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Subject: **Response to Portion of NRC Request for Additional Information Letter No. 119 Related to ESBWR Design Certification Application – Human Factors Engineering - RAI Numbers 18.8-2 S01, 18.8-8 S02, 18.8-16 S02, 18.8-17 S02, 18.8-18 S02, 18.8-31 S02, 18.8-32 S02, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02, 18.8-49 S02 and 18.8-50 through 18.8-59**

The purpose of this letter is to submit the GE Hitachi Nuclear Energy (GEH) response to NRC Letter 119, the U.S. Nuclear Regulatory Commission (NRC) Request for Additional Information (RAI), dated December 5, 2007, Reference 1.

RAI 18.8-2 S01 was originally responded to in MFN 06-443 (Reference 4).

RAIs, 18.8-8 S02, 18.8-16 S02, 18.8-17 S02, 18.8-18 S02, 18.8-31 S02, 18.8-32 S02, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02, and 18.8-49 S02 were originally responded to in MFN 06-443 (Reference 4). MFN 07-334 (Reference 2) provided the response to the first supplement for these RAIs. Enclosure 1 contains RAIs 18.8-50 through 18.8-59 original responses.

GEH's response to RAIs 18.8-2 S01, 18.8-8 S02, 18.8-16 S02, 18.8-17 S02, 18.8-18 S02, 18.8-31 S02, 18.8-32 S02, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02, 18.8-49 S02 and 18.8-50 thru 18.8-59 are addressed in Enclosure 1. Attachment 1 contains the proposed text changes and markups referenced in Enclosure 1.

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

The enclosed markup up pages may contain unverified changes in addition to the verified changes resulting from the RAI response. Pending DCD changes associated with this RAI response are shaded for emphasis. Other changes shown in the enclosed DCD markup may not be reflective of the final format and content of DCD Revision 5 when submitted (i.e., those markups may include changes that are not fully developed and approved for inclusion in the DCD).

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

Sincerely,

James C. Kinsey

James C. Kinsey
Vice President, ESBWR Licensing

References:

1. MFN 07-657 - Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Request For Additional Information Letter No. 119 Related To ESBWR Design Certification Application*, dated December 5, 2007
2. MFN 07-334 - Submittal of *"ESBWR DCD Chapter 18, Human Factors Engineering - RAI to DCD Roadmap Document"* dated June 27, 2007
3. Email from AE Cubbage to DL Lewis, *List of Chapter 18 RAIs for Roadmap Request*, dated May 18, 2007
4. MFN 06-443, *Response to Portion of NRC Request for Additional Information Letter No. 71 – ESBWR Human Factors Engineering NEDO-33268, Rev. 1, Human-System Interface Design Implementation Plan – RAI Numbers 18.8-1 through 18.8-49*, dated November 20, 2006
5. MFN 06-383, Letter from U.S. Nuclear Regulatory Commission to David Hinds, *Request for Additional Information Letter No. 71 Related to ESBWR Design Certification Application*, dated October 10, 2006
6. MFN 08-194 - Letter from U.S. Nuclear Regulatory Commission to Robert E. Brown, GEH, *Economic Simplified Boiling Water Reactor (ESBWR) Chapter 18 Open Items,* dated February 28 2008

Enclosures:

1. Response to Portion of NRC Request for Additional Information Letter No. 119 Related to ESBWR Design Certification Application ESBWR Human Factors Engineering - RAI Numbers 18.8-2 S01, 18.8-8 S02, 18.8-16 S02, 18.8-17 S02, 18.8-18 S02, 18.8-31 S02, 18.8-32 S02, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02, 18.8-49 S02 and, 18.8-50 through 18.8-59

2. Attachment 1, Markups and Added Text for RAI Numbers 18.8-2 S01, 18.8-8 S02, 18.8-16 S02, 18.8-17 S02, 18.8-18 S02, 18.8-31 S02, 18.8-32 S02, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02, 18.8-49 S02, 18.8-50, and 18.8-51

cc:	AE Cubbage	USNRC (with enclosure)
	RE Brown	GEH/Wilmington (with enclosure)
	DH Hinds	GEH/Wilmington (with enclosure)
	GB Stramback	GEH/San Jose (with enclosure)
	eDRF	0000-0079-8635

Enclosure 1

MFN 08-050

Response to NRC Request for Additional Information

Letter No. 119 Related to ESBWR Design Certification

Application Human Factors Engineering

RAI Numbers

18.8-2 S01, 18.8-8 S02, 18.8-16 S02, 18.8-17 S02, 18.8-18 S02, 18.8-31 S02, 18.8-32 S02, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02, 18.8-49 S02 and, 18.8-50 through 18.8-59

For historical purposes, the original text of RAIs 18.8-2, 18.8-8, 18.8-16, 18.8-17, 18.8-18, 18.8-31, 18.8-32, 18.8-33, 18.8-35, 18.8-41, 18.8-49 and, 18.8-50 through 18.8-59 and all previous supplements to these RAIs and their associated GE/GEH responses are included preceding each supplemental response. To prevent confusion, attachments and DCD mark-ups of previously submitted GE/GEH responses are not included.

NRC RAI 18.8-2

An implementation plan should provide step-by-step, specific guidance on how to perform the HSI design. The current document stops short of providing step-by-step procedures. To illustrate, in Section 4.2.3, the plan advises its user to design the Man-Machine Interface Systems (MMIS) giving due consideration to the "centralized or local philosophy," but the philosophy for the ESBWR is not provided. Much of the plan identifies considerations for design without providing designers with the basis or procedures to make decisions based on the considerations. Another example is that the "Auditory environment of the HSI is designed considering a relevant database of human capabilities and characteristics" (p. 24). Absence of these types of specific procedural steps will make this document difficult for users and the intended methodology may be incorrectly and inconsistently applied.

Special attention should be made to ensuring that the methodology used to address the General Human Factors Engineering (HFE) Requirements described in NEDO-33268, Section 3.3.3 is presented. Section 3.3.3 follows closely the staff's review criteria for HSI Design. However, the high-level discussion in 3.3.3 does not provided the methodological details as to how these commitments are achieved. While some the considerations are addressed in later sections of the NEDO, others are not. For example, Section 3.3.2 discusses General Electric's commitment to develop a concept of operations. However, none of the subsequent plan material or documentation descriptions address concept of operations. Please, provide step-by-step, specific guidance on how to perform the HSI design.

GE Response

NEDO-33268 is not a step-by-step, specific guidance manual on how to perform the HSI design or evaluation. NEDO-33268 is being revised to provide the description of the implementation process that will develop the Human-System Interface Design for the ESBWR. This document will provide directions to develop the step-by-step, specific guidance manual referred to as the ESBWR Human Factors Guidance Manual. Neither NEDO-33268 Rev 2 nor the ESBWR Human Factors Guidance Manual has been written at present.

DCD Impact/LTR Impact

No DCD changes will be made in response to this RAI.
LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-2 S01

In the initial RAI, the staff raised a concern about the lack of a detailed step-by-step methodology of HSI design. GEH's response to this question indicated that NEDO-33268 is a high-level document and that it will be revised to provide step-by-step guidance to develop the ESBWR Human Factor (HF) Guidance Manual that will include a style guide.

At the July 2007 HFE Audit, GEH said the detailed steps are in detailed work plans. The staff reviewed one sample work plan (for allocation of function), but that plan provided little additional guidance to that found in the implementation plan.

The HSI Design Implementation Plan, NEDO-33268, Revision 2, does not mention a Guidance Manual nor does it make reference to an HSI Design Work Plan. It does discuss the development of a style guide, but such a document would not typically include the detailed step-by-step design guidance to be used by engineers. Thus the initial concern still exists. To illustrate: The steps for developing a concept design are listed on Page 19. Step 3 addressed the alarm system design. The step says "The alarm system is defined including conceptual display hierarchy, presentation, and layout." This is a high-level step description that could not be used by an engineer to develop an alarm concept design.

Please clarify where the methodology to address HSI design is made available to the design team. The staff will need to review that document(s) before the review of the HSI design element can be completed. Note that many of the following HSI Design RAIs reflect concern over the lack of detail in the methodology description provided in NEDO-33268, Revision 2.

Similar issues arise when considering the development and use of the style guide. It is discussed in Sections 3.2 and 4.2 of NEDO-33268, Revision 2. However, little information is provided regarding its structure, content, level of detail and usage by the design team. NEDO-33268, Revision 2, contains many high-level guidelines pertaining to the HSI rather than the process. What is the relationship between these guidelines and those that will be developed for the style guide? Note that many of the responses to the RAIs for this section indicated that the details will be provided in the HF Manual (style guide). The treatment of Guidance in the Revision 0 Sections 5 and 6 seem to follow this approach (they were removed from the NEDO, see RAI 18.8-36). Yet much of this guidance is still in the NEDO. For example, the response to RAI 18.8-22 concerning operator access to suppressed alarms indicated that the topic would be addressed in the manual. The GEH Roadmap stated that the style guide has the details. But it is, in fact, addressed in NEDO-33268, Revision2 (on Page 70, last bullet above Workstations). Please clarify the relationship between the HIS guidelines in NEDO-33268 and those to be included in the style guide. Also, many of the individual guidelines are expressed in high-level form rather than specific design descriptions. At what level of specificity will the style guide guidance be presented?

Additionally, in NEDO-33268, Revision 2, the Tables, Figures, and Appendix may have been overlooked. There are three tables, but none are referenced in the document. The Appendix is not referenced. All six figures are referenced, but not always correctly. For example, on Page 14 a reference is made to Fig 3. That was correct for Revision 0, but should be changed to Fig 4 in new version. This should be addressed in the next revision.

GEH Response

We agree and have addressed the three separate questions associated with this RAI.

A. **The first question posed in this RAI is, "*Please clarify where the methodology to address HSI design is made available to the design team.*"**

ESBWR human-system interface work instructions will be used by the design team to guide: (1) Concept Design, (2) HSI Specific Guidance – Style Guide, and (3) HSI Detailed Design and Iteration as specified in separate sections within the Human-System Interface Design Implementation Plan. HSI Tests and Evaluations per NUREG-0711 will be built into each of these three successive phases. Additionally, the processes that are being used in the overall HSI design approach are being implemented in accordance with Reg. Guide 1.206.

GEH has standardized its terminology for project and technical documentation to be clearer and more consistent. The documentation for the Human-System Interface (HSI) design portion of Human Factors Engineering (HFE) are as follows:

1. ESBWR **Design Control Document**, Tier 2 Chapter 18 Human Factors Engineering, 26A6642BX, Revision 4, September 2007
2. 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.
3. ESBWR **Human-System Interface Design Implementation Plan**, NEDO-33268, Class I (non-proprietary), Revision 2, March 2007.
4. ESBWR **human-system interface work instructions**, Class III (proprietary).

The ESBWR **human-system interface (HSI) work instructions** replace what has been referred to previously as a guidance manual or work plan – these latter two terms will no longer be used.

The ESBWR HSI **work instructions** provide the methodology only. The overall approach to work instructions is to provide designers with a step-by-step approach in sufficient detail to complete the task consistently without compromising the ability of the designer to use good engineering judgment.

B. The ESBWR HSI **Style Guide**, discussed in response to the next part of this RAI question, is the design requirements document only, and does not describe the methodology. **The second question posed is, *"At what level of specificity will the style guide guidance be presented?"***

The HSI Style Guide contains the following guidelines and requirements. Associated design requirements will be entered into an industry-standard software requirements tracking/traceability tool:

The HSI Style Guide is a compilation of requirements and direction provided by regulatory documents (such as NUREG 0700 and NUREG 0711) that addresses two general areas of HSI/HFE design:

Hardware Characteristics: The hardware characteristics of the ESBWR HSI include display legibility and visual acuity, input devices, the visual display hardware, and general characteristics associated with hardware used in the control and display of

ESBWR Software Characteristics: Includes consideration for screen structure and contents, alphanumeric characters, icons and symbols, data display, data entry and point selection, user guidance, screen organization, visual encoding (including enhancement coding), information and screen formats and the overall presentation of the graphical interface, and response times. User dialogue is defined within the style guide relative to how the menus and details of actions appear to the operator and how they are encoded. Display formats and navigation within those displays are included for the various types of displays anticipated for ESBWR.

C. The third question concerns Tables, Figures and the Appendix and notes that may have been overlooked in Revision 2.

Tables 1-3, Figures 3-6, and the Appendix should have been deleted from Revision 2. Any remaining references to them will be removed in our next revision as the contents are described adequately in text.

Figures 1 and 2 will remain, and we will ensure that they are numbered, labeled, and called out appropriately in the text:

Figure 1 HFE Process
Figure 2 Human-System Interface Design Implementation Process

DCD Impact/LTR Impact

No DCD changes will be made in response to this RAI.
LTR NEDO-33268, Revision 2 will be revised for item "C" as noted in attached markup (See Attachment 1).

NRC RAI 18.8-8

NEDO-33268, Section 2 has many references to old documents - many to the 1980s. What role do these documents play in the plan? Many of the versions of the documents referenced have been replaced by newer, updated material. For example, MIL-STD-1472D is referenced, while that document has been revised and is now in Revision F. Some of the old documents may contain outdated and potentially incorrect guidance. For example, EPRI-NP3701 on Computer-Generated Display System Guidelines was published in 1984. Technology and display development approaches have advanced so much since 1984 that the guidance is not fully applicable to today's systems. These documents have been replaced by a new generation of guidance documents. Clarify the use of old document versions.

GE Response

NEDO-33268 will be revised and it will reference the latest industry standards and references that are listed in RAI 18.8-1. The existing references will be deleted.

DCD Impact/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-8 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/ Question	Resolved	Plan	Section	Resolution Description
18.8-8	8	8	N	LTR NEDO-33268	From GE response	32368	2	References updated
18.8-8	8	8	Y	Use of industry standards	From GE response	32368	Section 2	Reference list has been revised and updated. New list contains all documents referenced in RAI 18.8-1

NRC RAI 18.8-8 S02

In the original RAI, the staff noted that the HSI Design Implementation Plan, NEDO-33268, Section 2 had many references to old documents. GEH's response indicated the references would be revised and updated. NEDO-33268, Revision 2, Section 2 has provided a revised document list, however, many of the concerns raised in the original RAI still apply, specifically the large number of old, outdated documents. As noted in the original RAI, the applicability of such old documents to today's modern HSIs is questionable.

GEH Response

We agree. A revised Section 2, "Applicable Documents" is attached. References to out-of-date sources have been removed from text as shown in the attached.

The principal guiding human factors documents are NUREG-0700, NUREG-0711 and NUREG-0737, Supplement 1. Deviations from principles and guidance in these documents will be reviewed, defined and documented in the ESBWR Style Guide. The following statement will be added to Section 3.2, H S I Specific Guidance – Style Guide; "Deviations from NUREG-0700, if any, will be justified."

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-16

NEDO-33268, p. 38 discusses ARPS and computer-based aids. Will ESBWR have computer-based ARPs?
Alarms and corrective actions - NEDO-33268, p. 38 states that the display of alarms meets the following criteria. Criterion a. states "An alarm is annunciated where the operator has the necessary means for initiating corrective actions." Please clarify this statement, particularly as it applies to VDUs.

GE Response

On-line computer based procedures are planned. The Task Analysis and NUREG-0700, R2, Section 4 will be used to develop the required alarm requirements for the operator. NEDO-33268 will be revised to provide the implementation plan to produce the ESBWR Human Factors Guidance Manual to be used by the design engineers to develop the required alarming methodology. The details of these procedures and method of display will be developed using the guidance of NEDO 33268 and summarized in the HSI Design Summary Report.

NEDO-33268 will provide high-level guidance to provide displays (which includes alarms) in a close visual proximity to the controls that affect the parameters and functions monitored and controlled. The detailed guidance specifying control and display locations, visual characteristics and physical sizes will be provided in the ESBWR Human Factors Guidance Manual that will be developed under the guidance of NEDO-33268.

DCD Impact/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-16 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	**SEC**	**#**	**NRC Supplemental**	**DocName/ Question**	**Resolved**	**Plan**	**Section**	**Resolution Description**
18.8-16	8	16	N	LTR NEDO-33268	From GE response	33268	4.1.4	Guidance for Computer-based procedures is included in style guide and the output from concept
18.8-16	8	16	Y	Alarm design	From GE response			See first response

NRC RAI 18.8-16 S02

In the original RAI, the staff requested clarification of (1) whether the ESBWR Alarm Response Procedures will be computerized, and (2) a statement in NEDO-33268 that "An alarm is annunciated where the operator has the necessary means for initiating corrective actions." GEH's response to this RAI stated that on-line computer based procedures are planned and NEDO-33268, Revision 2. identifies them as an output of the design process in Section 4.1.4.

Thus this aspect of the RAI is acceptably addressed. However, GEH has not clarified the statement regarding corrective actions and the statement is still presented in Revision 2 (see Page 69). Please clarify the statement.

GEH Response

We agree and have rephrased this sentence to better reflect our intended meaning. We did not intend to imply that operators might not have the necessary means for taking corrective action. Thus, in Section 4.3.4.11 item 3.c we will change:

"An alarm is annunciated where the operator has the necessary means for initiating corrective actions"; to : "An alarm is annunciated where the operator is required to take action."

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-17

NEDO-33268, p. 39 states "Mechanical characteristics of control elements, such as size, operating pressure of force, tactile feedback, etc., meet capabilities and characteristics specified in the anthropometric database." What database is referred to here?

GE Response

The ESBWR Human Factors Guidance Manual will use the anthropometric data for physical characteristics of equipment based on body size and dimensions of the user population found in NUGEG-0700. Deviations from NUGEG-0700 will be documented and justified using the:

- Guides and standards listed in RAI 18.8-1
- Simulator operation
- Tests
- Mockups and/or
- Operator surveys

The ability of the operators to efficiently function within their environment will be observed. Physical barriers or impediments to the ease with which they are able to perform their tasks will be resolved. This includes ergonomic issues such as reach, force, grasp, size, distance, etc.

The statement in Section 4.2.8 of NEDO-33268 will be revised to clarify the anthropometric database will be specified in the ESBWR Human Factors Guidance Manual.

DCD Impact/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-17 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	**SEC**	**#**	**NRC Supplemental**	**DocName/ Question**	**Resolved**	**Plan**	**Section**	**Resolution Description**
18.8-17	8	17	N	LTR NEDO-33268	From GE response	33268	4.1.3 4.3.4.8 4.3.4.10 4.3.4.12 3.2	Anthropometric considerations added and style guide added to establish criteria
18.8-17	8	17	Y	Use of an anthropometric database	From GE response			See first response

NRC RAI 18.8-17 S02

In the original RAI, the staff requested clarification of the anthropometric database. GEH's response to this RAI clearly indicated that the anthropometric data will come from NUREG-0700 and deviations from it will be justified. GEH indicated that this information would be included in Revision 2. Section 3.2 of NEDO-33268, Revision 2, suggests the use of available anthropometric data from HFE guidelines (Page 20); however, the source of data is not clearly identified. Please clarify the source of anthropometric data.

GEH Response

GEH will use NUREG-0700 as the source for the anthropometric database. Any deviations from the NUREG-0700 database will be justified. The following changes to NEDO-33268, Revision 2 will be made to implement this response:

In first paragraph of Section 3.2, we will change:

"Other HSI guidelines and standards are also used as input to the style guide." to say: "Deviations from NUREG-0700, if any, will be justified."

Also in Section 3.2.1, we will delete the words "data and" to read: "Anthropometric and ergonomic design guidelines."

Also in Section 3.2, we will delete these sentences at the beginning of the paragraph following the numbered list: "The anthropometric and ergonomic data and design guidelines document provides the anthropometric and ergonomic data and guidelines that are used in the design of the HSI environment."

DCD/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-18

NEDO-33268, p. 39, Item 2 - iii states "Placement of controls in keeping with their conformance to safety functions." Please clarify what this statement means.
Form of controls - NEDO-33268, p. 40 states "The form of control adopted is consistent with HSI requirements." Please clarify what this statement means.

GE Response

NEDO-33268 will be revised to refer to the ESBWR Human Factors Guidance Manual for the guidance concerning the placement of controls and displays on the consoles and control panels. The Top-Down approach using the Task Analysis and the operator procedures will determine the parameters to be displayed and the controls required. The design philosophy of the ESBWR encompasses a fully digitized and largely automated environment. However the placement of data on displays, touch screen control dimensions, and placement of control positions along with the placement of the VDUs all require detailed HFE guidance. The ESBWR Human Factors Guidance Manual discussed in RAI 18.8-1 will provide the detailed guidance for developing computerized displays and controls, including the format of controls appropriate for the HSI requirements established in the operations analysis phase.

DCD/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-18 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	**SEC**	**#**	**NRC Supplemental**	**DocName/ Question**	**Resolved**	**Plan**	**Section**	**Resolution Description**
18.8-18	8	18	N	LTR NEDO-33268	From GE response	33268	3.3.5.1	Style guide provides placement and form of control principles
18.8-18	8	18	Y	Design of Controls	From GE response			See first response

NRC RAI 18.8-18 S02

In the original RAI, the staff requested clarification of two statements concerning the guidance on controls. GEH's response to this RAI clearly indicated that the NEDO-33268 would be revised to refer to the HF Guidance Manual for this guidance. While the first statement, "Placement of controls in keeping with their conformance to safety functions," has been removed, the second statement, "The form of control adopted is consistent with HSI requirements," still appears in NEDO-33268, Revision2, Section 4.3.4.9, as Item 3 (on Page 62). Please clarify this statement.

GEH Response

In Section 4.3.4.9 3, we will change numbered list item 3: "The form of control adopted is consistent with HSI requirements." to read as follows:
"The selection of the type of control is consistent with operator needs to navigate or take process control action, and with the associated guidance provided in NUREG-0700."

The method for making these selection decisions will be described in the HSI work instructions, and the specific control applications will be identified and described in the Style Guide.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-31

NEDO-33268, p. 64 contains a section 4.7.1, "Criteria Used in Selecting HFE/HIS Design and Evaluation Tools." The section discusses tools and techniques and presents a list of seven procedures appropriate to HSI evaluation in item 1. Item 2 goes on to provide criteria for selecting techniques. Section 4.7.2 is entitled "Definition of the Design/Evaluation Tools for the HSI Design Analysis." The introductory paragraph in this section addresses techniques. The section goes on to define four "techniques," including: checklists, drawings, mock-ups, and questionnaires/interviews. Two of these are the same as those identified in the listing of procedures in the previous section. Section 4.7.1 references Figures 4 & 5. Figure 4 identifies methods of data collection that are the same as the seven procedures listed on p. 64. Figure 5 identifies five methods of design evaluation, that include things like full-scope simulator. Please clarify the terms used and provide a consistent discussion in these sections of the NEDO.

GE Response

Procedures are meant as techniques, methods, tests, or evaluation options. Section 4.7.1 serves as an introduction and lists some of the various evaluative techniques that are likely to be employed to evaluate the HSI.

Section 4.7.2 provides a discussion of several of these design and evaluation tools for the HSI design analysis. Figures 4 and 5 are graphic representations to illustrate data collection methods and usefulness of the HFE design and evaluation tools. NEDO-33268 will be revised to replace the term "procedures" with "design evaluation tools", and a consistent discussion of the design and evaluation tools for the HSI design analysis will be incorporated into the document.

DCD Impact/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-31 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/ Question	Resolved	Plan	Section	Resolution Description
18.8-31	8	31	N	LTR NEDO-33268	From GE response	33268	4.3.4.6	The term techniques is used to refer to HFE tools instead of procedures
18.8-31	8	31	Y	Clarification of terms	From GE response			See first response

NRC RAI 18.8-31 S02

In the original RAI, the staff requested clarification of methods and criteria for design tests and evaluations. GEH's response to the RAI indicated that a consistent discussion of the design and evaluation tools would be provided in Revision 2. However, the material has been included in Revision 2 (in Section 3.3.5.5, Tests and Evaluations, specifically Pages 34-36) with little modification and without the requested clarifications. Note that Revision 0, Figure 4, is Figure 5 in NEDO-33268, Revision 2 and Revision 0, Figure 5, does not appear in Revision 2. Section 4.3.4.6 contains the same list of techniques and criteria as is listed on Pages 34-35 except an additional criteria related to "safety and/or risk significance" has been added. Why is this information relisted in Section 4 and why has an additional criterion been added. Please provide the clarifications requested.

GEH Response

There are two appearances of the list of "Criteria that may be used in selecting HFE techniques" that are in Section 3.3.5.6 under topic "HSI Design Analysis, Reviews & Evaluations (in the **METHODS** section) and repeated again in Section 4.3.4.6 2. (in the **IMPLEMENTATION** section) that need to be made consistent by including "Safety and/or risk significance" as the first item in both lists for consistency within the document.

Safety and/or risk significance was added to the list to recognize that the items under consideration may require a technique that will yield more rigorous results.

Tables 1-3, Figures 3-6, and the Appendix should have been deleted from Revision 2. Any remaining references to them will be removed in our next revision as the contents are described adequately in text.

The HSI work instructions will describe the methods for HSI Tests and Evaluations per NUREG-0711.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-32

NEDO-33268, p. 65, states "Considering the criteria listed in Section 3, Criteria to be used in selecting HFE/HSI Design and Evaluation Tools, the following techniques are used in the conduct of the HSI design analyses." How is the Section 3 material used for this purpose? Why are the criteria provided in Section 4.7.1 (including Figs 4 and 5) not used?

GE Response

Figures 4 and 5 are referred to in each section 3 and 4. Section 3 is a higher-level overview. Section 4 delineates further details. There are no discrepancies between the two.

DCD Impact/LTR Impact

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

No LTR NEDO-33268 changes will be made in response to this RAI.

NRC RAI 18.8-32 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/ Question	Resolved	Plan	Section	Resolution Description
18.8-32	8	32	Y	Use of Criteria in selecting design and evaluation methods	From GE response	33268	4.3.4.6	The statement in the original plan was in error and should have referred to the previous section 4.7.1. Section 4.3.4.6 in the revised plan describes the design evaluation, which includes the list of evaluation methods and a revised list of criteria for selecting the techniques. The statement with the error has been removed and the plan is clear on evaluation methods and criteria for selection.

NRC RAI 18.8-32 S02

In the original RAI, the staff requested clarification of the criteria in Section 3 of NEDO-33268, Revision 0. The statement referenced in the original RAI is now in Section 3.3.5.6 (on Page 35) and still references Section 3: "Considering the criteria listed in Section 3 and criteria to be used in selecting HFE/HSI Design and Evaluation Tools, the following techniques are used in the conduct of the HSI design analyses." Please clarify the Section 3 criteria being referred to and which criteria are being referred to by "criteria to be used in selecting HFE/HSI Design and Evaluation Tools"?

GEH Response

In Section 3.3.5.6, the lead-in sentence under the header "Definition of the Design/Evaluation Tools for the HSI Design Analyses" will be changed from:

"Considering the criteria listed in Section 3 and criteria to be used in selecting HFE/HSI Design and Evaluation Tools, the following techniques are used in the conduct of the HSI design analyses." to say: "Checklists, drawings, mock-ups, and questionnaires and interviews will be used as described below to gather HSI Tests and Evaluations data and information."

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-33

Figure 4 clarification - NEDO-33268, p. 95, Figure 4 lists HFE activities across the top of the matrix. Why were these activities chosen? What is meant by performance models? How are MMI Evaluation and Evaluation of Alternative Designs different? How were the ratings in the cells of the table determined?

GE Response

These are standard activities that are evaluation tools within the profession of human factors engineering that were used in the evaluation of the Lungmen human-computer interface design. However newer procedures and evaluation tools have been developed that GE plans to use in the design of the ESBWR plant such as:

- PRA accident scenarios
- Task Analysis actions and procedures to define scenarios
- Simulator or mockup studies to gage effectiveness of design
- Tag out process studies
- Use of observers who are experienced with models of human error
- Documentation formats that help identify areas to enhance interface design

NEDO-33268 will be revised and this table will be eliminated. GE will provide descriptions of the procedures and evaluation tools used to design the HSI features of the ESBWR.

DCD Impact/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-33 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/ Question	Resolved	Plan	Section	Resolution Description
18.8-33	8	33	N	LTR NEDO-33268	From GE response	33268	Figure 5 3.3.5.6	Figure is still included, because it has basic methods.
18.8-33	8	33	Y	Display design constraints	From GE response	33217	1.4.2(4)	Additional description of evaluation methods will be established in teamwork plans per MMIS and HFE Implementation plan guidance (33217:1.4.2(4)) and will be input to the style guide.

NRC RAI 18.8-33 S02

In the original RAI, the staff requested clarification of the HFE activities listed in Figure 4 of NEDO-33268, Revision 0. GEH's response indicated that the plan would be revised for clarification and that the "Table" (Figure 4?) would be eliminated. However, the clarification has not been provided and the figure remains in the plan (now Figure 5). Please clarify.

GEH Response

Tables 1-3, Figures 3-6, and the Appendix should have been deleted from Revision 2. Any remaining references to them will be removed in our next revision as the contents are described adequately in text.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-35

NEDO-33268, Section 4.7.2.5.2, Methods of Evaluation, lists three such methods. However, the actual methods are not described. For example, the first item listed is "Electronic Evaluation." The section does not describe how a user of the document conducts this evaluation. Also, why have several of the methods (listed in Figure 5 and shown on Fig 7) been omitted from this section, e.g., full-scope simulator?

GE Response

Other evaluation methods will be considered in addition to those listed and discussed in NEDO-33268.

The instructions and procedures in question are common to the discipline of human factors engineering. The methods and results of the selected techniques will be summarized in the results summary report.

Other types of evaluations to be considered and their merit and conduct, including the simulator, will be further discussed in the next revision.

DCD Impact/LTR Impact

DCD Tier #2, Section 18.8 will be revised as appropriate.

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-35 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName /Question	Resolved	Plan	Section	Resolution Description
18.8-35	8	35	N	LTR NEDO-33268	From GE response	33217 33268	1.4.2(4) 3.3.5.6	Additional description of evaluation methods will be established in teamwork plans per MMIS and HFE Implementation plan guidance (33217:1.4.2(4)) and will be input to the style guide.
18.8-35	8	35	Y	Methods of evaluatio n 2	From GE response			See previous response

NRC RAI 18.8-35 S02

In the original RAI, the staff requested clarification of the methods of evaluation to be used. The descriptions of the methods of evaluation from the original RAI are now on Pages 37-38 of NEDO-33268, Revision 2 and have been slightly abbreviated. The same need for clarification still exists. The section still does not describe how a user of the document conducts the evaluations. Also, the lead-in paragraph references Figure 6, but Figure 6 does not address methods of evaluation. In Revision 0, the same paragraph referenced Figure 7, which did illustrate how multiple methods of evaluation can be sequenced, but this Figure has been removed in Revision 2. Please clarify.

GEH Response

The HSI work instructions will describe the methods for HSI Tests and Evaluations per NUREG-0711.

Tables 1-3, Figures 3-6, and the Appendix should have been deleted from the back of Revision 2. Any remaining references to them will be removed in our next revision as the contents are described adequately in text.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-41

NEDO-33268, Figure 2 lists a number of design inputs. Questions related to some of them are:

Where are the general human factors requirements listed?
What does HSI technology refer to?
Describe how is the minimum displays, controls and alarms list an input.
What does operating crew refer to?

GE Response

These questions clearly inquire about the contents of the first box in Figure 2. Human factors engineering takes a systems approach to the evaluation of tasks, situations, interfaces, or environment. Thus these are standard commonly known elements or contributing variables of systems, particularly related to the nuclear industry. These elements all bare information regarding the human in the system and each lends information about that system and the persons within the system.

Where are the general human factors requirements listed?

See RAI 18.8-1

What does HSI technology refer to?

HSI technology refers to conventional HSI, the predominant means for providing control input via hard-wired, spatially dedicated control devices that have fixed functions, and advanced HSI, the predominant means for providing control input via digital technology. GE will use NUREG-0700 for guidance of conventional HSI and NUREG/CR-6635 for guidance of advanced HSI. NUREG/CR-6635 provides guidance for:

- Soft Controls
- Computer-based procedures
- Information (display) design and organization
- Design analysis, evaluation, and implementation of hybrid HSIs
- Maintenance of digital systems

NEDO-33268 will be revised to establish the preparation of the ESBWR Human Factors Guidance Manual to include the above guidance for HSI design.

Describe how is the minimum displays, controls and alarms list an input.

Those items are elements with which the operating crew interfaces to work within the system and are derived from the operations analysis (See RAI 18.8-42).

What does operating crew refer to?

The preliminary staffing assumption for ESBWR crew for control and monitoring will consist of the following assignments:

Quantity	Qualification	Assignment
1	Control Room Supervisor[1]	Provides overall supervision of control room operations
2	Reactor Operators[2]	First operator is assigned to normal control actions at MCR HSI. Second operator is assigned to control of testing, surveillance and maintenance activities, including blocking and tagging permits.
1	Senior Reactor Operator (Shift Manager)[1]	Assigned to shift but not necessarily in the Main Control Room (MCR). Acts as manager of and relief for shift supervisor.
2	Auxiliary Operators[3]	Qualified to operate equipment in the plant.

[1] Licensed by the NRC as a Senior Reactor Operator (SRO)
[2] Licensed by the NRC
[3] Non-licensed, often called Auxiliary Equipment Operators (AEOs)

DCD Impact/LTR Impact

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

LTR NEDO-33268 Rev. 2 will include a revision as described above.

NRC RAI 18.8-41 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/ Question	Resolved	Plan	Section	Resolution Description
18.8-41	8	41	N	LTR NEDO-33268	From GE response	33268	3.2	Element added was the style guide see 18.8-1
18.8-41	8	41	Y	Design inputs	From GE response	33268	2.3	Guidance is appreciated and adopted. NUREG/CR-6635 was not referenced in the new revision.

NRC RAI 18.8-41 S02

In the original RAI, the Staff requested clarification of Figure 2 of NEDO-33268, Revision 0. GEH provided clarification in their response to RAIs of the staff's questions concerning the Figure. GEH indicated the NEDO would be revised to include the clarifying material, but it was not included. These clarifications included revising NEDO-33268 to establish the preparation of the ESBWR Human Factors Guidance Manual to include the guidance for HSI design from the RAI response (Note: Figure 2 is now Figure 3). These clarifications should be included in the next revision.

GEH Response

Tables 1-3, Figures 3-6, and the Appendix should have been deleted from Revision 2. Any remaining references to them will be removed in our next revision as the contents are described adequately in text.

Also in NRC RAI 18.8-2 S01, we noted that the ESBWR **human-system interface (HSI) work instructions** replace what has been referred to previously as a guidance manual or work plan – these latter two terms will no longer be used.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-49

The description of the standard features is not exactly the same when comparing the Tier 2 DCD and the HSI Design Implementation Plan. Please reconcile inconsistencies.

GE Response

These documents are under review and revision. All in-consistencies will be reconciled.

DCD Impact/LTR Impact

DCD Tier 2 changes will be made, if necessary, in Rev. 3 to resolve inconsistencies between the DCD and the LTR NEDO-33268.

LTR NEDO-33268 Rev. 2 will include a revision that resolves discrepancies between it and the DCD Tier 2.

NRC RAI 18.8-49 S01

(Editorial Note: GEH was asked by NRC to provide a Roadmap Document (MFN 07-334) that provided an explanation of where information went that was previously discussed in the original RAI response. This was Roadmap Document provided to NRC and the responses were considered to be supplemental responses based on the NRC requests. The following excerpt from the Roadmap Document provides the GEH response provided as the Supplement 1 response to this RAI.)

GEH Response

Chapter 18 Roadmap Document								
RAI NO	SEC	#	NRC Supplemental	DocName/ Question	Resolved	Plan	Section	Resolution Description
18.8-49	8	49	N	LTR NEDO-33268	From GE response	33268 DCD 2	3.3.5.1 18.1.3.1	DCD Tier 2 and 33268 documents are consistent on the topic of standard design features
18.8-49	8	49	Y	Standard features description	From GE response			See previous response

NRC RAI 18.8-49 S02

The HSI Design process is described in Section 18.8 of DCD Rev 3. The described process in not consistent with the process described in NEDO-33268, Revision 2. For example, the plan describes three major activities: concept design, style guide development, and detailed design and integration. Concept design is not addressed in DCD Section 18.8. Similarly, DCD Section 18.8 discusses "procedures governing permissible operator initiated changes to HSIs" that is not addressed in NEDO-33268, Revision 2. The DCD should be revised to be consistent with NEDO-33268, Revision 2 and any changes that result from modifications made as a result of these RAIs.

GEH Response

The HSI design process described in Section 18.8 of DCD Rev. 4 is consistent with the process described in NEDO-33268, Revision 2. NEDO-33268 describes three major activities: concept design, style guide development, and detailed design and integration. Concept design is summarily covered by section 18.8.1 HSI Design Implementation Plan of DCD Rev. 4. Although the term "concept" is not specifically mentioned, numerous concept design development approaches are included in section 18.8.1(1). NEDO-33268 applies these three major activities by method and then develops them through an implementation section. However, in order to provide consistency in documentation, the DCD section 18.8 will be enhanced to reflect the three sections for ease of use. Section 18.8.1(3) will be renamed 18.8.1(4) for the information concerning the results summary report.

DCD section 18.8.1(5) defers the HSI maintenance and update processes to DCD section 18.13 Human Performance Monitoring (HPM) that will be performed after the plant is in operation, by which: modifications are made, temporary modifications are made, operator defined HSIs are created, and procedures governing permissible operator initiated changes to HSIs. This process is contained in the Results Summary Report (RSR). The RSR is outlined in section 5.1 of NEDO-33268. NEDO-33268 will be changed to reflect this enhancement.

Specifically, NEDO-33268 will be revised to add the following at the end of Section 1.2 Scope:
"Operational aspects of the HSI process are addressed in the Human Performance Monitoring program, reference 2.1.2(12). These involve the process for refining and updating the HSI design, including:

- Modifying and updating the HSI
- Making temporary changes to the HSI
- Creating operator defined HSIs (temporary displays defined by operators for monitoring specific plant situations)
- Procedures governing permissible operator initiated changes to HSIs"

NEDO-33268, Section 5.1 Results Summary Report will be changed to remove the following:

- " The process for refining and updating HSI design including:
    - Modifying and updating the HSI
    - Making temporary changes to the HSI
    - Creating operator defined HSIs (temporary displays defined by operators for monitoring specific plant situations)
    - Procedures governing permissible operator initiated changes to HSIs"

DCD Impact/LTR Impact

DCD Tier #2, Section 18.8, Rev 4 will be revised as noted in the attached markup.

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-50

Concept of operations is briefly mentioned in Sections 3.1.3 and 3.3.5.4 of NEDO-33268, Revision 2. Additional clarification is needed as to how the concept of operations will be developed by the HFE team, what factors will be included in the concept of operations description, and how it will be documented. Note that the concept of operations is not identified in NEDO-33268, Revision 2, Section 5, Results.

GEH Response

To follow the guidelines regarding concept of operations as described in NUREG-0711, the Human-System Interface team will coordinate and collaborate with other GEH teams working on the following related NEDOs:

- NEDO-33219, ESBWR HFE Functional Requirements Analysis Plan Implementation Plan
- NEDO-33220, ESBWR HFE Allocation of Functions Implementation Plan
- NEDO-33221, ESBWR HFE Task Analysis
- NEDO-33266, ESBWR HFE Staffing and Qualifications Plan

The method for this coordination and collaboration will be described in HSI work instructions.

A new bullet, "Concept of operations from a Human-System Interface perspective", will be added to Section 5 Results.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-51

NEDO-33268, Revision 2, Section 3.1.3, states that the HFE team will develop functional requirements for the HSI that encompass the considerations identified in the two criteria for the Functional Requirements Specification. However, no additional information is provided. Additional clarification is needed as to how the requirements will be developed by the HFE team and how it will be documented. Note that the functional requirements are not identified in Section 5, Results.

GEH Response

To follow the guidelines regarding functional requirement specification as described in NUREG-0711, the team will follow the process illustrated in Figure 2 of NEDO-33268:

NEDO-33268

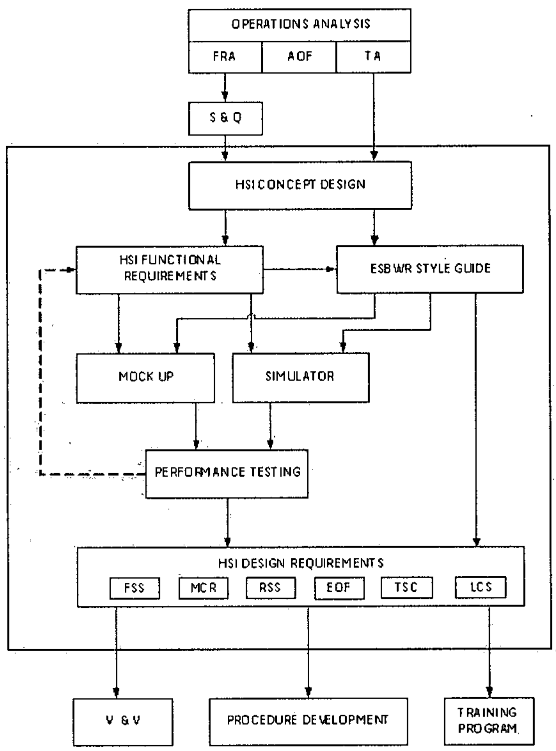


Figure 2 Human-System Interface Design Implementation Process

Human-System Interface Design Implementation Plan 83

The HSI work instructions provide the methodology.

The HSI Style Guide is the design requirements document. Design requirements will be entered into an industry-standard software requirements tracking/traceability tool.

A new bullet, "Functional requirement specification from a Human-System Interface perspective" will be added to Section 5 Results.

DCD Impact/LTR Impact

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

LTR NEDO-33268, Revision 2 will be revised as noted in the attached markup (See Attachment 1).

NRC RAI 18.8-52

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that with respect to risk-important actions, the design seeks to minimize the probability that errors occur and maximize the probability that an error is detected if one is made. However, no guidance is provided in the methodology for how this design objective will be achieved.

GEH Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items in Section 3.3.4, General Approach, list item numbers 3-9. Our response to each of these is the same:

The HSI work instructions provide the methodology.

DCD Impact/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 18.8-53

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that the factors identified in the criterion are to be considered in the development of requirements for monitoring and control capabilities. However, no guidance is provided in the methodology for how this design objective will be achieved.

GEH Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items in Section 3.3.4, General Approach, list item numbers 3-9. Our response to each of these is the same:

The HSI work instructions provide the methodology.

DCD Impact/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 18.8-54

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that the layout of HSIs will be based on the considerations presented in the review criterion. However, no guidance is provided in the methodology for how this design objective will be achieved.

GEH Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items in Section 3.3.4, General Approach, list item numbers 3-9. Our response to each of these is the same:

The HSI work instructions provide the methodology.

DCD Impact/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 18.8-55

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that personnel performance during minimal, nominal, and high staffing levels should be considered. However, no guidance is provided in the methodology for how this design objective will be achieved.

GEH Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items in Section 3.3.4, General Approach, list item numbers 3-9. Our response to each of these is the same:

The HSI work instructions provide the methodology.

DCD Impact/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 18.8-56

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that the designer should consider use of the HSIs over a shift. However, no guidance is provided in the methodology for how this design objective will be achieved.

GEH Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items in Section 3.3.4, General Approach, list item numbers 3-9. Our response to each of these is the same:

The HSI work instructions provide the methodology.

DCD Impact/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 18.8-57

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that the designer should consider use of HSIs under a full range of environmental conditions. However, no guidance is provided in the methodology for how this design objective will be achieved.

GEH Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items in Section 3.3.4, General Approach, list item numbers 3-9. Our response to each of these is the same:

The HSI work instructions provide the methodology.

DCD Impact/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 18.8-58

In NEDO-33268, Revision 2, Section 3.3.4 General Approach, GEH states that the designer should consider HSI support for test, inspection, and maintenance activities. However, no guidance is provided in the methodology for how this design objective will be achieved.

GE Response

NRC RAI 18.8-52 through NRC RAI 18.8-58 are 7 RAIs that address the same list of items on pages 27-28, 3.3.4 General Approach, list item numbers 3-9. Our response to each of these is the same:

The ESBWR HSI Work Instructions provide the methodology.

DCD Impact/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 18.8-59

With respect to trade-off evaluations, how are the factors identified in NEDO-33268, Revision 2, Page 33 used to develop selection criteria and how are they applied by the HFE engineer. And how will the HFE engineer determine the relative benefits of design alternatives and document the bases for their selection. In addition, what guidance will be provided to design engineers for the conduct of performance-based tests, including the selection of participants, testbeds, performance measures, and analyses?

GEH Response

To follow the guidelines for HSI Tests and Evaluations as described in NUREG-0711, the methodology for the conduct of performance-based tests, including the selection of participants, test beds, performance measures, and analyses will be detailed within the HSI work instructions. The results will be included in the results summary report.

The HSI Style Guide is the design requirements document. Design requirements will be entered into an industry-standard software requirements tracking/traceability tool.

Trade-off evaluations will be done on a case-by-case basis, and any design decisions that deviate from the original requirements will be documented as part of the requirements tracking and in the results summary report.

DCD Impact/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.

MFN 08-050

Attachment 1

Markups and Added Text for RAIs

18.8-2 S01, 18.8-8 S02, 18.8-16 S02,

18.8-17 S02, 18.8-18 S02, 18.8-31 S02,

18.8-32 S02, 18.8-33 S02, 18.8-35 S02,

18.8-41 S02, 18.8-49 S02, 18.8-50, and 18.8-51

Attachment for RAIs

18.8-2 S01, 18.8-33 S02, 18.8-35 S02, 18.8-41 S02

3 METHODS

This document meets the following objectives:

1. Describes the HSI design process
2. Presents the HSI Implementation Plan and the proposed HSI style guide that is used to execute the design process
3. Provides guidance to the HSI design team members to understand their roles and direct their design activities
4. Provides illustration to regulatory authorities that the new HSI is designed following the process guidance found in the respective industry documents
5. Means to select technology for design application (presented in the HISI style guide)

3.1 Concept Design

The HFE team uses several approaches for developing a concept design as described in NUREG-0711, Rev. 2. The operational analysis (including development of a functional requirement specification), modification of predecessor designs, surveys of the state-of-the-art in HSI technologies, and predecessor and ABWR reference designs contribute significantly to HSI development. Human performance issues identified from previous operating experience with the predecessor designs are resolved in the conceptual design.

Evaluation of the conceptual design includes comparison with operating experience and literature analyses, tradeoff studies, engineering evaluations, and experiments. Alternative concept designs are considered for elements of the HSI. Evaluations provide reasonable assurance that the selection process is based on a thorough review of design characteristics and a systematic application of selection criteria. Tradeoff analyses, based on the selection criteria, provide a rational basis for the selection of concept designs. HSI design performance requirements are identified for components of the selected HSI concept design. These requirements are based on the functional requirement specifications but are refined to reflect HSI technology considerations identified in the survey of the state of the art in HSI technologies and human performance considerations identified in the human performance research. ~~A flow chart that illustrates the process for designing computer-generated displays is shown in Figure 3~~[r1].

3.1.1 Background

Revision 2 of NUREG-0700 provides the base guidance for the ESBWR HSI design process. NUREG-0700 was first published (Revision 0) in 1981 as a response to the Three Mile Island (TMI) accident. Following TMI, all U.S. nuclear power plants were required to conduct detailed control room design reviews (DCRDRs), including review of remote shutdown panels, to identify and correct human factors design deficiencies. NUREG-0700 Revision 0 provided extensive guidelines to support those reviews. Revision 1 to NUREG-0700, published in June 1996, updates the guidance to address the emergence of advanced HSI technologies into nuclear power plant design. Revision 2 published in May 2002 has expanded the guideline information included in the following areas:

- Training program
- Procedure program
- Validation and Verification (V&V)
- Human Performance Monitoring (HPM)
- HFEITS

Figure 2 outlines the flow of information and processes within the HSI design process. The first step in this process is the HSI concept design, which lays out the overall framework from which the ESBWR style guide and the detailed HSI design are developed and refined.

~~The data input into HSI concept design is processed as shown in Figure 3.~~ A summary of the HSI design process is presented in the following steps:

Step 1: Workspace and Environmental Conditions Design

The external MCR and RSS display features are defined including general layout, fields of vision, access and egress, seating, procedure lay down areas, general anthropometric dimensions, and environmental temperature/humidity expectations.

Step 2: Panel Layout Design

The components mounted on the MCR and RSS panels and console, and their organization and arrangement are defined.

Step 3: Alarm System Design

The alarm system is defined including conceptual display hierarchy, presentation, and layout.

Step 4: Displays and Control Design

The information and controls requirements derived from the operational analysis and other inputs ~~(Figure 3)~~ are implemented into the MCR and RSS components.

Step 5: Communication System Design

Design aspects of a communication system are defined.

3.1.5 Application

A most critical question for the behavioral specialist is: Who is the user and/or operator of the system to be designed? More important, what is this human supposed to do? The behavioral specialist is aware of the physical functions to be performed by the system (because these determine the behavioral functions the human performs), but the primary concern is the derivation of behavioral functions from physical ones.

For example, if a display is presented to the operator of a system, the behavioral functions of monitoring, analyzing, and interpreting are inevitably involved. The more information provided been used to facilitate HSI designs that support safe, efficient and reliable operator performance during all phases of normal plant operation, abnormal events and accident conditions, as well as for maintenance, test, surveillance, and inspection activities. To achieve operator performance goals, information, displays, controls, and other interface devices in the control room and other plant areas are systematically designed and implemented consistent with good HFE practices.

3.3.5.6 Tests and Evaluations

The HFE team develops testing and evaluation plans for the HSI designs that are iteratively conducted throughout the HSI development process. The types of tests and evaluations performed vary depending on the specific point in the design process ~~(Figure 4)~~.

The methodology used for testing applies the following criteria:

Trade-Off Evaluations

To adequately consider human performance the HFE team uses the following example factors when performing trade-off analyses and evaluations to make design choices.

- Personnel task requirements
- Human performance capabilities and limitations
- HSI system performance requirements
- Inspection and testing requirements
- Maintenance requirements
- Use of proven technology and the operating experience of predecessor designs

The HFE team makes trade-off evaluations to determine the relative benefits of selected design alternatives.

Performance-Based Tests

The HFE team plans performance-based tests to address the specific questions and design features being addressed. The tests and selection of participants, depends on the purpose of the evaluation, the questions being addressed, and the maturity of the design. The performance measures consider measurement characteristics, identification and selection of variables, and performance criteria. Testbed selection is based on test requirements and design maturity.

To the degree possible the test design minimizes bias, confounds, and error variance (noise). ~~Test data is collected using appropriate techniques such as those shown in Figure 5.~~ Design solutions are developed to address problems that are identified during the testing and evaluation of the HSI design.

The following performance measures are included in the test plan as appropriate for the specific test being performed:

- Systems measures relevant to plant safety (avoiding alarm conditions and technical specification violations)

- ~~Relative complexity~~
- ~~Relative cost~~
- ~~Relative cost effectiveness~~
- ~~Demonstrated by use of dynamic displays, simulator, and so forth~~

Criteria [r4]that may be used in selecting HFE techniques are the following:

a. Safety and/or risk significance

b. Type of design (taking into account the type of design, there are some techniques that may not apply)

c. Type of technology

d. Relative time to perform

e. Relative complexity

f. Relative cost

g. Relative cost effectiveness

h. Demonstrated by use of dynamic displays, simulator, and so forth

The design evaluation is based on the objectives of the systems design. What should the system do, who will use it, where will it be used and when will it be used? If the objectives are clear, the evaluation of the results is made simpler. Numerous methods are available for evaluation of designs. ~~Figures 4 and 5 provide guidance on selecting appropriate and useful methods.~~

Definition of the Design/Evaluation Tools for the HSI Design Analyses

~~Considering the criteria listed in Section 3 and criteria to be used in selecting HFE/HSI Design and Evaluation Tools, the following techniques are used in the conduct of the HSI design analyses.~~ Checklists, drawings, mock-ups, and questionnaires and interviews will be used as described below to gather HSI Tests and Evaluations data and information.

Design Criteria Checklist

A checklist includes a series of equipment and facilities design requirements taken from human engineering standards and guides that address HSIs. The checklist is divided into categories of design criteria corresponding to major equipment or facilities. These categories might consist of visual displays, audio displays, controls, and so forth; NUREG-0700 Rev. 2 provides examples of checklist formats.

Drawings

Engineering drawings or sketches of interest to the HFE Design Team may be further categorized as:

Evaluation is an integral part of the design process, with the results of evaluation efforts leading to interaction through the other phases of the design process. Therefore, planning for evaluation proceeds in parallel with design rather than after a prototype design has emerged.

It is necessary to establish the objectives of the design prior to the evaluation.

The evaluation process, which is to be efficient in terms of both time and cost, is an integral part of design. The evaluation process is iterative in the sense of including multiple phases of evaluation, with the results of each phase being used to enhance the design of the system as necessary to meet HFE goals.

The combined objectives of efficiency and design-oriented successive refinement dictate that the overall evaluation process includes multiple evaluation methods. Alternative methods may range from checklists or paper/electronic evaluations to part-task and full-scope simulator evaluations. The sequencing of these methods depends on the nature of the evaluative issues being addressed. There are three basic types of issues:

1. Compatibility

   A system is compatible to the extent that the physical presentations to the operator and the responses expected from the operator are consistent with human input-output abilities and limitations.

2. Understandability

   A system is understandable if the structure, format and content of the operator-system dialogue result in meaningful communication.

3. Effectiveness

   A system is effective to the extent that it supports an operator (or crew) in a manner that leads to improved performance, results in a difficult task being less difficult, or enables accomplishing a task that could not otherwise be accomplished.

Methods of Evaluation

~~Figure 6 illustrates how multiple methods are sequenced to pursue the evaluation issues. This figure is not meant to imply that all five types of evaluation (that is, electronic, paper, part-task, full-scope, and in-plant) are required for every evaluation effort. The methods employed first are those that are relatively fast and inexpensive and that can be employed earliest in the design process.~~

Electronic, paper and part-task simulator evaluation methods are used in the design phase. Full-scope simulator and in-plant evaluation methods are used in the integrated verification and validation process.

1. Electronic Evaluation

Figure ~~3~~2 shows how the system functional requirements analysis, allocation of functions and task analysis implementation plans are interrelated and provide input to the HSI design.

The system functional requirements analysis determines the performance requirements and constraints of the HSI design and establishes the functions, which are accomplished to meet these requirements.

The allocation of functions to personnel, systems or personnel-system combinations is made to reflect: sensitivity, precision, time and safety requirements, required reliability of system performance, and the number and level of skills of personnel required to operate each system.

The task analysis identifies the behavioral requirements of the tasks associated with individual functions.

The types of task requirements information that are identified in the task analysis, include:

a. Information and Decision-Making Requirements
b. Response Requirements
c. Feedback required for monitoring and evaluating the adequacy of actions taken.
d. Cognitive and physical workload demands
e. Task Support Requirements
f. Workplace Factors
g. Staffing and Communication Requirements
h. Potential Hazard Identification

The HSI design is based on the staffing requirements defined in the staffing and qualification plan. The MCR staff, size and roles are finalized after the completion of the V&V activities.

Operating Experience Review of Previous NPP MMIS Designs

Operating experience lessons learned from events, operational problems, and enhancement opportunities from previous plant HSI designs is gathered, categorized, and provided to HSI designers. This information has been gathered and maintained in the OER/BRR database for generating lessons learned involving HFE issues. It is used to correct and enhance HSI design issues to improve overall HSI effectiveness. This process also provides for the continuous review and improvement of the HSI as ESBWR specific operating experience is gathered over time.

Other Industries

The HFE Design Team reviews HSIs being used in other industries such as fossil plants, aerospace, petrochemical, and so forth for features and approaches applicable to the ESBWR. Some design features used in other industries and considered for use in the ESBWR HSI include:

b. Type of design (taking into account the type of design, there are some techniques that may not apply)

c. Type of technology ~~(in accordance with EPRI URD NP-5795, the MCR design uses proven technology. Advanced systems, equipment, software and firmware may be justified if proven in other applications as defined in the EPRI URD NP-5795, or in ABWRs)~~

d. Relative time to perform

e. Relative complexity

f. Relative cost

g. Relative cost effectiveness

h. Demonstrated by use of dynamic displays, simulator, and so forth

The design evaluation is based on the objectives of the systems design. What should the system do, who will use it, where will it be used and when will it be used?. Numerous methods are available for evaluation of designs. ~~Figures 4 and 5 provide guidance on selecting appropriate and useful methods[r6].~~

4.3.4.7 **Procedures**

An implicit design goal in most discussions of human-system interfaces is that system design enables users, to be in control of the technology.

Procedures enable users to accomplish daily tasks adequately. However, without at least a common-sense understanding of how the procedures relate to the underlying system, users are unable to adapt them to new situations, to deal with either system malfunctions or the consequences of their own errors, or to adapt to new or evolving systems.

The HSI pertinent to procedures and their use is applied in meaningful ways that accommodate these concerns. A basis of user system understanding is developed along with procedures. Thus full generalization and well-informed procedure development and use are enabled.

4.3.4.8 **Panels and Consoles**

The physical elements of the HSI are organized into workstations at which plant personnel carry out the tasks of monitoring and controlling the ESBWR. Workstations are stand-up, sit-down or a combination of both. HFE principles governing attributes such as reach, field of vision, and comfort are integral to the alternatives contained in the HSI style guide and are therefore incorporated into the design.

Size and shape of HSI equipment such as: control consoles, desks, boards, panels and chairs are determined from the anthropometric requirements and other human engineering considerations. Details considered during workstation design include (adapted from NUREG-0700, Rev. 2):

- Workstation height (operators, supervisors, and any other)

Table 1

Summary of accident monitoring variable types/source documents

Type[1]	Selection Criteria for a measured plant variable [1]	Typical Source Documents[2]
A	Variable supports planned manual controlled actions to accomplish safety related function for which there is no automatic control.	Plant Accident Analysis Licensing Basis EPGs or plant specific EOPs[3] Plant AOPs[3]
B	Variable supports the process of assessing actions for accomplishing or maintaining plant critical safety functions.	Functional restoration EPGs or plant specific EOPs[3] Plant critical safety functions related to the EOPs Plant Critical safety function status tree
C	Variable indicates the potential for or actual breach of the three fission product barriers.	Plant Accident Analysis Licensing Basis Design basis for the fission product barriers EPGs or plant specific EOPs[3]
D	Variable indicates the performance of safety systems. Variable indicates the performance of auxiliary supporting features Variable indicates the performance of other systems necessary to achieve and maintain safe shutdown conditions. Variable verifies safety status	Plant Accident Analysis Licensing Basis Event specific EPGs or plant specific EOPs[3] Functional restoration EPGs or plant specific EOPs[3] Plant AOPs[3]
E	Variable monitors the magnitude of radioactive material releases through identified pathways Variable monitors the environment conditions used to determine the impact of releases of radioactive material through identified pathways Variable monitors the radiation levels and radioactivity in the plant environs. Variable monitors the radiation levels and radioactivity in the control room and selected plant areas where access may be required for recovery.	Procedures for determining radiological releases through plant identified pathways Procedures for determining plant environs radiological concentration Procedures for determining plant habitability

Notes

[1] The classification and definitions are from IEEE Std. 497-2002

[2] The identification of the manual action is developed through the Allocation of functions, the Task Analysis and the PRA/HRA

[3] During Design the results of allocation of functions and task analysis are substituted prior to EPG, EOP and AOP development

~~Table 2~~
~~Example of Coding Scheme~~

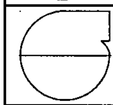
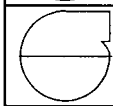
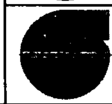
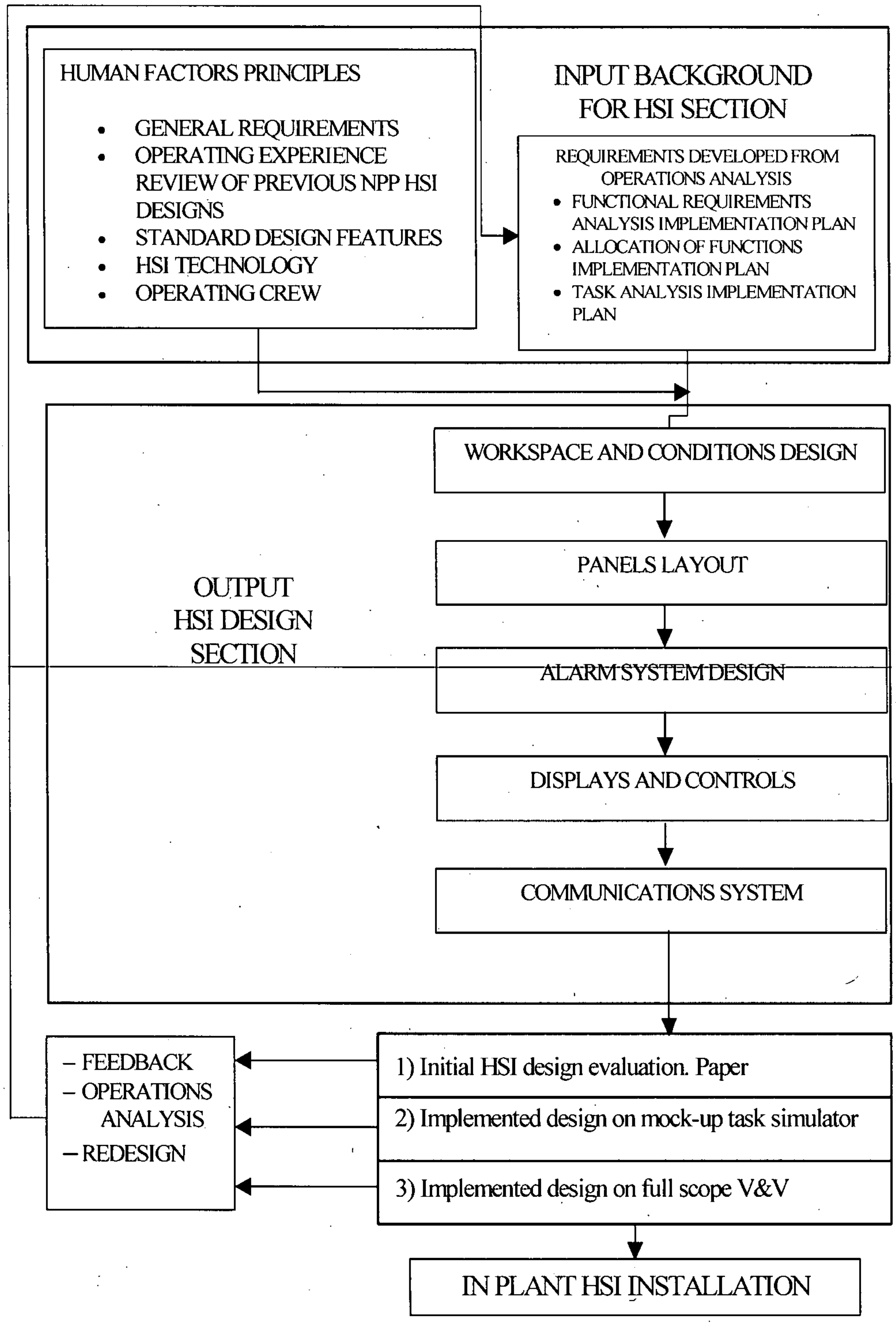
~~Equipment/ Component~~	~~Symbol~~	~~Color~~	~~Shape~~	~~Status~~	~~Condition~~
~~Pump~~		~~tbd~~	~~Filled~~	~~Running~~	~~Normal~~
		~~tbd~~	~~Hollow~~	~~Not Running~~	~~Normal~~
		~~tbd~~	~~Hollow~~	~~Not Running~~	~~Abnormal (Should be running)~~
		~~tbd~~	~~Filled~~	~~Running~~	~~Abnormal (Should not be running)~~

Table 3
Example Displays and Controls for DCIS Operation

System Operating Mode/Task	Qualitative Information Needed	Quantitative Information Needed	Controls Needed	MCR	Back Panel	Local
Normal	PAS Subloop Automation Failure Status	None	None	x		
Normal	PAS Mode Status Pushbutton Switch	None	PAS Manual Mode PAS Semi-Automatic Mode PAS Automatic Mode	x		
Normal	PAS Phase Pushbutton Switch	None	PAS Startup PAS Shutdown PACS Power Range			
Normal	DCIS Operating Status	None	None	x		
Normal	Alarm Processing Operating Status	None	None	x		
Normal	Display Processing Operating Status	None	None	x		
Normal	Procedure Tracking Operating Status	None	None	x		
Normal	Fixed Mimic Display Operating Status	None	None	x		
Normal	Data Acquisition/ Communication Operating Status	None	None	x		
Normal	Data Recording Operating Status	None	None	x		
Normal	Data Archive Operating Status	None	None	x		
Normal	Reactor Core Monitoring Operating Status	None	None	x		
Normal	Tech Spec Monitoring Operating Status	None	None	x		
Normal	Safety System Monitoring Operating Status	None	None	x		
Normal	Thermal Performance Monitoring Operating Status	None	None	x		
Normal	SPDS Operating Status	None	None	x		
Normal	Large Variable Display Operating Status	None	None	x		



~~**Figure 3 Design Process Block Diagram**~~

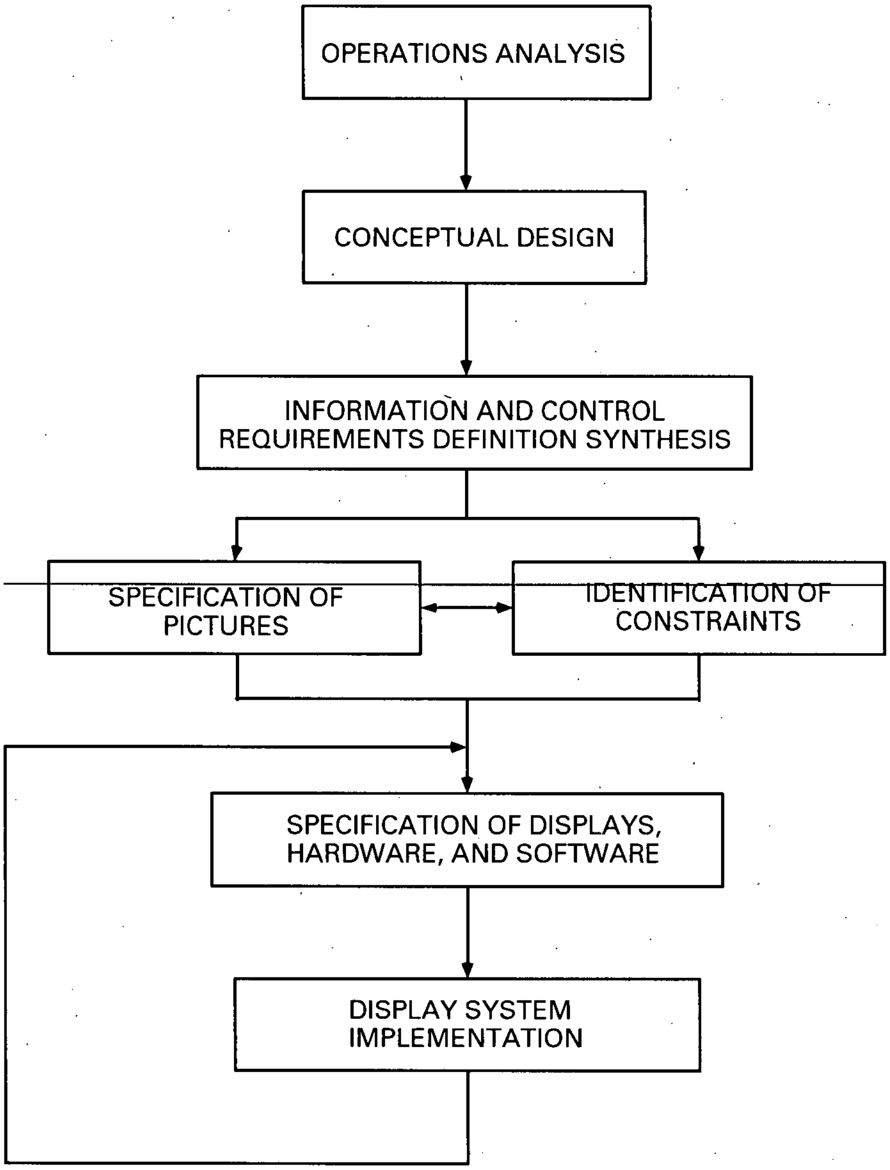


Figure 4 Flow Chart of Elements for Design of Computer-Generated Displays

	SCENARIO GENERATION	WORKLOAD ANALYSIS	PERFORMANCE MODELS	MMI EVALUATION	EVALUATION OF ALTERNATIVE DESIGNS	AUTOMATION IMPACT
~~CHECKLISTS~~	~~1~~	~~na~~	~~na~~	~~1~~	~~1~~	~~2~~
SUBJECT MATTER EXPERT INTERVIEWS	1	2	1	2	2	1
SUBJECT MATTER EXPERT RATINGS, RANKINGS	2	1	1	1	1	1
DIRECT OBSERVATION	2	1	1	1	2	na
EXPERIMENTS	na	2	2	1	1	1
DIRECT MEASUREMENTS	na	na	na	1	na	na
ANALYSIS OF HISTORIES	2	2	1	2	2	na

1 = VERY USEFUL
2 = USEFUL
na = NOT APPLICABLE

~~**Figure 5 Appropriate Data Collection Methods for HFE Activities**~~

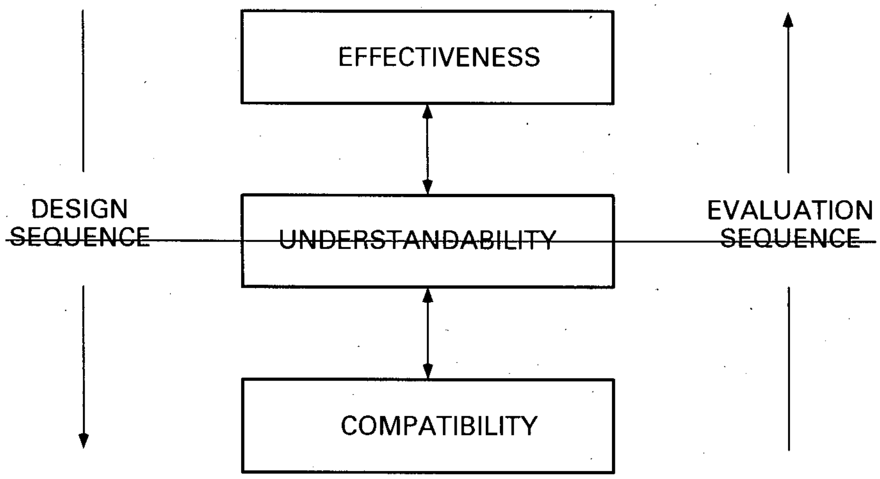


Figure 6 Levels of Design and Evaluation

Appendix A: Human Factor Principles Derived From Operating Experience Reviews of Previous NPP HSI Designs

A.1 Control Room Design

1. The large size of the control room and console and their configuration contributed to operator dissatisfaction.
2. Traffic flows should not be impeded by placement of consoles.
3. Adequate levels of illumination are necessary to ensure that visual effectiveness is sufficient for task performance. Emergency lighting should be available.
4. Noise levels in the MCR should be maintained within acceptable industry levels.
5. The climate control system in the control room should be capable of continuously maintaining temperature and humidity within the human comfort zone.
6. Convenient storage should be provided so that procedures, logs, and drawings needed for routine job performance are conveniently available. Storage should also be provided for equipment needed for emergency operation.

A.2 Control Board Design

1. Control boards should be optimized for minimum manning.
2. Panels in the control rooms were observed to have large arrays of identical controls and displays and repetitive labels. The systems, subsystems, and components should be separated by appropriate demarcation methods.
3. Controls and related displays should be located in close proximity so that the two items are readily associated and can be used conveniently with one another. Controls should be placed in an obvious and consistent order. The displays and controls used to monitor major system functions should be assigned to and arranged in functional groups.
4. Flow arrangements between VDU display formats and controls on panels should not differ.
5. Flow mimics should be used to aid (and not unintentionally mislead) the operators.
6. Panel arrangements for similar systems should be the same.
7. Location of controls in areas and orientations that render them vulnerable to accidental contact and disturbance should be avoided.
8. Unclear, illogical, overly complex, or mirror-imaged control board or panel layout arrangements have been observed to promote operational mishaps and should be avoided.

A.3 Computer

1. Computer data should be available on VDU.
2. Computer audible alarms should not be distracting.

A.4 VDU Displays

1. The nomenclature, labeling, and arrangement of systems on the VDU displays should be similar to the panels.

2.VDU displays should be comprehensible with a minimum of visual search. When data is presented in lines and columns, the lines of data should be separated by a space (blank line), one character high, every 4-5 lines.

3.Display access should be efficient and require a minimum of keystrokes.

4.VDU displays should have convenient brightness, focus, and degauss controls.

5.The character height should be the appropriate height for the viewing distance during normal and emergency conditions.

6.Visibility of VDU displays should not be affected by glare.

A.5 Anthropometric

1.Panel dimensions should accommodate the 5th- to 95th-percentile range of the user population to ensure that personnel can see and reach the displays and controls or the front and back panels. Displays should not be placed beyond the visual range of the operators.

2.Controls should not be located in the control panels that require the operator to lean into the panel. This is a potential health risk to the operator and to the equipment.

A.6 Controls

1.Large controls were observed to have been used in place of preferred smaller controls. Larger controls impact panel size and should be avoided.

2.Labeling or coding techniques should be used to differentiate controls and indicator lights of similar appearance.

3.Control configurations should not introduce parallax problems.

4.Control switches that must be held by the operator for operation should be avoided unless necessary.

5.Projecting control handles should not cover or obstruct labels.

6.Key lock switches requiring administrative control should be avoided if possible.

7.Control handles should not be difficult to operate and should not cause the operators to resort to using unauthorized mechanical leveraging devices (that is, "cheaters") to achieve reduced difficulty in operation.

8.Controls should be built and installed following standard conventions for OPEN/CLOSE and INCREASE/DECREASE. Setpoint scales should not move up in response to a downward movement of the controller thumbwheel.

9.Inadvertent operation of adjacent controls may be reduced through the use of shape coding such as using similar shaped handles for similar functions (that is, pistol grips for pumps and round handles for valves).

A.7 Indicator Lights

1.Instances of improper use of qualitative indicators were observed where quantitative displays such as meters would be more effective.

2.Light status (on/off) should be visible to the operator. Extinguished bulbs should be obvious and a test method provided. Lamp designs should allow for easy access for lamp removal.

~~3.The use of so-called negative indications (the absence of an indication) should not be used to convey information to the operator.~~

~~4.Indicator design selection and layout should be standardized to conserve panel space.~~

~~5.A color code standard should be established for indicating lights.~~

~~A.8 Display and Information Processing~~

~~1.Plant parameter validity should not have to be inferred. In addition to secondary information, the quality or validity of the displayed parameter should be available to allow operators to readily identify improper ESF or other safety equipment status under various operating modes.~~

~~2.Necessary information should be available during events such as SBO (Station Black Out) and LOOP (Loss Of Offsite Power). Systems and indications such as Neutron Monitoring System, control rod position indication, and drywell area radiation indication should all be available during these events.~~

~~3.The MCR should contain an integrating overview display. The overview display should provide a limited number of key operating parameters.~~

~~4.The operators should use the same displays that are used during normal operation during accident conditions to ensure their familiarity with the interface.~~

~~A.9 Meters~~

~~1.Proper use of minor, intermediate, and major scale markings in association with scale numerals should be made. Formats should be customized to take into account identification of normal operating values and limits. Scale numerical progressions and formats should be selected for the process parameter being presented.~~

~~2.Placement of meters above and below eye level, making the upper and lower segment of the scale difficult to read, (especially with curved scales), can present parallax problems.~~

~~3.Meters were observed that fail with the pointer reading in the normal operating band of the scale. The instrument design should allow the operator to determine a valid indication from a failed indication.~~

~~4.Placement of meters on panels should prevent glare and reflections caused by overhead illumination.~~

~~5.Where redundant channels of instrumentation exist, software-based displays should provide for easy inspection of the source data and intermediate results without the need to display them continuously.~~

~~6.Data presented to the operator should be in a usable form and not require the operator to calculate its value. Scale graduations should be consistent and easily readable. Zone markings should be provided to aid in data interpretation.~~

~~7.Meter pointers should not obscure the scale on meters.~~

~~8.Process units between the control room instruments and the operating procedures should be consistent.~~

~~A.10 Chart Recorders~~

1.Recorders should not be used in place of meters. Recorders should be selected with consideration given to minimizing required maintenance and high reliability.

2. A recorder designed to monitor 24 parameters was observed to have 42 parameters assigned to it. This makes it extremely difficult to read the numerical outputs on the chart paper. The inputs assigned should be consistent with the design of the recorder.

3.Operational limits should be defined on recorders. Proper selection of recorder scales will eliminate the need for overlays. The units for the process should be labeled on the recorder.

4.Monitored inputs should be assigned to recorder pens in alphabetical order. The correlation of pen color to input parameter should be clearly defined by multi-pen recorder labels.

5.The change of chart speed should also be noted on the chart paper when the paper is changed. The paper scales should match the fixed scales.

6.Recorders should have fast speed and point select capability.

7.Proper placement of recorders and adequate illumination should prevent glare and parallax problems with recorder faces.

8.The pointers should not cover the graduation marks.

9.When upper and lower pens coincide, the printout of the upper scale should still be visible.

A.11 Annunciator Warning Systems

1.Annunciators should be located near the control board panel elements to which they are related. Divisional arrangements should be consistent. Annunciators should be functionally located near the applicable System.

2."Advisory alarms" reporting expected conditions should not be grouped with true alarms. The audio and visual warning system signal should be prioritized to reduce the audio and visual burden placed on the operators during an event.

3.Some alarms were observed to lack specificity. Multi-input alarms, for example, xyz pressure/levels, hi/lo, frustrate, rather than inform the operator.

4.Excessive alarms were observed during emergency conditions. Auditory signals should be coded to aid the operator in determining the panel location.

5.Alarm operating sequence control should be placed at specific locations to encourage operator acknowledgment.

6.For standing and sit-down workstations, window size and lettering height should be consistent with the viewing distance.

7.The labels should use consistent abbreviations and nomenclature and not be ambiguous.

8.For traceability to response procedures, the windows should be identified with a location reference code.

9.A consistent color-coding convention should be employed.

10.A "First Out" feature should be provided that presents prioritized parameters important to safety parameters for immediate operator response.

11.Means should be provided for identification of out-of-service annunciators.

12. Annunciators for conditions, which signal an EOP entry condition, should be located based on the functional analysis.

A.12 Coding of Displays and Controls

1. The color codes for the control boards should be systematically applied. Effective color-coding should be used to aid in differentiating between identical controls placed in close proximity.

2. The coding of indicators should inform the operator whether a valve is open or closed.

3. Systematic approach to color and shape coding of controls should be taken.

A.13 Labeling

1. Label abbreviations, numbering, and nomenclature should be consistent. A label placement standard for the control room should be established. Labels should be placed consistently above or below the panel elements being identified and not placed between two components.

2. Hierarchical labeling schemes including size coding or differentiation of labels should be used to identify major console panels, sub-panels, and panel elements. Hierarchical labeling will eliminate the need to place redundant labels on control or display devices.

3. The content of the labels should be consistent with the procedures used by the operators.

4. The labels should meet the readability guidelines and should not be obscured by the equipment that they mounted near. A control room standard for labels should be established that address label character size and font.

5. Maintenance tags should not obscure or panel components such as displays.

6. To minimize the mispositioning of valves and other equipment, the controls and displays should be labeled with the unique number or name of the valve or piece of equipment.

A.14 Communications

1. Communications in the control room should consider the ambient noise levels in the control room and plant. The control room operator should be able to communicate with necessary personnel in the plant. Communication equipment should also be provided at the remote shutdown panel.

2. Communications equipment design should not limit the operator's access to the controls or displays.

3. The communication system should be accessible from the operator's workstations.

A.15 Task Analysis

1. Controls and displays should be located for effective operator response to postulated events. Information needed by the operator in the control room should be readily available and not located at remote panels in the plant.

2. In addition to normal and emergency conditions, plant displays and controls should also consider low power and shutdown scenario information requirements.

A.16 Procedures

1. The measurement units in the procedure and the values indicated on display scales should be consistent.
2. Control board designs should make provisions for the operator's simultaneous referral to the procedures and the operation of the control boards.
3. The parameters displayed on electronic information systems or on the control boards should be designed to support the EOPs as well as other required monitoring tasks.
4. The safety function parameter status should be presented in an organized, readily accessible format compatible with the EOPs.
5. A procedure should address operator action in the event of computer, VDU, or printer problems or complete failure.

A.17 Operator Errors

1. Operator mishaps were observed to be caused by the absence of a timely, attention-getting indication (either qualitative or quantitative) that informs the operator that some element of the system is not operating properly.
2. Operator mishaps were also observed to result from incorrect lineup of valves.

A.18 Maintenance and Testing

1. The MCR should be designed in such a way that minimizes the need for maintenance and test personnel to work, or at least limit their presence, in the control room.
2. Control room displays should be designed and installed for easy calibration and replacement.
3. Access for inspection, operation, and routine maintenance of components should not be restrictive.

Attachment for RAI

18.8-8 S02

2 APPLICABLE DOCUMENTS

2.1 Supporting and Supplemental GE Documents

2.1.1 Supporting Documents

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

1. NP-2010 COL Owner's Group Demonstration Project Quality Assurance Plan, NEDO-33181

2. ESBWR Design Control Document Chapters 7 (26A6642AW)

3. ESBWR Design Control Document Chapter 18 (26A6642BX)~~(26A6642BX)~~

2.1.2 Supplemental Documents

1. NEDO-33262, ESBWR HFE Operating Experience Review Implementation Plan
2. NEDO-33219, ESBWR HFE Functional Requirements Analysis Plan Implementation Plan
3. NEDO-33220, ESBWR HFE Allocation of Functions Implementation Plan
4. NEDO-33221, ESBWR HFE Task Analysis
5. NEDO-33266, ESBWR HFE Staffing and Qualifications Plan
6. NEDO-33267, ESBWR HFE Human Reliability Analysis Implementation Plan
7. NEDO-33217~~68~~, ESBWR Man-Machine Interface System and Human Factors Engineering Implementation Plan
8. NEDO-33223, ESBWR HFE Verification and Validation Plan
9. NEDO-33224, ESBWR HFE Procedure Development Plan
10. NEDO-33275, ESBWR HFE Training Program Development Plan
11. NEDO-33278, ESBWR HFE Design Implementation Plan
12. NEDO-33277, ESBWR HFE Human Performance Monitoring Implementation Plan

2.2 ~~Codes and Standards~~

~~1.IEEE Std 1023-2004, Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating stations~~

~~2.IEEE Std 1012-1998, IEEE Standard for Verification and Validation Plans~~

2.3 Regulatory Guidelines

1. 10 CFR 50, Domestic Licensing of Production and Utilization Facilities, December 1981

2. 10 CFR 73, Physical Protection of Plants and Materials, Paragraph 55, August 1980

3. NUREG-0696, Functional Criteria for Emergency Response Facilities, 1980

4. 1. NUREG-0700, Rev. 2 Human System Interface Design Review Guideline, 2002

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

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

6. NUREG-0737, Supplement 1, Requirements for Emergency Response Capability, 1980

7. NUREG-0800, Standard Review Plan (SRP), Chapter 18 – Human Factors Engineering, 2004

8. NUREG-0835, Human Factors Acceptance Criteria for the Safety Parameter Display System, 1983

9. NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982

10. NUREG/CR-3331, A Methodology for Allocating Nuclear Power Plant Control. Functions to Human and Automated Control, 1983, (US Nuclear Regulatory Commission)

11. NUREG/CR-4227, Human Engineering Guidelines for the Evaluation and Assessment of Video Display Units, 1985

12. NUREG/CR-5228, Techniques for Preparing Flowchart Format Emergency Operating Procedures (Vols. 1 & 2), 1989

13. NUREG/CR-5439, Human Factors Issues Associated with Advanced Instrumentation and Controls Technologies in Nuclear Plants, 1990

14. Regulatory Guide 1.97, Rev. 4, Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident

2.4 DOD and DOE Documents

1. AD/A223 168, System Engineering Management Guide. (Defense Systems Management College, Kockler, F., et. al.), 1990

2. DOD-HDBK-761A, Human Engineering Guidelines for Management Information Systems, 1989

3. DOD-HDBK-763, Human Engineering Procedures Guide, 1987

4.DOE-HDBK-1140-2001 Human Factors/Ergonomics Handbook for the Design for Ease of Maintenance

5.ESD-TR-86-278, Guidelines for Designing User Interface Software, 1986

6.MIL-H-46855B, Human Engineering Requirements for Military Systems, Equipment and Facilities, 1995

7.MIL-HDBK-759A, Human Factors Engineering Design for Army, Material, 1981

8.MIL-STD-1472F, August 1999, Human Engineering Design Criteria for Military Systems, Equipment and Facilities: Department of Defense Design Criteria Standard Human Factors Engineering

2.5 Industry and Other Documents

1.Advanced Light Water Reactor, Utility Requirements Document, Volume III, Chapter 10, Man-Machine Interface Systems

2.ANSI HFS-100, American National Standard for Human Factors Engineering of Visual Display Terminal Workstations (American National Standards Institute), 1988

3.ANSI/ISA-S-18.1, Annunciator Sequences and Specifications (Instrument Society of America), 1992

4.ANSI/ISA-S5.5, Graphic Symbols for Process Displays (Instrument Society of America), 1985

5.Bikson T. K., & Gutek B. A. (1983). Advanced office systems: An empirical look at use and satisfaction. *Proceedings of the AFIPS National Computer Conference*, *52*,319-328

6.BNL-TR-E2090-T4-1-9/96, Human-Systems Interface Design Process and Review Criteria, 1996

7.BNL-TR-E2090-T4-4-12/94, R1. (1996). Group-View Displays: Functional Characteristics and Review Criteria

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11. ~~Buxton W., Fiume E., Hill R., Lee A., & Woo C. (1983). Continuous hand-gesture driven input. *Proceedings of Graphics Interface 83*, 191-195~~

12. ~~Buxton W., Lamb M., Sherman D., & Smith K. C. (1983). Towards a comprehensive user interface management system. *Computer Graphics, 17*(3), 35-42~~

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15. ~~Draper, S. W. & Norman, D. A. (1986). User centered system design: New perspectives on human-computer interaction. New Jersey: Lawrence Erlbaum~~

16. ~~Enderwick, T. P., & Meister, D. (2002). *Human factors in system design, development, and testing*. New Jersey: Lawrence Erlbaum.~~

17. ~~Endsley, M. R. Towards a Theory of Situation Awareness in Dynamic Systems. Human Factors, 37, 65-84. 1995~~

18. ~~Gould J. D., & Lewis C. (1985). Designing for usability: Key principles and what designers think. In B. Shackel (Ed.), *INTERACT '84: First conference on human-computer interaction*. Amsterdam: North-Holland~~

19. ~~EPRI NP-3659, (1984). Human factors guide for nuclear power plant control room development. Electric Power Research Institute~~

20. ~~FAA HFDS 2003 Human Factors Design Standard~~

21. ~~Hix, D. & Hartson, H. R. (1993) *Developing user interfaces: Ensuring usability through product and process*. NY, Wiley~~

22. ~~NASA-STD-3000, Rev. B 1995 Man-Systems Integration Standards~~

23. ~~Rasmussen, J. (1986). Information processing and human-machine interaction: An approach to cognitive engineering. New York: North-Holland~~

24. ~~Woods, D. D., & Roth, E. M. (1988). Cognitive systems engineering. In M. Helander (Ed.), *Handbook of human- computer interaction* (pp. 3-43). New York: Elsevier~~

25. ~~Woods, D. D., Watts, J. C., Graham, J. M., Kidwell, D. L., & Smith, P. J. (1996). Teaching cognitive systems engineering. *Proceedings*, 259-263~~

3. Combinations of personnel and system elements (for example, shared control and automatic systems with manual backup)"

The function allocation is a human factors engineering process that is used to determine the level of automation for a system. The function allocation process exploits the strengths of personnel and system elements.

The function allocation process is based on HFE principles using a structured and well-documented methodology that seeks to provide plant operators with logical, coherent, and meaningful tasks. Function allocation is not based solely on technology considerations that allocate to plant personnel everything the designers cannot automate. Such an approach results in activities that are likely to negatively affect operator performance. The design does not embrace automation for the sake of automation, but rather selectively automates in order to maintain operator situational awareness and vigilance.

The function allocation report describes the top-down approach to determining function allocation and presents the results for safety functions. ~~NUREG/CR-3331 and the top-down approach are used to develop the approach for making the function allocation decisions.~~

For each system identified in the functional requirements analysis, the function allocation methodology is applied and a level of automation is specified and documented. The result summary report includes a specification of the current level of automation and personnel responsibility for safety functions, and the associated safety-related processes and systems. The rationale for the current plant function allocation decisions, pertaining to the ESBWR safety functions, is also documented.

The function allocation results summary report also includes a description of HFE activities that are conducted as part of the HSI design process to verify the adequacy of current function allocation decisions, and establishes the capability of operators to perform the role assigned to them. This includes:

- How human factors input is provided early in the design process
- How the role of the operator is considered in assigning function allocation
- Mechanisms available for reconsidering, and if necessary, changing function allocations in response to operating experience and the outcomes of ongoing analyses and trade-off studies

While this initial function allocation documents the current level of automation (and the rationale) for systems affecting the safety systems, the function allocation is revised, if needed, following completion of the OER/BRR report. If, after considering OER/BRR results, a function allocation decision changes the current level of automation (function allocation) and the respective system is part of the decomposition of one of the critical safety functions (functional requirements analysis), then the function allocation documentation is revised.

3.1.2 Goals

The primary goal for HSI designs is to facilitate safe, efficient and reliable operator performance during all phases of normal plant operation, abnormal events and accident conditions. Maintenance, test, and inspection activities are also considered. To achieve the operator performance goals, information, displays, controls, and other interface devices in the control room and other plant areas are designed and implemented in a manner consistent with good HFE practices. The goals can be summarized as fulfilling the following:

- Maximize plant capacity/output power levels
- Achieve and maintain high reliability
- Achieve and maintain high availability
- Maintain high levels of safety
- Maintain high levels of operator awareness of the plant and equipment states
- Minimize the likelihood of human errors
- Integrate fault tolerance and fault recovery into the systems (both from potential human and equipment errors)

The objective of the HSI concept design process is to produce an HSI design that presents plant information and controls in a useful, effective, and operator-friendly manner and allows the operators to safely monitor and control the plant under all operating conditions. A well-defined design process that incorporates industry-accepted human factors engineering principles is used to achieve this objective.

3.1.3 Basis and Requirements

The HFE team develops functional requirements for the HSI to address the concept of operations; personnel functions and tasks defined in the operations analysis; task and staffing/qualifications analysis; and requirements for a safe, comfortable working environment. The HSI requirements address the various types of HSIs, for example, alarms, displays, and controls. The three components of HSI design: concept design, style guide, and detailed design share similar bases and requirements.

The concept design uses human factor elements, as defined in the DCD Chapter 18 and the MMIS and HFE Implementation Plan, to address HFE issues during the HSI design process. The HSI design, hardware, software, logic, controls, indications and the style guide that governs their creation conform to the principles set forth in regulations including:

- NUREG-0700 Rev. 2
- NUREG-0711 Rev. 2

~~•NUREG-0800 Section 18~~

~~•ANSI/ISA-S-18.1~~

- ~~DG-1145, Section C.I.18~~

The HFE design team reviews and verifies that the HSI concept design uses accepted HFE principles in its form and presentation of information and in its interactions with plant personnel. Additionally, the Computer Based Procedures (CBPs) presented by the HSI conform to the principles set forth in ~~NUREG/CR-6634 and~~ NUREG-0700 Rev. 2.

3.1.4 General Approach

Due to increasing regulatory and utility requirements, and demands for greater plant availability, it is necessary to incorporate innovative designs reflecting advances in computer-based technology. In recent years, the major nuclear plant vendors have been developing control complexes that make use of computers to process plant parameter data and display information to personnel. Computer based applications reduce the number of hardwired instruments needed to provide information about plant operations. In addition, computer-aiding routines are incorporated to unburden plant personnel, thereby allowing them to direct their attention to monitoring, and analysis and decisions regarding plant operations.

Figure 1 outlines the overall flow of the HFE process and the portions of the process that provide input to HSI design. Processes that receive input from HSI design are also shown. The primary input to HSI design is data processed through operational analysis. Operational analysis receives input from:

- HRA/PRA results and risk significance determinations
- OER/BRR results and lessons learned
- Defense-in-Depth and Diversity (D3) requirements
- Design Control Document (DCD) specifications and requirements
- System Design Specifications (SDS)

These inputs are processed through design, detailed, and economic analyses in the functional requirements analysis, allocation of function, and task analysis phases of operational analysis. Outputs from task analysis form the inputs to HSI design. Operational analysis provides or refines:

- Requirements to the HSI Implementation Plan
- Detailed procedure outlines to the Procedure Development Plan
- Task sequence and interlock logic for plant automation and auto control of functions

Operational analysis identifies the individual mental and physical tasks necessary to support the functions allocated to humans, machine, or shared.

The Staffing and Qualification (S&Q) process provides additional input to HSI Design that when combined with operational analysis specifications in accordance with the HSI style guide generate HSI specifications.

Feedback inputs to the HSI design process include issues and lessons learned impacting HSI design from:

by the technology, the more detailed is the derivation of the human function/sub function. If the designer of an interface merely says a display is provided, the specialist can deduce only that perceptual-cognitive activity is required. If the designer says that the display is a multivariate display reporting the interactions of multiple dimensions (level, pressure, temperature, and so forth), the specialist is able to decompose the perceptual-cognitive function into more meaningful sub functions ~~(Enderwick & Meister, 2002)~~.

The conceptual design portion of the overall HSI design process analyzes the basic HSI requirements generated in operational analysis and the human factors insight gained from HFE specialists and generates the HSI conceptual design. The conceptual design meets the process goals by satisfying the HSI design requirements in a manner that takes advantage of human strengths while avoiding human weaknesses.

3.2 HSI Specific Guidance – Style Guide

The purpose of the HSI style guide is to provide a set of HSI design guidelines to be used by the HSI designers to help ensure that a consistent design philosophy is applied. As suggested throughout NUREG-0700, ESBWR implementation guidelines are developed by tailoring the requirements of NUREG-0700 to the ESBWR specific applications. ~~Other HSI guidelines and standards are also used as input to the style guide.~~ Deviations from NUREG-0700, if any, will be justified. The resulting HSI implementation guidelines include the following:

1. Anthropometric and ergonomic ~~data and~~ design guidelines
2. HSI display format philosophy
3. Display implementation guidelines

~~The anthropometric and ergonomic data and design guidelines document provides the anthropometric and ergonomic data and guidelines that are used in the design of the HSI environment.~~ The anthropometric data include 5th percentile female and 95th percentile male data from the United States populations for measures such as arm length, sitting eye height, functional reach, and so forth. This helps designers produce guidelines for physical clearances and reach envelopes. Employing these guidelines ensures that objects in the control room do not impede operator actions, and that a wide range of operators is accommodated.

Ambient and direct lighting, glare, and viewing distance guidelines are noted to provide sufficient readability of all text-based and color-coded items in the control room. Auditory thresholds and guidelines are outlined so alarms and auditory signals are designed for maximum operator detection.

Guidelines for environmental factors such as temperature, humidity, and radiation exposure are addressed to provide comfort and safety for the operators in the control room at all times.

The HSI display format philosophy document establishes the basic philosophy requirements for the display formats made available to the operators. Descriptions of display hierarchy, presentation, and navigation are provided in the style guide.

As the design progresses the HFE team identifies other requirements that become inputs to the HSI design.

3.2.2 Goals

The style guide defines the HSI structure, layout, color schemes, screen hierarchy, and hardware options from which the HSI is designed and developed. It also provides direction regarding how the criteria are to be applied. Compliance with style guide criteria when designing the HSI to meet the requirements set forth by operational analysis ensures the following goals are met:

- Standardization
- Consistency
- Uniformity
- Relevancy of meaning
- Discrimination of alarms and states
- Accommodation of user expectations
- Navigability
- Compliance with good HFE practices
- Minimize human error

3.2.3 Basis and Requirements

The design uses human factor elements, as defined in the DCD Chapter 18 and the MMIS and HFE Implementation Plan, to address HFE issues during the HSI design process. The HSI design, hardware, software, logic, controls, indications and the style guide that governs their creation conform to the principles set forth in regulations including:

- NUREG-0700 Rev. 2
- NUREG-0711 Rev. 2
- ~~NUREG-0800 Section 18~~
- ~~ANSI/ISA-S 18.1~~
- ~~DG-1145, Section C.I.18~~

The HFE design team reviews and verifies that the HSI design uses accepted HFE principles in its form and presentation of information and in its interactions with plant personnel. Additionally, the CBPs presented by the HSI conform to the principles set forth in ~~NUREG/CR-6634 and~~ NUREG-0700 Rev. 2. The style guide generated in this portion of the process presents design options for use in the ESBWR and the requirements for use and presentation of the HSI elements and CBPs. The HFE design team uses the style guide to properly combine and structure the HSI design elements and operational analysis requirements.

3.2.4 General Approach

The ESBWR HSI style guide is both a product of the HSI design effort and a governing input to it. The style guide is one of the first products generated by the HSI design team. The style guide will be created using input from similar guides from previous designs such as the ABWR, HSI style guides from other industries, NUREG-0700~~, NUREG/CR-4539~~[r2], and other applicable documents. The style guide is a compilation of HSI equipment, control, display, interface, and structures from which designers can select the most appropriate option for a given application. Additionally, the style guide sets requirements for when and how to incorporate the various hardware options.

Similar guidance is provided in the area of HSI software including workstation design and presentation content, format, and logic. Style guide requirements maintain consistency in presentation, navigation, and interface mechanisms between various portions of the HSI. Because human factors criteria and best practices are infused in the style guide requirements, its use ensures HSI design minimizes the likelihood of human error.

3.2.5 Application

Having better theories of users and task domains allows building more usable human-computer interfaces, but it is important to realize that the ultimate usability of a system in a given environment is governed as much by the organization of work around the system as it is by fundamental characteristics of the technology itself. ~~Boddy and Buchanan (1982), in a report on case studies of new technology applications, note how the technology can be used to complement or replace human capabilities, and that both the level of worker satisfaction and the overall use of the technology were sensitive to the organization of work as a whole rather than to specific aspects of systems.~~

~~Bikson and Gutek (1983) found that a key feature that predicts how well users integrate information technology into their work and how happy they are involves the amount of variety they have in their work. This does not imply that lower-level issues of user interface design are unimportant, rather it points out that the design of interfaces includes a concern for how features of the interface might accommodate different kinds of work organization, allowing for flexible tailoring of the system to accommodate particular user groups~~[r3]~~.~~

Although the technology does not determine the work organization, it can bias things so that certain kinds of procedures are more likely to be adopted than others. It is at this level that designers can influence how work gets done. This argues for a more thorough analysis of the operating philosophy beyond traditional task analysis and examining the social and organizational context that influences the operation of work activities. Restricting a person to abstract work procedures and designing systems at this level can lead to unworkable systems.

Insight gained in this area is infused in the criteria contained in the ESBWR HSI style guide. This ensures that HFE goals are met when the technical requirements defined in operational analysis are incorporated into the HSI design in accordance with the style guide.

- NUREG-0711 Rev. 2

~~NUREG-0800 Section 18~~

~~ANSI/ISA-S 18.1~~

~~DG-1145, Section C.I.18~~

The HFE design team reviews and verifies that the HSI detailed design uses accepted HFE principles in its form and presentation of information and in its interactions with plant personnel. Additionally, the CBPs presented by the HSI conform to the principles set forth in ~~NUREG/CR-6634 and~~ NUREG-0700 Rev. 2. Detailed design including software and hardware elements are generated in accordance with the style guide.

3.3.4 General Approach

1. Specific HFE design guidance is developed using operational analysis requirements and the HFE principles incorporated into the style guide. This guidance is used in the design of the HSI features, layout, and environment.

2. The HSI detailed design supports personnel in their primary role of monitoring and controlling the plant while minimizing personnel demands associated with use of the displays (for example, window manipulation, display selection, display system navigation). High-level HSI design review principles reflect NUREG-0700 Rev. 2 guidelines.

3. For risk-important Human Actions (HAs), the design seeks to minimize the probability that errors occur and maximize the probability that an error is detected if one is made.

4. When developing detailed HSI design requirements for monitoring and control capabilities provided either in the control room or locally in the plant, the following factors are considered:

    a. Communication, coordination, and workload

    b. User feedback

    c. Local environment

    d. Inspection, test, and maintenance

    e. Risk-important elements

5. The layout of HSI within consoles, panels, and workstations is based upon

    a. Analyses of operator roles (job analysis)

    b. Systematic strategies for organization such as arrangement by importance, frequency of use, and sequence of use

    c. Accommodation of diversity and defense-in-depth (train segregation)

6. Personnel and task performance is supported during minimal, nominal, and high-level staffing.

- Personnel primary task performance (task times and procedure violations)
- Personnel errors (intention errors related to assessing the plant conditions, and execution errors related to using the HSI)
- Situation awareness
- Workload (cognitive: decision making; physical: motion)
- Personnel communications and coordination (information sharing and coordinated control actions, and crew synchronization)
- Dynamic anthropometry evaluations (reach and dexterity issues)
- Physical positioning and interaction with the HSI (physical motion between panels and workstations and information display-space navigation)
- Secondary task control (display format navigation, information search, and so forth)

HSI Design Analyses, Reviews and Evaluations

This section provides a description of the methods and tools to be used for analysis, reviews and evaluations of the HSI during the design process.

Techniques are appropriate for the evaluation of HSI include, but are not limited to:

- Checklists
- Structured interviews
- Direct observation of operator behaviors
- Analysis of historical records of operational problems with similar equipment
- Physical measurements
- Experiments
- Subject Matter Expert (SME) rating of alternative designs

~~Criteria that may be used in selecting HFE techniques are the following:~~

~~Type of design. Taking into account the type of design, there are some techniques that may not apply.~~

~~Type of technology (proven or not). In accordance with Section 3.2 of the EPRI URD NP-5795, the MCR design uses proven technology. Advanced systems, equipment, software and firmware may be justified if proven in other applications as defined in the EPRI URD NP-5795, or in ABWRs.~~

~~Additional considerations in the selection of FE techniques include:~~

~~•Relative time to perform~~

•Relative complexity

•Relative cost

•Relative cost effectiveness

- Demonstrated by use of dynamic displays, simulator, and so forth

Criteria [r4]that may be used in selecting HFE techniques are the following:

a. Safety and/or risk significance

b. Type of design (taking into account the type of design, there are some techniques that may not apply)

c. Type of technology

d. Relative time to perform

e. Relative complexity

f. Relative cost

g. Relative cost effectiveness

h. Demonstrated by use of dynamic displays, simulator, and so forth

The design evaluation is based on the objectives of the systems design. What should the system do, who will use it, where will it be used and when will it be used? If the objectives are clear, the evaluation of the results is made simpler. Numerous methods are available for evaluation of designs. Figures 4 and 5 provide guidance on selecting appropriate and useful methods.

Definition of the Design/Evaluation Tools for the HSI Design Analyses

Considering the criteria listed in Section 3 and criteria to be used in selecting HFE/HSI Design and Evaluation Tools, the following techniques are used in the conduct of the HSI design analyses. Checklists, drawings, mock-ups, and questionnaires and interviews will be used as described below to gather HSI Tests and Evaluations data and information.

Design Criteria Checklist

A checklist includes a series of equipment and facilities design requirements taken from human engineering standards and guides that address HSIs. The checklist is divided into categories of design criteria corresponding to major equipment or facilities. These categories might consist of visual displays, audio displays, controls, and so forth; NUREG-0700 Rev. 2 provides examples of checklist formats.

Drawings

Engineering drawings or sketches of interest to the HFE Design Team may be further categorized as:

3.3.5.13.1 Grouping of operating areas

The MCR and LCS are divided into operating areas where each operator has all the controls and indications required to perform the tasks assigned in various operating conditions including start up, normal operation, shutdown and emergencies. Consideration is also given to tasks related to maintenance, testing, and inspection activities. The configuration minimizes interference among operator tasks.

Control Boards and Arrangement

The arrangement of control panels, desks and boards in the MCR, RSS, and LCSs include:

a. Allowing each operator to have sufficient space among the panels for immediate and direct access to the information and controls pertinent to tasks
b. Eliminating conflicting paths for the various operators
c. Facilitating communications and coordination among the operators

3.3.5.14 Environment

Environmental conditions in the MCR are such that the operators can perform tasks effectively and comfortably. The environmental conditions are consistent with the MCR habitability requirements.

The MCR environmental specification includes requirements for:

1. Heating, Ventilation and Air-Conditioning (HVAC)

   The MCR ventilation system design accommodates postulated accident conditions of the plant. The HSI is designed in accordance with the MCR environmental conditions.

2. Illumination

   MCR lighting system gives special attention to uniformity, and control of shadows, glare, reflections, and highlighting.

   An emergency lighting system continuously provides illumination necessary for task performance even on failure of the normal system.

3. Auditory Environment

   Auditory environment of the HSI is designed considering a relevant database on human auditory capability and characteristics.

~~The special environmental requirements for the MCR are defined in the post accident monitoring references RG 1.97 and IEEE 497~~[r5].

- Use of flat panel and Video Display Unit (VDU) displays
- Use of electronic on-screen controls
- Use of Wide Display Panel (WDP)
- Use of prioritized alarm systems
- Automation of process systems
- Operator workstation design integration

Operating experience reviews are performed on potential applications and include:

- Review of reports provided by industry organizations (NRC, ~~EPRI,~~ INPO, and so forth)
- Review of applicable research in these design areas, as may be documented in reports from universities, national laboratories, the NRC, and in proceedings published by HFE professional societies
- Review of applicable research and experience reports published by HSI equipment vendors

Operating experience review in each of the three areas specified above also includes feedback obtained from actual users. If the documents selected for the conduct of the operating experience review for a particular area do not include the results of user feedback, then interviews with users of at least two applications of that particular technology area are also conducted.

4.1.3 Process

HFE criteria are applied along with all other design requirements to select and design the particular equipment for application to the MCR and RSS HSI. The HSI design implements the information and control requirements that have been developed in the task analysis, including the displays, controls, and alarms necessary for the execution of those tasks identified in the task analyses as being critical tasks. The configuration of the equipment design is established to satisfy the functional and technical design requirements and the design process ensures the HSI is consistent with HFE principles.

The HSI design criteria applied to the ESBWR MCR is also used in the design of the information displayed on the VDUs located in the TSC and EOF. The information displayed in the TSC/EOF and Emergency Operating Procedures (EOPs), a subset of information, is available to the operator in the MCR. HSI as defined for ESBWR also includes the operator interface at the RSS displays and risk significant LCSs.

Typically, the order in which various kinds of HSI are addressed is dictated by the amount of lead-time required for construction, progressive availability of design information, and time needed to satisfy training requirements. Human factors efforts are completed within the option with associated HFE usage and supporting detail specifications, or is rejected as an option for use in the ESBWR. The technical option inputs are analyzed using HFE principles and practices provided by the HSI design team HFE specialist, along with the desired attributes established in the operations analysis. Options selected are used to generate style guide HSI element alternatives with associated human factors usage specifications.

The training, procedures, V&V, and HPM processes provide feedback inputs that can result in revisions to the lists of allowable elements and their specifications and requirements contained in the style guide.

4.2.3 Process

The style guide is created using input from similar guides from previous designs such as the ABWR, HSI style guides from other industries, NUREG-0700~~, NUREG/CR-4539~~, and other applicable documents. As operational analysis requirements are processed for implementation in the HSI design, the HSI design team will consider existing alternatives contained in the style guide. If style guide alternatives do not adequately address the requirement being considered or if potential enhancements to options are proposed, then additional HSI element options are evaluated for use in the ESBWR HSI. If approved, the new element options are incorporated into the style guide and are made available for use by HSI design team. The style guide is a compilation of HSI equipment, control, display, interface, and structures from which designers can select the most appropriate alternative for a given application. Additionally, the style guide sets requirements for when and how to incorporate the various hardware alternatives.

Similar guidance is provided in the area of HSI software including workstation design and presentation content, format, and logic. Style guide requirements maintain consistency in presentation, navigation, and interface mechanisms between various portions of the HSI.

This iterative process continues throughout the HSI design process.

4.2.4 Outputs

The output of the style guide design activity is a document presenting hardware, software, and usage alternatives from which the HFE design team constructs the ESBWR HSI. Additionally, the guide outlines the basic requirements and formatting specifications associated with each alternative incorporated into the HSI. The guide is a living document that takes input from the conceptual design process (HSI design elements being considered). The guide in turn provides input back into the conceptual design process in the form of approved human factors alternatives and usage specifications. Through this iterative process, the HSI design team is provided the flexibility and the HFE guidance to create an HSI that meets ESBWR goals.

4.3 HSI Detailed Design

The detailed design uses the alternatives and features selected in the conceptual design process and the guidance contained in the style guide to generate detailed HSI designs. The detailed design process addresses all hardware, software, layout, formatting, and features incorporated into the HSI design to meet ESBWR human centered design goals.

Coding principles are established in an early stage of HSI design. The coding principles are consistent with guidelines of NUREG-0700, Rev. 2. The coding system is consistent throughout the HSI. This applies to location, information, color, and illumination codes. Coding is consistent among HSI in the MCR, LCS, and back panels.

The simulator coding is consistent with the plant MCR. The equipment symbols, abbreviations, and acronyms are defined in the DCD. Use of symbols for coding of components should be consistent with the shapes defined in the DCD. New shapes are defined and documented in the style guide.

The coding method selected for application is determined considering the relative advantages of the types of coding.

Coding method and guidelines are as follows:

1. Physical Coding

   a. Size coding - Not more than three different sizes are used for discrimination by absolute size.

   b. Shape coding - Number of shapes is limited in shape coding.

   c. Color-coding - The number of colors used for coding is kept to the minimum to provide necessary information. Less than eight colors are preferable and not more than 12 colors, including black and white, are used.

      To ensure the correct use of color-coding, the following rules are applied:

      i. Color is used in a redundant mode. This is necessary to allow for variations in lighting conditions.

      ii. The choice of colors allows all users to discriminate between each color under all conditions of use.

      iii. The colors used contrast adequately with the background of the display. In addition, adjacent colors contrast adequately with each other.

      iv. Consistency of meaning assigned to each color is essential. The use of color codes with symbols is consistent across all applications within the control room and LCS.

      v. For VDU display, the background color is pure and free from noise patterning.

      vi. In selecting color codes, common human perception of the color meaning (for example, red-stop, green-go, and so forth.) as well as industry standards and practices which have been identified for advanced control rooms are used.

   d. Auditory coding - Auditory coding by frequency is permissible but not more than five separate frequencies should be used. Auditory coding may be implemented based on frequency, rate of change, patterns, and location of auditory device. ~~EPRI has performed studies related to alarm systems and these are considered.~~

data structure sequence by required human action of some kind. The required action can be an acknowledgement of a HSI queue alerting the operator to impending action or it can be more detailed. One example of when this allocation is selected is where economic impacts may result if the machine sequence continues.

Machine, Human Backup – This output allocates the function to plant equipment and automation for performance. Plant personnel monitor the machine and perform or complete performance of the function in the event that the machine does not complete its execution. Analysis has shown that while the machine is best suited to perform the function sequence, plant personnel are capable of performing the sequence if called upon. Additionally, analysis has determined that the consequences of partial or incorrect performance are such that operator performance of the functions following machine failure is warranted.

Human, Machine Assist – This output allocates the function to plant personnel for performance. Equipment and automation assist plant personnel in performance of the function. Analysis has shown that the human is capable of mitigating the consequences he may make. One or more forms of machine assistance are provided to aid in the performance of the function.

Human, Machine Backup – This output allocates the function to plant personnel for performance. The machine monitors human performance of the function and performs or completes performance of the function in the event that the human does not complete its execution. Analysis has shown that while the human is best suited to perform the function sequence, potential error consequences are unacceptable and the machine is capable of mitigating the consequences of potential human errors.

4.3.4.4 Staffing and Qualifications

The HSI design process receives input from the staffing and qualifications process when establishing HSI conceptual design specifications. Conceptual design combines the requirements and ownership allocations generated in operational analysis with the most appropriate human owner based upon qualifications and number of personnel available in the required location.

Feedback is provided from HSI detailed design to the staffing and qualification and operational analysis processes when the design process is unable to generate detailed design output that meets the requirements of operational analysis and staffing and qualifications concurrently. Additionally, feedback is provided in the form of cumulative workload for specific staff positions and qualifications for use in workload analyses.

4.3.4.5 Mockups, Part-Task Simulation, and Full Scope Simulation

The detailed HSI design is used to develop mockups, part task simulators, and full scope simulators that emulate the final plant design~~ to the requirements of 10 CFR55.46, Regulatory Guide 1.149, ANSI/ANS-3.5-2005 and other applicable requirements~~. These mockups and simulators are used to V&V the work performed and the results obtained during implementation of the HFE design process shown in Figure 1.

b. Type of design (taking into account the type of design, there are some techniques that may not apply)

c. Type of technology ~~(in accordance with EPRI URD NP-5795, the MCR design uses proven technology. Advanced systems, equipment, software and firmware may be justified if proven in other applications as defined in the EPRI URD NP-5795, or in ABWRs)~~

d. Relative time to perform

e. Relative complexity

f. Relative cost

g. Relative cost effectiveness

h. Demonstrated by use of dynamic displays, simulator, and so forth

The design evaluation is based on the objectives of the systems design. What should the system do, who will use it, where will it be used and when will it be used?. Numerous methods are available for evaluation of designs. ~~Figures 4 and 5 provide guidance on selecting appropriate and useful methods[r6].~~

4.3.4.7 **Procedures**

An implicit design goal in most discussions of human-system interfaces is that system design enables users, to be in control of the technology.

Procedures enable users to accomplish daily tasks adequately. However, without at least a common-sense understanding of how the procedures relate to the underlying system, users are unable to adapt them to new situations, to deal with either system malfunctions or the consequences of their own errors, or to adapt to new or evolving systems.

The HSI pertinent to procedures and their use is applied in meaningful ways that accommodate these concerns. A basis of user system understanding is developed along with procedures. Thus full generalization and well-informed procedure development and use are enabled.

4.3.4.8 **Panels and Consoles**

The physical elements of the HSI are organized into workstations at which plant personnel carry out the tasks of monitoring and controlling the ESBWR. Workstations are stand-up, sit-down or a combination of both. HFE principles governing attributes such as reach, field of vision, and comfort are integral to the alternatives contained in the HSI style guide and are therefore incorporated into the design.

Size and shape of HSI equipment such as: control consoles, desks, boards, panels and chairs are determined from the anthropometric requirements and other human engineering considerations. Details considered during workstation design include (adapted from NUREG-0700, Rev. 2):

- Workstation height (operators, supervisors, and any other)

Anthropometric data takes two forms: static data and dynamic data. Static data is derived from a person in static postures; dynamic data is based on movements, which approximate most work environments.

Regardless of the type of data, it follows a statistical phenomenon known as normal frequency distribution. When the frequency of occurrences is plotted on a graph against the actual measurement, it forms a normal (bell) frequency distribution curve. The significance of this is that designers of products, tools, equipment, and so forth have a quantifiable design basis on which to make design decisions where human factors are involved.

At various points along the distribution curve, it is determined what percentage of the population fall below and above the given dimension. These points are referred to as percentiles. At the 50th percentile, 50 per cent of the population is smaller or larger than the given size measurement. Likewise, at the 5th percentile, five percent are smaller and 96 per cent are larger, and at the 95th percentile, only five percent are larger.

Using this information, it can be seen that there are definite dangers in using the 50th percentile in design criteria, as only half of the population would be accommodated unless adjustability was built in. In keeping with the desire to accommodate as many people as possible (and practical), normal design is for either the 5th or 95th percentile depending on the component in question.

4.3.4.13 Workplace

The proposed dimensions for the MCR and the consoles are defined to assure that the MCR arrangement allows for the necessary support staff work areas. ~~Initial minimum requirements were based on the EPRI NP-5795, 1991.~~ The arrangement may be modified in accordance with the detailed human factors analysis and requirements.

4.3.4.14 Environment

Environmental considerations are taken into account to ensure that they do not adversely impact the ability of humans to effectively use the HSI. Environmental variables considered include:

- Noise
- Lighting
- Flooring and slip, trip, and fall potential
- Accessibility
- Vibration
- Temperature

c. Eliminate unnecessary information
d. Use concise, unambiguous wording for instructions and messages
e. Use easy to recognize icons
f. Use a balanced screen layout – do not put too much information at the top of the screen - try to balance information in each screen quadrant
g. Use plenty of 'white space' around text blocks - use at least 50% white space for text screens
h. Group information logically
i. Structure the information rather than just presenting a narrative format (comprehension can be 40% faster for a structured format)

11. Individual differences
    a. Accommodate individual differences in user experience (from the novice to the computer literate)
    b. Accommodate user preferences by allowing some degree of customization of screen layout, appearance, icons and so forth
    c. Allow alternative forms for commands (for example, key combinations through menu selections) ~~(Hix and Hartson, 1993[r7])~~

In order to effectively apply these design principles, one needs to understand users' tasks and requirements. Understanding and applying principles is meaningless if users are unhappy with the final product.

The goal for user interface design is to have the interface positively support users' endeavors and never intrude adversely. The interface should be transparent to the task the user is trying to accomplish and be efficient, satisfying.

Design Principles

Simplicity: Do not compromise usability for function

Keep the interface simple and straightforward. Users benefit from function that is easily accessible and usable. A poorly organized interface cluttered with many advanced functions distracts users from accomplishing their everyday tasks. A well-organized interface that supports the user's tasks fades into the background and allows the user to work efficiently.

Basic functions should be immediately apparent, while advanced functions may be less obvious to new users. Function should be included only if a task analysis shows it is needed. Therefore, keep the number of objects and actions to a minimum while still allowing users to accomplish their tasks.

Support: Place the user in control and provide proactive assistance

5 RESULTS

5.1 Results Summary Report

The results of the HSI design process outlined in this plan are summarized in a Results Summary Report (RSR). The RSR provides a list of the design specifications for the HSI, instruments required to comply with regulations, and the HSI style guide developed during implementation of this plan. The RSR is written with sufficient detail to document how the methodology outlined in this plan was implemented to provide the results. In addition, the RSR outlines:

- General approach including the purpose and scope of HSI design
- HSI design team members and backgrounds
- HFE standards and documents used in the HSI design activity
- Concept of operations from an HSI perspective
- Functional requirement specification for HSIs
- Style guide and design specifications for HSI design including:
  - The development and basis for the guide
  - The scope, topical contents, and procedures contained in the guide
  - Procedures used to maintain the style guide
- ~~List of instruments that complies with RG 1.97 and supporting analysis~~
- The methods used for the evaluation and verification of the HSI

~~•The process for refining and updating HSI design including:~~

~~Modifying and updating the HSI~~

~~Making temporary changes to the HSI~~

~~Creating operator defined HSIs (temporary displays defined by operators for monitoring specific plant situations)~~

~~Procedures governing permissible operator initiated changes to HSIs~~

- Overall assessment of how well the methodology and implementation of the procedure development process and results adhere to this plan.

5.2 Periodic Reports

The ~~COLOG~~COL owner's group defines the periodicity and content of any HSI design process periodic reports.

5.3 Technical Output Reports

The ~~COLOG~~COL owner's group defines the periodicity and content of any HSI design process technical output reports.

Attachment for RAI

18.8-16 S02

Moreover, for each alarm, a procedure document, (for example, alarm sheet or alarm response procedures) are provided to explain to the operator the likely reasons of the alarm and the corrective actions required. Computer based operator aids may be used for explaining the importance of particular combinations of alarm signals.

3. Display of Alarms

The display of alarms on alarm-tiles, the WDP or on VDUs meets the following:

a. Combining relevant process and alarm information in the WDP mimic display provides spacially dedicated alarm overview under all process conditions, improving management of alarm overload.

b. Alarms are integrated into process displays, using symbols and icons close to the components or functions to which they are related.

c. ~~An alarm is annunciated where the operator has the necessary means for initiating corrective actions~~ An alarm is annunciated where the operator is required to take action;

d. Any new alarm starts an audible warning and flashes a tile light or VDU symbol;

e. An alarm may be steadied after it has been acknowledged;

f. The steadied alarm is indicated to ensure that its existence is not forgotten;

g. When the cause of alarm has been corrected, the alarm display may be returned to the normal mode manually or automatically. In either case, the control room staff is notified by audible and visual cues that the cause has been corrected.

h. Navigation in alarm displays allows quick access to additional information, such as online alarm procedures, and to displays that offer more, real-time detail.

Alarm Processing Logic

Alarm prioritizing and filtering logic enhances the presentation of meaningful alarm information to the operator and it reduces the amount of information, which the operators must absorb and process during abnormal events.

Signal filtering is used to prevent measurements that fluctuate around their alarm limits from generating useless, repeated alarms that are a nuisance and might contribute to alarm flooding. Low pass filtering and dead-bands can remove process noise and fluctuations around the alarm limit. Dead-bands may be adjustable by the operator with administrative controls. Time-delay and time limit mechanisms may also be employed where low pass filtering is not possible.

Alarm suppression, on the other hand, is used to ensure that the presented alarms at any time are relevant to the operator's most important task under the current plant conditions and to avoid alarm flooding. Alarm suppression must be documented in such a way that it is familiar and understandable to the operator. In order to trust the alarm system, it is important that operators understand why some alarms are suppressed while others are not.

Attachment for RAI

18.8-17 S02

by the technology, the more detailed is the derivation of the human function/sub function. If the designer of an interface merely says a display is provided, the specialist can deduce only that perceptual-cognitive activity is required. If the designer says that the display is a multivariate display reporting the interactions of multiple dimensions (level, pressure, temperature, and so forth), the specialist is able to decompose the perceptual-cognitive function into more meaningful sub functions ~~(Enderwick & Meister, 2002)~~.

The conceptual design portion of the overall HSI design process analyzes the basic HSI requirements generated in operational analysis and the human factors insight gained from HFE specialists and generates the HSI conceptual design. The conceptual design meets the process goals by satisfying the HSI design requirements in a manner that takes advantage of human strengths while avoiding human weaknesses.

3.2 HSI Specific Guidance – Style Guide

The purpose of the HSI style guide is to provide a set of HSI design guidelines to be used by the HSI designers to help ensure that a consistent design philosophy is applied. As suggested throughout NUREG-0700, ESBWR implementation guidelines are developed by tailoring the requirements of NUREG-0700 to the ESBWR specific applications. ~~Other HSI guidelines and standards are also used as input to the style guide.~~ Deviations from NUREG-0700, if any, will be justified. The resulting HSI implementation guidelines include the following:

1. Anthropometric and ergonomic ~~data and~~ design guidelines

2. HSI display format philosophy

3. Display implementation guidelines

~~The anthropometric and ergonomic data and design guidelines document provides the anthropometric and ergonomic data and guidelines that are used in the design of the HSI environment.~~ The anthropometric data include 5th percentile female and 95th percentile male data from the United States populations for measures such as arm length, sitting eye height, functional reach, and so forth. This helps designers produce guidelines for physical clearances and reach envelopes. Employing these guidelines ensures that objects in the control room do not impede operator actions, and that a wide range of operators is accommodated.

Ambient and direct lighting, glare, and viewing distance guidelines are noted to provide sufficient readability of all text-based and color-coded items in the control room. Auditory thresholds and guidelines are outlined so alarms and auditory signals are designed for maximum operator detection.

Guidelines for environmental factors such as temperature, humidity, and radiation exposure are addressed to provide comfort and safety for the operators in the control room at all times.

The HSI display format philosophy document establishes the basic philosophy requirements for the display formats made available to the operators. Descriptions of display hierarchy, presentation, and navigation are provided in the style guide.

Attachment for RAI

18.8-18 S02

- Benchboard slope, angle, depth, available lay down space
- Control device locations
- Display device locations
- Accommodations for human body positioning including leg clearances, arm rests, and so forth

Display and control equipment layout

Style guide HFE principles address both individual elements of the HSI and their grouping. The aggregate main control console, RSS, and LCS workstation configurations are consistently and logically laid out to enhance human awareness, understanding, control, and long-term use. Details considered during workstation layout design include (adapted from NUREG-0700, Rev. 2):

- Grouping of related controls
- Placement of controls to provide ease of access and minimize inadvertent actuation
- Placement and arrangement of display devices
- Overall grouping of controls and displays

The primary design function served in this portion of the detailed HSI design is the aggregate HFE treatment of all of the workstations and displays at a given control location.

4.3.4.9 **Control Systems**

Control Display Integration

Controls and their associated displays are correctly integrated to ensure effective operation of the plant. Control-display integration is in accordance with the proposed method of plant operation as identified in the operations analysis performed for each system by the HFE Design Team.

The control-display integration meets the following principal requirements:

1. Hardware controls should be located near the associated display. Operation of controls should produce a compatible change in the relevant display.

2. The operation of systems and components by "soft" and "hard" switches. Soft switches are controls located in the VDUs.

3. ~~The form of control adopted is consistent with HSI requirements.~~ The selection of the type of control is consistent with operator needs to navigate or take process control action, and with the associated guidance provided in NUREG-0700.

4. The grouping of controls and their associated displays reflect the need to achieve system objectives that are consistent with the user's mental thought process.

Attachment for RAI

18.8-31 S02

Clarifier: The enclosed markup up pages may contain unverified changes in addition to the verified changes resulting from the RAI response. Pending DCD changes associated with this RAI response are shaded for emphasis. Other changes shown in the enclosed DCD markup may not be reflective of the final format and content of DCD Revision 5 when submitted (I.e., those markups may include changes that are not fully developed and approved for inclusion in the DCD).

- Personnel primary task performance (task times and procedure violations)
- Personnel errors (intention errors related to assessing the plant conditions, and execution errors related to using the HSI)
- Situation awareness
- Workload (cognitive: decision making; physical: motion)
- Personnel communications and coordination (information sharing and coordinated control actions, and crew synchronization)
- Dynamic anthropometry evaluations (reach and dexterity issues)
- Physical positioning and interaction with the HSI (physical motion between panels and workstations and information display-space navigation)
- Secondary task control (display format navigation, information search, and so forth)

HSI Design Analyses, Reviews and Evaluations

This section provides a description of the methods and tools to be used for analysis, reviews and evaluations of the HSI during the design process.

Techniques are appropriate for the evaluation of HSI include, but are not limited to:

- Checklists
- Structured interviews
- Direct observation of operator behaviors
- Analysis of historical records of operational problems with similar equipment
- Physical measurements
- Experiments
- Subject Matter Expert (SME) rating of alternative designs

~~Criteria that may be used in selecting HFE techniques are the following:~~

~~Type of design. Taking into account the type of design, there are some techniques that may not apply.~~

~~Type of technology (proven or not). In accordance with Section 3.2 of the EPRI URD NP-5795, the MCR design uses proven technology. Advanced systems, equipment, software and firmware may be justified if proven in other applications as defined in the EPRI URD NP-5795, or in ABWRs.~~

~~Additional considerations in the selection of FE techniques include:~~

~~•Relative time to perform~~

- ~~Relative complexity~~
- ~~Relative cost~~
- ~~Relative cost effectiveness~~
- ~~Demonstrated by use of dynamic displays, simulator, and so forth~~

Criteria that may be used in selecting HFE techniques are the following:

a. Safety and/or risk significance

b. Type of design (taking into account the type of design, there are some techniques that may not apply)

c. Type of technology

d. Relative time to perform

e. Relative complexity

f. Relative cost

g. Relative cost effectiveness

h. Demonstrated by use of dynamic displays, simulator, and so forth

The design evaluation is based on the objectives of the systems design. What should the system do, who will use it, where will it be used and when will it be used? If the objectives are clear, the evaluation of the results is made simpler. Numerous methods are available for evaluation of designs. ~~Figures 4 and 5 provide guidance on selecting appropriate and useful methods.~~

Definition of the Design/Evaluation Tools for the HSI Design Analyses

~~Considering the criteria listed in Section 3 and criteria to be used in selecting HFE/HSI Design and Evaluation Tools, the following techniques are used in the conduct of the HSI design analyses.~~ Checklists, drawings, mock-ups, and questionnaires and interviews will be used as described below to gather HSI Tests and Evaluations data and information.

Design Criteria Checklist

A checklist includes a series of equipment and facilities design requirements taken from human engineering standards and guides that address HSIs. The checklist is divided into categories of design criteria corresponding to major equipment or facilities. These categories might consist of visual displays, audio displays, controls, and so forth; NUREG-0700 Rev. 2 provides examples of checklist formats.

Drawings

Engineering drawings or sketches of interest to the HFE Design Team may be further categorized as:

Attachment for RAI

18.8-32 S02

Clarifier: The enclosed markup up pages may contain unverified changes in addition to the verified changes resulting from the RAI response. Pending DCD changes associated with this RAI response are shaded for emphasis. Other changes shown in the enclosed DCD markup may not be reflective of the final format and content of DCD Revision 5 when submitted (I.e., those markups may include changes that are not fully developed and approved for inclusion in the DCD).

~~•Relative complexity~~

~~•Relative cost~~

~~•Relative cost effectiveness~~

- ~~Demonstrated by use of dynamic displays, simulator, and so forth~~

Criteria [r4]that may be used in selecting HFE techniques are the following:

a. Safety and/or risk significance

b. Type of design (taking into account the type of design, there are some techniques that may not apply)

c. Type of technology

d. Relative time to perform

e. Relative complexity

f. Relative cost

g. Relative cost effectiveness

h. Demonstrated by use of dynamic displays, simulator, and so forth

The design evaluation is based on the objectives of the systems design. What should the system do, who will use it, where will it be used and when will it be used? If the objectives are clear, the evaluation of the results is made simpler. Numerous methods are available for evaluation of designs. ~~Figures 4 and 5 provide guidance on selecting appropriate and useful methods.~~

Definition of the Design/Evaluation Tools for the HSI Design Analyses

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Design Criteria Checklist

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Drawings

Engineering drawings or sketches of interest to the HFE Design Team may be further categorized as:

Attachment for RAI

18.8-49 S02

Clarifier: The enclosed markup up pages may contain unverified changes in addition to the verified changes resulting from the RAI response. Pending DCD changes associated with this RAI response are shaded for emphasis. Other changes shown in the enclosed DCD markup may not be reflective of the final format and content of DCD Revision 5 when submitted (I.e., those markups may include changes that are not fully developed and approved for inclusion in the DCD).

18.8 HUMAN-SYSTEM INTERFACE DESIGN

References 18.8-1 and 18.8-2 describe the process by which areas of operator interfaces are established and evaluated. The primary areas of human interface are the ESBWR MCR, RSS, TSC, EOF, and LCSs with safety-related functions or identified through high-level task analysis. These results of HSI efforts are summarized in the HSI results summary report and are available for the conformance reviews.

The Human Performance Monitoring (HPM) activity described in Section 18.13 addresses the HSI change process, after the plant is in operation, by which:

- HSIs are modified and updated;
- Temporary HSI changes are made;
- Operator defined HSIs are created (as temporary displays defined by operators for monitoring specific plant situations); and
- The procedures governing permissible operator initiated changes to HSIs are described.

Satisfaction of the specific requirements described in Reference 18.8-1 results in full compliance with the Certified Design Commitment and the corresponding requirements presented in the Tier 1 (Rulemaking) Design Acceptance Criteria (DAC).

18.8.1 HSI Design Implementation Plan

The HSI Design Implementation Plan, Reference 18.8.2 is comprised of three technical sections.

(1) The HSI ~~Design Implementation Plan, Reference 18.8-2,~~Concept Design establishes:

a. Methods and criteria for HSI equipment design and evaluation of HSI human performance, equipment design, and associated work place factors, (for example, illumination, noise, and ventilation) consistent with accepted HFE guidelines, principles, and methods;

b. Information and control requirements, including the displays, controls, and alarms necessary for the execution of identified tasks;

c. Methods for comparing the consistency of the HSI human performance equipment, design, and associated workplace factors as modeled and evaluated in the completed task analysis;

d. Equipment (hardware and software) functions as determined in the task analysis;

(2) The HSI Detailed Design and Integration establishes:

~~e.~~a. Design criteria and guidance for control room operations during periods of maintenance, test, and inspection of control room HSI equipment and human interfaces; and

~~f.~~b. Test and evaluation methods for resolving HFE/HSI design issues including the criteria to be used in selecting HFE/HSI design and evaluation tools which:

i. Incorporate the use of static mockups and models for evaluating access and workspace-related HFE issues; and

ii. Require dynamic simulations and HSI prototypes for conducting evaluations of the human performance associated with the activities in the critical tasks identified in the task analysis.

~~(2)~~(3) The ~~HSI~~ HSI Specific Guidance – Style Guide ~~Design Implementation Plan includes~~addresses:

a. Identification of the specific HFE standards and guidelines documents;

b. Substantiation that selected HSI Design Evaluation Methods and Criteria are based upon accepted HFE practices and principles;

c. Definition of standardized HFE design conventions;

d. Verification that the design features, the HSI equipment technologies, and the displays, controls, and alarms are incorporated as requirements on the HSI design; and

e. Definition of the design/evaluation tools (for example, prototypes) which are to be used in the conduct of the HSI design analyses, the specific scope of evaluations for which those tools are to be applied, and the rationale for the selection of those specific tools and their associated scope of application.

18.8.2 HSI Results Summary Report

~~(3)~~The results of the HSI Design Implementation are summarized in the RSR including:

- General approach including the purpose and scope of HSI design
- HSI design team members and backgrounds
- HFE standards and documents used in the HSI design activity
- Style guide and design specifications for HSI design
- List of instruments that complies with RG 1.97 and supporting analysis
- The methods used for the evaluation and verification of the HSI
- Overall assessment of how well the methodology and implementation of the procedure development process and results adhere to this plan.

~~a. The style guide developed for the detailed design.~~

~~i. The development and basis for the guide,~~

~~ii. The scope, topical contents and procedures; and~~

~~iii. Procedures used to maintain a style guide.~~

~~b. Final HSI design.~~

~~i. Overview of HSI design and key features.~~

~~ii. Safety aspects of the HSI.~~

The HSI results summary report is included as ITAAC item 6 of Table 3.3-1 in DCD Tier 1.

(4) The Human Performance Monitoring (HPM) activity described in Section 18.13 addresses the HSI change process, after the plant is in operation, by which:

i. HSIs are modified and updated;

ii. Temporary HSI changes are made;

iii. Operator defined HSIs are created (as temporary displays defined by operators for monitoring specific plant situations); and

iv.i. The procedures governing permissible operator initiated changes to HSIs are described.

18.8.2 18.8.3 COL Information

None

18.8.3 18.8.4 References

18.8-1 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.

18.8-2 GE Energy, "ESBWR Human-System Interface Design Implementation Plan," NEDO-33268, Class I (non-proprietary), Revision 2, March 2007.

1.1 Purpose

This plan develops the process by which the ESBWR HSI design requirements are identified, refined, and established. The purpose is to ensure consistency with accepted HFE guidelines, principles, and methods. The result is a safe, simple, and standardized plant design.

This plan systematically delineates the requisite HFE principles necessary to translate functional and task requirements to the design of alarms, displays, controls, and other aspects of the control and instrumentation systems and HSI. Figure 1 shows where this HSI Design Implementation Plan fits into the overall HFE Process.

1.2 Scope

The scope of this HSI Design Implementation Plan establishes:

1. The methods and criteria for designing the HSI in accordance with accepted human factors guidelines, principles, and methods
2. HSI information and control requirements
    a. Support critical tasks identified through the operational analyses
    b. Identify the displays, controls, and alarms necessary for the execution of those tasks
    c. Ensure identified plant parameters used for calculation of operational limits are presented as alarms, displays, and controls
    d. Eliminate errors associated with risk-important human actions
    e. Identify error-likely situations
3. Methods for comparing the consistency of the HSI human performance, equipment design, and associated workplace factors with those identified and evaluated through the operational analysis
4. HSI design criteria and guidance for operations during periods of maintenance and test
5. Test and evaluation methods to identify HFE/HSI design issues
6. Documentation for any human engineering discrepancies (HEDs) as well as strategies for HED resolution

Operational aspects of the HSI process are addressed in the Human Performance Monitoring program, reference 2.1.2(12). These involve the process for refining and updating the HSI design, including:

- Modifying and updating the HSI
- Making temporary changes to the HSI
- Creating operator defined HSIs (temporary displays defined by operators for monitoring specific plant situations)

Procedures governing permissible operator initiated changes to HSIs

5 RESULTS

5.1 Results Summary Report

The results of the HSI design process outlined in this plan are summarized in a Results Summary Report (RSR). The RSR provides a list of the design specifications for the HSI, instruments required to comply with regulations, and the HSI style guide developed during implementation of this plan. The RSR is written with sufficient detail to document how the methodology outlined in this plan was implemented to provide the results. In addition, the RSR outlines:

- General approach including the purpose and scope of HSI design
- HSI design team members and backgrounds
- HFE standards and documents used in the HSI design activity
- Concept of operations from an HSI perspective
- Functional requirement specification for HSIs
- Style guide and design specifications for HSI design including:
  - The development and basis for the guide
  - The scope, topical contents, and procedures contained in the guide
  - Procedures used to maintain the style guide
- List of instruments that complies with RG 1.97 and supporting analysis
- The methods used for the evaluation and verification of the HSI
- The process for refining and updating HSI design including:
  - Modifying and updating the HSI
  - Making temporary changes to the HSI
  - Creating operator defined HSIs (temporary displays defined by operators for monitoring specific plant situations)
  - Procedures governing permissible operator initiated changes to HSIs
- Overall assessment of how well the methodology and implementation of the procedure development process and results adhere to this plan.

5.2 Periodic Reports

The COLOGCOL owner's group defines the periodicity and content of any HSI design process periodic reports.

5.3 Technical Output Reports

The COLOGCOL owner's group defines the periodicity and content of any HSI design process technical output reports.

Attachment for RAI

18.8-50

Clarifier: The enclosed markup up pages may contain unverified changes in addition to the verified changes resulting from the RAI response. Pending DCD changes associated with this RAI response are shaded for emphasis. Other changes shown in the enclosed DCD markup may not be reflective of the final format and content of DCD Revision 5 when submitted (I.e., those markups may include changes that are not fully developed and approved for inclusion in the DCD).

1.1 Purpose

This plan develops the process by which the ESBWR HSI design requirements are identified, refined, and established. The purpose is to ensure consistency with accepted HFE guidelines, principles, and methods. The result is a safe, simple, and standardized plant design.

This plan systematically delineates the requisite HFE principles necessary to translate functional and task requirements to the design of alarms, displays, controls, and other aspects of the control and instrumentation systems and HSI. Figure 1 shows where this HSI Design Implementation Plan fits into the overall HFE Process.

1.2 Scope

The scope of this HSI Design Implementation Plan establishes:

1. The methods and criteria for designing the HSI in accordance with accepted human factors guidelines, principles, and methods

2. HSI information and control requirements

    a. Support critical tasks identified through the operational analyses
    b. Identify the displays, controls, and alarms necessary for the execution of those tasks
    c. Ensure identified plant parameters used for calculation of operational limits are presented as alarms, displays, and controls
    d. Eliminate errors associated with risk-important human actions
    e. Identify error-likely situations

3. Methods for comparing the consistency of the HSI human performance, equipment design, and associated workplace factors with those identified and evaluated through the operational analysis

4. HSI design criteria and guidance for operations during periods of maintenance and test

5. Test and evaluation methods to identify HFE/HSI design issues

6. Documentation for any human engineering discrepancies (HEDs) as well as strategies for HED resolution

Operational aspects of the HSI process are addressed in the Human Performance Monitoring program, reference 2.1.2(12). These involve the process for refining and updating the HSI design, including:

- Modifying and updating the HSI
- Making temporary changes to the HSI
- Creating operator defined HSIs (temporary displays defined by operators for monitoring specific plant situations)

Procedures governing permissible operator initiated changes to HSIs

5 RESULTS

5.1 Results Summary Report

The results of the HSI design process outlined in this plan are summarized in a Results Summary Report (RSR). The RSR provides a list of the design specifications for the HSI, instruments required to comply with regulations, and the HSI style guide developed during implementation of this plan. The RSR is written with sufficient detail to document how the methodology outlined in this plan was implemented to provide the results. In addition, the RSR outlines:

- General approach including the purpose and scope of HSI design
- HSI design team members and backgrounds
- HFE standards and documents used in the HSI design activity
- Concept of operations from an HSI perspective
- Functional requirement specification for HSIs
- Style guide and design specifications for HSI design including:
  - The development and basis for the guide
  - The scope, topical contents, and procedures contained in the guide
  - Procedures used to maintain the style guide
- List of instruments that complies with RG 1.97 and supporting analysis
- The methods used for the evaluation and verification of the HSI
- The process for refining and updating HSI design including:
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Attachment for RAI

18.8-51

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1. The methods and criteria for designing the HSI in accordance with accepted human factors guidelines, principles, and methods

2. HSI information and control requirements

    a. Support critical tasks identified through the operational analyses
    b. Identify the displays, controls, and alarms necessary for the execution of those tasks
    c. Ensure identified plant parameters used for calculation of operational limits are presented as alarms, displays, and controls
    d. Eliminate errors associated with risk-important human actions
    e. Identify error-likely situations

3. Methods for comparing the consistency of the HSI human performance, equipment design, and associated workplace factors with those identified and evaluated through the operational analysis

4. HSI design criteria and guidance for operations during periods of maintenance and test

5. Test and evaluation methods to identify HFE/HSI design issues

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Operational aspects of the HSI process are addressed in the Human Performance Monitoring program, reference 2.1.2(12). These involve the process for refining and updating the HSI design, including:

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The ~~COLOG~~COL owner's group defines the periodicity and content of any HSI design process periodic reports.

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