US-APWR

Human Factors Engineering (HFE)
Program Management Plan

June 2013

Revision History

Rev.	Date	Page (Section)	Description
0	June 2009	All	Original issued
1	December 2011	General	Revised "Implementation Procedure" to "Implementation Plan." Revised Figure and Table number. Revised "US Basic" to "US-Basic." Referred latest revision of the reference documents. Revised "shift supervisor" to "shift manager." Revised "Reference 0" to "Reference 11-1" for RAI Response No. 797 (Question No. 18-184). Revised "expert panel" to "HFE design team" for RAI Response No. 728 (Question No. 18-114). Revised number of Section, Table, and Figure. "3.8" to "3.9", "3.9" to "3.10" Revised "NUREG " to "NUREG-."
		p. xi (Abstract)	Revised the description.
		p. xviii (List of Acronyms)	Revised "SS Shift Supervisor" to "SM Shift Manager."
		p. 1 (Part 1 Section 1)	Revised the description.
		p. 1 (Part 1 Section 1.1)	Revised the description.
		p. 2 (Part 1 Section 2.1)	Added the last paragraph.
		pp. 2–3 (Part 1 Section 2.3)	Revised the description for RAI Response No. 728 and 780 (Question No. 18-108 and 18-129).

Rev.	Date	Page (Section)	Description
		p. 3 (Part 1 Section 3.1)	Revised the description.
		pp. 3–5 (Part 1 Section 3.2)	Revised the description for RAI Response No. 728 (Question No. 18-109).
			Revised Figure 1 for RAI Response No. 728 (Question No. 18-109).
			Added the fourth paragraph for RAI Response No. 728 (Question No. 18-111).
			Added the last paragraph.
		p. 6 (Part 1 Section 3.3.1)	Revised the description for RAI Response No. 728 (Question No. 18-111).
		p. 7 (Part 1 Section 3.3.2)	Revised the description.
		p. 7 (Part 1 Section 3.3.3)	Revised the description.
		p. 8 (Part 1 Section 3.3.4)	Revised the description.
		p. 8 (Part 1 Section 3.4)	Revised the description.
		p. 8 (Part 1 Section 4)	Revised the description.
		p. 8 (Part 1 Section 4.1)	Revised the description.
		pp. 8–9 (Part 1 Section 4.2)	Revised the description.
		p. 9 (Part 1 Section 4.3)	Revised the description.
		p. 10 (Part 1 Section 4.4.2)	Added the last sentence.
		pp. 10–13 (Part 1 Section 5)	Added (1), (2) and (3) for RAI Response No. 728 (Question No. 18-112).
			Added Figure 5 and 6 for RAI Response No. 728 (Question No. 18-112).

Rev.	Date	Page (Section)	Description
		p. 13 (Part 1 Section 5.1)	Revised the description.
		p. 13 (Part 1 Section 5.2)	Revised the description.
		p. 13 (Part 1 Section 5.3)	Revised the description.
		p. 14 (Part 1 Section 5.6)	Revised the description.
		p. 15 (Part 1 Section 5.7.1)	Revised the description.
		p. 15 (Part 1 Section 5.7.2)	Revised the description.
		p. 15 (Part 1 Section 5.7.3)	Revised the description.
		pp. 16–17 (Part 1 Section 6.1)	Revised the description for RAI Response No. 728 (Question No. 18-114).
		p. 17 (Part 1 Section 6.3)	Added the last sentence.
		p. 18 (Part 1 Section 6.4)	Added the last sentence.
		p. 18 (Part 1 Section 6.4.1)	Revised the first sentence.
		p. 19 (Part 1 Section 6.4.2)	Revised “describe on” to “described in.”
		pp. 19–20 (Part 1 Section 6.5)	Revised the description.
		p. 20 (Part 1 Section 6.6)	Revised the description.
		p. 21 (Part 1 Section 7.2)	Revised Table 1.
		p. 21 (Part 1 Section 7.2.1)	Revised the description.

Rev.	Date	Page (Section)	Description
		p. 22 (Part 1 Section 7.2.2)	Revised the section title and Table 3.
		pp. 22–23 (Part 1 Section 7.2.3)	Revised Table 4.
		p. 23 (Part 1 Section 7.2.4)	Revised the description and Table 5.
		pp. 23–25 (Part 1 Section 8)	Revised the description for RAI Response No. 728 and 780 (Question No. 18-108 and 18-129).
		p. 25 (Part 1 Section 8.1)	Revised “MCR” to “HSIS.” Revised “rather it is focused of” to “, but rather it is focused on.”
		p. 26 (Part 1 Section 8.1.1.2 and 8.1.2.1)	Revised “”an implementation procedure” to “a procedure.”
		p. 27 (Part 1 Section 8.1.2.2)	Added the second sentence. Revised last sentence.
		p. 28 (Part 1 Section 8.1.3)	Revised the description.
		p. 28 (Part 1 Section 8.1.4)	Added “in.”
		p. 28 (Part 1 Section 8.1.5)	Revised the last sentence.
		p. 29 (Part 1 Section 8.2)	Added “analyze, ”.
		p. 29 (Part 1 Section 8.2.1)	Revised the description.
		p. 29 (Part 1 Section 8.2.1.1)	Added the last sentence.
		pp. 29–30 (Part 1 Section 8.2.1.2)	Revised the description.

Rev.	Date	Page (Section)	Description
		p. 30 (Part 1 Section 8.2.2)	Revised the description.
		p. 30 (Part 1 Section 8.2.2.1)	Revised the description.
		pp. 30–31 (Part 1 Section 8.2.2.2)	Revised the description.
		pp. 31–32 (Part 1 Section 8.2.2.3)	Revised the last sentence in the third paragraph for RAI Response No. 728 and 780 (Question No. 18-108 and 18-129). Revised description.
		p. 32 (Part 1 Section 8.2.2.4)	Revised the description.
		p. 32 (Part 1 Section 8.2.2.5)	Revised the description.
		p. 32 (Part 1 Section 8.2.3)	Revised the description.
		p. 32 (Part 1 Section 8.2.4)	Revised the description.
		p. 33 (Part 1 Section 8.3)	Revised the description.
		p. 33 (Part 1 Section 8.3.1)	Revised the description. Revised the last paragraph for RAI Response No. 728 and 780 (Question No. 18-108 and 18-129)
		p. 33 (Part 1 Section 8.3.2)	Revised the description.
		p. 34 (Part 1 Section 8.3.3)	Revised the description.
		p. 34 (Part 1 Section 9.1)	Revised “Process” to “Program”.

Rev.	Date	Page (Section)	Description
		p. 34 (Part 1 Section 9.3)	Revised “plants” to “plant.”
		p. 34 (Part 1 Section 10)	Revised the description.
		p. 36 (Part 2 Section 1.1)	Revised “will be” to “was” for RAI Response No. 594 (Question No.18-80).
		p. 36 (Part 2 Section 1.2)	Revised “will be” to “was” and deleted “will” for RAI Response No. 594 (Question No. 18-80).
		p. 38 (Part 2 Section 1.4)	Revised Figure 1.4-1.
		pp. 39–40 (Part 2 Section 1.4.1)	Revised “broken” to “faulted.”
			Added the last paragraph for RAI Response No. 793 (Question No. 18-143).
		p. 41 (Part 2 Section 1.4.2)	Revised “broken” to “faulted.”
		pp. 45–46 (Part 2 Section 1.4.3)	Revised the description of the third bullet for RAI Response No. 793 (Question No. 18-149).
			Revised Figure 1.4-2 for RAI Response No. 793 (Question No. 18-141).
		pp. 50–66 (Part 2 Appendix 1.8.1)	Revised Appendix 1.8.1 for RAI Response No. 594 (Question No. 18-70).
			Revised to include the spent fuel for RAI Response No. 793 (Question No. 18-141).
			Revised Table 1.8-1 to include the expansion of associated parameter columns to reflect and align with Section 18.3.3 of the DCD for RAI Response No. 793 (Question No. 18-147).
		pp. 67–72 (Part 2 Appendix 1.8.2)	Added a reference to DCD Chapter 7 to the Source Document ID column for RAI Response No. 793 (Question No. 18-147).
			Revised Table 1.8-2 to better format and to include more detailed DCD reference information for RAI Response No. 793 (Question No. 18-147).

Rev.	Date	Page (Section)	Description
		pp. 73–97 (Part 2 Appendix 1.8.3)	Revised to include the spent fuel for RAI Response No. 793 (Question No. 18-141). Revised to correct where Table 1.8-3 was mistakenly labeled Table 1.8-4 for RAI Response No. 793 (Question No. 18-147). Revised the description.
		pp. 98–114 (Part 2 Appendix 1.8.4)	Added the title of Table 1.8-4 for RAI Response No. 594 (Question No. 18-73). Revised Table 1.8-4 for RAI Response No. 594 (Question No. 18-73). Revised to include the spent fuel for RAI Response No. 793 (Question No. 18-141). Added assumptions of manual actions in the case of automation failure in each "Comment" column which was assigned as "Machine" for RAI Response No. 793 (Question No. 18-143). Added the description of shared control in each "Comment" column for RAI Response No. 793 (Question No. 18-145).
		p. 115 (Part 2 Appendix 1.8.5)	Added Appendix 1.8.5.
		p. 116 (Part 2 Section 2.2)	Revised the first paragraph. Added to second paragraph for RAI Response No. 664 (Question No. 18-97).
		p. 118 (Part 2 Section 2.4.2.1)	Revised "such as" to "of" for RAI Response No. 595 (Question No. 18-86).
		p. 120 (Part 2 Section 2.4.2.2.1 B)	Deleted the second sentence for RAI Response No. 797 (Question No. 18-182).
		p. 122 (Part 2 Section 2.5)	Added "Integration" to the first sentence.

Rev.	Date	Page (Section)	Description
		p. 124 (Part 2 Section 2.9)	Added Reference 2.9-6 and 2.9-7.
		pp. 127–195 (Part 2 Appendix 2.10.2)	Deleted "(from Ref. 2.9-2)." Revised the description.
		p. 196 (Part 2 Appendix 2.10.3)	Revised the description.
		p. 197 (Part 2 Section 3.2)	Revised the first paragraph and added the second paragraph for RAI Response No. 781 (Question No. 18-131). HRA Report Part 2 Section 2 refers to that same document for RAI Response No. 664 (Question No. 18-95). Revised the last paragraph for RAI Response No. 595 (Question No. 18-87).
		pp. 198–201 (Part 2 Section 3.4)	Revised the description. Revised Table 3.4-1 for RAI Response No. 781 (Question No. 18-132).
		p. 201 (Part 2 Section 3.6.1)	Revised the first sentence.
		pp. 201–203 (Part 2 Section 3.7)	Revised the description. Added the new description after the last paragraph for RAI Response No. 781 (Question No. 18-137).
		p. 204 (Part 2 Section 3.8)	Added as a new Section 3.8 (from Section 3.8.1 to Section 3.8.3.7) for RAI Response No. 781 (Question No. 18-132).
		pp. 208–245 (Part 2 Section 3.8.3.8)	Added as a new Section 3.8.3.8 for RAI Response No. 781 (Question No. 18-131). Revised Table 3.7-1 for RAI Response No. 781 (Question No. 18-132).

Rev.	Date	Page (Section)	Description
		pp. 248–255 (Part 2 Appendix 3.10.1)	Revised the description.
		pp. 257–283 (Part 2 Appendix 3.10.2)	Revised the description. Revised Table 3.10-1 and 3.10-3. Added Table 3.10-4.
		p. 284 (Part 3 Section 1)	Deleted “The” in the second paragraph.
		p. 289 (Part 3 Section 4.2.2)	Revised “@” to “at.”
		p. 290 (Part 3 Section 4.2.3)	Revised “the” to “The” at the last sentence in the first paragraph.
		p. 292 (Part 3 Section 5.1)	Revised “The” to “the.”
2	October 2012	All pages	Revised to incorporate comments by the NRC in March 2012 to keep consistency in technical description with DCD Chapter 18, MUAP-09019, MUAP-10008, MUAP-10012, MUAP-10013 and MUAP-10014.
3	July 2013	All	Complete re-write. Revised to align closely with NUREG-0711 order and format.

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Abstract

This program plan provides the Human Factors Engineering (HFE) Program Management Plan for the US Advanced Pressurized Water Reactor (US-APWR), which expands on HFE program management as described in the US-APWR Design Control Document (DCD) Chapter 18, Section 18.1 (Reference 8-2). This plan applies to the complete US-APWR HFE program, which conforms to the guidance in NUREG-0711, Revision 2 (Reference 8-2).

The goal of the HFE program is to describe the technical HFE program elements in enough detail to demonstrate that aspects of the human-system interface (HSI), procedures, and training are developed, designed, and evaluated on the basis of accepted HFE principles. The HFE program as a whole also considers and addresses deterministic and risk important aspects of design. The US-APWR HFE program starts with the development of the US-Basic Human-System Interface System (HSIS), which the U.S. Nuclear Regulatory Commission (NRC) has approved for applications in new nuclear plants and for modernization of existing plants. The US-APWR HFE program continues through the implementation of the US-APWR HSIS and culminates in the HSIS for a site-specific US-APWR application (referred to as a US-APWR site-specific HSIS). The US-APWR HSIS combines the generic control, monitoring, alarm, and computerized procedure methods of the US-Basic HSIS with the specific HSI inventory needed for the US-APWR plant design.

The US-APWR HSIS scope includes the main control room and its HSI derivatives (i.e., remote shutdown room, technical support center, and the safety parameter information requirements for the emergency offsite facility). This program plan is also applicable to local control stations used by licensed and non-licensed plant operators, referred to as US-APWR Local HSI. The US-APWR HSIS and US-APWR Local HSI include site-specific assumptions to encompass a complete plant. This US-APWR HFE program encompasses the confirmation or modification of those assumptions to achieve a US-APWR site-specific HSIS and US-APWR site-specific Local HSI.

This program plan establishes generic requirements reflected in the implementation plans (IPs) and results summary reports (ReSRs) for each of the HFE program elements described here. These requirements encompass the qualifications of the personnel who will conduct the analyses and develop the HSI designs, as well as the documentation requirements.

Through the aggregate of all HFE program elements, the US-APWR HFE process employs multiple converging methods to create an integrated HSIS that fully supports human performance needs. As in any normal course of design, analysis or design issues may be identified that necessitate rework within a previous program element. Design or analysis issues are documented as human engineering discrepancies (HEDs). This program plan governs the identification, evaluation, and resolution of HEDs and the tracking of HEDs through their life cycle.

Multiple organizations make up the overall HFE team. Engineering management has the authority and organizational placement to assure all areas of responsibility are accomplished, and to identify problems in the implementation of the overall plant design. The HFE manager requests resources from other technical management areas to accomplish the HFE process. The HFE manager is responsible for the following:

- Management decisions regarding the HFE program
- Assuring that HFE elements are appropriately scheduled and implemented in accordance with the HFE program IPs
- Organizing the HFE team
- Oversight of the HFE processes
- Controlling HFE resources
- Making HFE design decisions and controlling HFE design changes

Once approved by the NRC, IPs establish the required content and review and inspection acceptance criteria for each corresponding ReSR. ReSRs are used to demonstrate compliance with the IP. NRC review of an ReSR can occur during the US-APWR DCD review for those HFE program elements that are completed during the DCD review process. Alternately, NRC inspection of an ReSR can occur after the DCD review is completed through the inspections, tests, and analysis acceptance criteria (ITAAC) closure process; the IP establishes the acceptance criteria for ITAAC closure.

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Acronyms

ANS	American Nuclear Society
ANSI	American National Standards Institute
AO	auxiliary operator (non-licensing plant personnel)
APWR	advanced pressurized water reactor
ASME	American Society of Mechanical Engineers
BISI	bypassed and inoperable safety system status indication
CAD	computer-aided design
CAS	central alarm station
CBP	computer-based procedure
CFR	*Code of Federal Regulations*
COL	combined license
CPNPP	Comanche Peak Nuclear Power Plant
D3CA	defense-in-depth and diversity coping analysis
DCA	design change analysis
DCD	Design Control Document (US-APWR)
DI	design implementation (HFE)
DIHA	deterministically important human action
DTM	design team manager
EMD	engineering management director
EOF	emergency operations facility
EOP	emergency operating procedure
EU	English units
FA	function allocation
FRA	functional requirements analysis
GDC	general design criterion
HA	human action
HD	human-system interface design
HED	human engineering discrepancy
HEP	human error probability
HFE	human factors engineering
HPM	human performance monitoring
HRA	human reliability analysis
HSI	human-system interface
HSIS	human-system interface system
HSISIM	human-system interface system implementation manager
I&C	instrumentation and control
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IHA	important human action
IP	implementation plan

ISV	integrated system validation
ITAAC	inspections, tests, analyses, and acceptance criteria
LCS	local control station
LDP	large display panel
MCR	main control room
MELCO	Mitsubishi Electric Corporation
MEPPI	Mitsubishi Electric Power Products, Inc.
MHI	Mitsubishi Heavy Industries, Ltd.
MNES	Mitsubishi Nuclear Energy Systems
NPP	nuclear power plant
NRC	U.S. Nuclear Regulatory Commission.
OER	operating experience review
PMP	program management plan
PRA	probabilistic risk assessment
PWR	pressurized-water reactor
QA	quality assurance
QAP	quality assurance program
RG	regulatory guide
RIHA	risk-important human action
RO	reactor operator
ReSR	results summary report
RSR	remote shutdown room
S&Q	staffing and qualifications
SAS	secondary alarm station
SDCV	spatially dedicated continuously visible
SME	subject-matter expert
SPDS	safety parameter display system
SRM	staff requirements memorandum
SRO	senior reactor operator
STA	shift technical advisor
TA	task analysis
TAA	transient and accident analyses
TMI	Three Mile Island
TSC	technical support center
US, U.S.	United States
US-APWR	US Advanced Pressurized Water Reactor
US NPP	U.S. nuclear power plant
V&V	verification and validation (HFE)
VDU	visual display unit
VTM	V&V team manager

1.0 PURPOSE

This US Advanced Pressurized Water Reactor (US-APWR) Human Factors Engineering (HFE) Program Management Plan (PMP) (hereafter referred to as the "HFE PMP") provides a comprehensive HFE program management plan and expands on the program plan described in Chapter 18 of the US-APWR Design Control Document (DCD) (Reference 8-2).

The purposes of this program management plan are the following:

- Establish the goals and scope of the HFE program

- Define a US-APWR HFE design team organizational structure with the responsibility, authority, placement within the organization, and composition to verify that the design commitment to HFE is met. Demonstrate that the team is guided in a way that provides reasonable assurance that the HFE program is properly developed, executed, overseen, and documented.

- Describe the key objectives and interfaces of the HFE program elements to ensure that all aspects of the human-system interface (HSI) are developed, designed, and evaluated on the basis of accepted "state of the art" HFE principles.

- Define a process that integrates HFE into the US-APWR plant development, design, and evaluation processes.

- Establish a process that results in US-APWR HSIs that promote safe, efficient, and reliable performance of operation, maintenance, test, inspection, and surveillance tasks.

This HFE PMP is based on application of the US-Basic HSI System (HSIS) that establishes generic monitoring, alarm, control, and computerized procedure technologies to be employed in the main control room (MCR) for all plant systems. When a Basic HSIS is combined with the HSI inventory (i.e., alarms, indications, controls, and procedures) for a specific plant, an HSIS is created for that complete plant.

The generic HSI technologies of the US-Basic HSIS are combined with the specific HSI inventory needed for the US-APWR plant design to create the US-APWR HSIS. The US-APWR HSIS standard design includes site-specific assumptions to encompass a complete plant. The development process for a US-APWR site-specific HSIS confirms or changes those assumptions to reflect an actual site-specific plant.

This program plan is written to achieve a US-APWR HSIS that supports both safe plant operation and plant power production. The HFE PMP governs the HFE activities needed to do the following:

- Build on a previously developed and tested Japanese-Basic HSIS to achieve the US-Basic HSIS.

- Develop the HSI inventory for the US-APWR and integrate that with the US-Basic HSIS to achieve the US-APWR HSIS.

- Modify the US-APWR HSIS as necessary to achieve a US-APWR site-specific HSIS.

Each HFE program element (as defined in NUREG-0711, “Human Factors Engineering Program Review Model,” issued February 2004 (Reference 8-3)) covered by this plan has a specific methodology. The work aspects of a particular program element are governed by the methodology specific to that element. For HFE activities completed within the scope of the US-APWR design certification application (i.e., operating experience review (OER), functional requirements analysis and functional allocation (FRA/FA), task analysis (TA), staffing and qualifications (S&Q) analysis, human reliability analysis (HRA), HSI design (HD), human factors verification and validation (V&V), and design implementation (DI), , the program element methodology is described within an implementation plan (IP) and the output of that element is documented in a results summary report (ReSR).

2.0 GENERAL HUMAN FACTORS ENGINEERING PROGRAM AND SCOPE

2.1 Human Factors Engineering Program Goals

The US-APWR HFE program assures that each HSI reflects modern human factors principles and satisfies the applicable regulatory requirements. The HFE PMP describes how the overall implementation is conducted in accordance with NRC approved IPs.

The general objectives of the HFE program are intended as "human-centered" terms that, as the HFE program develops, are defined and used as a basis for HFE test and evaluation activities. The specific HFE program ensures that the following occur:

- Personnel tasks are accomplished within the required time and in accordance with specified performance criteria.
- The HSI, staffing, qualifications, procedures, training, management, and organizational support result in a high degree of operating crew awareness of plant conditions.
- The plant design and allocation of functions results in an integrated HD that maintains operational vigilance and provides acceptable workload levels to minimize periods of operator underload and overload.
- The operator interfaces minimize operator error and provide error detection and recovery capability.

The scope of HFE program management includes the following topics:

- HFE design team and organization
- HFE process and procedures
- HFE issues tracking
- HFE technical program

The US-APWR HFE program is accomplished through the activities implemented by the US-APWR HFE team. The US-APWR HFE team uses and implements the US-APWR HFE processes and procedures. The US-APWR HFE team is responsible for writing all HFE IPs and for the execution of the following HFE IPs: OER, FRA/FA, HRA, S&Q analysis, TA, HD and V&V.

The US-APWR HFE team is also responsible for the site-specific recurring execution of the DI IP, which (1) converts the US-APWR HSIS and US-APWR Local HSI to the US-APWR site-specific HSIS and US-APWR site-specific Local HSI, respectively, and (2) ensures the site-specific as-built HSI accurately reflects the US-APWR HSIS and US-APWR Local HSI with the approved site-specific changes.

The licensee is responsible for HPM and manages and executes those HPM procedures over the life of the plant through various site-specific organizations, including those responsible for operations and training.

The US-APWR site-specific HFE team is also responsible for the detailed design of the emergency operations facility (EOF). This includes creating the HSI that will display the safety parameter display system information requirements that are created by the US-APWR HFE team as part of the US-APWR HSIS, and creating the HSI to implement the MCR communication interface requirements, which are also established by the US-APWR HFE team.

Site-specific HFE processes and procedures are used for all site-specific HFE team responsibilities, including HD changes after the US-APWR site-specific HD is turned over to the US-APWR site-specific HFE team. The responsibilities of the US-APWR site-specific HFE team are outside the scope of this US-APWR HFE PMP.

2.2 Assumptions and Constraints

The assumptions and constraints of the design or the use of specific HSI technology are inputs to the HFE program.

2.2.1 Background

The Japanese-Basic HSIS was developed in the late 1990s. The Japanese-Basic HSIS design process employed elements of NUREG-0711, Revision 2 (Reference 8-3). Approximately 200 Japanese nuclear power plant (NPP) operators participated in the evaluation process. The Japanese-Basic HSIS is being used in Japan for new pressurized-water reactor (PWR) NPPs and for operating PWR NPP control board replacement projects. The Japanese-Basic HSIS is functioning at the Tomari 3 and Ikata 1 and 2 nuclear plants. Mitsubishi has also reached agreement with other Japanese utilities to install the Japanese-Basic HSIS in new NPPs and for replacement of existing main control boards in other operating Japanese NPPs.

The US-APWR HSIS development is divided into three phases:

(1) Phase 1 yields the generic US-Basic HSIS.

(2) Phase 2 develops the US-APWR Inventory and combines that with the US-Basic HSIS to yield the US-APWR HSIS. The US-APWR HSIS includes site-specific assumptions to establish a complete plant HSIS.

(3) Phase 3 confirms the site-specific assumptions of Phase 2 or makes minor site-specific changes to the US-APWR HSIS to yield a US-APWR site-specific HSIS.

Development activities and products for each phase are described in Appendix C to MUAP-07007 (Reference 8-1). Each phase is divided into two steps. The activities associated with each step for each phase are different. The phases and steps are activities performed at overlapping times. Figure 2-1 shows the logic and overlapping steps for Phases 1 and 2. Phase 3a develops the US-APWR site-specific HSIS and creates the site-specific operator training simulator. Operator training in conducted in Phase 3b.

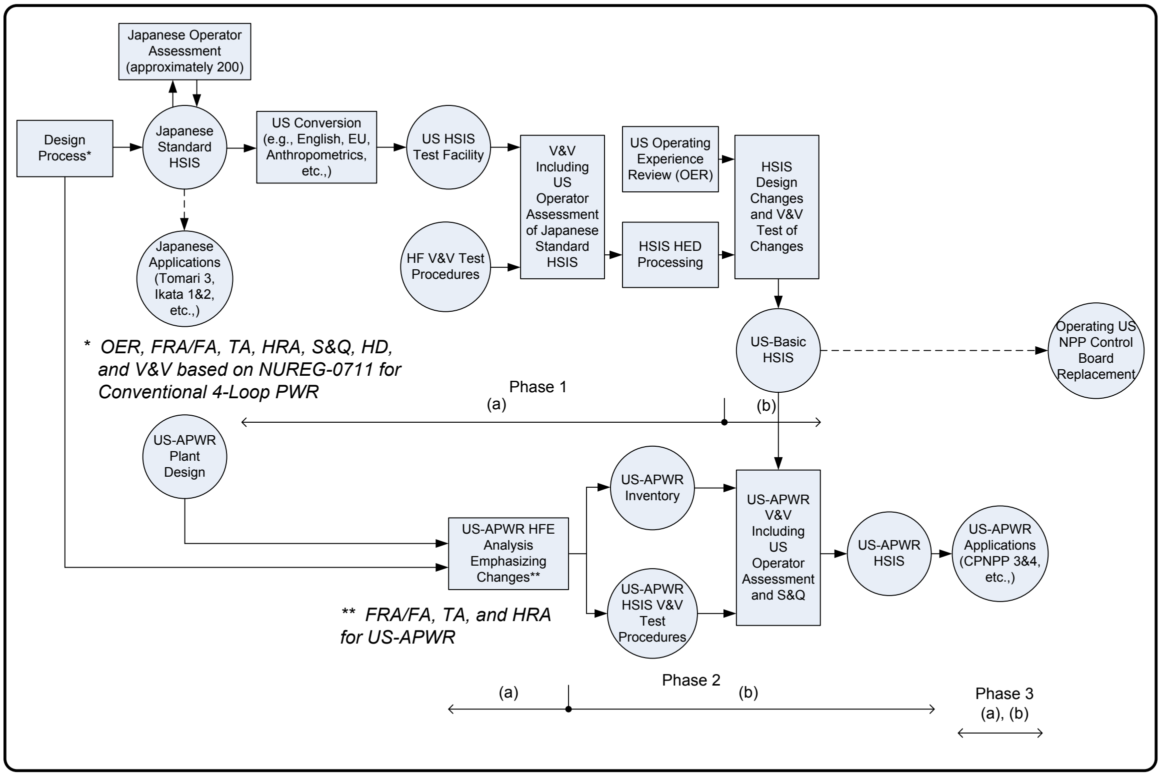

Figure 2-1 US-APWR Main Control Room Development High-Level Logic

The primary benefits of using the Japanese-Basic HSIS design as the initial input for U.S. applications are as follows:

- To learn from the Japanese experience applying key NUREG-0711, Revision 2, program elements to the Japanese-Basic HSIS.
- To achieve a US-Basic HSIS from input based on extensive full-scope simulator testing with Japanese operators.
- To benefit from the Japanese operating experience (the Japanese-Basic HSIS will have been in operation for years at several nuclear plants prior to operation of the US-Basic HSIS in the United States).

The U.S. Nuclear Regulatory Commission (NRC) has approved the US-Basic HSIS as described in the safety evaluation of MUAP-07007 (Reference 8-14). This approval was based on the resulting design (Section 4 of MUAP-07007) and the design process for compliance with the NUREG-0711 program elements (Section 5 of MUAP-07007), as that process pertains to the HSI methods encompassed by the US-Basic HSIS. The US-Basic HSIS conforms to regulatory guidance in NUREG-0700, “Human-System Interface Design Review Guidelines,” issued May 2002 (Reference 8-16); the HFE aspects or style guide applied to the US-Basic-HSIS are approved.

The descriptions of the HFE program elements in MUAP-07007, “HSI System Description and HFE Processes,” Revision 5, issued November 2011 (Reference 8-1), as they pertain to developing a plant-specific HSI inventory, are written at a programmatic level. Therefore, they are superseded by the program elements described in this document. This includes the referenced IPs, which are written at a detailed level to fully explain how each program element is executed and thereby demonstrate conformance to the review criteria in NUREG-0711. The HFE program elements described in this document and associated references are applied to the development of the US-APWR HSIS. The US-APWR HSI inventory developed through these IPs is combined with the approved HD of the US-Basic HSIS to establish the complete and fully integrated US-APWR HSIS.

2.2.2 HSIS Starting Point

The NRC-approved US-Basic HSIS is the primary input for the design of the US-APWR HSIS; therefore, it is considered a constraint of the US-APWR HSIS. The inventory of controls, indications, alarms, and procedures needed to operate the US-APWR will be implemented using the HSI components of the US-Basic HSIS. These HSI components include the large display panel (LDP), operational visual display units (VDUs), alarm VDUs, computer-based procedure (CBP) VDUs, safety VDUs, and conventional HSI. The HSI components incorporate the HD bases and methods for control, indication, alarm, and procedures. In a broader sense, the US-Basic HSIS incorporates the general arrangement and integration of these HSI components. These aspects of the US-Basic HSIS are subjected to the HFE program elements to become the US-APWR HSIS. This process identifies the unique issues for the US-APWR plant that represent changes from the US-Basic HSIS. The design assumptions and constraints of the US-Basic HSI System are clearly identified in MUAP-07007 (Reference 8-1)

2.2.3 Minimum Main Control Room Staffing

The MCR staffing meets the regulatory requirements of Title 10 of the *Code of Federal Regulations* (10 CFR) 50.54(m)(2)(iii) (Reference 8-17). The normal MCR staff is supplemented by one additional SRO and one additional RO who is to be at the plant to accommodate unexpected design conditions, including conditions in which the HSIS is degraded. In addition, the minimum staff includes one more person present at the facility during its operation with SRO or STA qualifications. During emergency conditions, this person will relieve the MCR supervisor of either the supervisor or STA responsibilities. The person can be shared by multiple units.

A design constraint of the US-Basic HSIS that also applies to the US-APWR HSIS is that the plant can be operated with just one reactor operator (RO) and one senior reactor operator (SRO) in the MCR during plant operating modes (US-APWR DCD Chapter 18, Reference 8-2, Section 4.1.f). Plant operating modes are defined as technical specification MODES 1 and 2, including plant stabilization after abnormal events, including events within and outside the design basis. The SRO fulfills the role of MCR supervisor and shift technical advisor (STA) during normal operation.

The minimum staffing design constraint is accommodated through HD and is confirmed through OER, HRA, TA, S&Q, and V&V.

The minimum staffing organization is shown in Figure 18.1-2 of the US-APWR DCD (Reference 8-2).

2.2.4 Maximum Main Control Room Staffing

While the HSIS is designed to accommodate the minimum MCR and plant staffing described above, maximum staffing also represents a design constraint. The space and layout of the MCR are designed to accommodate the foreseen maximum number of operating and temporary staff.

The maximum MCR operating staff is shown in Figure 18.1-3 of the US-APWR DCD (Reference 8-2). In addition, physical and habitability accommodations are provided within the MCR envelope for several active observers. The quantities and expected roles of the observers are defined in the DCD (Reference 8-2).

The maximum staffing design constraint is accommodated through HD and is confirmed through V&V and DI.

2.2.5 US-APWR Human System Interface Design Methodology

The US-Basic HSIS was developed from the Japanese HSIS. This development process included design testing with U.S. plant operators. While the testing demonstrated a design that complied with its regulatory basis and functional requirements, operators were encouraged to generate human engineering discrepancies (HEDs) during that testing to facilitate design improvements.

The development of the US-APWR HSIS and US-APWR Local HSI starts with the evaluation of design inputs, including personal task requirements, system requirements, and regulatory requirements that lead to a concept of operations, HSI functional requirements specification, and, ultimately, an HD concept. The US-Basic HSIS established the functional specifications for HD elements used by plant operators, including indications, alarms, controls and procedures. These specifications include methods of information and control presentation on video displays, methods of navigation to those displays, and the methods by which those HSI elements are fully integrated together to provide an HSI environment that fully supports the concept of operations. These methods include standards for detailed design, which are documented in the US-Basic HSIS style guide. This detailed design is the starting point for the activities governed by the US-APWR HFE program.

The scope of the US-APWR HSIS includes the portions of the plant design that are encompassed by the US-APWR DCD and the portions of the plant design that are site specific (e.g., ultimate heat sink). For the site-specific portions, assumptions are made to establish a complete plant design that is reflected in a complete HSI inventory for the US-APWR HSIS. The fully integrated US-APWR HSIS is ultimately verified and validated through the V&V program element.

After defining the standard US-APWR HSIS, the HSIS is modified as necessary to reflect an actual site-specific application. At this point in the design process, site-specific differences in plant system designs (as compared to the site-specific assumptions made to create the US-APWR HSIS, discussed above) are evaluated. A design change analysis (DCA) determines the impact on previous US-APWR HFE analyses (i.e., FRA/FA, HRA, TA, and S&Q) and the potential need for reanalysis. Ultimately, the US-APWR HSI inventory is reviewed and modified to reflect the actual site-specific design in the US-APWR HSIS simulator. The DCA also determines the extent of additional V&V required. Site-specific activities, including the DCA, any reanalysis, incorporation of changes to the US-APWR HSIS design, and any V&V are governed by the DI IP. All HFE design activities fall within the design control process described in the Mitsubishi Heavy Industries, Ltd. (MHI) quality assurance program (QAP) (Reference 8-13), including design changes and revision control aspects.

2.3 Applicable Plant Facilities

The US-APWR HFE program applies to the following areas or facilities:

- MCR
- Remote shutdown room (RSR)
- Technical support center (TSC)

  Note: For each of the three facilities above, the scope of this HFE program includes defining voice communication interfaces with the EOF, central alarm station (CAS), and secondary alarm station (SAS), which are site-specific facilities that are outside the scope of the US-APWR HFE program.

- Local control stations (LCSs) – HFE analysis and HD activities are limited to those LCSs used by licensed or non-licensed operators. For other LCSs (e.g., LCSs specific to support chemistry, radiological control, maintenance, testing), the V&V program element encompasses communication between the operators in the MCR and RSR and personnel using these local stations.
- EOF – The US-APWR HFE program scope is limited to defining the plant safety information requirements (i.e., safety parameter display system) and requirements for voice communication with plant operators in the MCR, RSR, and TSC.

2.3.1 Site-Specific Facilities

2.3.1.1 Central Alarm Station/Secondary Alarm Station

The US-APWR HFE program encompasses the communication interface between the MCR and the CAS/SAS. The US-APWR HFE team determines the voice communication needed between the CAS/SAS and the MCR, in accordance with regulatory requirements and guidance, and incorporates this information in the HD and the V&V process. The CAS/SAS design itself is outside the scope of the US-APWR HFE IPs.

2.3.1.2 Emergency Operations Facility

Voice communications requirements between the EOF and MCR, RSR, and TSC are defined by the US-APWR HFE team. The US-APWR HFE team also determines the HSI for safety parameter display system (SPDS) information that must be transmitted from the plant to the EOF. This is the same SPDS information displayed in the MCR, which includes the following:

- Meteorological displays
- Offsite radiation monitoring
- Post-accident monitoring

For the EOF, the *site-specific* HFE team defines other communication and HSI inventory needs, and all human factors and HD considerations. The EOF HFE design is developed in accordance with NUREG-0696, “Functional Criteria for Emergency Response Facilities,” issued February 1981 (Reference 8-15).

2.4 Applicable Human-System Interfaces, Procedures, and Training

The applicable HSIs, procedures, and training developed and evaluated by the HFE program support normal, abnormal, and emergency operations. In addition, the HFE program includes the development of HSIs, procedures, and training for local monitoring, test, and maintenance performed by operations personnel.

However, the scope of procedures within the responsibility of the US-APWR HFE program is limited to the computer-based operating procedures and paper operating procedures that are used for the scenarios conducted during integrated system validation (ISV). Other procedures that are unrelated to the V&V scenarios are not in the scope of the HD program element because they have their own development and verification program, as described in Chapter 13 of the US-APWR DCD (Reference 8-3).

For activities performed locally by non-operations personnel, the HFE program is limited to the operator interface with those personnel. For local activities performed by other personnel, the HFE program is limited to the operator interface with those personnel; this is addressed only within the Operational Condition Sampling of the V&V program element.

HSIs for the MCR and its derivatives (i.e., RSR, TSC, and EOF) are referred to as the US-APWR HSIS. However, for the EOF, the scope of the US-APWR HSIS is limited to the plant information requirements (i.e., SPDS).

HSIs used by operators outside the MCR (LCSs) are referred to as US-APWR Local HSI. Other local HSIs are outside the scope of the HFE program.

Other engineering departments provide local controls on motor control centers and skid-mounted equipment used by plant operators. Design outputs related to these local HSIs are included in the US-APWR HFE program. HFE team review and control of these local HSIs applies to both internal and external departments/suppliers.

2.5 Applicable Plant Personnel

Plant personnel positions addressed by the HFE program include licensed control room operators as defined in 10 CFR Part 55, “Operators’ Licenses” (Reference 8-18), and the categories of personnel defined by 10 CFR 50.120, “Training and Qualification of Nuclear Power Plant Personnel” (Reference 8-17). The HFE program addresses the activities of operations personnel through FRA/FA, HRA, TA, HD, V&V, and DI. The activities for operators and these other plant personnel are evaluated in the OER IP (Reference 8-4) and in the S&Q IP (Reference 8-9). This encompasses plant personnel who perform local monitoring, test, and maintenance of safety-significant plant equipment.

The plant personnel addressed by the S&Q analysis (see Section 6.1.5, below) include licensed control room operators as defined in 10 CFR 50.54(m) (Reference 8-17) and the following categories of personnel defined in 10 CFR 50.120 (Reference 8-17):

- Non-licensed operators
- Shift supervisors and managers
- Shift technical advisor
- Instrumentation and control (I&C) technicians
- Electrical maintenance personnel
- Mechanical maintenance personnel
- Radiological protection technicians
- Chemistry technicians
- Engineering support personnel

Other aspects of the HFE analyses are limited in scope as follows:

- OER includes analysis of human performance errors by plant personnel, as defined above.

- FRA, HRA, TA, HD, V&V, and DI include only tasks performed by SROs, ROs, and auxiliary operators (AOs).

2.6 Effects of Modifications on Personnel Performance

The design process encompassed by all HFE program elements up to and including DI evaluates the effects on personnel performance for any modifications in the plant design or HD. These evaluations occur directly or through the resolution of HEDs.

Beginning at initial loading of the plant's fuel, the licensee will initiate the HPM program. HPM evaluates impacts on human performance for design changes occurring after close-out of all US-APWR pre-fuel-load inspections and tests. Through HPM, ongoing evaluations and corrective actions ensure operators maintain the same level of proficiency demonstrated during the US-APWR V&V program. This includes time-critical performance for operator actions that are credited in various plant safety analyses. HPM proactively identifies human performance degradation that may occur for any reason, including changes to the plant design HD, training, and procedures. The execution of the ongoing HPM program is the responsibility of the licensee.

Separate from HPM, licensees conduct plant modifications in accordance with regulatory requirements, such as 10 CFR 50.59, "Changes, Tests, and Experiments" (Reference 8-17). These requirements invoke additional HFE analysis or testing as deemed necessary by the responsible site-specific HFE team. The plant modification process is outside the scope of HPM.

3.0 HFE TEAM AND ORGANIZATION

The following subsections describe the US-APWR HFE team and organization.

3.1 HFE Responsibility

The US-APWR HFE team is responsible (with respect to the scope of the HFE program) for the following:

- Development of HFE plans and procedures
- Oversight and review of HD, development, test, and evaluation activities
- Evaluation of problems and solution development for problems identified in the implementation of the HFE activities
- Verifying that team recommendations are implemented
- Assurance that all HFE activities comply with the HFE plans and procedures
- Scheduling of activities and milestones

3.2 HFE Organizational Placement and Authority

The organizational structure to manage the HFE team is shown in Figure 3-1. As illustrated in Figure 3-1, multiple organizations are involved. The engineering management director (EMD) or the technical discipline managers that report to the EMD have the authority and organizational placement to assure all areas of responsibility are accomplished, and to identify problems in the implementation of the overall plant design. The HFE manager can request the other managers (or the EMD) to assign resources from other technical management areas to accomplish the HFE process.

The HFE manager has the authority to limit further processing, delivery, installation, or use of HFE products until the disposition of a nonconformance, deficiency, or unsatisfactory condition has been achieved.

The roles and responsibilities for the key sections of the organization are as follows.

3.2.1 Engineering Management Director

The EMD is responsible for controlling engineering resources/organizations and directing responsible organizations to resolve critical design or engineering issues that include HFE issues (referred to as HEDs). Verifies assumptions related HFE design elements including features of the MCR such as physical sizing boundary, air conditioning pathways and controls for temperature and pressure, security, power supplies, cable separation, measurement scales, etc. are compatible with other design organization inputs to the design.

3.2.2 HFE Manager

The HFE manager is responsible for management decisions regarding the HFE program. The HFE manager assures that all HFE elements are appropriately scheduled and implemented in accordance with the HFE IPs, including design reviews. The HFE manager is responsible for organizing the HFE team, oversight of the HFE processes, and controlling HFE resources. The HFE manager is responsible for making HFE design decisions and controlling HFE design changes within the overall design parameters. Where a discrepancy exists between HFE requirements and the plant design, an HED is generated. Technical discipline staffs (i.e., engineering divisions) are engaged in HED resolutions and are required to change the plant design based on HED resolutions.

The HSIS design team manager (DTM) and the HSIS V&V team manager (VTM) report to the HFE manager. HFE team members consist of multidisciplinary engineers from each engineering division. HFE members are responsible for resolving HEDs in accordance with their engineering responsibilities and gaining approval of the proposed resolution from the Expert Panel (see Section 3.3.1).

3.2.3 Technical Discipline Managers

The technical managers and their staffs implement the assigned work responsibilities.

3.2.4 HSIS Design Team Manager

The DTM is responsible for implementing each of the HFE program elements with the exception of the V&V and DI, which are the responsibility of the HSIS VTM. The design team conducts functional design activities for hardware and software. The DTM assures that the design team correctly performs design activities based on the technical requirements and the development process in accordance with MUAP-07007 (Reference 8-1). The DTM is also responsible for the following:

- Developing HFE IPs, associated work procedures, and ReSRs as described in Section 6.0, below
- The initiation, recommendation, and provision of solutions through designated channels for problems identified in the implementation of the HFE activities (i.e., HEDs)
- Implementation of HFE program elements, with the exception of the V&V
- Assuring HFE activities comply with HFE plans and procedures
- Scheduling and design review activities
- Controlling HD and HFE documentation configuration
- HD decisions, including design changes required for resolution of HEDs
- The development of US-APWR HSIS design specifications, either directly or indirectly through other engineering disciplines

The DTM on the HFE team has at least 10 years of nuclear experience in his or her expert field and an education background that supports his or her expert credentials. The DTM is also experienced in the management of the design and operation of complex control technologies.

3.2.4.1 HSIS Design Team

The HSIS design team conducts analysis and design activities for HFE program elements with the exception of the V&V and DI, which are conducted by the V&V team. The HSIS design team consists of a multidisciplinary technical staff as assigned by the HFE manager. The team is under the leadership of the DTM.

The term "HSIS design team" is used in a generic sense to refer to the personnel who are contributors to the HSIS design. Many of the technical disciplines that make up the overall HFE team (Table 3-1) are assigned to support HSIS design on a "matrixed" basis but report organizationally through other technical groups. These disciplines are organized into separate groups for HFE analysis and HD.

3.2.5 HSIS V&V Team Manager

The VTM is responsible for V&V. The VTM ensures sufficient resources are available and ensures that V&V activities are not adversely affected by commercial and schedule pressures. The VTM is responsible for formal design testing of HFE products during the V&V of the US-APWR HSIS. The VTM is responsible for defining HFE V&V processes, generating V&V procedures, and defining and generating V&V data collection forms. The VTM ensures that the V&V activities are conducted in accordance with the US-APWR V&V IP (Reference 8-11).

The VTM is also responsible for DI. The VTM ensures all activities, including DCA and as-built HSI confirmation, are conducted with qualified resources and in accordance with the DI IP.

The VTM on the HFE team has at least 10 years of nuclear experience in his or her expert field and an education background that supports his or her expert credentials.

3.2.5.1 HSIS V&V Team Organization and Composition

The HSIS V&V team conducts the HSI V&Vs in accordance with the US-APWR HSI V&V IP (Reference 8-11). The HSI V&V team includes personnel with the following technical skills:

- HFE
- Plant operations
- Personnel training
- HSI/I&C engineering

The V&V team adds other technical disciplines as defined by the V&V and DI IPs (References 8-11 and 8-12).

Discretion regarding the independence of the design and review team members rests with the HFE manager. As a result, V&V team members may contribute to the HD and HSIS design team members may participate in V&V activities with the approval of the HFE manager.

3.2.6 HSIS Hardware and Software Implementation Manager

The HFE team interfaces with others for detailed hardware and software implementation. The HSIS implementation manager (HSISIM) is responsible for implementing the hardware and software of the HSI design. The US-HSIS test facility manager is responsible for the US-Basic test facility (see Section 3.3, below). The HSISIM and the US-Basic HSIS test facility manager report to an implementation project manager (see Figure 3-1).

3.2.7 Quality Assurance Organization

The quality assurance (QA) organization establishes QA procedures and conducts periodic QA audits of the US-APWR HFE program to ensure the HFE program is conducted in accordance with applicable licensing commitments, including IPs.

3.3 HFE Organizational Composition

This section describes the organizational composition of the US-APWR HFE team.

As shown in Figure 3-1, the US-APWR HFE team comprises several organizations in order to execute the program. The HFE team is multidisciplinary and draws from multiple organizations.

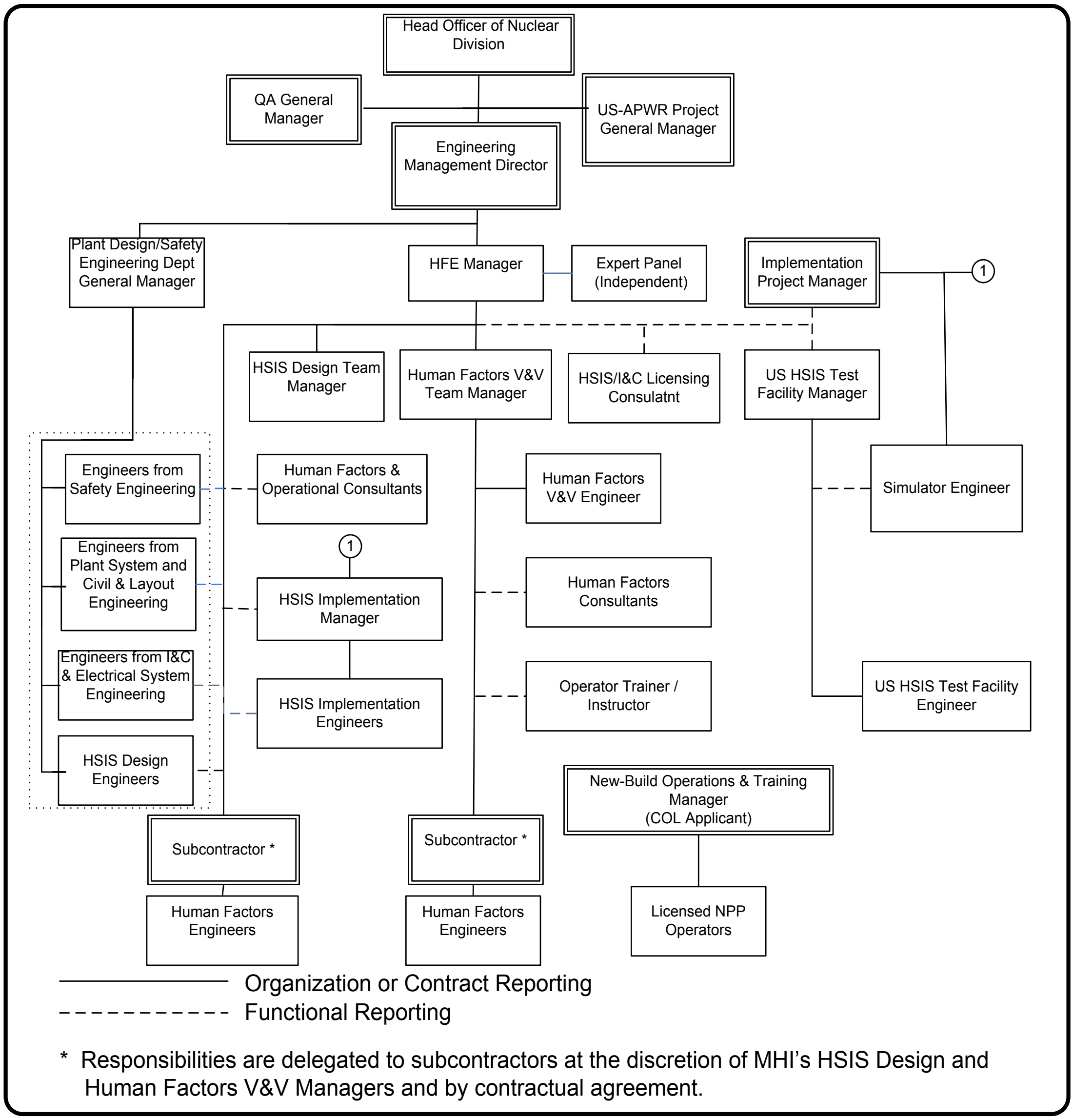

Figure 3-1 HFE Team Organization

The HFE team consists of an HSIS design team, an HSIS V&V team, and an Expert Panel. The organization is composed of team members from the following:

- MHI
- Mitsubishi Nuclear Energy Systems (MNES), a wholly owned subsidiary of MHI
- Mitsubishi Electric Corporation (MELCO)
- Mitsubishi Electric Power Products, Inc. (MEPPI), a wholly owned subsidiary of MELCO
- Consultants to MHI/MNES and MELCO/MEPPI
- Subcontractors to MHI/MNES
- US-APWR combined license (COL) applicants

The HFE manager assigns appropriate members from each engineering function to ensure sufficient knowledge and experience to execute the process. In general, the qualifications of the complete HFE team meet those shown in Table 3-1, below, from Appendix A to NUREG-0711, Revision 2.

Table 3-1 HFE Team General Qualifications

Technical Discipline	Minimum Qualifications
HFE	• Bachelor's degree in HFE, engineering psychology, or related science • 4 years of cumulative experience related to the human factors aspects of human-computer interfaces. Qualifying experience should include at least the following activities within the context of large-scale human-machine systems (e.g., process control): design, development, and test and evaluation • 4 years of cumulative experience related to the human factors aspects of workplace design. Qualifying experience should include at least two of the following activities: design, development, and test and evaluation.
Technical Project Management	• Bachelor's degree • 5 years of experience in NPP design or operations • 3 years of management experience
Systems Engineering	• Bachelor of Science degree • 4 years of cumulative experience in at least three of the following areas of systems engineering; design, development, integration, operation, and test and evaluation
Nuclear Engineering	• Bachelor of Science degree • 4 years of nuclear design, development, test, or operations experience.
HSI/I&C Engineering	• Bachelor of Science degree • 4 years of experience in design of HSI aspects of process control systems • Experience in at least one of the following areas of engineering: HSI development, power plant operations, and test and evaluation • Familiarity with the theory and practice of design QA and control
Architect Engineering	• Bachelor of Science degree • 4 years of experience in design of power plant control rooms
Plant Operations	• Has or has held an SRO license • 2 years of experience in relevant NPP operations
Computer System/Simulator Engineering	• Bachelor's degree in electrical engineering or computer science, or graduate degree in another engineering discipline (e.g., mechanical engineering or chemical engineering) • 4 years of experience in the design of digital computer systems and real-time systems applications • Familiarity with the theory and practice of software QA and control
Plant Procedure Development	• Bachelor's degree • 4 years of experience in developing NPP operating procedures
Personnel Training	• Bachelor's degree • 4 years of experience in the development of personnel training programs for power plants • Experience in the application of systematic training development methods
Systems Safety Engineering	• Bachelor's degree in Science • 4 years of experience in system safety engineering

Technical Discipline	Minimum Qualifications
Maintainability/ Inspectability Engineering	• Bachelor's degree in science • 4 years of cumulative experience in at least two of the following areas of power plant maintainability and inspectability engineering activity: design, development, integration, and test and evaluation • Experience in analyzing and resolving plant system and/or equipment-related maintenance problems

IPs define the specific disciplines needed for conduct of that activity and any specific or additional qualification requirements. Unique disciplines (i.e., not described above) and the qualifications for those disciplines are also defined in the IP for which the discipline is required.

ReSRs define specific individuals who fulfilled the discipline qualifications (either from Table 3-1 or from a unique need for that activity). Resumes for those individuals associated with each activity are maintained as QA records.

MHI is the lead technical organization for the overall US-APWR HFE program, including HFE analysis, HSIS design, V&V, and DI. The HSIS V&V team is independent from the HSIS design team, though team members may be exchanged at the discretion of the HFE manager while maintaining independence between originators and reviewers. The HFE manager, the DTM, and the VTM are MNES/MHI employees. Subcontractors perform work at the direction of MHI.

The HFE team conducts HFE activities in accordance with applicable HFE implementation plans and within MHI's QAP (Reference 8-13). Figure 3-1 shows the HFE team positions in relationship to the team members from other MHI engineering organizations controlled under the MHI QAP (Reference 8-13). HFE team members are assigned from each engineering organization according to the needs of the HFE manager.

The HFE team also has the responsibility for identifying HEDs in the overall plant design, overseeing their correction, and tracking the results. As assigned by the HFE manager, HFE team members coordinate with other organizations to resolve HEDs using the following approach:

(1) Organize Expert Panel meetings with plant design and HFE experts to identify and discuss solutions to HEDs.

(2) Designate a responsible design organization to lead issue resolution. Lead plant design organizations are responsible for resolving HEDs.

(3) Monitor the progress of resolution of HEDs through their completion.

(4) Verify the effectiveness of HED resolution through performance of technical reviews and/or the conduct of V&V activities using prototype models or simulators.

The technical discipline/plant design organizations are responsible for resolving design issues that are identified by the HFE program. Resolution is achieved through improving plant design specifications. The HFE team is responsible for initiating HEDs, tracking HEDs, and coordinating with experts and plant design organizations to establish HED resolutions. The design organizations are also responsible for verifying HFE resolutions are implemented through changes in the plant design and through pertinent HFE activities.

MELCO is the lead organization for conversion of the HSI functional design, which is the responsibility of MHI, into software and hardware for the U.S. HSIS test facilities, operator training facilities, and the actual plants (i.e., HSIS hardware and software implementation).

"HSIS test facilities" refers to the facilities for testing the US-Basic HSIS and the US-APWR HSIS (see Figure 3-2). Facilities for this testing are described in the Phase 1 V&V report (Reference 8-8) and V&V IP (Reference 8-11).

MEPPI (a U.S. subsidiary of MELCO), operates the US-Basic HSIS test facility. The facility is located near Pittsburgh, PA. The US-Basic HSIS test facility (not for the US-APWR; see Reference 8-1) includes a full-scale MCR simulator. The US-Basic HSIS test facility manager is a MEPPI employee. Although MEPPI is responsible for managing and maintaining the US-Basic HSIS test facility, the hardware and software design and manufacture for the MEPPI test facility are the responsibility of MELCO.

3.3.1 Expert Panel

The Expert Panel contains experts in HFE, I&C, nuclear plant systems, and plant operations. Experts have at least 10 years of experience in their respective fields.

The Expert Panel provides an independent assessment and approval of proposed HED resolutions. As shown in Figure 3-1, the Expert Panel reports to the HFE manager but is independent of the HSI design team and V&V team.

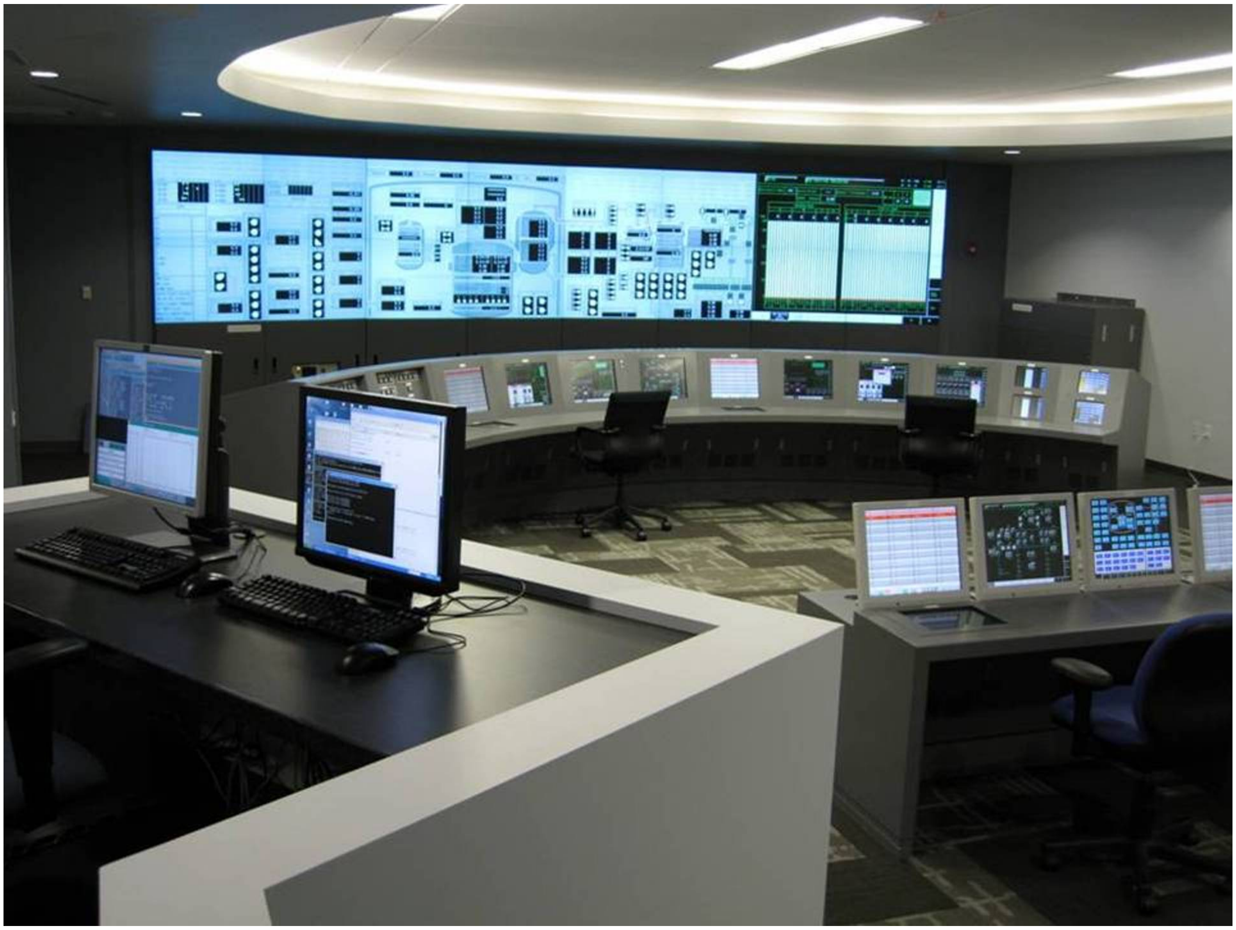

Figure 3-2 US-Basic HSIS Test Facility

4.0 HFE PROCESSES AND PROCEDURES

HFE activities are performed in accordance with this HFE PMP and the IPs referenced below. The HFE PMP and referenced IPs are supported by additional internal implementing procedures. HFE activities governed by these documents are executed under the MHI QAP for the US-APWR (Reference 8-13).

4.1 General Process Procedures

4.1.1 HFE Team Assignment

The HFE manager's responsibility is described in Sections 3.2.2 and 3.3. The HFE manager assigns personnel to the DTM and VTM so that they can effectively execute each HFE activity within their respective areas of responsibility.

The HFE manager assigns appropriate members from each engineering discipline to ensure sufficient knowledge and experience to execute the process, as specified in each IP. While the specific team qualifications and responsibilities for each HFE activity, the contributions from each discipline, and the responsibilities of each organizational role are described in each IP and ReSR for that activity, the overall qualifications of the complete HFE team meet those shown in Table 3-1, taken from Appendix A to NUREG-0711, Revision 2.

4.1.2 Governing the Internal Management of the Team

As described in Section 3.3, the HFE manager governs the HFE team's resource management. If the HFE manager needs additional resources to implement an HFE process, the HFE manager obtains those resources from the EMD or technical management of each discipline based on direction from the EMD. The HFE manager can delegate authority to the DTM regarding HFE design activity support (i.e. HFE analysis, HSI designs). The HFE team members, including subcontractors, are controlled by the HFE manager. The HFE manager can assign the team resources under HFE design activities that are controlled by the DTM or V&V activities that are controlled by the VTM.

4.1.3 Making Management Decisions Regarding HFE

As described in Section 3.3, the HFE manager has primary authority to make management decisions for HFE activities. The HFE manager normally delegates HFE design management decisions to the DTM and V&V management decisions to the VTM based on areas for which the DTM or the VTM is in charge. The HFE manager has oversight of the HFE process. If the HFE manager finds conflicts in the execution of the HFE process, the HFE manager or delegated staffs initiate corrective actions to address those issues.

4.1.4 Making HFE Design Decisions

HFE design decisions are proposed by any member of the HFE design team and approved by the HFE manager. Any member of the HFE team can identify problems with HFE decisions or HSI designs by generating an HED, which is then tracked to resolution with engagement of the Expert Panel.

4.1.5 Governing Equipment Design Changes

The DTM is responsible for governing equipment design changes, with input from HFE team members. The DTM and his or her designated management staff monitor HFE input information changes and coordinate with the HFE team to identify HFE design changes or impacts from those input information changes. The HED database described in Section 5 can be used to help the HFE team member to identify HFE impacts when input information is changed.

4.1.6 Design Team Review of HFE Products

The HFE manager is responsible for assigning reviewers to review the HFE products, where additional review is required by a specific IP. Members from associated engineering disciplines are involved and review the product for completeness and accuracy. The HFE manager can engage the Expert Panel for review at his discretion.

4.2 Process Management Tools

HFE, like other US-APWR engineering disciplines, is subject to the design control process described in the MHI QAP for the US-APWR (Reference 8-13):

- Design inputs are documented, retrievable, and appropriate (i.e., relevant to the process and activity being performed).
- Final design is relatable to design inputs in order to permit design review, specifies required inspections and tests, and includes or references appropriate acceptance criteria.
- Design analyses, including calculations, are performed in a manner such that a person technically qualified in the subject can review and understand the analyses and verify the adequacy of the results. Design analyses are clearly documented.
- The accuracy and adequacy of engineering work products are confirmed by the performance of design reviews or the use of alternate calculations. The extent of independence in the design review process is based on importance to safety.
- Interface controls include procedures for the review, approval, release, distribution, and revision of design interface documents. Design information transmitted from one department or group to another is documented and controlled. Design information transmitted to an outside entity or organization is documented in an approved specification and controlled/transmitted via purchase order.
- Engineering change requests are submitted for review, approval, and action. Proposed design changes are screened for acceptability and processed in accordance with departmental/project level procedures.

The following HFE tools and techniques (e.g., review forms) are used by the team to ensure that they fulfill their design review responsibilities. After each HFE product is completed (e.g., analysis, design document, or test), preparers or developers provide review forms to reviewers, which include the following:

- Title of document being reviewed, including draft version control identifier)
- Date of draft document being reviewed
- Printed name and signature of the reviewer
- Minimum items to be confirmed by the reviewer (as defined in each IP) with “review fulfilled” initials by the reviewer
- A reference to the location of the reviewer’s comments (e.g., a file with embedded comments)

The process above is repeated as necessary using additional review forms (each referencing new draft versions and new comments) until a final review achieves “review fulfilled with no comments.”

Reviewers send review forms and comments back to preparers and developers. Preparers and developers resolve reviewers’ comments and incorporate them in HFE products. After completion of reviewers’ dispositions and prior to approving the document, the DTM reviews the review forms to make sure comments are resolved.

This is a generic design review process applicable to the results generated from all IPs. Therefore, this process is not repeated in the IPs. Each IP identifies the specific results that require review, the minimum items with which those results are to be confirmed by the reviewer, and the qualifications of the reviewer.

4.3 Integration of HFE and Other Plant Design Activities

The integration of design activities uses inputs from other plant design activities to the HFE program and outputs from the HFE program to other plant design activities. The iterative nature of the HFE design processes are shown in Figure 4-1 and Figure 4-2, below. HFE design controls are described in the MHI QAP for the US-APWR (Reference 8-13).

The US-APWR HFE work flow (Figure 4-1) involves activities performed by the HFE team and activities performed by other US-APWR design groups.

Figure 4-2 does not depict a once-through process. Like most development processes, the US-APWR HSIS development process is iterative with feedback loops. Feedback comes from HFE analysis and the HSIS V&V, but also from design of interrelated systems.

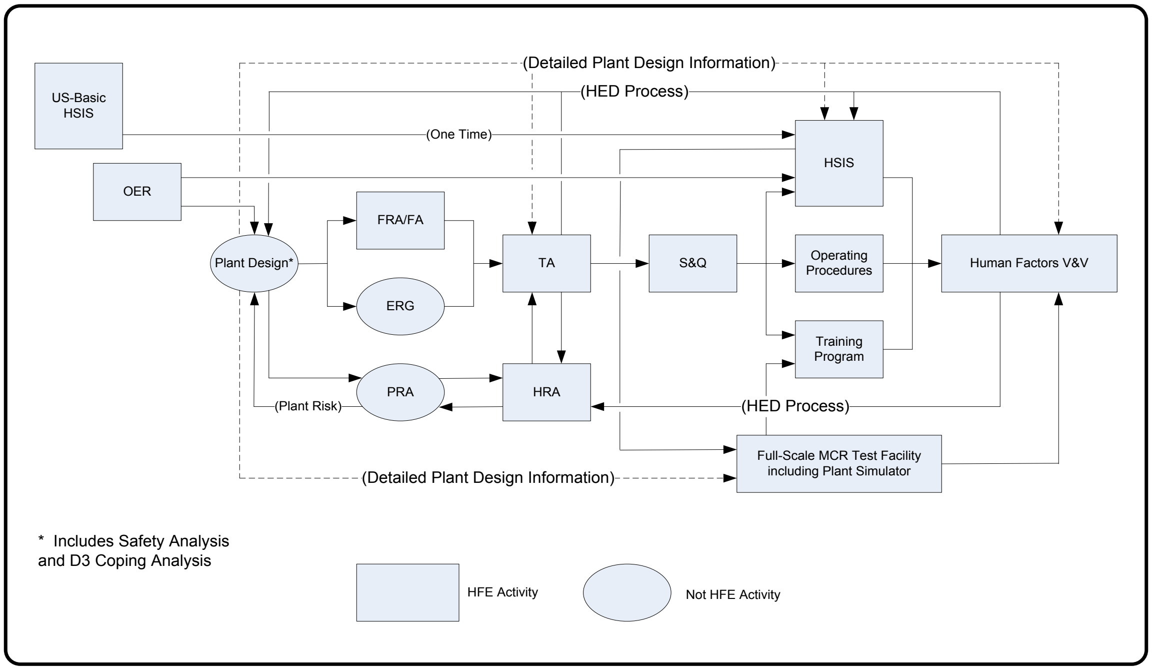

Figure 4-1 HFE Work Flow

Figure 4-2 shows engineering work processes and integration with plant design organizations. Table 4-1 and Figure 4-2 describe similar interactions (i.e., inputs from other plant design activities to the HFE program and the outputs from the HFE program to other plant design activities). The ReSRs identify which documents and sources are used as input and output and any HEDs generated. During HFE activities, if there are HFE issues identified that impact plant design engineering, an HED is used to document the item/action and potential solutions. The HED is used to track the issue until it is adequately addressed in the US-APWR plant design. Anyone in the HFE team can initiate an HED for problems identified during the HFE activities.

Iterations occur within an HFE program element up to the point of ReSR approval, either through DCD review or inspections, tests, analyses, and acceptance criteria (ITAAC) closure. After ReSR approval, changes are managed through HEDs. HEDs are closed as required by subsequent IPs, either as a prerequisite for an IP or as a product of an IP as follows:

- TA requires closure of HEDs from FRA/FA, as a prerequisite to conducting the TA for the areas affected by that HED.
- S&Q requires closure of all IPs that impact staffing from all previous program elements, as a prerequisite to the staffing evaluation.
- Since HD creates the US-APWR HSIS that will undergo V&V, HD requires closure of all HEDs; this is also a prerequisite of V&V.
- DI requires closure of all HEDs generated during or after V&V.

Table 4-1 INPUT and OUTPUT Between HFE Activities and Other Plant Design Organizations

HFE Element	INPUT from other plant design activities	OUTPUT from the HFE program to other plant design activities
OER	Plant system descriptions to determine the extent that the US-APWR design addresses past issues	HEDs identifying the OER issues not addressed by current design specifications.
FRA/FA	Critical function and success path descriptions from safety analysis and plant system descriptions, including current man-machine allocations, to determine any mismatches.	HEDs identifying FAs that are not consistent with the current plant design.
TA	Design descriptions of plant systems including I&C, to identify operator tasks.	HSI inventory (controls, alarms, and indicators) and accommodations for operator staff, required in the plant design to support operator tasks. HEDs are generated if the output of TA conflicts with the plant system design, including plant design features needed to achieve the minimum staffing design constraint for plant operating modes (see Section 2.2).
HRA	Risk-important human actions (RIHAs) are identified from the probabilistic risk assessment (PRA), and deterministically important human actions (DIHAs) are identified from the transient and accident analyses (TAA) and defense-in-depth and diversity coping analysis (D3CA). These are collectively referred to as important human actions (IHAs). All of these analyses assume HSI characteristics for IHAs that are confirmed in HRA.	HEDs are generated if the assumptions regarding HSI characteristics do not accurately reflect the US-APWR HD.
S&Q	Design descriptions of plant systems, including descriptions of operations, maintenance, testing, and surveillance, to allow assessment of differences from predecessor plants that affect staffing.	HEDs are generated if plant system design changes are needed to achieve the minimum staffing design constraint (see Section 2.2) for plant operating modes or if there is inconsistency between the plant system designs and the operator staffing required by S&Q analysis for shutdown modes.
HD	Detailed design specifications of plant systems including I&C. HSI “minimum inventory” from DCD Ch. 7. EOPs for degraded HSI conditions. These provide inputs to the HD and performance-based tests.	Functional specifications for all HSI designs are provided to the HSIS implementation team. HEDs are generated if problems are identified during performance-based tests.
V&V	PRA, TAA, and D3CA to develop ISV scenarios and acceptance criteria for IHAs.	HEDs are generated to identify recommended HSI or plant design improvements or required design changes due to noncompliance with ISV acceptance criteria.

HFE Element	INPUT from other plant design activities	OUTPUT from the HFE program to other plant design activities
DI	Detailed configuration of as-built US-APWR HSIS hardware and software to confirm traceability to the configuration tested in V&V, including CBPs. Operator training program material to confirm traceability to the training given to operators who participated in V&V. As-built US-APWR Local HSI documentation to confirm traceability to the documentation previously approved by the HFE team. Plant procedures to confirm suitability of US-APWR Local HSI; this HSI is not included in V&V. For facilities that were not included in V&V (i.e., RSR, TSC, and local) plant walkdowns confirm conformance to documentation previous approved by the HFE team.	HEDs are generated to identify nonconformance in the as-built plant design.

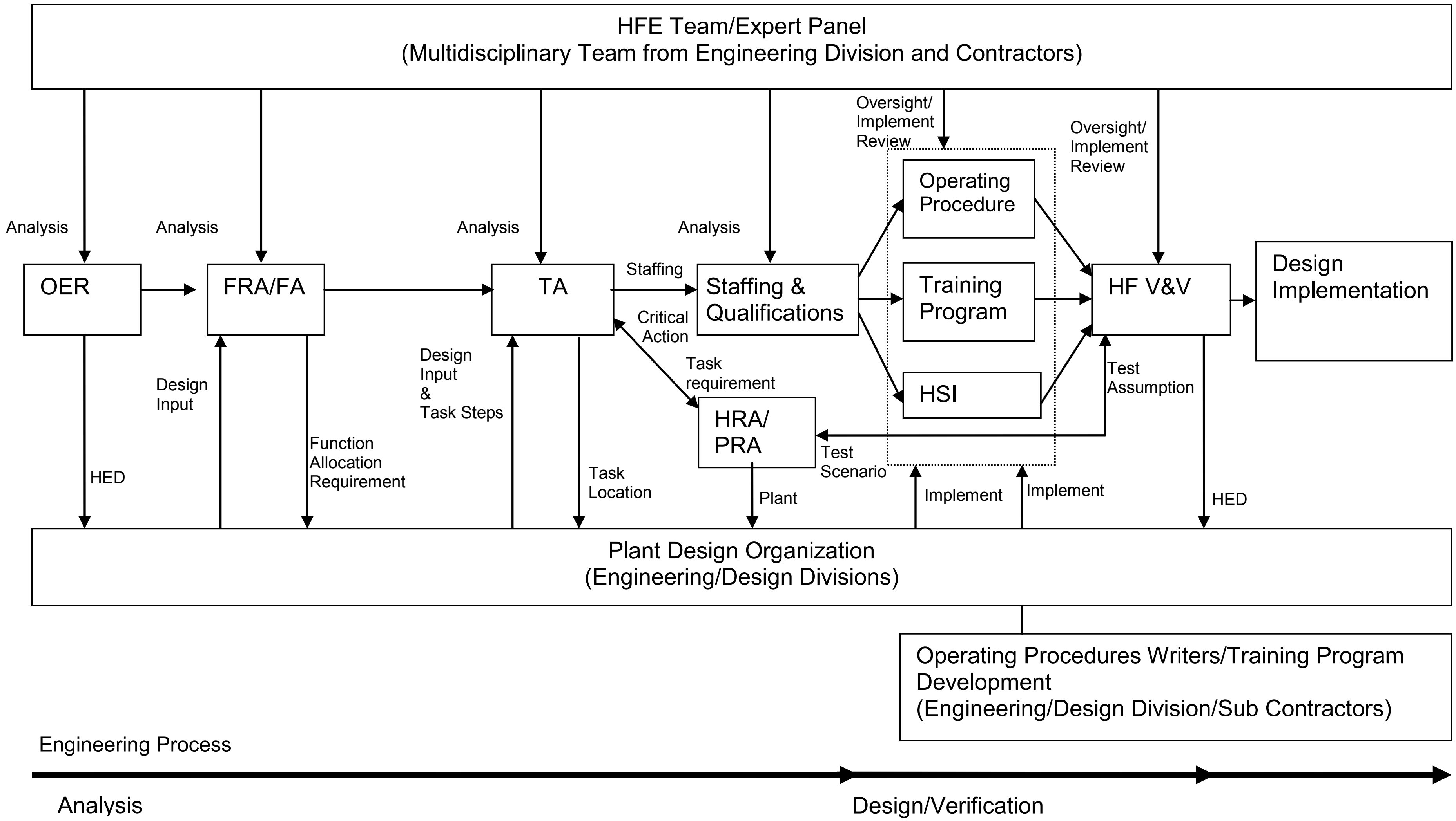

Figure 4-2 Engineering Work Process and Integration Between HFE Team and Plant Design Organization

4.4 HFE Program Milestones

HFE program milestones are used to evaluate HFE program effectiveness at critical checkpoints and the relationship to the integrated plant sequence of events. Once each HFE program element is completed, the HFE team confirms that the activity meets the intent of the IP and then produces an ReSR. In each program element, consistency is confirmed between the US-APWR HSIS and the US-APWR plant design. These checks confirm design consistency during each plant phase (system design, analysis, detailed design and procurement, construction, and operation) as illustrated in Figure 4-3. For example, in V&V, plant design consistency checks are a fundamental part of the Inventory and Characterization process. Each element IP specifies a design review process for that element.

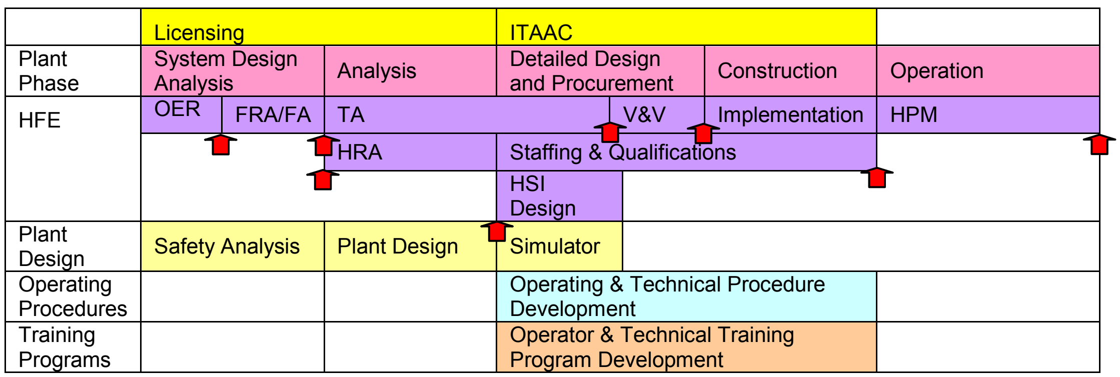

Figure 4-3 HFE Program Milestones Embedded in the Plant Design, Procurement, Construction, and Operation

4.5 HFE Documentation

Table 4-2 identifies the reference documentation created for each HFE program element. HFE IPs and ReSRs are considered design-basis documents and are therefore retained for the life of the plant. The document retention process is described in the MHI QAP for the US-APWR (Reference 8-13). The IPs follow a standard format consisting of the following parts:

- An abstract functioning as an executive summary
- Table of contents, including tables, figures, and appendices
- Acronyms
- Specifically numbered sections covering the purpose, scope, methodology overview, methodology detail, implementation team (subject-matter expert (SME) requirements), results summary report content, a NUREG-0711 compliance evaluation, and references
- Definitions (as needed)
- Appendices (as needed)

The ReSRs follow a standard format consisting of the following parts:

- An abstract functioning as an executive summary
- Table of contents, including tables, figures, and appendices
- Acronyms
- Specifically numbered sections covering the purpose, scope, methodology and results overview, methodology changes from IP (if any), implementation team (actual names and SME role fulfilled), results of IP execution, NUREG-0711 compliance changes (if any), and references
- Definitions (as needed)
- Appendices

Information contained in the methodology, implementation team, and results of IP execution sections addresses the review criteria of NUREG-0711 (Reference 8-3) for each individual program element. The remaining parts, including the other numbered sections, are intended to provide summary, supplemental, and/or contextual information to support the specific information addressing the acceptance criteria contained in the methodology and implementation team sections. Changes to parts other than the methodology and implementation team sections (including references to them contained in the methodology and implementation team sections) may be considered editorial.

Table 4-2 HFE Documentation Requirements

DCD sub-section	Title	Reference Document
18.1	HFE Program Management	HFE Program Management Plan, MUAP-09019
18.2	Operating Experience Review	OER Implementation Plan, MUAP-13005
		OER Results Summary Report
18.3	Functional Requirements Analysis & Functional Allocation	FRA/FA Implementation Plan, MUAP-13007
		FRA/FA Results Summary Report
18.4	Task Analysis	TA Implementation Plan, MUAP-13009
		TA Results Summary Report
18.5	Staffing and Qualifications	S&Q Implementation Plan, MUAP-10008
		S&Q Results Summary Report
18.6	Human Reliability Analysis	HRA Implementation Plan, MUAP-13014
		HRA Results Summary Report
18.7	Human-System Interface Design	HD Implementation Plan, MUAP-10009
		US-Basic HSIS Verification and Validation (Phase 1) Report, MUAP-08014
		HD Results Summary Report
18.8	Procedure Development	N/A
18.9	Training Program	N/A
18.10	Human Factors Verification and Validation	V&V Implementation Plan, MUAP-10012
		V&V Results Summary Report
18.11	Design Implementation	DI Implementation Plan, MUAP-10013
		DI Results Summary Report

4.6 Subcontractor HFE Efforts

If a subcontractor is involved in HFE activities, the HFE team verifies the subcontractor is properly trained and complies with the US-APWR HFE IPs and MHI's internal work procedures. The MHI QA organization verifies subcontractors conduct their work in accordance with the MHI QAP (Reference 8-13) or the subcontractor's QAP as contracted.

5.0 HFE ISSUES TRACKING

HEDs that are not immediately resolved are entered in the HFE issues tracking system, also referred to as the HED database. The HFE design team members are responsible for issue reporting, logging, tracking, and resolution.

The HFE issues tracking system is integrated into the issues tracking system used for the US-APWR design effort as a whole. The HFE issues tracking system addresses human factors issues that are (1) known to the industry and not resolved by the US-Basic HSIS or US-APWR plant design as identified in the OER or (2) identified throughout the execution of the other US-APWR HFE program elements.

The HFE issues tracking system provides a mechanism to address the items that need to be addressed later in the project to ensure that they are not overlooked. The HFE issues tracking system provides assurance that HEDs are tracked from identification until resolution has been fully documented and approved by an independent Expert Panel. HED closure requirements include testing where the adequacy of the resolution cannot be expertly judged or where the problem resulted in failure of a previous test (failure is determined by the test acceptance criteria, not by the HED). The HED process ensures the potential for negative effects on human performance is reduced to an acceptable level.

5.1 Human Engineering Discrepancy Process

The HED process has four steps:

(1) Discrepancy identification and problem statement
(2) Discrepancy evaluation
(3) Discrepancy resolution
(4) Discrepancy closure

The problem statement is formulated by the person identifying the HED. Any member of the HFE team may initiate an HED. HEDs may also be generated by operators who participate in HSI testing.

The HFE team is responsible for evaluating, resolving, and closing HEDs. HEDs may be generated to resolve issues discovered during HFE design reviews, static and dynamic HSI design testing and V&V testing, or any of the HFE elements contained in the HFE program.

The HFE team evaluates each HED and formulates a proposed resolution. Depending on the complexity or significance of the needed change, HED closure may require only documentation of the change; others may also require development and implementation of a documented test plan and/or demonstration of satisfactory test execution.

Proposed resolution and closure requirements for each HED are assessed by the Expert Panel. The Expert Panel has access to technical consultants from the US-APWR HFE team, including the HSIS implementation team and US-APWR plant process and systems experts. The Expert Panel may approve a no-action resolution for cases in which the HED significance is low.

The HED process also defines the HED closure requirements. HED closure occurs when the requirements of the HED closure actions are documented satisfactorily as determined by the

HFE team and by the Expert Panel.

5.1.1 Human Engineering Discrepancy Identification

HEDs may be generated from many different US-APWR design activities, including the following:

- During any HFE program activity, such as the OER
- Directly by licensed NPP operators during the HD testing or during V&V
- Extracted from operator questionnaires and surveys completed by the licensed NPP operators after each test scenario and at the end of the validation test week
- Observer surveys completed during the HSI validation test scenarios or from individual or consensus survey results at the end of the validation test week
- HFE and NPP process control experts from operator performance data
- Miscellaneous visitors to the V&V facility (e.g., potential US-APWR customers, visiting HFE and NPP process experts, visiting representatives from the NRC)

5.1.2 Human Engineering Discrepancy Evaluation

Outstanding HEDs are evaluated periodically and prior to completing any of the HFE phases. At a minimum, HEDs are reviewed every 6 months for what has been closed, design decisions, and progress of design changes. HFE IPs define the HEDs that must be closed to initiate or complete a specific program element. For example, all HEDs must be closed prior to initiating the V&V program element and any HEDs generated during or after V&V must be closed prior to completing the DI program element.

To support efficient examination, like HEDs may be grouped together or evaluated individually. As part of the grouping process, one HED may be placed into more than one group because it may have been written with multiple discrepancies. Grouping shall be done by members of the HFE team or Expert Panel using engineering judgment.

5.1.3 Human Engineering Discrepancy Resolution

5.1.3.1 Human Engineering Discrepancy Classification

At critical phases of design or construction, it may be appropriate to classify the significance of HEDs so that resolution can be prioritized. Resolutions of HEDs that have the potential for direct or indirect safety significance have higher priority than those that do not. This classification is determined by the HSIS design team and the Expert Panel. Classification for prioritization does not negate the need to close HEDs as required by specific HFE IPs.

5.1.3.2 Human Engineering Discrepancy Processing

All HEDs are processed to closure whether the result is a design change, an administrative change, or does not require any change. HED closure requirements must be clear and unambiguous. Example resolution and closure requirements are listed below, but other criteria may be developed as necessary.

(1) HED will be resolved by a correction in the simulator or a modification to the simulator to reflect the US-Basic HSIS design. HED can be closed when correction/modification is implemented in the simulator and a test plan is reflected in an HFE program activity (Phase 1 or 2 as appropriate).

(2) HED will be resolved by additional operator training. HED can be closed when training material is documented/updated and reflected in a V&V program activity (Phase 2 or 3 as appropriate).

(3) HED refers to an HD feature that correctly reflects the US-APWR plant design. HED can be closed when the US-APWR plant design is evaluated and resolved.

(4) HED will be resolved upon addition of an HSI inventory element or a change to a currently documented HSI inventory element. HED can be closed when the design change is documented and a test plan is reflected in an HFE program activity (Phase 1, 2, or 3 as appropriate).

(5) HED requires updating of US-Basic HSIS documentation. HED can be closed when documentation is updated and the subject of the HED is reflected in a test plan (Phase 1 or 2 as appropriate).

(6) HED will be resolved through a US-Basic HSIS design change that is not yet developed, documented, or implemented. HED can be closed when testing of this design change is reflected in an HFE program activity (Phase 1 or 2 as appropriate).

(7) HED will be resolved through an operating procedure change. HED can be closed when the procedure change is documented and reflected in a V&V program activity (Phase 2 or 3 as appropriate).

(8) HED requires no corrective action. The HED can be closed immediately. The HED record includes the basis for this determination.

Where a resolution and closure requirement is applicable to multiple HEDs, the related HEDs may be grouped and closed together. Where HEDs are grouped together for closure, the Expert Panel ensures the resolution is sufficient for each HED in the group. Where an HED addresses multiple issues, a resolution may resolve only part of the HED; therefore, that HED shall remain open until all of its parts are resolved.

5.1.4 Human Engineering Discrepancy Closure

Some HED closure requirements require only updated documentation, others require a documented plan for testing, and others require actual test completion. This determination is made by the HFE design team and the Expert Panel based on considering the extent of the change and the degree of confidence in the resolution. Where a documented test plan is required, HED closure does not require the test to be completed, because if the test is not successful, additional HEDs will be generated during that test. This HED closure process avoids keeping HEDs open for extended durations, since there may be several years between the time when an HED is first identified and when an actual retest will occur. The US-APWR

HSIS will be considered acceptable only when ISV testing is completed with no HEDs pertinent to the ISV acceptance criteria.

An HED can be closed when the resolution is documented and the closure requirements are met, as defined by the HED closure requirement. An HED closure agreement must be reached between the HSIS design team and the Expert Panel.

5.2 Human Engineering Discrepancy Database (Documentation/Responsibilities)

HEDs are entered into an HED database.

5.2.1 Human Engineering Discrepancy Database Basic Requirements

In order to manage an HED, the HED database contains fields to track the HED status through the entire evaluation process to closure.

The database has security measures to prevent access by non-HFE team members. The database has a system administrator. Only predefined users have access to the database. Only the system administrator is able to delete an HED from the database. Administratively, the system administrator may not delete an HED from the database without agreement of the Expert Panel.

5.2.2 Human Engineering Discrepancy Database Description

The HEDs are managed and tracked using an issue tracking software application (the "issue tracker"). The issue tracker is a portal into the HED database. The issue tracker provides the user interface through which data are entered, extracted, or displayed. The issue tracker can be used for simple data analysis or report generation. The issue tracker can also export the data for analysis in other software applications. Since the issue tracker is the only interface into the HED database, the terms "issue tracker" and "database" are used synonymously.

The issue tracker allows each HED to be captured along with a set of metadata that further describes or categorizes the HED issue. These metadata are entered or viewed as a set of data fields that correspond to a workflow step in the HED tracking process. The fields can be used to organize, filter, and search the data. The issues are organized such that they can be grouped to simplify the analysis or resolution of similar issues.

The HEDs progress through the issue tracker in a series of discrete workflow steps. An HED is assigned a "Status" field to indicate its present workflow step. There are four workflow steps that an HED may traverse. Much of the metadata associated with each HED are grouped by workflow step.

Many of the data fields are list-type fields that provide a fixed set of values for that field. Others are free-form text fields. In addition to the predefined data fields, a "Comment" may be added to an issue by any user to add additional information about an issue.

5.2.2.1 Human Engineering Discrepancy Creation

The first workflow step is "Create." In this step, an HED is entered into the database by the issue "Reporter." A Reporter is simply an authorized user of the issue tracking application. Other personnel who are not authorized users of the issue tracking database may create

HEDs using paper forms, which are then given to an authorized user who will enter the HED into the database. Upon reporting of an issue, the issue tracker automatically assigns a unique issue "Key" (i.e., HED-123). The issue is assigned an initial status of "Open." The data fields associated with this workflow step are shown in Table 5-1, below.

Table 5-1 HED Creation Data Fields

Data Identifier	Description
Summary	A brief one- or two-sentence interpretive summary of the HED.
Description	An un-interpreted detailed description of the original HED.
Display Number	Screen identifier of the HED, if applicable.
Originator	Person who actually identified the HED, either directly through an HED form or HFE survey, or indirectly through an HFE interview.
Originators Company	The Originator's company of employment.
Origination Date	The date the HED was originated.
Originators Background	The Originator's primary area of expertise or training as applicable to the V&V process.
Originators Role	The Originator's group or organizational affiliation as applicable to the V&V process.
Observer	The Observer is an HFE expert who indirectly records an HED that is indirectly identified by an Originator.
Source	The Source is the project phase in which the HED was identified.
Week Number	The Week Number identifies which week during the project phase that the HED was identified.
HSI Area	The HSI Area is a broad description of the location or equipment with which the HED is associated.
Guidance	Guidance is a general description of the basis for identifying an HED.
Design Reference	Design Reference is a specific reference to a document that provides information related to the HED.
Significance	The Significance is the Originator's or Observer's opinion of the significance of the HED.
Recommended Resolution	The Recommended Resolution is the Originator's or Observer's opinion of the resolution to this HED.

5.2.2.2 Human Engineering Discrepancy Evaluation

A number of data fields are available to add information to an HED during the evaluation workflow step. The data fields associated with this workflow step are shown in Table 5-2, below.

Table 5-2 HED Evaluation Data Fields

Data Identifier	Description
Evaluator	Person(s) or group(s) performing evaluation
Due Date	Expected evaluation completion date
Evaluation Process	Process(es) by which the evaluation was performed
Evaluation Recommendations	Recommendations from the evaluation

5.2.2.3 HED Resolution and Closure Requirement

A number of data fields are available to add information to an HED during the resolution and closure requirement workflow step. The data fields associated with this workflow step are shown in Table 5-3, below.

Table 5-3 HED Resolution Data Fields

Data Identifier	Description
Description	Functional description of resolution
Resolution Cost Estimate	Cost estimate to implement the resolution
HED Closure Requirements	Identify the documentation and testing needed to close the HED (e.g., design specification, test plan, training plan, procedures)
Resolver	Person(s) or group(s) responsible for implementing the closure requirements
Closure Schedule	Milestones for meeting the HED closure requirements
HFE Team Approval	Person representing HFE team who approved the HED closure requirements
Expert Panel Approval	Person representing Expert Panel who approved the HED closure requirements
Other Considerations	Other items that are required to fully implement the resolution, but these are not required for HED closure (e.g., considerations for detailed design implementation)

5.2.2.4 HED Closure

When the HED closure requirements are documented, the HED may be closed. Otherwise an issue may remain with “Resolved” status and closed when the required closure activities are complete. Additional information can be added to the issue using the issue “Comment” field. The data fields associated with this workflow step are shown in Table 5-4, below.

Table 5-4 HED Closure Data Fields

Data Identifier	Description
Closure Documentation	Identify the documents reviewed to facilitate HED closure. Include configuration control identifiers (e.g., document and revision numbers).
HFE Team Approval	Person representing HFE team who approved the HED closure
Expert Panel Approval	Person representing Expert Panel who approved the HED closure

6.0 HFE TECHNICAL PROGRAM

As described in MUAP-07007 (Reference 8-1), the US-Basic HSIS is based on the Japanese-Basic HSIS. The US-APWR HSI inventory is combined with the US-Basic HSIS to create the US-APWR HSIS. The US-APWR HFE program elements refine the US-Basic HSIS and develop the US-APWR HSI inventory, as described below. The US-APWR HFE program elements are described in terms of how they are applied to earlier designs, to the US-APWR design, and to analyses of the gaps. The following sections describe the general development of IPs, analyses, and evaluations.

6.1 Implementation Plans, Analyses, and Evaluations

6.1.1 Operating Experience Review

The US-APWR HFE program includes an OER. The OER IP (Reference 8-4) describes the OER process and includes the output documentation requirements. The OER ReSR describes the findings from the OER.

The US-APWR plant design is based on conventional PWR designs. The OER includes the analysis of known HFE-related problems in conventional PWR plants in the United States and Japan including a review of events which include important human actions (IHAs) determined by the HRA program element. The OER also analyzes non-nuclear industrial applications of digital technology that use a screen-based HSI. The OER identifies aspects of the US-Basic HSIS, as documented in MUAP-07007 (Reference 8-1) and aspects of the US-APWR plant design or US-APWR HSI inventory that adequately address historical human factors problems. Where a problem is not adequately resolved by the US-APWR HSIS, an HED is generated to document the problem and potential solutions. The process of evaluating, tracking, resolving, and closing HEDs is described in Section 5 above.

6.1.2 Functional Requirements Analysis/Function Allocation

The US-APWR HFE program includes an FRA/FA. The FRA/FA IP (Reference 8-5) describes the FRA/FA process and includes the output documentation requirements. The FRA/FA ReSR describes the findings from the FRA/FA.

The FRA determines the plant functions that must be maintained to satisfy the plant safety objectives. The FRA also identifies the plant power production functions because maintaining stable and reliable plant power production is an important aspect of plant safety. The aggregate of plant safety functions and plant power production functions are referred to as the “critical functions.” The FRA analyzes each critical function to determine (1) the plant systems, (2) the key components within those systems and (3) the key component actions that are needed to maintain the critical function or restore the critical function to normal during plant transients. The aggregate of plant system, key components, and key actions are referred to as a “success path.” The FRA determines the preferred normal and emergency success paths for both normal (full power, low power, and shutdown) and abnormal plant conditions. These success paths encompass the deterministically important human actions (DIHAs) identified in the TAA.

The FRA also encompasses the DIHAs identified in the defense-in-depth and diversity coping analysis (D3CA) and the risk-important human actions (RIHAs) identified in the probabilistic risk assessment (PRA). The RIHAs may include some of the DIHAs in the TAA and D3CA.

The FA allocates the success paths for plant safety and plant power production identified in the FRA to human resources, to automated resources, or to shared resources. The FA considers various success path control characteristics pertinent to HFE, including time available, control complexity, decision complexity, and operator workload. Workload is considered for the specific success path under evaluation, as well as the combined workload of maintaining multiple critical functions concurrently. The FA also considers any OER information pertinent to these success paths or to similar actions that may influence the allocations.

The US-APWR is an evolutionary design. Therefore, the system designs and FAs are based on historical FAs with few changes. These historical allocations did not thoroughly evaluate HFE characteristics as assessed in this FRA/FA. The FA results are compared to the US-APWR system designs, and HEDs are generated for any discrepancies.

6.1.3 Task Analysis

The US-APWR HFE program includes a TA. The TA IP (Reference 8-6) describes the TA process and includes the output documentation requirements. The TA ReSR describes the findings from the TA.

The functions assigned to plant personnel define their roles and responsibilities. Functions are accomplished through human actions (HAs). Related HAs are combined into groups to form a task. The purpose of the TA is to identify requirements for accomplishing tasks. The requirements in turn identify items that populate the HSI inventory, including display screens, alarms, controls, data processing, operating procedures, and training programs that support the accomplishment of the tasks.

TA supports defining a job and the management of crew members' physical and cognitive workload, taking into consideration the number of crew members, crew member skills, and allocation of monitoring and control tasks.

The TA considers task complexities, constraints, or performance-shaping factors identified in the OER for comparable tasks. The TA encompasses the manual allocations for plant functions that are identified by FRA/FA, including the shared allocations and tasks related to monitor and backup automation. The TA confirms the task-related assumptions for the manual actions identified in the HRA, including the adequacy of the HSI inventory, numbers of personnel and skill levels, and conformance to time constraints.

HEDs are generated during TA for any discrepancies identified between the HSI inventory requirements and the US-APWR plant design, and between the staffing requirements and the minimum staffing design constraint for plant operating modes or the staffing identified in HRA for plant shutdown modes.

6.1.4 Human Reliability Analysis

The US-APWR HFE program includes an HRA. The HRA IP (Reference 8-7) describes the HRA process and includes the output documentation requirements. The HRA ReSR describes the findings from the analysis and resolutions.

The HRA identifies RIHAs from the PRA. For completeness, the HRA IP (Reference 8-7) provides an overview of the PRA method, including the method used to determine human error probability (HEP) and the method used to determine the risk significance of those potential errors. But this methodology is not within the scope of the HFE program.

The HRA also establishes the methodology to extract the DIHAs from the TAA and the D3CA. Where these analyses document the time required for an operator to execute the action, the HRA confirms those numbers. Where the time required is not documented, it is determined by the HRA. For either case, HFE personnel assess the DIHAs to confirm with reasonable confidence that they can be carried out within the time available. An additional detailed quantitative analysis of workload and time constraints is performed for these same actions in the TA.

6.1.5 Staffing & Qualification Analysis

The US-APWR HFE program includes an S&Q analysis. The S&Q IP (Reference 8-9) describes the S&Q analysis process and includes the output documentation requirements. The S&Q ReSR describes the findings from the S&Q analysis.

Operator staffing levels for shutdown to full-power operation have been established based on experience with previous plants, government regulations, and staffing reduction goals. The minimum and maximum MCR staffing levels (described in Section 2.2, above) are constraints for the US-APWR HD and plant design. The staffing constraints impact requirements for the HD, including the number of physical interfaces, data processing, operating procedures, display screens, alarms, controls, and support aids needed to support the accomplishment of the tasks. The operator staffing constraints impact the extent to which monitoring and control can be manually executed or requires automation. The minimum staffing design constraint is applicable to plant operating modes. For shutdown modes, the minimum staffing is defined by TA on a task-by-task basis. The acceptability of the minimum staffing constraints for all modes and for the aggregate of all tasks assigned to operating personnel is confirmed in the S&Q analysis.

In addition, the S&Q analysis determines the number and background of other plant personnel for the full range of plant conditions and tasks.

The S&Q analysis confirms that OER issues related to licensed operator or non-licensed operator staffing positions are adequately addressed despite any changes in staffing or qualifications for the US-APWR from current operating plants.

HEDs are generated where challenges are identified for the minimum staffing design constraint for operating modes or the staffing defined by the TA for shutdown modes.

6.1.6 Human-System Interface Design

The US-APWR HFE program includes HD. The HD IP (Reference 8-10) describes the HD process and includes the output documentation requirements. The HD ReSR describes the outputs of HD.

HD resolves outstanding HEDs from the US-Basic HSIS Phase 1 V&V program.

HD also generates the US-APWR HSIS design, which is the translation of the US-APWR HFE analysis outputs into the design of the US-APWR inventory of alarms, displays, controls, and operating procedures. A key output of the HD program element is a complete US-APWR HSIS that is implemented in a full-scope simulator for subsequent V&V. The simulator includes all the functions of the US-APWR HSIS, which encompass the HSI for the US-APWR MCR, RSR, and TSC (and including only communications with the EOF and CAS/SAS; see Section 2.3.1). HD also generates the physical designs for each of these facilities.

HD generates the US-APWR Local HSIs' design and the requirements for their physical locations.

The OER identifies issues addressed by the US-Basic HSIS and the US-APWR plant design. These assessments are made by the HFE team analysts at the time the OER is conducted. The HD program element confirms that the OER issues remain adequately addressed despite any changes in the US-Basic HSIS or US-APWR plant designs.

The HD program element uses the critical function and success path HSI inventory outputs from FRA/FA to define the HSI inventory for the LDP and related operational visual display unit task screens.

The HRA identifies assumptions regarding the characteristics of the HSI used for RIHAs and DIHAs. The HD program element ensures these assumptions are implemented in the HD (e.g., control accessibility from the MCR and/or spatially dedicated continuously visible (SDCV) HSI to reduce time required for human actions).

The HD program element uses the HSI inventory and characteristic outputs from TA to establish alarm priority and applicability logic, display and control designs, and procedure step acceptance criteria. The HD program element also uses these TA outputs to establish the grouping of HSI inventory for task-based display screens and conventional control panels.

The S&Q analysis confirms the minimum and maximum operating staffing for all plant modes and for all facilities. The HD program element designs the MCR, RSR, and local facilities to support that staffing.

HD uses paper operating procedures developed as part of the US-APWR plant design (i.e., outside the HFE program) to generate CBPs. The US-APWR HSIS includes the paper procedures and CBPs needed to support the ISV of the V&V program element. Other procedures are outside the scope of the US-APWR HSIS because they have their own development and V&V program.

All HEDs generated during HD or from prior program elements are resolved during HD so that the final output of HD is a complete HSI design suitable for V&V.

6.1.7 Procedure Development

Procedure development is the responsibility of the COL applicant. Though there are procedure development activities integrated with the overall US-APWR HFE program, no IP or ReSR for procedures is produced as part of the US-APWR HFE program.

6.1.8 Training Program Development

Operators who support the V&V program element are trained in accordance with the US-APWR training program.

The training program itself is not part of the HFE program. Training program development is the responsibility of the COL applicant. Though there are training program development activities integrated with the overall US-APWR HFE program, no IP or ReSR for training program is produced as part of the US-APWR HFE program.

6.1.9 Human Factors Verification and Validation

The US-APWR HFE program includes V&V. The V&V IP (Reference 8-11) describes the V&V process and includes the output documentation requirements. The V&V ReSR describes the outputs of V&V.

V&V evaluations comprehensively determine that the US-APWR HSIS conforms to HFE design principles and that the HSIS enables plant personnel to successfully perform their tasks to achieve plant safety and other operational goals. Demonstrating conformance to the acceptance criteria defined in the V&V IP for the ISV is the final design acceptance milestone for the US-APWR HSIS. The scope of the V&V activity includes the MCR, RSR, TSC, EOF (information requirements and communications), CAS/SAS (communications) and LCS as defined in Section 2.3, above. V&V of the EOF is outside the scope of the US-APWR V&V program; V&V of the EOF is conducted in accordance with the site-specific HFE program to confirm compliance to NUREG-0696 (Reference 8-15). V&V of the CAS/SAS is outside the scope of the HFE program.

V&V is conducted using a dynamic full-scope simulator that reflects the output of HD.

6.1.10 Design Implementation

The US-APWR HFE program includes DI. The DI IP (Reference 8-12) describes the DI process and includes the output documentation requirements. The DI ReSR describes the outputs of DI.

DI demonstrates that the design that is implemented (i.e., the US-APWR site-specific HSIS as-built design) accurately reflects the design that has been verified and validated during V&V. If the DI program element identifies differences from the US-APWR-HSIS, such as site-specific aspects that were not included in V&V or design changes that occur after V&V, those differences are evaluated to determine any impact to the analysis results from all previous HFE program elements, including V&V. This is referred to as the DCA.

While successful ISV marks the end of V&V for the US-APWR HSIS, the HD continues to be challenged during the operator training program. Any HEDs generated during V&V that do not affect the ISV acceptance criteria and any HEDs generated after completion of V&V are resolved during DI.

6.1.11 Human Performance Monitoring

HPM begins after DI is completed and continues for the life of the plant. Human performance during the ISV of the V&V program element is a key factor in determining the acceptance of the US-APWR HSIS. Operator performance during ISV establishes the performance baseline for HPM. HPM is intended to detect degradation in operator performance compared to the performance observed during ISV. Degradation may be due to many factors that occur over the life of the plant, including changes in personnel, changes in plant culture, changes in training methods, or changes in the HD itself. The HPM program is a catalyst for corrective actions over the life of the plant; the COL applicant manages its own corrective actions program.

HPM is a responsibility of the COL applicant.

6.1.12 Revisions to HFE Program Element Results

All HEDs are closed prior to V&V; that HED closure is summarized in the HD ReSR. All HEDs generated during V&V that are pertinent to the ISV acceptance criteria are closed during V&V; that HED closure is summarized in the V&V ReSR. Similarly, other HEDs generated during or after V&V are closed prior to completing the DI program element; that HED closure is summarized in the DI ReSR. Revisions to results documentation from any previous HFE program element may be required to close HEDs. These program element results revisions are conducted as part of the HED closure process. The details of HED closure, including references to all updated results documents, are maintained in the HED database. Updated results documents are also referenced in the ReSRs that summarize the HED closure, as described above. Therefore, ReSRs that had been previously approved are not resubmitted for NRC approval. All updated HFE program element results are available for NRC inspection.

6.2 Human Factors Engineering Requirements

This section identifies the HFE requirements found in applicable codes, standards, and regulatory guidance. Requirements that do not apply specifically to the US-APWR HFE program but to the overall plant design are found in DCD Chapter 1. Unless specifically noted, the latest version of the codes and standard or regulatory guidance issued as of the date of this document is applicable.

I&C-specific requirements related to the design of the HSIS and connected systems are found in MUAP-07007 (Reference 8-1).

Other specific requirements and guidance are referred to and listed in each HFE IP and ReSR as applicable.

6.2.1 *Code of Federal Regulations*

(1) 10 CFR Part 50, “Domestic Licensing of Production and Utilization Facilities,” Appendix A, “General Design Criteria for Nuclear Power Plants,” General Design Criterion (GDC) 19, “Control Room” (Reference 8-17)

- The HSI system provides the safety-related and nonsafety-related HSI for the control room. Details are discussed in the HD IP (Reference 8-10).

(2) Applicable 10 CFR 50.34(f)(2) post-Three Mile Island (TMI) requirements (Reference 8-17)

- (iii) Control room design

The human factors design aspects of the HSI and the control room are described in MUAP-07007, Section 4.2.1 and 4.3 (Reference 8-1).

- (v) Bypassed and inoperable safety system status indication (BISI)
  BISI is part of the US-Basic HSIS. The specific BISI US-APWR HSI inventory is developed in HD.

(3) 10 CFR 50.36, "Technical Specifications" (Reference 8-17)

- 3) Surveillance requirements
  The HSIS provides extensive automatic testing. It is used for periodic surveillances to confirm the operability of the automatic test features and to manually test features of the system that are not tested automatically. Most manual tests may be conducted with the plant on line. Functions that cannot be tested with the plant on line are tested during plant shutdown.

(4) 10 CFR 50.54(m)(2)(iii) (Reference 8-17)

- The US-APWR minimum staffing design constraint complies with this regulation. MUAP-07007 (Reference 8-1) describes how the HSIS supports the minimum MCR staffing design constraint:

6.2.2 Staff Requirements Memoranda

(1) Staff Requirements Memorandum (SRM) to SECY 93-087, "Policy, Technical, and Licensing Issues Pertaining to Evolutionary and Advanced Light-Water Reactor (ALWR) Designs," July 21, 1993 (Reference 8-19)

- Item II.T Control Room Annunciator (Alarm) Reliability
  Alarm annunciators described in DCD Chapter 7 comply with this SRM (Reference 8-2).

6.2.3 NRC Regulatory Guides

(1) Regulatory Guide (RG) 1.8, "Qualification and Training of Personnel for Nuclear Power Plants" (Reference 8-20)

- The HSIS is integral to the training system for operator staffs. The RG endorses American National Standards Institute/American Nuclear Society (ANSI/ANS)-3.1-1993, "Selection, Qualification, and Training of Personnel for Nuclear Power Plants" (Reference 8-21), and ANSI/American Society of Mechanical Engineers(ASME) NQA-1-1983, "Quality Assurance Requirements for Nuclear Facility Applications" (Reference 8-22).

(2) RG 1.47, "Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems" (Reference 8-23)

- See compliance with 10 CFR 50.34(f)(2), above: (v) Bypassed and inoperable safety system status indication (BISI) (Reference 8-17).

(3) RG 1.62, "Manual Initiation of Protective Actions" (Reference 8-24)

- The HSI provides manual initiation at the system level for all reactor protection system and engineered safety feature actuation system safety functions by conventional SDCV switches located in the MCR.

(4) RG 1.114, “Guidance to Operators at the Controls and to Senior Operators in the Control Room of a Nuclear Power Unit” (Reference 8-25)

- See compliance with 10 CFR 50.54(m)(2)(iii), above (Reference 8-17).

(5) RG 1.149, Revision 4, “Nuclear Power Plant Simulation Facilities for Use in Operator Training, License Examinations, and Applicant Experience Requirements” (Reference 8-26) (endorses ANSI/ANS-3.5-2009, “Nuclear Power Plant Simulators for Use in Operator Training and Examination” (Reference 8-27))

- The HFE program plans to develop an operator training program are described in DCD Chapter 13 (Reference 8-2).

(6) RG 1.196, “Control Room Habitability at Light-Water Nuclear Power Reactors” (Reference 8-28)

- Control room habitability systems ensure the MCR environment is adequate to allow operators to maintain plant control limits during normal operation and to maintain plant safety limits during and after anticipated transients or design-basis accidents. The systems to ensure control room habitability are described in DCD Chapter 9 (Reference 8-2). HFE V&V tests include control room habitability environment simulations.

6.2.4 NUREG-Series Publications (NRC Reports)

(1) NUREG-0696, “Functional Criteria for Emergency Response Facilities,” February 1981 (Reference 8-15)

- The HSI provides plant information at the emergency response facilities, such as TSC, EOFs, and others.

(2) NUREG-0700, “Human-System Interface Design Review Guidelines,” May 2002 (Reference 8-16)

- The US-APWR HSIS and US-APWR Local HSI comply with these guidelines. This guideline is referenced in the HD IP (Reference 8-10).

(3) NUREG-0711, “Human Factors Engineering Program Review Model,” February 2004 (Reference 8-3)

- The US-APWR HFE design process complies with this guideline.

(4) NUREG-0737, Supplement 1, “Clarification of TMI Action Plan Requirements: Requirements for Emergency Response Capability,” November 1980 (Reference 8-29)

- The HSI system is used to comply with the following TMI Action Plan requirements:
  - Plant Safety Parameter Display – The HSI system provides safety parameter displays for the control room and for emergency support facilities.
  - Indication and Control for Safety Components (e.g., relief valves, pressurizer heaters, containment isolation valves).
  - Inadequate Core Cooling Monitoring and Instrumentation for Accident Monitoring – The HSI system provides nonsafety-related and safety-related displays for monitoring safety-related instruments and nonsafety-related and safety-related controls for safety-related plant components.

(5) NUREG-0800, Chapter 18, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition – Human Factors Engineering,” February 2004 (Reference 8-30)

- The US-APWR HFE design process complies with this guideline.

(6) NUREG-0899, “Guidelines for the Preparation of Emergency Operating Procedures,” August 1982 (Reference 8-31)

- The HSIS is used to display and execute emergency operating procedures (EOPs).

(7) NUREG-1220, “Training Review Criteria and Procedures,” January 1993 (Reference 8-32)

- The training phase of the HFE program complies with these requirements.

(8) NUREG-1358, “Lessons Learned from the Special Inspection Program for Emergency Operating Procedures,” September 1992 (Reference 8-33)

- The procedure development phase of the HFE program complies with these requirements.

(9) NUREG-1764, “Guidance for the Review of Changes to Human Actions,” September 2007 (Reference 8-34)

- See the HRA IP (Reference 8-7).

(10) NUREG/CR-6400, “HFE Insights for Advanced Reactors Based upon Operating Experience,” January 1997 (Reference 8-35)

- See the OER IP (Reference 8-4).

(11) NUREG/CR-4772, “Accident Sequence Evaluation Program Human Reliability Analysis Procedure,” February 1987 (Reference 8-36)

- The US-APWR HRA provides HEPs and the analysis for Type A (pre-initiating event) and Type C (post-initiating event) human interactions based on this guideline.

(12) NUREG/CR-1278, “Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications,” August 1983 (Reference 8-37)

- In the US-APWR PRA, the HEP analysis for Type B human interactions (i.e., errors that cause an initiating event) is implemented based on this guideline.

6.2.5 IEEE/IEC Standards

(1) International Electrotechnical Commission (IEC) 60964, “Nuclear Power Plants – Control Rooms – Design” (Reference 8-38)

- See the FRA/FA IP (Reference 8-5), the TA IP (Reference 8-6), and the TA ReSR.

(2) Institute of Electrical and Electronics Engineers (IEEE) 497-2002, “IEEE Standard Criteria for Accident Monitoring Instrumentation for Nuclear Power Generating Stations” (Reference 8-39)

- The method of display for all variable types is defined by the US-Basic HSIS. For example, the Type A variables have SDCV displays on the LDP and on the SDCV safety VDU.

6.2.6 Other Industry Standards

(1) ANSI/ANS 3.1, R1999, “Selection, Qualification, and Training of Personnel for Nuclear Power Plants” (Reference 8-21)

- See compliance with RG 1.8, above (Reference 8-20).

6.3 HFE Facilities, Equipment, Tools, and Techniques

The HFE design activities rely on the development of dynamic models for evaluating the overall plant response as well as the performance of individual control systems, including operator actions. The dynamic models implemented in the US-APWR simulator are used to do the following:

- Analyze steady state and transient behavior.
- Estimate operator’s actions for display navigations and control and monitoring actions, which support TA’s operator’s action time estimations.
- Confirm the design of the advanced alarm system concepts.
- Confirm the adequacy of control schemes.

- Confirm the allocation of control functions to a system or an operator.
- Confirm the HSI basic functions, display layout, display navigations, CBP functions, LDP information, and so forth.
- Validate plant operating procedures.
- Develop full-scope and part-task simulators for ISV and operator training.

Part-task or engineering modeling/simulation is used to develop an initial set of plant control parameters, including the development of associated graphical user interfaces. The part-task simulator is used in the preliminary US-APWR design and then expanded to include specific US-APWR design features. As the US-APWR design progresses, the part-task simulator proceeds through a series of iterative evaluations, resulting in the development of a full-scope control room simulator. The simulator facility is the focal point for HFE development, engineering design review, and operator evaluations/validation throughout the HSI design process.

The physical mockup and three-dimensional computer-aided design (CAD) to simulate console layout are also applied to help console shapes and console layout that are discussed in the HD IP (Reference 8-10).

6.4 Modifications

The NUREG-0711, Section 2.4.5(4) and (5) criteria related to the HFE plan assuring that plant modifications meet current regulations or do not compromise defense-in-depth do not apply to the US-APWR HFE program design certification activities.

7.0 NUREG-0711 COMPLIANCE EVALUATION

Table 7-1 lists the criteria from NUREG-0711, Revision 2 (Reference 8-3) and cross-references to the section in this report where compliance is demonstrated.

Table 7-1 Compliance with NUREG-0711

Review Criteria Stated in NUREG-0711, Rev. 2	HFE PMP Section No.
2.4.1 General HFE Program Goals and Scope *HFE Program Goals* - The general objectives of the program should be stated in "human-centered" terms, which, as the HFE program develops, should be defined and used as a basis for HFE test and evaluation activities. Generic "human-centered" HFE design goals include the following: • personnel tasks can be accomplished within time and performance criteria • the HSIs, procedures, staffing/qualifications, training and management and organizational support will support a high degree of operating crew situation awareness • the plant design and allocation of functions will maintain operation vigilance and provide acceptable workload levels i.e., to minimize periods of operator underload and overload • the operator interfaces will minimize operator error and will provide for error detection and recovery capability	Section 2.1
Assumptions and Constraints - An assumption or constraint is an aspect of the design, such as a specific staffing plan or the use of specific HSI technology that is an *input* to the HFE program rather than the result of HFE analyses and evaluations. The design assumptions and constraints should be clearly identified.	Section 2.2, including all subsections
Applicable Facilities - The HFE program should address the main control room, remote shutdown facility, technical support center (TSC), emergency operations facility (EOF), and local control stations (LCSs).	Section 2.3
Applicable HSIs, Procedures and Training - The applicable HSIs, procedures, and training included in the HFE program should include all operations, accident management, maintenance, test, inspection and surveillance interfaces (including procedures).	Section 2.4

Review Criteria Stated in NUREG-0711, Rev. 2	HFE PMP Section No.
Applicable Plant Personnel - Plant personnel who should be addressed by the HFE program include licensed control room operators as defined in 10 CFR Part 55 and the following categories of personnel defined by 10 CFR 50.120: non-licensed operators, shift supervisor, shift technical advisor, instrument and control technician, electrical maintenance personnel, mechanical maintenance personnel, radiological protection technician, chemistry technician, and engineering support personnel. In addition, any other plant personnel who perform tasks that are directly related to plant safety should be addressed. For plant modifications, the HFE program should include the involvement of plant personnel to provide reasonable assurance that the following are considered from a user's perspective in establishing modification requirements and evaluating the design process's outputs: • user's understanding of how plant systems are structured and behave • task demands and constraints of the existing work environment • existing work processes • organizational goals that affect the implementation and use of the modification	Section 2.5
Effects of Modifications on Personnel Performance - The goals of the HFE program should address the need to consider the effects that the modification may have on the performance of personnel. The transition from the existing plant configuration to the modification configuration can pose demands on human performance that differ from either the initial or final configurations. Therefore, it should be planned so it places minimal demands for adapting to the change. The considerations should include the following: • planning the installation to minimize disruptions to work • coordinating training and procedure modifications with implementing the modification to provide reasonable assurance that both accurately reflect its characteristics. • conducting training to maximize personnel's knowledge and skill with the new design before its implementation	Section 2.6
2.4.2 HFE Team and Organization *Responsibility* - The team should be responsible (with respect to the scope of the HFE program) for (a) the development of all HFE plans and procedures; (b) the oversight and review of all HFE design, development, test, and evaluation activities; (c) the initiation, recommendation, and provision of solutions through designated channels for problems identified in the implementation of the HFE activities; (d) verification of implementation of team recommendations; (e) assurance that all HFE activities comply with the HFE plans and procedures; and (f) scheduling of activities and milestones.	Section 3.1

Review Criteria Stated in NUREG-0711, Rev. 2	HFE PMP Section No.
Organizational Placement and Authority - The primary HFE organization(s) or function(s) within the organization of the total program should be identified, described, and illustrated (e.g., charts to show organizational and functional relationships, reporting relationships, and lines of communication). When more than one organization is responsible for HFE, the lead organizational unit responsible for the HFE program plan should be identified. The team should have the authority and organizational placement to provide reasonable assurance that all its areas of responsibility are accomplished and to identify problems in the implementation of the overall plant design. The team should have the authority to control further processing, delivery, installation, or use of HFE products until the disposition of a nonconformance, deficiency, or unsatisfactory condition has been achieved.	Section 3.2; Section 3.3, Figure 3-1
Composition - The HFE design team should include the expertise described in the Appendix.	Section 3.3, Table 3-1
Team Staffing - Team staffing should be described in terms of job descriptions and assignments of team personnel.	Sections 3.3, 4.1.1
2.4.3 HFE Process and Procedures *General Process Procedures* - The process through which the team will execute its responsibilities should be identified. The process should include procedures for:	Section 4.1
· assigning HFE activities to individual team members	Sections 3.3, 4.1.1
· governing the internal management of the team	Sections 3.3, 4.1.2
· making management decisions regarding HFE	Section 4.1.3
· making HFE design decisions	Section 4.1.4
· governing equipment design changes	Section 4.1.5
· design team review of HFE products	Section 4.1.6
Process Management Tools - Tools and techniques (e.g., review forms) to be utilized by the team to verify they fulfill their responsibilities should be identified.	Section 4.2 paragraphs 2–5
Integration of HFE and Other Plant Design Activities - The integration of design activities should be identified, that is, the inputs from other plant design activities to the HFE program and the outputs from the HFE program to other plant design activities. The iterative nature of the HFE design process should be addressed.	Section 4.3 Figures 4-1, 4-2, Table 4-1
HFE Program Milestones - HFE milestones should be identified so that evaluations of the effectiveness of the HFE effort can be made at critical check points and the relationship to the integrated plant sequence of events is shown. A relative program schedule of HFE tasks showing relationships between HFE elements and activities, products, and reviews should be available for review.	Section 4.4 Figures 2-1, 4-3
HFE Documentation - HFE documentation items should be identified and briefly described along with the procedures for retention and access.	Section 4.5 Table 4-2
Subcontractor HFE Efforts - HFE requirements should be included in each subcontract and the subcontractor's compliance with HFE requirements should be periodically verified.	Section 4.6

Review Criteria Stated in NUREG-0711, Rev. 2	HFE PMP Section No.
2.4.4 HFE Issues Tracking *Availability* - A tracking system should be available to address human factors issues that are (a) known to the industry (defined in the Operating Experience Review element, see Section 3) and (b) identified throughout the life cycle of the HFE aspects of design, development, and evaluation. Issues are those items that need to be addressed at some later date and thus need to be tracked to provide reasonable assurance that they are not overlooked. It is not necessary to establish a new system to track HEDs that is independent from the rest of the design effort. An existing tracking system may be adapted to serve this purpose (such as a plant's corrective action program, CAP).	Sections 5.0, 5.2 including all subsections
Method - The method should document and track HEDs from identification until the potential for negative effects on human performance has been reduced to an acceptable level.	Section 5.1 including all subsections
Documentation - Each issue or concern that meets or exceeds the threshold established by the design team should be entered into the system when first identified, and each action taken to eliminate or reduce the issue or concern should be thoroughly documented. The final resolution of the issue should be documented in detail, along with information regarding design team acceptance.	Section 5.1 paragraphs 4, 5; Section 5.1.2 paragraph 2; Section 5.1.4; Section 5.2 including all subsections
Responsibility - When an issue is identified, the tracking procedures should describe individual responsibilities for issue logging, tracking and resolution, and resolution acceptance.	Section 5.0 paragraph 1; Section 5.1 paragraph 3; Section 5.2.1 paragraph 2; Section 5.2.2.1 paragraph 1
2.4.5 Technical Program The general development of implementation plans, analyses, and evaluation of the following should be identified and described:	Section 6.1
· operating experience review	Section 6.1.1
· functional requirements analysis and function allocation	Section 6.1.2
· task analysis	Section 6.1.3
· staffing and qualifications	Section 6.1.5
· human reliability analysis	Section 6.1.4
· HSI design	Section 6.1.6
· procedure design	Section 6.1.7
· training design	Section 6.1.8
· human factors verification and validation	Section 6.1.9
· design implementation	Section 6.1.10
· human performance monitoring	Section 6.1.11

Review Criteria Stated in NUREG-0711, Rev. 2	HFE PMP Section No.
The HFE requirements imposed on the design process should be identified and described. The standards and specifications that are sources of HFE requirements should be listed.	Section 6.2 and all subsections
HFE facilities, equipment, tools, and techniques (such as laboratories, simulators, rapid prototyping software) to be utilized in the HFE program should be specified.	Section 3.3, 7^{th}–9^{th} paragraphs after Table 3-1; Figure 4-1; Section 5.2 and all subsections; Section 6.1.6, paragraphs 3 and 10; Section 6.1.9, paragraph 3; Section 6.3, paragraphs 2–3; also see Reference 8.11
The applicant should provide assurance in the HFE plan that a plant modification meets current regulations, except where specific exemptions are requested under 10 CFR 50.12 or 10 CFR 2.802. An exemption might be granted under one or more of the following regulations: 10 CFR 20, 10 CFR 50 Appendix A, Criterion 19, and 10 CFR 50 Appendices C through R.	N/A Section 6.4

Review Criteria Stated in NUREG-0711, Rev. 2	HFE PMP Section No.
The applicant should provide assurance in the HFE plan that a modification does not compromise defense-in-depth. Defense-in-depth is one of the fundamental principles upon which the plant was designed and built. Defense-in-depth uses multiple means to accomplish safety functions and to prevent the release of radioactive materials. Defense-in-depth is important in accounting for uncertainties in equipment and human performance, and for ensuring some protection remains even in the face of significant breakdowns in particular areas. Defense-in-depth may be changed but should be maintained overall. Important aspects of defense-in-depth are identified in RG 1.174, and include: • A reasonable balance is preserved among prevention of core damage, prevention of containment failure, and consequence mitigation. • There is no over-reliance on programmatic activities to compensate for weaknesses in plant design. This may be pertinent to changes in credited human actions (HAs). • System redundancy, independence, and diversity are preserved commensurate with the expected frequency, consequences of challenges to the system, and uncertainties (e.g., no risk outliers). • Defenses against potential common cause failures are preserved, and the potential for the introduction of new common cause failure mechanisms is assessed. Caution should be exercised in crediting new HAs to verify that the possibility of significant common cause errors is not created. • Independence of barriers is not degraded. • Defenses against human errors are preserved. For example, establish procedures for a second check or independent verification for risk-important HAs to determine that they have been performed correctly. • The intent of the General Design Criteria (GDC) in Appendix A to 10 CFR Part 50 is maintained. GDC that may be relevant are 3 - Fire Protection, 13 - Instrumentation and Control, 17 - Electric Power Systems, 19 - Control Room, 34 - Residual Heat Removal, 35 - Emergency Core Cooling System, 38 - Containment Heat Removal, and 44 - Cooling Water. • Safety margins often used in deterministic analyses to account for uncertainty and provide an added margin to provide adequate assurance that the various limits or criteria important to safety are not violated. Such safety margins are typically not related to HAs, but the reviewer should take note to see if there are any that may apply to the particular case under review. It is also possible to add a safety margin (if desired) to the HA by demonstrating that the action can be performed within some time interval (or margin) that is less than the time identified by the analysis.	N/A Section 6.4

8.0 REFERENCES

8-1 HSI System Description and HFE Process, MUAP-07007, Revision 5, MHI, November 2011.

8-2 Design Control Document for the US-APWR, Revision 3, MHI, March 2011.

8-3 Human Factors Engineering Program Review Model, NUREG-0711, Revision 2, U.S. Nuclear Regulatory Commission, February 2004.

8-4 Operating Experience Review Implementation Plan, MUAP-13005, Revision 0, MHI, July 2013.

8-5 Functional Requirements Analysis and Function Allocation Implementation Plan, MUAP-13007, Revision 0, MHI, July 2013.

8-6 Task Analysis Implementation Plan, MUAP-13009, Revision 0, MHI, July 2013.

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