as noted in the attached markup (see Attachment).

NEDO-33267 Section 3.2.1.1 will be revised as noted in the attached markup (see Attachment).

NRC RAI 18.11-32

A methodology for the evaluation and resolution of HEDs identified as part of the V&V process is not fully described. NEDO-33276 states "Significance Category is a temporary field for potentially future HED compilation, ranking and screening purposes. It is a methodology to rank or prioritize new and unresolved issues in terms of their significance and potential impact on plant safety and performance. The intent is to facilitate evaluation and resolution of HEDs in a manner consistent with the guidelines of NUREG-0700 and NUREG 0711. The Significance Category methodology is depicted in Figure 3." Figure 3 provides an outline of a categorization methodology, but it does not stand alone.

- A. While the staff agrees on the importance of ranking and prioritizing HEDs, the method by which this valuation will take place should be described in order for the staff to determine whether or not, the methodology is consistent with the review criteria in NUREG 0711.*
- B. Regarding Figure 3, what is the significance of an HED being classified into the different category levels, that is, what are the design implications of the various categories?*

GE Response

Figure 3 will be modified as follows:

- A. The process in Figure 3 will be revised to address the safety and risk significance of each HED as outlined in NUREG-0711R2. In this case the HEDs are classified by safety significance rather than error potential. The design implications are that the MMIS will be prioritized to address the human actions, which most impact safety and risk and are, required for operation.
- B. Figure 3 of NEDO-33276 shows how the HEDs can be screened for their potential impact on human error which is not necessarily linked to risk and safety significance. Thus, from a human performance monitoring viewpoint Figure 3 provides a link between the HFEITS HED data set and the human performance monitoring implementation plan. It is expected that resolution of HEDs by enhanced MMIS display and features will reduce the human error probability for the key actions, the human performance monitoring system will benefit from a listing of actions whose MMIS has been improved as a basis for selecting the action. Moreover, the human performance monitoring task will be able to demonstrate the enhanced impact of the MMIS features used in resolution of HEDs.

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 18.11-32 Supplement 1

Section 4.6 NEDO-33226, Rev. 1, describes the resolution process for addressing HFE issues identified in V&V. The process is depicted graphically in Figure 4. GEH's process considers the impact on human performance and risk importance of issues from both quantitative (PRA) and qualitative perspectives. Where issues are found to qualitatively impact risk, the methodology seeks to determine if they can be addressed in PRA. While the methodology appears generally complete, there are three points of clarification requested.

- A. Is there a provision for justifying a discrepancy, e.g., deviation from the style guide with justification?*
- B. In Figure 4, at decision point 4, "Does Issue Meet Style Guide Requirements," actions are described for answering the question as "yes" or "no." However, for some issues meeting the style guide requirements is irrelevant. For example, an issue may be identified in integrated system validation, that a task could not be completed in time due to operator workload. In this case, the style guide requirements are not likely to be related to the issue. Instead, task reallocation to other personnel or automation may be the solution. Why is there no path to follow when the analyst concludes the issue is not related to style guide compliance?*
- C. Another point of clarification relates to the final solutions identified. They appear to be overly restrictive. For example, if an issue cannot be addressed in PRA, the analyst is guided to consider changing training, procedures, or staffing/qualifications. However, as in the example above, task redesign or increased automation may be warranted. Are the proposed solutions limited to those shown in the figure?*

GEH Response

Questions A. / B. / C.

Deviations from the style guide will be required and need to be justified. The style guide requirements statement will be removed from Figure 4 in order to provide a more inclusive review and follow-up flow path and to more accurately match DCD and NUREG-0711 requirements.

The following revisions will be made to NEDO-33276, Rev 1 to clarify this position:

1. Figure 4 will be replaced in its entirety. See new Figure 4 Attachment.
2. Section 4.6 will be revised in its entirety and will include two new subparagraphs: See new Section 4.6 Attachment.
 - 4.6.1 Evaluation of HFE Issue Safety and Risk Importance Category 1 and 2
 - 4.6.2 Normal Engineering Processing Category 3 and 4.

Note: While this RAI indicates that NEDO-33226 is the affected document, the response from GEH is written under the assumption that this RAI was intended to refer to NEDO-33276. Therefore GEH's response is based on the content in NEDO-33276.

DCD Impact

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

LTR NEDO-33276, Rev 1 will be revised as noted above and shown in the attached markups of new Figure 4 and revised section 4.6 (see Attachment).

NRC RAI 18.12-2

NEDO-33278, Section 4.3.2 provides acceptance criteria. These criteria address acceptance that the verification has been completed. What criteria will be used to determine that the as-built design is acceptable?

GE Response

The specific criteria for each item is established in step 2 of the Actions/Tasks described in Section 4.3.4. There may be direction provided for acceptance criteria in the recommendations from the V&V activity (e.g., that a task performance take no longer than a specified interval), but primarily the acceptance criteria will be derived from the ESBWR HFE Style Guide. It is important, however, that these criteria be developed specifically to address the source and context of the issue, and that they are reviewed and accepted by the senior task leader.

To ensure that the criteria are appropriate and complete, a step will be added to Section 4.3.4 Actions/Tasks for the task leader to review and sign-off on the established criteria. Also, an additional Acceptance Criteria in Section 4.3.2 will be added to include the acceptance of the verification criteria. The HFE Style Guide will be referenced in the Section and added to the Supporting Documents.

DCD/LTR Impact

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

LTR NEDO-33278, Rev 1 will be revised as described above.

NRC RAI 18.12-2 Supplement 1

A question was raised in the original RAI concerning the acceptance criteria for final design verification. In GEH's response, they indicated the criteria are derived from the "ESBWR style guide," which is included in the "HF Guidance manual." NEDO-33278, Rev. 2, states that the criteria for final design verification will be derived from an "HSI Report." Please clarify what specific document will be used for the criteria to determine that the as-built design is acceptable.

GEH Response

GEH will revise NEDO-33278 based on guidance suggested in RAI 18.12-3 S01, but the acceptance criteria will not change. NEDO-33278 discusses 4 different activities, each with its own acceptance criteria discussed in the applicable sections:

<u>Sections</u>	<u>Activity</u>
3.1, 4.1	Verification of Final As-Built HSI Requirements
3.2, 4.2	Confirmation of Standard Plant Procedures and Training
3.3, 4.3	Verification of HFE Design Not Performed in the Simulated HF V&V Activity
3.4, 4.4	Resolution of HEDs and Open Issues in HFEITS

The original RAI referenced section 4.3.2 that would primarily use the HFE Style Guide as a reference in defining and applying the criteria for the verification of HFE design not performed in the simulated HF V&V. The question concerning the acceptance of the as-built design would involve sections 3.1 and 4.1. Section 3.1 of NEDO 33278 states: "The Human-System Interfaces and their design characteristics (HSIs) are established in the HSI Design activity. The HSI adheres to applicable guidance. The HSIs are subsequently evaluated and confirmed in the HFE Verification and Validation. Following the HF V&V, the standard plant HSI Report is revised and becomes the basis for the requirements and acceptance criteria for the fabrication/procurement of the equipment for the "as-built" installation."

In the current revision, GEH would then confirm through audit of the fabrication/procurement documentation that the HSI design requirements are accurately re-produced in the as-built. In the next revision, described in RAI 18.12-3 S01, the HSI and their design characteristics from the HSI results summary report is also the basis for the revised approach to the as-built confirmation.

DCD/LTR Impact

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

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

NRC RAI 18.12-3

The methodology to perform this verification is identified in NEDO-33278, Section 3.1 and 4.1.

It is noted that following HFE V&V, the standard plant HSI Report is revised and becomes the basis for the requirements and acceptance criteria for the as-built design verification. The methodology described primarily addresses the review of procurement and construction documents, including engineering change documentation. An HED is written if that documentation is not consistent with the HSI report. While a document review is an important step to ensuring that the design will reflect the HSI report description, the focus of this verification is on the as built- design. Therefore, it is expected that the design itself would be verified, not just its documentation. Please provide clarification for how the as-built design can be verified based on a review of documentation alone.

GEH Response

As acknowledged in Section 12 of NUREG-0711 Rev 2, “for a new plant, the implementation phase is well defined and carefully monitored by start-up procedures and testing”. Documentation will be reviewed in accordance with GEH internal quality procedures for the development of the procurement specification documents to ensure compliance with the HSI Report. Again, GEH internal quality procedures will direct the acceptance of the final equipment to ensure compliance with procurement specifications, in essence confirming the “as-built” design for first, the simulator, and again for the control room applications. It is important to note that the “as-built” design confirmations are not based on a review of documentation alone, but an audit of the well defined and carefully monitored process and procedures in place to ensure a quality installation based on the HFE established criteria and specifications.

During the V&V activity, the HSI design derived from the HSI Report are evaluated and confirmed to comply with the Style Guide and the characteristics established in the HSI design activity. From this point, modifications to the HSI are controlled by the GEH engineering change process and procedures. Confirmation of “as-built” HSI to the verified and validated design can certainly be accomplished by comparing the procurement documents to ensure the identical equipment was specified, and the construction and build documents to ensure the identical equipment was installed, tested, and confirmed. An HED is called to be written for any variance in the documents, or if the documents are not clear in the confirmation of the HSI to the verified and validated design.

DCD/LTR Impact

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

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

NRC RAI 18.12-3 S01

GE's response to RAI 18.12-2 indicates that the style guide will provide acceptance criteria. The staff expects these criteria to be applied by verifying that the as-built design conforms to these criteria. The staff expected the verification to be made using the HFE Style Guide. Yet GEH's response to this RAI discusses procurement documents and the HSI Report. Please explain in more detail the HSI Report and the acceptance criteria for the final design implementation verification. NEDO-33278, Rev. 2, describes a final design verification methodology that appears to be based on a review of documentation rather than a review of the actual as-built design. Section 3.1.4, "General Approach" indicates that the review is conducted on documents. The individual implementation sections are all consistent with this general approach and focus on documents, not the implemented design. As per NUREG-0711, Section 12.4.6, criterion 2, it should be the design itself, as-built that is verified against the design documentation. Verifying documents with documents only establishes that the documents are in agreement, not that the controls and displays in the control room are in agreement with the design documentation. Provide justification of the proposed approach to address this concern.

GEH Response

RAI 18.12-2 S01 clarifies the acceptance criteria to be used for the as-built verification. GEH will implement the guidance in the question and will revise the methodology for the HSI as-built verification described in sections 3.1 and 4.1 in the next revision to NEDO-33278 as shown in the attachment. The corresponding changes to the DCD section 18.12 are also shown in the attachment.

DCD/LTR Impact

DCD Tier 2, Subsection 18.12.2.1 will be revised in Revision 5 as noted above and shown in the attached markup (see Attachment).

LTR NEDO-33278, Rev 2 will be revised as noted above and shown in the attached markup (see Attachment).

MFN 08-154

Enclosure 1

Attachment 1

Markups and Added Text

For RAIs

18.2-19, 18.4-21 S01, 18.4-25 S01, 18.7-7 S02,

18.11-32 S01, 18.12-3 S01

Attachment for RAI

18.2-19

ESBWR

18.1.7 COL Information

None

18.1.8 References

- 18.1-1 [*GE Energy, "ESBWR Man-Machine Interface System and Human Factors Engineering Implementation Plan," NEDE-33217P, Class III (Proprietary), Revision 3, March 2007, and NEDO-33217, Class I (non-proprietary), Revision 3, March 2007.*]*
- 18.1-2 Nuclear Energy Institute, "Severe Accident Issue Closure Guidelines," NEI 91-04, Revision 1, December 1994.

Attachment for RAI

18.4-21 S01

3.1.1.2 Basis and Requirements

The AOF approach follows applicable guidance in NUREG-0800 section 18, NUREG-0711 section 4, NUREG-0700, and NUREG/CR-3331. Categories of allocated functions are in accordance with NUREG-0700 and a breakdown of the shared function category is shown in Table 1. The AOF process is based upon a top-down iterative process as shown in ~~Figures 2-4~~ Figures 2, 3, and 4 and is an integral part of the overall HFE design process as shown in Figure 1.

3.1.1.3 General Approach

Operational analysis is designed as a multi-step process, as illustrated in Figure 2. Subsequent iterations contain more detailed information about the system and further establish the roles of various personnel. The functional requirements analysis generates the following system level outputs:

- Plant goals,
- Plant states,
- Plant processes,
- Procedure process (EPG, IOP, and EAL) outlines
- Plant process and function redundancies,
- Critical safety functions,
- Plant functions and sub-functions, and
- Inventory of critical safety parameters
- Requirement for HSI design
- Outlines for simulator scenarios.
- System Operating Modes
- System Change Modes
- Component Lineups
- Component Operational Requirements (i.e. components required to be remotely operated)
- Component control requirements (i.e. automatic, manual, etc.)

- Component manipulations required to change modes (as defined for normal and abnormal system operating procedure development), and
- Functional logic diagrams

Each of these sets of functions are processed and presented by FRA as sequenced data structures. These data structures provide inventories of required parameters, indication and controls, and outline sequences to be processed by AOF. The general approach to AOF is shown in Figure 2 with specific actions required to implement this approach shown in Figures 3 and 4. Tables A1 and A2 in Appendix A provide additional insight into human capabilities and limitations to assist analysts in making allocation decisions. The function outline sequences are evaluated using the AOF process. Each function or sub-function in the sequence is evaluated and allocated to one of the following resources for execution:

- Human Only – the function is executed entirely by plant personnel. The HSI is used to carry out the actions and monitoring performed by humans. The machine has no direct control, backup, or limiting actions associated with the function(s) being allocated.
- Machine Only - the function is executed entirely by plant automation. Humans have no direct control, backup, or limiting actions associated with the function(s) being allocated.
- Shared – the function is executed using a combination of both human and machine resources. Table 1 outlines the various combinations of human/machine sharing that can be allocated. Shared functions are broken down into initiation, control, termination, and monitoring sub-functions. These sub-functions are assigned to the most efficient and appropriate combination of human and/or machine performance, limitation, and backup. Most functions are allocated as shared.

The allocated function data structures produced by AOF are provided as inputs to the task analysis process. Task analysis processes the allocated functions and generated detailed task sequences and associated logic to meet the goals and requirements determined by FRA when implemented by the resource to which the function was allocated in AOF.

The resulting task sequences provide IOP outlines and PAS logic used by HSI design, procedures, training, and S&Q. Procedures and machine logic generated by a common data structure minimize potential errors when transferring control from manual to automatic, as well as when human action is required.

The V&V, HSI design, procedures, S&Q, training, and HPM processes provide feedback that is evaluated to determine whether or not additional iterations of the operational analysis process are warranted in specific areas. When feedback is received, the HFE design team evaluates potential resolutions including changes to operational analysis determinations, HSI design, plant design, training, procedures, etc. If a solution is not identified through this normal feedback loop, the issue is entered into HFEITS for tracking and resolution. Once all issues are resolved and the appropriate changes are made, the HPM process monitors performance over time. Future enhancements are identified as they become apparent.

3.1.1.4 Application

When the allocation of function plan is implemented in the method shown in ~~Figures 2-4~~ Figures 2, 3, and 4 the goals of the plan are fulfilled. Allocations are made using criteria that seeks to take advantage of human strengths and avoid human weaknesses [NUREG-0711, Rev 2]. Additionally, AOF is performed in a manner that seeks to eliminate human error and minimize the impact of latent and active errors should they occur. All FRA data structures will be allocated to the implementing resource that is best suited to meet AOF goals. Functions and sub-functions will be allocated to human, machine, or shared ownership for implementation.

3.1.1.5 Design Allocation of Functions

The design allocation of functions shown in Figure 2 processes tasks at the plant and system level that support all aspects of all normal operating modes. Using the HRA/PRA, OER/BRR, D3 Plan, and DCD normal operating inputs are processed and presented by FRA as sequenced data structures. These data structures provide inventories of required parameters, indication and controls, and outline sequences for normal operations to be processed by AOF. These normal operating function outline sequences are evaluated using the AOF process. Each function or sub-function in the sequence is evaluated and allocated to the most appropriate resource for execution.

3.1.1.6 Detailed Allocation of Functions

The detailed allocation of functions processes tasks that support all aspects of abnormal and emergency operations. Using the HRA/PRA, OER/BRR, D3 Plan, and DCD abnormal/emergency operating inputs are processed and presented by FRA as sequenced data structures. These data structures provide inventories of required parameters, indication and controls, and outline sequences for abnormal/emergency operations to be processed by AOF. These abnormal/emergency operating function outline sequences are evaluated using the AOF process. Each function or sub-function in the sequence is evaluated and allocated to the most appropriate resource for execution.

System And Human Factors Engineering Implementation Plan. They are formally chartered and contain members presenting expert opinions from the perspective of operations, engineering, and HFE as a minimum. The team utilizes the structured process shown in Figures 2-4 Figures 2, 3, and 4, the descriptions and criteria presented in this section, and tables A1 and A2 in Appendix A when making allocation decisions. This process insures that:~~The teams use the processes outlined in Figures 2-4 to insure that:~~

- Conservatism is fundamental to the judgment process and no allocation is made that does not support:
 - Safe, reliable, and efficient operation of the ESBWR in compliance with regulations
 - Allocations place reasonable demands on and provide reasonable support of personnel.
 - Allocations meet HFE principles
 - Allocations take advantage of human strengths and avoid human weaknesses
- All available information is gathered and made available, including:
 - Past performance of analogous systems including OER/BRR results
 - Quantified engineering predictions including PRA results
 - Human factors experimental data
 - Previous system cost data and future cost estimates
 - Input/output data from connected subsystems of the design
 - Previously completed allocations of identical or substantially similar functions
- Allocation decisions are broken into their logical elements
- Allocations are the sum of expert professional judgments
- Judgment is made by a consensus of qualified people
- Each judgment is informed by an expanding body of analysis and design data
- All aspects are considered
- Allocation is closely responsive to other design decisions, and change when the other design decisions change.

- Formal records are kept that capture the criteria, rationale, and analysis method for use during later cycles of redesign or plant modifications. [compiled and adapted from NUREG/CR-3331]

Figure 2 presents the phases in which allocations of function are performed and the expected outcomes. Figure 3 presents the methodology, logic, and sequence by which allocation decisions are made. Figure 4 presents the methodology, logic, and sequence by which the details of shared allocation decisions are made. Each of the decision points in the attached Figures are described below.

4.1.3.1 Allocation of Function Flow Chart Process

1. **Safety Related Function** – Those plant structures, systems, and components (SSCs) that prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public (see Appendix B to Part 50 of Title 10 of the U.S. Code of Federal Regulations). These are the SSCs on which the design-basis analyses of the safety analysis report are performed. ESBWR DCD and Technical Specifications further define which systems are safety related or have functions that support the operability of safety related systems.
2. **Automatic Actuation Required** – Functions that must be carried out by the machine due to regulatory requirement, design, or expert judgment. Later steps in the allocation of function logic will determine if human actions are also required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if automatic actuation is required include:
 - Regulatory requirement
 - Design requirement
 - PRA basis assumption
 - ~~HRA significance~~ HRA/PRA risk significance
 - OER/BRR significance
 - Human cognitive limitations
 - Human response time limitations

- Human physical limitations
 - Hostile environment including atmosphere, temperature, and radiation
3. **Human Backup Required** – Functions allocated to the machine that due to their importance or nature require either concurrent or supporting human action as specified by regulatory requirement, design, or expert judgment. Later steps in the allocation of function logic will determine the nature of human actions required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if human backup is required include:
- Regulatory requirement
 - Design requirement
 - PRA basis assumption
 - Economic risk
 - OER/BRR significance
 - Consequence of automation failure
 - Vesting ultimate control in the human
 - Insuring the human retains necessary emergency control
 - Qualitative, discretionary, or deductive decision making required
4. **Automatic Backup Required** – Functions allocated to the human that due to their importance or nature require either concurrent or supporting machine action as specified by regulatory requirement, design, or expert judgment. Later steps in the allocation of function logic will determine the nature of machine actions required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if automatic backup is required include:

- Regulatory requirement
- Design requirement
- PRA basis assumption
- HRA/PRA risk significance
- Economic risk
- OER/BRR significance
- Consequence of human failure
- Human limitations/machine capabilities
- Cognitive overload
- Human workload

5. **Configuration Change Required** – Functions which have been analyzed and found not to be safety-related and for which the affected component(s) do not change state during normal, abnormal, or emergency operation. An example of such a component is a feed water manual isolation valve inside containment. The feed water isolation valve is only operated when the plant is shutdown, feed water is to be isolated, and personnel are inside containment. Such a valve does not need automation but may need remote operation capability due to its physical location inside containment.

6. **Remote Operation Required** – Functions that must be carried out from a location detached from the component(s) to be monitored, controlled, or manipulated due to regulatory requirement, design, or expert judgment. Later steps in the allocation of function logic will determine if machine actions are also required to support successful completion of the function. Some criteria considered when determining if remote operation is required include:

- Regulatory requirement
- Design requirement
- PRA basis assumption
- ~~HRA significance~~ HRA/PRA risk significance
- OER/BRR significance

- Design layout – is the SSC accessible
 - Human response time limitations
 - Human physical limitations
 - Broader plant control or monitoring requirements than is available locally
 - Hostile environment including atmosphere, temperature, and radiation
 - Human workload
 - Safety or economic risk associated with local operation
 - Economic benefit – centralized work location, fewer humans required, or other considerations
7. **Plant Automation System** – Functions that are carried out using the ESBWR’s HSI computers, their associated programming and logic, and linked remote control and indication capabilities. Later steps in the allocation of function logic will determine if human actions are also required to support successful completion of the function.
8. **Machine Only** – This output allocation assigns the function data sequences generated in FRA for the function being analyzed exclusively to the machine for implementation.
9. **Shared** - This output allocation assigns the function data sequences generated in FRA for the function being analyzed to a combination of both human and machine for implementation. Figure 4 outlines the process used to refine and define shared allocations so as to take advantage of human strengths and avoid human weaknesses. Table 1 summarizes the possible shared function allocations.
10. **Human Only** - This output allocation assigns the function data sequences generated in FRA for the function being analyzed exclusively to the human for implementation.

4.1.3.2 Shared Function Detailed Flowchart Process

1. **Machine Control Required** – Functions that must be carried out by the machine due to regulatory requirement, design, or expert judgment. Later steps in the allocation of function logic will determine what human actions are also required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred

unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if machine control is required include:

- Regulatory requirement
- Design requirement
- PRA basis assumption
- ~~HRA significance~~ HRA/PRA risk significance
- OER/BRR significance
- Human cognitive limitations
- Human response time limitations
- Human physical limitations
- Hostile environment including atmosphere, temperature, and radiation

2. **Machine Control Practical** – Functions to be carried out by the machine due to regulatory requirement, design, or expert judgment. This decision point evaluates whether or not functions allocated to the machine can be realistically carried out. Later steps in the allocation of function logic will determine if design changes to the ESBWR are required and what human actions are also required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if machine control is practical include:

- QER/BRR findings
- Technically feasible
- Economically feasible
- Reliability
- Predictability
- Development time

- Component availability
- Cost

3. **Human Backup Desired** – Functions allocated to the machine that due to their importance or nature require either concurrent or supporting human action as specified by regulatory requirement, design, or expert judgment. These supporting human actions take the form of either limitations requiring human action for automation to proceed or human backup in the form of human execution of functions allocated to the machine but which were not completed. This logic block is used when deciding between human backup and human limitations to machine functions. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining whether to allocate human backup or human limitation include:

- Regulatory requirement
- Design requirement
- PRA basis assumption
- Economic risk
- OER/BRR significance
- Consequence of automation failure
- Vesting ultimate control in the human
- Insuring the human retains necessary emergency control
- Qualitative, discretionary, or deductive decision making required
- Human workload
- Human limitations/machine capabilities
- Cognitive overload

4. **Machine Control Desired** – Functions that can be carried out by either human or machine assigned the machine due to design or expert judgment. Later steps in

the allocation of function logic will determine what human actions are also required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if machine control is desired include:

- PRA risk significance
- ~~HRA significance~~ HRA/PRA risk significance
- OER/BRR significance
- Human cognitive limitations
- Human response time limitations
- Human physical limitations
- Hostile environment including atmosphere, temperature, and radiation
- Risk to the operator
- Degree to which function is predictable or repeatable
- Impact on vigilance and situational awareness
- Effectiveness of humans for:
 - Functions which are lengthy
 - Functions which require high consistency
 - Functions which require high accuracy
 - Functions which involve boredom or monotony for the operator
 - Function requires heuristic or inferential knowledge and flexibility

5. **Error Consequence Acceptable** – Functions for which machine control is neither required nor desired that are to be carried out by the human due to design or expert judgment. This logic block is used when deciding whether the consequences of potential human errors of omission or commission are acceptable. Later steps in the allocation of function logic will determine what

machine actions are also required to support successful completion of the function. Some criteria considered when determining if potential human error consequences are acceptable include:

- Can the error be corrected to eliminate adverse consequences
- Could the error cause a scram, turbine trip, or initiate a transient
- Could the error prevent the performance of a safety-related function
- Could the error result in an release of radionuclides
- Could the error result in unplanned radiation exposure
- Could the error result in exceeding environmental or other regulatory limits
- Cognitive overload should an error occur
- Human workload should an error occur
- Economic risk
- Regulatory margin
- HRA/PRA results

6. **Human Control Practical** – Functions for which machine control is neither required nor desired that are to be carried out by the human due to design or expert judgment. The consequences of potential human errors of omission or commission have been evaluated and found acceptable. This decision point evaluates whether or not functions allocated to the human can be realistically carried out. Later steps in the allocation of function logic will determine what machine actions are also required to support successful completion of the function. Appendix A is referenced when making this determination. Should any of the human limitations presented in Table A1 be part of the function being evaluated, automation is preferred unless otherwise precluded. Should any of the uniquely human capabilities presented in Table A2 be part of the function being evaluated, human participation is required. Some criteria considered when determining if human control is practical include:

- Cognitive abilities of humans
- Physical capabilities of humans

Attachment for RAI

18.4-25 S01

- (3) The results of the FRA are summarized in the FRA RSR. The RSR provides the plant functional requirements, along with an outline of the analysis that was used. Reports are generated following each phase of the analysis, that is, high-level Plant FRA, Design FRA, Detailed FRA and Economic FRA. A report will also summarize the results of the System Functional Gap Analysis (SFGA). The FRA RSR may be combined with the RSR(s) from AOF and TA.

~~Other RSR outputs include:~~

- ~~□ Initial inventory of plant parameters, indications, and controls;~~
- ~~□ Emergency Procedure Guidelines outlines;~~
- ~~□ HSI design inputs and recommendations;~~
- ~~□ Initial inventory of simulator scenarios for V&V;~~
- ~~□ Emergency Action Level (EAL) procedure outlines;~~
- ~~□ Staffing requirements and recommendations;~~
- ~~□ Outlines and inputs to System and Integrated Operating Procedures (SOPs/IOPs);~~
- ~~□ Outlines and inputs to Annunciator Response Procedures (ARPs);~~
- ~~□ Outlines and inputs to General Plant Procedures (GPP);~~
- ~~□ Outlines and inputs to Abnormal Operating Procedures (AOPs); and~~
- ~~□ Outlines and inputs to Calibration, Inspection, and Testing Procedures.~~

The FRA results summary report is included as ITAAC item 2 of Table 3.3-1 in DCD Tier 1.

18.4.2 Allocation of Function Implementation Plan

- (1) The AOF Implementation Plan, Reference 18.4-3, establishes:
- a. Methods and criteria for the execution of function allocation consistent with accepted HFE practices and principles;
 - b. System and function definitions generating human performance requirements based on the expected user population;
 - c. Documentation of the allocation of functions to personnel, system elements, and personnel system combinations reflects:
 - i. Areas of human strengths and limitations;
 - ii. Sensitivity, precision, time, and safety requirements;
 - iii. Reliability of system performance; and
 - iv. Necessary personnel (numbers and skills) required for operating and maintaining the SSC.
 - d. Documentation of the allocation criteria, rationale, analyses, and procedures; and

- e. Analysis plan for confirming that personnel can perform tasks allocated to them while maintaining operator situational awareness, workload and vigilance.
- (2) The AOF Implementation Plan includes:
- a. Establishment of a structured basis and criteria for function allocation; and
 - b. Definition of function allocation analyses requirements, including:
 - i. Objectives and requirements;
 - ii. Alternative function allocations;
 - iii. Selection criteria;
 - iv. Evaluation criteria;
 - v. Test and analysis methods, and
 - vi. Assessment methods.
- (3) The results of the Function Allocation are summarized in the AOF RSR. The RSR provides the plant function allocations, along with an outline of the analyses that were used. A separate report is generated following each phase of the analysis, that is, high-level Plant FRA, Design FRA, Detailed FRA and Economic FRA. The AOF RSR may be combined with the RSR(s) from FRA and TA.

~~Other RSR outputs include:~~

- ~~Initial inventory of plant parameters and controls;~~
- ~~EPG outlines;~~
- ~~HSI design inputs and recommendations;~~
- ~~Initial inventory of simulator scenarios for V&V;~~
- ~~EAL procedure outlines;~~
- ~~Staffing requirements and recommendations;~~
- ~~Outlines and inputs to SOPs and IOPs;~~
- ~~Outlines and inputs to ARPs;~~
- ~~Outlines and inputs to GPPs;~~
- ~~Outlines and inputs to AOPs; and~~
- ~~Outlines and inputs to calibration, inspection, and testing procedures.~~

The AOF results summary report is included as ITAAC item 2 of Table 3.3-1 in DCD Tier 1.

18.4.3 COL Information

None

Attachment for RAI

18.7-7 S02

ESBWR design certification PRA shows that the design meets the objectives stated in Section 19.1.

The ESBWR PRA defines potentially risk-significant SSC and HI events and information that contribute to CDF and LRF using conservative thresholds such as FV greater than 0.01, and a RAW greater than 5.0 for individual basic events and a RAW greater than 50.0 for common cause failure events. The goal of the HRA and HFE operational analysis in DCD Chapter 18 is to verify that the means are provided in the plant design to keep the quantitative risk importance of all potentially risk important human interactions modeled in the PRA below a FV value of 0.1 and RAW of 2.0. The goals are met by ensuring that information for identifying, planning and implementing the needed action within the time permitted is provided in the design or by providing automated support to carry out the needed action. For example, the operator can identify the need for manual actions through the HSI, plan through procedures and training and implement with tools as needed.

19.2.2.1.1 Use of PRA in Support of Design

In the design phase, various aspects of probabilistic analyses are employed to enhance the ESBWR and reduce the overall risk profile. At the conceptual design phase, qualitative risk analyses are used to ensure that vulnerabilities of existing boiling water reactors (BWRs) have been addressed in the ESBWR design. Table 19.2-1 contains a comparison of ESBWR design features versus design issues in BWRs.

The diversity and redundancy level of certain systems has been established, in part, by qualitative risk insights. Consistent with other conceptual design methods, the risk insights applied at the conceptual design phase are not explicitly documented in the PRA. Table 19.2-2 lists design features that have been applied to the conceptual design of the ESBWR to reduce risk. Extensive use of operating experience in the design phase has led to significant improvements, over conventional BWRs, in the plant's ability to respond to severe accidents. Significant design improvements include:

- (1) The ESBWR front-line safety functions are passive and, therefore, have significantly less reliance on the performance of supporting systems or operator actions. In fact, ESBWR does not require operator actions for successful event mitigation until 72 hours after the onset of an accident.
- (2) The ESBWR design reduces the reliance on AC power by using 72-hour batteries for several components. Diesel-driven pumping has been added as a diverse makeup system. The core can be kept covered without any AC sources for the first 72 hours following an initiating fault. This ability significantly reduces the consequences of a loss of preferred (offsite) power initiating fault.
- (3) Anticipated Transients Without Scram (ATWS) events are low contributors to plant core damage frequency (CDF) because of the improved scram function and passive boron injection.
- (4) The ESBWR design reduces the frequency and consequences of loss of coolant accidents (LOCA) due to large diameter piping by removing the recirculation system altogether.

Table 19.2-1 Comparison of ESBWR Features With Existing BWRs

NUREG-1560 IPE Key Observations	ESBWR Features
<p data-bbox="303 357 495 385">Human Actions</p> <p data-bbox="303 423 915 853">Only a few specific human actions are consistently important for either BWRs or PWRs as reported in the IPEs. For BWRs, the actions include manual depressurization of the vessel, initiation of standby liquid control during an ATWS, containment venting, and alignment of containment or suppression pool cooling. Manual depressurization of the vessel is more important than expected, because most plant operators are directed by the emergency operating procedures to inhibit the automatic depressurization system (ADS) and, when ADS is inhibited, the operator must manually depressurize the vessel.</p>	<p data-bbox="941 423 1476 1051">No operator actions are required for safety function success in the ESBWR for the first 72 hours of an event. Several of the manually initiated actions in BWRs and PWRs are automatically actuated in the ESBWR (e.g., ADS, ADS inhibit, SLCS, Suppression Pool Cooling). <u>By design, operator actions are not required for any safety function success in the ESBWR for the first 72 hours of an event as long as the plant is operated within its design basis. Many important actions can be actuated or inhibited either manually or automatically. Example manual actions in predecessor plants that are automatic in the ESBWR include reactor vessel depressurization, ADS inhibit, actuation of standby liquid control, and equipment alignments for reactor core and suppression pool cooling.</u></p>
<p data-bbox="303 1442 508 1470">Station Blackout</p> <p data-bbox="303 1534 872 1770">With the SBO rule implemented, the average SBO CDF is approximately $9E-6$/yr. Although the majority of the plants that implemented the SBO rule have achieved the goal of limiting the average SBO contribution to core damage to about $1E-5$/yr, a few plants are slightly above the goal.</p>	<p data-bbox="941 1534 1433 1700">Implementing the design requirements in the Utility Requirements Document has significantly reduced the SBO contribution to core damage for ESBWRs.</p>

human actions can be treated with the same risk criteria as equipment when evaluating their risk importance and taking actions to manage the risk.

3.2.1.1 Quantitative goal and use of importance measure

The ESBWR PRA defines potentially risk significant SSC and HI events and information using conservative thresholds such as FV greater than or equal to 0.01, and a RAW greater than or equal to 5.0 for individual events and a RAW greater than or equal to 50 for common cause failures. The quantitative goal for ESBWR HFE program is to keep the quantitative risk importance of all potentially risk important HIs below a RAW value of 2.0 and a FV value of 0.1. These two risk IMs represent the range of conditions for setting limits on the risk contribution for human interactions. The goals are met by providing levels of automation to support the HI and ensuring that the task can be identified through the HSI, planned through training and procedures, and implemented with tools as needed.

The ESBWR PRA defines potentially risk-significant SSC and HI events and information that contribute to CDF and LRF using conservative thresholds such as FV greater than 0.01, and a RAW greater than 5.0 for individual basic events and a RAW greater than 50.0 for common cause failure events. The goal of the HRA and HFE operational analysis in DCD Chapter 18 is to verify that the means are provided in the plant design to keep the quantitative risk importance of all potentially risk important human interactions modeled in the PRA below a FV value of 0.1 and RAW of 2.0. The goals are met by ensuring that information for identifying, planning and implementing the needed action within the time permitted is provided in the design or by providing automated support to carry out the needed action. For example, the operator can identify the need for manual actions through the HSI, plan through procedures and training and implement with tools as needed.

GEH commits to using each individual PRA model for CDF and LRF to evaluate HI importance. The importance of each modeled HI is measured using the RAW and FV risk importance ranking at each stage of PRA development and when the PRA results are combined into a total risk model. Each importance measure is individually applied to the top event of all ESBWR PRA submodels. These models include the CDF for level 1 internal events, LRF for level 2, all of the external events such as fire and flooding, and special analysis such as the shutdown PRA.

The individual PRA application models are used to compare each HI event with the top event total to ensure that the potentially important HIs modeled do not exceed the quantitative limits for HI contribution to the risk. If the HIs are below the cutoff value for individual PRA models, they are expected to be below the cutoff for the total PRA model. When all the PRA submodels are combined for CDF and LRF, the same importance measures are applied to verify that each modeled HI's risk contribution is below the RAW and FV risk importance cutoff limits.

3.2.1.2 Application Process

The application process involves three main steps. These are: identifying potentially risk important HIs, evaluating the HIs against qualitative criteria and verifying that the quantified HI is below these quantitative IM cutoff values. The HFE program addresses the verification that

Attachment for RAI

18.11-32 S01

4.6 Implementation of HFEITS

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

- Evaluate the HEDs to determine the level of need for their correction,
- Identify design solutions to address significant HEDs, and
- Verify implementation of design solutions to resolve HEDs.

Records within the database include the following (as fields within a HED issue record). An example of anThe HFEITS database record for an issue includes the following fields:

Evaluate the HEDs

1. HFE Issue tracking identifier - number, date entered, title, initiator and status
2. Brief description of the issue and reference (documents can be attached)
3. Design lifecycle process ~~(or activity, issue type and category thereof)~~ that led to the identified issue
4. Impact of issue resolution on the project schedule
- ~~3-5.~~ Area of plant (e.g., MCR, RSS, Simulator, or LCS) ~~(of MCR, RSS, Simulator, or LCS)~~ affected by the issue.

Identify design solutions

6. Proposed solution to resolve the HED issue
- 4.7. HFE principle or guideline pertinent to the issue (e.g., workspace, legibility, screen content, etc.)
 - a. Plant system(s) affected
 - b. Control panel(s) affected
 - c. Component(s) or feature affected (e.g., switch, mimic, display, lighting)
 - d. Operator task(s)/function(s) affected
 - e-e. Human performance characteristic affected (e.g., vision, hearing, cognitive, motor skill, etc.)

~~5. Date that the issue was identified~~

~~Brief description of the issue~~

- ~~7.8.~~ Name of person, ~~(or group, or organization)~~ identifying qualified to evaluate the issue
9. Issue priority and HED category
10. Safety/Risk Significance evaluation (see discussion below ~~in section 4.6~~)

- ~~8.11.~~ Qualified evaluator's "Yes/No" designation that the issue requires corrective action
- ~~9.12.~~ Qualified evaluator's justification statement if no corrective action is needed
- ~~13.~~ Qualified evaluators definition and assignment of tasks needed to resolve the issue
- ~~14.~~ Qualified engineers assessment of effected documents, notifications and resources needed.
- ~~15.~~ Name of the engineer(s) responsible for performing resolution task Safety/Risk Significance (see below)
- ~~12.16.~~ Description of the proposed corrective action d
- ~~13.~~ Date, when the corrective action is needed, and a Yes/No completion assessment
- ~~13.~~ ~~Date that the corrective action was proposed~~
- ~~14.17.~~ Name of engineering discipline(s) responsible for proposed corrective action
- ~~15.18.~~ Organization responsible for evaluation of proposed corrective action
- ~~16.19.~~ Date that the ~~evaluation~~ corrective action was completed
- ~~17.20.~~ Statement (and/or summary of findings) confirming completion of corrective action

Verify implementation

- ~~18.21.~~ Name of person confirming completion of corrective action
- ~~19.22.~~ Date of confirmation statement
- ~~20.23.~~ Name of HFE Group Member authorized to signify that the issue has been closed
- ~~21.24.~~ Date of HED issue closure
- ~~25.~~ Continued improvement of HPM program.

The HFE issue safety/risk significance classification process methodology, is shown in Figure 4, is for HFE issue compilation, ranking, and screening purposes. It is a methodology to rank or prioritize new and unresolved issues in terms of their significance and potential impact on plant safety and performance. The intent is to facilitate evaluation and resolution of issues in a manner consistent with the guidelines of NUREG-0700 and NUREG-0711r2. It will be used by the HFE team to qualitatively classify the HED issue according to its safety significance. For example, the following are the priority categories are used:

- Category 1 = Consequence to safety either Direct or Indirect;
Category 2 = Consequence to plant or personnel performance;
Category 3 = Departs from HFE Guidelines without Category 1 or 2 consequence
General plant HSI improvement, plant mod, task redesign, or other, and
and Category 4 = Handled within the Use normal design engineering process.

4.6.1 Evaluation of HFE issue safety and risk importance Category 1 and 2

~~However,~~ In order to assure that resources are applied in a risk informed manner, it is important to first evaluate for HFEITS ~~Priority Category 1 or 2~~ and the safety/risk significance of each HFE issue. If it is determined that the issue is not HFEITS ~~Category Priority-1 or 2~~ and not significant to safety, further evaluation ~~may to determine that an the need for out of normal engineering process corrective action is may not be needed for HFEITS Category 3 issues, or that an issue classified as Category 4 is adequately addressed in the normal design engineering process.~~

As shown in Figure 4, if the HFE issue is safety or risk-important, a risk reduction strategy is determined. For example, if ~~(e.g., the issue addresses design basis event assumptions, or is addressed in the ESBWR PRA is in important PRA accident sequences, or appears in the importance measures listings of the PRA models), and is addressed in the ESBWR PRA,~~ a risk reduction strategy is determined. ~~it is safety or risk important.~~ The ~~Priority Category 1 issues is~~ are then closed out using all methods for risk reduction. Design change resolutions of HED issues might involve implementing as changes to plant features such as adding redundancy or diversity, making a system design change, or revising the S&Q plan indicated in the lower right side box to ensure that the issues risk contribution is below the cut off values for the risk importance measures¹.

~~If the issue is not risk important and is a Priority 2 issue (e.g., is not a Priority 1 issue or in top events is below a cutoff frequency, or not in importance ranking and the evaluation involves consequences to plant or personnel performance), then a Priority 2 solution goes to Question 4 is required.~~

Also, ~~as shown in Figure 4 is a path for qualitatively evaluating potentially risk important HFE issues that are not explicitly addressed in the PRA. Each , if the HFE issue is is qualitatively assessed not addressed in the ESBWR PRA as potentially risk important via a qualitative description and there is increased potential for an increase of in frequency of core damage/large early releases (CD/LERF),).~~ For example, the HFE issue ~~this could involve , e.g., unsafe an unsafe conditions, a technical specification violation, a contribution to common cause and dependencies, dependencies with other HFE issues that impact component reliability, system availability or accident sequence frequency.~~ Then the issue is evaluated for risk significance via HRA/PRA and reanalyzed for risk importance as shown in Figure 4.

If the issue is or can be addressed in the ESBWR PRA, this the evaluation may require development of a performance shaping factor (PSF) that modifies a human error probability— to reassess the risk importance and show that the associated human actions are below the importance measure cut off values.

¹ The quantitative cutoff measures for explicitly identified HFE issues in the PRA models are Fussell-Vesely = 0.1 and RAW of 2.0.

If the HED issue is a Category 2 issue (e.g., is not a Category 1 issue and is below the risk importance cutoff value for associated human actions, but evaluation of the HED indicates that there are consequences to plant or personnel performance), then the Category 2 resolution process for the HED issue is used. Category 2 resolutions primarily include improvements to the training, enhancements to the procedures, revisions to the staffing and qualifications, reallocation of task responsibilities, but can also use the Category 3 approaches. If it cannot be addressed in the PRA, then the Priority 2 issue is closed out via consideration of training, procedures or S&Q as shown.

4.6.2 Normal engineering processing Category 3 and 4

Category 3 and 4 HED issues are not expected to be risk significant, but depart from HFE guidance or impact normal work activities. Figure 4 also shows that if the HED the issue is not in HFEITS Priority Category 1 or 2, not addressed in the design basis accidents or in the PRA, and does not qualitatively increase the potential for core damage/large early releases, and the issue does not conform to style guide violate any HFE guidance, it can be closed out by using Priority Category 3 or 4 resolutions. Category 3 resolutions include solution changes to HSI design such as color, display screen layout, navigation level, modifications to the plant, task redesign and other changes to enhance the HSI. Category 4 resolutions to HED issues are typically justified as being addressed as part of the normal design engineering process. Some issue resolutions are addressed by establishing situation or parameter to monitor in the Human Performance Monitoring program operated by the operating utility. Resolutions in all categories potentially contribute to HPM programs.

~~or by justifying and resolving this nonconformity. If style guide conformity is met, then the issue can be closed with consideration of future human performance monitoring.~~

Document Justification, Close Issue & continue HPM

The HFEITS software database tracking tool provides the status of the HED issues at any point in time. The issue can be closed by the HFE team by agreeing with the closure justification provided by responsible engineers. The issues recommended for the HPM can be listed through the search routines and provided for the continued improvement/development of the plant HPM program.

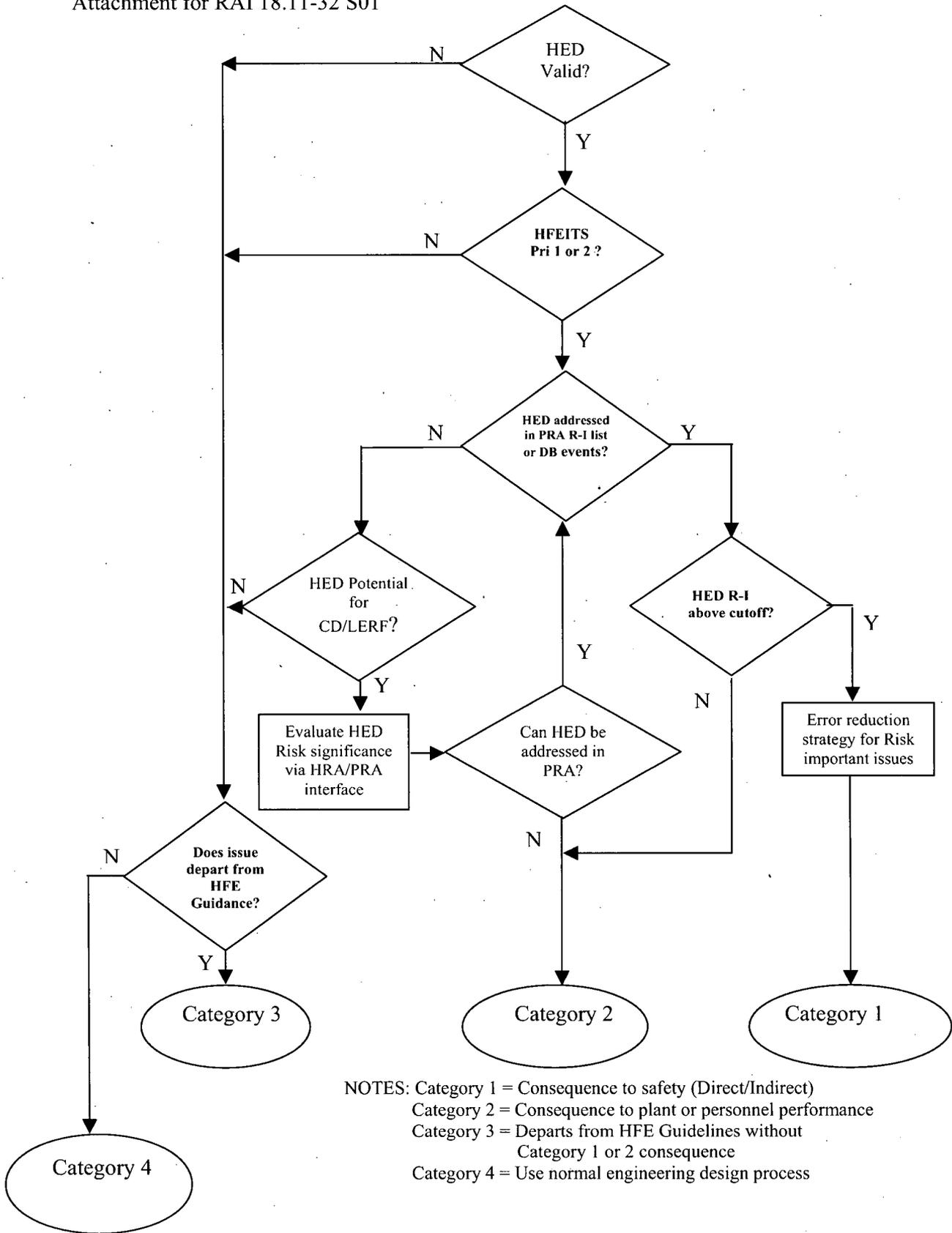


Figure 4 HFE Issue Safety/Risk Significance Methodology

Attachment for RAI

18.12-3 S01

18.12 DESIGN IMPLEMENTATION

The Design Implementation plan, Reference 18.12-2, addresses the final “as-built” implementation of the HFE plant design for new plants constructed using the ESBWR standard plant. The implementation team executes their responsibilities under the plans described in Reference 18.12-1. The HFE aspects of the ESBWR standard plant including design of the HSIs, standard plant procedures, and baseline training documentation are verified and validated using the Full Scope Simulator during the HFE V&V process.

18.12.1 Objectives and Scope of Design Implementation

The ESBWR HFE Design Implementation Plan has the following objectives:

- Confirm that the final HSIs, procedures and training (as-built) HFE design conforms to the ESBWR standard plant design resulting from the HFE design process and V&V activities;
- Verify aspects of the design and any physical or environmental (for example, noise, lighting, and so forth) differences between those present at the V&V process and the “as-built” MCR; and
- Verify that the resolution of HEDs and open HFE issues are identified and tracked.

The “as-built” confirmations, verifications, and validations described in the Design Implementation plan apply to the COL plants constructed using the ESBWR standard plant design. The ESBWR standard plant design against which the “as-built” comparison is made is derived from the revised HSI design and the standard plant procedures and training documents. These include the corrections and improvements from the HF V&V process.

18.12.2 Methodology of Design Implementation

18.12.2.1 HSI Verification (As-Built)

The HSIs and their design characteristics are established in the HSI Design activity using the guidance in the Style Guide for Graphical User Interfaces and issued ~~as-in~~ the HSI Results Summary Report. The HSIs are subsequently evaluated and confirmed in the HFE V&V. Following the HFE V&V, the list of HSI and characteristics standard plant in the HSI Results Summary Report is revised and becomes the basis for the requirements and acceptance criteria for the fabrication/procurement verification of the equipment ~~for-in~~ the “as-built” installation. The process and the rationale for the HSI design are documented and managed under GEEN Quality Assurance and ESBWR specific design program plans.

The “as-built” ~~confirmation-verification~~ for the HSIs involves ~~an auditing of the procurement, start-up, and testing process~~ confirmation that the as-built HSI and their design characteristics correspond to the acceptance list established in the HSI Results Summary Report.

18.12.2.2 Procedures and Training Confirmation (As-Built)

The standard plant procedures and training documentation are established in development activities. The HFE V&V validates the adequacy of the proposed HSIs and the standard plant procedures and training to support personnel performance.

3 METHODS

3.1 HSI Verification (As-Built)

3.1.1 Background

The Human-System Interfaces and their design characteristics (HSIs) are established in the HSI Design activity. The HSI adheres to applicable guidance. The HSIs are subsequently evaluated and confirmed in the HFE Verification and Validation. Following the HFE V&V, the standard plant HSI Results Summary Report is revised and becomes the basis for the requirements and acceptance criteria for the fabrication/procurement of the equipment for the “as-built” installation. The software that drives the HSI displays in the as-built system will be the same as was used during the HFE V&V. The process and the rationale for the HSI design are documented and managed under General Electric Energy Nuclear (GEEN) Quality Assurance (QA) and ESBWR specific design program plans.

3.1.2 Goals

The goal of the “as-built” ~~verification confirmation~~ for the HSIs is to ~~audit the procurement, start-up, and testing process to confirm (1) the GE/COL applicant’s procurement and construction specifications include that~~ the verified and validated HSIs and ~~(2) that these designs are implemented.~~

3.1.3 Requirements

The final (“as-built”) HSIs and their design characteristics are compared with the complement of HSIs in the detailed standard plant design to verify that they conform to the design that resulted from the HFE design process and V&V activities (NRC, 2004a, Section 12.4.6 (2)). Comparing the as-built HSI to the design as evaluated in the HFE V&V will ensure that any design changes that occur after HFE V&V will cause an HED to be generated to document and evaluate the change.

3.1.4 General Approach

To complete the approach, the following shall be confirmed:

- ~~1. The GE/COL applicant’s applicable procurement and construction documents contain the elements of the HSI Report.~~
- ~~2. The applicable procurement and construction documents reflect the current and correct revision of the HSI Report.~~
- ~~3. A review of the engineering/vendor change documentation verifies that the HSI design characteristics remain intact.~~
1. Verification that the As-Built HSIs and their design characteristics correspond to the HSI Results Summary Report. This verification will be accomplished by performing a physical as-built of the MCR, panels and HSIs, and verification that the HSI screens are the same file/revision as was used for the HFE V&V.
- ~~4.2. An HED is written, if needed, to resolve the following issues:~~

- a. If the ~~procurement/construction documents or engineering change causes as-built verification indicates~~ a variance from the ~~HSI Report~~HSI Results Summary Report.
- b. If there is not sufficient documentation to confirm that the software installed in the as-built HSI is the same as the software that was verified in the HFE V&V as documented in the the procurement, start up, and testing process has resulted in the HSIs as contained in the HSI ReportHSI Results Summary Report.

3.2 Procedures and Training Confirmation (As-Built)

3.2.1 Background

The standard plant procedures and training documentation are established in development activities using applicable guidance documents. The HFE V&V validates the adequacy of the proposed HSIs and the standard plant procedures and training to support personnel performance.

Some changes to the standard plant procedures and training may result from the HFE V&V. If the nature of the changes is minor (e.g., confined to nomenclature and equipment numbering distinctions), the previous HFE validation remains applicable. If changes affect the sequence or content of procedures and training, these may impact the confidence of the validation results, and HEDs are written to resolve differences.

3.2.2 Goals

The goal of the “as-built” confirmation for the procedures and training is to conduct an audit of the standard plant procedures and training, compare the “as-built” documents to the corresponding documents used in the HFE V&V, and assess any differences.

3.2.3 Requirements

The final (as-built) procedures and training are compared with the standard plant procedures and documentation to verify that they conform to the design that resulted from the HFE design process and V&V activities (NRC, 2004a, Section 12.4.6 (2)).

3.2.4 General Approach

The procedures and training confirmation consists of:

1. Auditing the standard plant procedures and training. The audit results are compared to the corresponding standard plant procedures and training documents used for the HFE V&V.
2. Writing an HED to resolve any deviations or changes.

3.3 Final HFE Design Verification Not Performed in the Simulated HFE V&V Activity

3.3.1 Background

Some HFE design aspects may not be able to be addressed in the simulated HFE V&V. These would include:

1. Designs and features that are modifications to the standard design

4 IMPLEMENTATION

4.1 Verification of Final As-Built HSI Requirements

The As-Built verification of HSI requirements is to ensure that the installed HSIs are the same as those derived from the HFE design process and verified during the HFE V&V.

~~The documentation review audits the procurement and construction documents to determine that the HSI requirements derived from the HFE design process and V&V activities are specified and verified within the normal plant equipment acquisition process.~~

4.1.1 Inputs

1. HSI Requirements (See Definitions)
2. Procurement Documents (See Definitions)
3. Construction Documents (See Definitions)

4.1.2 Process

4.1.2.1 Acceptance Criteria

~~The documentation review is considered sufficient if the Task Leader (TL) determines that the process is complete in complying with the following acceptance criteria:~~

~~1.HSI requirements listed in the revised HSI Report are invoked within the applicable procurement and construction documentation. The revision of the HSI Report is verified to be current to the list confirmed/amended in the HF V&V activity.~~

1. As-Built HSIs and their design characteristics correspond to the HSI Results Summary Report.

2. Differences/modifications to the as-built HSIs from what was documented in HSI Report the HSI Results Summary Report are identified in the form of HEDs and entered in the HFEITS database.

~~3.Manufacturing detailed specifications, plans, and drawings called out in the procurement and construction documents reviewed make direct reference to the HSI requirements contained in the HSI Report.~~

~~4.Manufacturing and/or procurement quality procedures are invoked that are in compliance with NEDO 33181.~~

~~5.Engineering change documentation from the applicable quality systems is reviewed and any changes affecting the HSI design requirements contained in the HSI Report are identified in the form of HEDs and entered in the HFEITS database.~~

~~6.3.Task reports and summary report documentation are completed.~~

4.1.2.2 Resources

1. Data resources
 - HFE standard plant database files

- HSI Results Summary Report
 - HFEITS
 - Plant procurement, construction, and contract documentation
2. Staffing resources
 - Design implementation task leader (TL)
 - HFE responsible engineer (RE)

4.1.2.3 Actions/Tasks

1. Establish detailed plan and schedule and brief team. (TL)
- ~~2. Gain access to plant bid specification and contract documentation. (RE)~~
- ~~3. Conduct review of plant bid specification and contract documentation. (RE)~~
2. Conduct an "As-Built" verification of the MCR using the design that resulted from the HFE V&V. This As-Built is to ensure that any critical dimensions, or physical attributes that may effect the operators interaction with the HSI are the same as was tested in the HFE V&V.(RE)
3. Conduct a review of the HSI screen files to verify the file name and revision is the same as was used for the HFE V&V. (RE)
4. Document results on plan forms, prepare HEDs as needed, and deliver outputs to Task Leader. (RE)
5. Review output documentation for compliance to acceptance criteria. (TL)
6. Prepare task Results Summary Report. (RE)
7. Summarize findings for incorporation into Design Implementation Results Summary Report. (TL)

4.1.3 Outputs

1. Confirmation signature of the TL documenting compliance to acceptance criteria.
2. HEDs for deviations from ESBWR standard plant HSIs.
3. Summary of findings for incorporation into Results Summary Report.

4.2 Confirmation of Standard Plant Procedures and Training

An audit of the standard plant procedures and training is conducted. The auditor compares the "as-built" documents with the corresponding standard plant documents used in the HFE V&V to identify adapted (changed or revised) sections (if any) and assesses the nature of the modifications. If modifications other than equipment nomenclature are observed, HEDs are written to assess and address the deviation.

4.2.1 Inputs

1. Standard plant procedures (as-built) (See Definitions)