US-APWR

HSI Design

Non-Proprietary Version

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Signature History

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Prepared	Yusuke Yamada	Eisuke Noda	Satoshi Hanada	
	Kenji Mashio	Satoshi Hanada		
	Koji Ito	Koji Ito	Koji Ito	
Reviewed	Hideaki Tokunaga	Hideaki Tokunaga	Hideaki Tokunaga	
Approved	Masanori Yokoyama	Masanori Yokoyama	Masanori Yokoyama	
	Toshio Tanaka	Yuzuru Yasui	Yuzuru Yasui	

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)	
		pp. 67-72 (Part 2 Appendix 1.8.2)	

Rev.	Date	Page (Section)	Description
		pp. 73-97 (Part 2 Appendix 1.8.3)	
		pp. 98-114 (Part 2 Appendix 1.8.4)	
		p. 115 (Part 2 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)	
		p. 196 (Part 2 Appendix 2.10.3)	
		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).

Rev.	Date	Page (Section)	Description
		pp. 248-255 (Part 2 Appendix 3.10.1)	
		pp. 257-283 (Part 2 Appendix 3.10.2)	Revised the description.
		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.

Mitsubishi Heavy Industries, Ltd.
16-5, Konan 2-chome, Minato-ku
Tokyo 108-8215 Japan

Abstract

This technical report contains three parts:

Part 1 is the overall US-APWR Human Factors Engineering (HFE) Program Plan, which expands on the program plan as described in the US-APWR DCD Chapter 18, Section 18.1 (Ref. 11-2). This plan is applicable to the complete US-APWR HFE program, which starts with the development and NRC approval of the US-Basic Human System Interface System (HSIS), and continues through the implementation of the US-APWR HSIS for a site specific application. 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 design. Similarly, the generic control, monitoring, alarm and computerized procedure methods of the US-Basic HSIS can be applied to the modernization of existing plants with the specific HSI inventory needed for that plant.

Part 2 documents the US-APWR HFE Analysis methodologies and results summary reports for Functional Requirement Analysis and Functional Allocations (FRA/FA), Task Analysis (TA) for Risk Important Human Actions (RIHAs) and Human Reliability Analysis (HRA), as described in Sections 18.3, 18.4 and 18.6 of Ref. 11-2, respectively. The TA section also includes the US-APWR TA Implementation Plan for additional TA that will be conducted in the future. The complete US-APWR HFE program is defined by the results summary reports and results summary reports described above, the Implementation Plan for future TA activities described above, and the following Implementation Plans for other future HFE activities:

- Staffing and Qualification Analysis Implementation Plan, MUAP-10008
- HSI Design, MUAP-10009
- Design Implementation Plan, MUAP-10013
- Human Performance Monitoring (HPM) Implementation Plan, MUAP-10014.

Part 3 provides the US-APWR Phase 1b Verification and Validation (V&V) methodology and results. The Phase 1b V&V program concludes Phase 1 of a three phase V&V program for the US-APWR, as described in Section 18.10 of Ref. 11-2. The Phase 1a V&V program was described in MUAP-08014. In Phases 1a and 1b U.S. licensed operators evaluated the Japanese-Basic HSIS. The HSI tested in Phases 1a and 1b, along with changes resulting from the resolution of key Human Engineering Discrepancies (HEDs), constitute the US-Basic HSI System, which is documented in MUAP-07007 and for which a Nuclear Regulatory Commission (NRC) Safety Evaluation Report (SER) has been written by the NRC Staff and commented on by MNES. The V&V Implementation Plan for Phases 2 is provided in MUAP-10012.

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List of Acronyms

ALR	Automatic Load Reduction (turbine control)
AO	Auxiliary Operator (Non licensing plant personnel)
AOO	Anticipated Operational Occurrences
AOP	Abnormal operating procedure
APWR	Advanced Pressurized Water Reactor
ARI	All Rods In
ARP	Alarm Response Procedure
ASEP	Accident Sequence Evaluation Program HRA Procedure
ATWS	Anticipated Transient Without Scram
BD	Blow-Down
BHEP	Basic Human Error Probability
BISI	Bypassed or Inoperable Status Indication
BU	Back-Up
CB	Control Bank
C_B	Boron Concentration
CAS	Central Alarm Station
CBD	Control Bank D
CBP	Computer-based Operating Procedure
CCF	Common Cause Failure
CCW	Component Cooling Water
C/C	Control Center
CDF	Core Damage Frequency
CET	Core Exit Thermo-couple
CFR	Code of Federal Regulations
Chg	Charging
COL	Combined License
COLA	Combined operating license application
COTS	Commercial-Off-The-Shelf
CPNPP	Comanche Peak Nuclear Power Plant
CPU	Central Processing Unit
CRDM	Control Rod Drive Mechanism
CS	Containment Spray
CSF	Critical Safety Function
C/V	Containment Vessel
CVCS	Chemical and Volume Control System
D3	Defense-in-Depth and Diversity
DAC	Design Acceptance Criteria
DAS	Diverse Actuation System
DBA	Design Basis Accident
DC	Design Certification
DCD	Design Control Document
DF	Dependency Factor

DHP	Diverse HSI Panel
DMC	Data Management Console
DPM	Decades Per Minute
D-RAP	Design Reliability Assurance Program
DRPI	Digital Rod Position Indicator
DTM	Design Team Manager
ECCS	Emergency Core Cooling System
EF	Error Factor
EFC	Error-Forcing Contexts
EFW	Emergency Feed Water
ELM	Engineering Line Manager
EOF	Emergency Operations Facility
EOP	Emergency Operating Procedure
EP	Back Feed Electric Power
ERG	Emergency Response Guidelines
ESF	Engineered Safety Feature
ESFAS	Engineered Safety Features Actuation System
FA	Function Allocation
FMEA	Failure Modes and Effects Analyses
FC	Fail to Close
FC	First Concrete
FCV	Flow Control Valve
FK	Flow Control Valve (Automatically controlled)
FO	Fail to Open
F.O.	First Out
FOP	Full-Out Position
FRA	Functional Requirements Analysis
FSAR	Final Safety Analysis Report
FTA	Fault Tree Analysis
FV	Fussell-Vesely importance measure
FW	Feedwater
GDC	General Design Criteria
GOMS	Goals, Operators, Methods, and Selection rules
GTG	Generic Technical Guidelines
GUI	Graphical User Interfaces
HA	Human Action
HAZOP	Hazards and Operability Analysis
HCV	Hand Control Valve
HDSR	Historical Data Storage and Retrieval
H.E	Human Error
HED	Human Engineering Discrepancy
HEP	Human Error Probability
HEPA	High-Efficiency Particulate Air
HFE	Human Factors Engineering
HFEVTM	HFE V&V Team Manager

HPM	Human Performance Monitoring
HRA	Human Reliability Analysis
HSI	Human System Interface
HSIS	Human System Interface System
HVAC	Heating, Ventilation, and Air Conditioning
I&C	Instrumentation and Control
ID	Identifier
IR	Intermediate Range
ITAAC	Inspections, Tests, Analyses, and Acceptance Criteria
ITV	Industrial Television
LAR	License Amendment Request
LBB	Leak Before Break
LBLOCA	Large Break Loss Of Coolant Accident
LC	Locked to Close
LCO	Limiting Condition for Operation
LCS	Local Control Station
LDP	Large Display Panel
LER	Licensee Event Report
LERF	Large Early Release Frequency
Lo	Low
LO	Locked to Open
LOCA	Loss Of Coolant Accident
LPSD	Low Power and Shut Down
LTOP	Low Temperature Over Pressure
LRF	Large Release Frequency
M	Main Control Room Ventilation System Isolation Signal
MCB	Main Control Board
MCR	Main Control Room
M/C	Metal Clad Gear
MELCO	Mitsubishi Electric Corporation
MELTAC	Mitsubishi Electric Total Advanced Controller
MEPPI	Mitsubishi Electric Power Products, Inc.
MHI	Mitsubishi Heavy Industries
MNES	Mitsubishi Nuclear Energy Systems
MS	Main Steam
MSIV	Main Steam Isolation Valve
MSLB	Main Steam Line Break
MSRV	Main Steam Relief Valve
NIS	Nuclear Instrumentation System.
NPP	Nuclear Power Plant
NR	Narrow Range
NRC	Nuclear Regulatory Commission, U.S.
OER	Operation Experience Review
OPPS	Over Pressure Protection System
OSD	Operational Sequence Diagram

P	Containment Vessel Spray Signal
PA	Postulated Accidents
PAM	Post Accident Monitoring
PB	Push-Button
PCMS	Plant Control and Monitoring System
PCV	Pressure Control Valve
PM	Project Manager
Pmp	Pump
POS	Plant Operational State
PRA	Probabilistic Risk Assessment
PRC	Process Recording Computer
Press	Pressure
Przr	Pressurizer
PSF	Performance Shaping Factor
PSMS	Protection and Safety Monitoring System
QA	Quality Assurance
RAW	Risk Achievement Worth
RC	Reactor Coolant
RCP	Reactor Coolant Pump
RCS	Reactor Coolant System
R.G.	Regulatory Guide
RHR	Residual Heat Removal
RIHA	Risk Important Human Action
RMS	Radiation Monitoring System
RO	Reactor Operator
RPS	Reactor Protection System
RSC	Remote Shutdown Console
RSR	Remote Shutdown Room
RSS	Remote Shutdown Station
RTB	Reactor Trip Breaker
RWSP	Refueling Water Storage Pit
Rx	Reactor
SAR	Safety Analysis Report
SAS	Secondary Alarm Station
SAT	Systematic Approach to Training
SBA	Shutdown Bank A
SBO	Station Black Out
SDB	Shutdown Bank
SDCV	Spatially Dedicated Continuously Visible
SER	Safety Evaluation Report
SFP	Spent Fuel Pit
SG	Steam Generator
SGTR	Steam Generator Tube Rupture
SI	Safety Injection
SLS	Safety Logic System
SME	Subject Matter Expert

SOER	Significant Operating Experience Reports
SPDS	Safety Parameter Display System
SR	Source Range
SRO	Senior Reactor Operator
SM	Shift Manager
STA	Shift Technical Advisor
SUR	Start-Up Rate
T	Containment Vessel Isolation Signal
TA	Task Analysis
Tavg	Reactor Coolant Average Temperature
TB	Turbine-Bypass
TBV	Turbine-Bypass Valve
Tcold	Reactor Core Inlet Coolant Temperature
T/C	Thermocouple
Thot	Reactor Core Outlet Coolant Temperature
THERP	Technique for Human Error Rate Prediction method
TMI	Three Mile Island
Tref	Reactor Coolant programmed Tavg Reference Temperature
TSC	Technical Support Center
UMC	Unit Management Computer
UPS	Uninterruptable Power Supply
URS	United Research Services (an architect engineer subcontractor)
US, U.S.	United States
US-APWR	US Advanced Pressurized Water Reactor
UV	Under Voltage
V	Containment Vessel Ventilation Control System Isolation Signal
V&V	Verification and Validation
VDU	Visual Display Unit
Vlv	Valve
VTM	V&V Team Manager
WR	Wide Range

Part 1 Human Factors Engineering (HFE) Program Plan

1.0 PURPOSE

Part 1 is the overall US-APWR Human Factors Engineering (HFE) Program Plan, which expands on the program plan described in Chapter 18 of the US-APWR DCD.
This HFE Program Plan is written to achieve a US Human System Interface System (HSIS) which supports both safe plant operation and plant power production. The HFE Program Plan governs the HFE activities needed to:

1. Build on a previously developed and tested Japanese-Basic HSIS to achieve the US-Basic HSIS.
2. Define and obtain NRC approval for the US-Basic HSIS that is derived from the Japanese-Basic HSIS and is applicable to both the US-APWR and to operating US PWR plants.
3. Define the development process for the US-APWR HSIS that will be used for all US-APWR applications, and obtain NRC approval of the US-APWR HSIS development process and the portions of that development process which are completed within the scope of the US-APWR DCD.
4. Define the development process for the US-APWR HSIS for site specific applications, and obtain NRC approval of the US-APWR HSIS development process for site specific applications.

The starting point for the US-Basic HSIS is the HSI design that Mitsubishi developed for Japanese PWR nuclear plants, the Japanese-Basis HSI System.

1.1 Background

The Japanese-Basic HSIS was developed in the late 1990s. The Japanese-Basic HSIS design process was based on NUREG-0711, Revision 2. Approximately 200 Japanese nuclear power plant operators participated in the evaluation process. The Japanese-Basic HSIS is being utilized in Japan for new PWR nuclear power plants and for operating PWR nuclear power plant control board replacement projects. The Japanese-Basic HSIS is functioning at the Tomari 3 and Ikata 1 & 2 nuclear plants. Mitsubishi has also reached agreement with other Japanese utilities to install the Japanese-Basic HSIS in new nuclear power plants and for replacement of existing main control boards in other operating Japanese nuclear power plants.

1.2 US Licensing Approach

Each HFE program element covered by this plan will have a specific methodology. The work aspects of a particular program element are governed by the methodology that is specific to that element. Each element’s methodology shall describe pertinent HFE facilities, equipment, tools, and techniques. For HFE activities completed within the scope of the US-APWR DCD (i.e., Operating Experience Review (OER), Functional Requirement Analysis and Functional Allocation (FRA/FA), Human Reliability Analysis (HRA) and Task Analysis (TA) for RIHAs), the program element methodology is described within the document that provides the program element report. For HFE activities that will be completed after US-APWR DCD, the methodology is described within an Implementation Plan (IP). The IP is the basis for the Inspection, Test and Analysis Acceptance Criteria (ITAAC), which is defined in Tier 1 of the US-APWR Certified Design.

The primary benefits that Mitsubishi foresees in starting with the Japanese-Basic HSIS design are:

- To learn from the Japanese experience applying the NUREG-0711, Revision 2 program elements to the Japanese-Basic HSIS
- To involve US nuclear power plant operators early in the US-Basic HSIS design process
- 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 US)

2.0 APPLICABILITY

This HFE Program Plan shall govern the overall management and execution of all HFE program elements as defined by DCD Chapter 18. Limitations and exclusions are described in sections 2.2 and 2.3, below.

2.1 Implementation Plans and Results Reports

A results report for completed program elements (i.e., OER, FRA/FA and HRA), which describes the implementation methodology and results, a results report for partially complete program elements (i.e., TA for RIHAs), which describes the implementation methodology and results, or an implementation plan for program elements to be completed in the future with a separate results summary report (except as specifically noted below) shall be developed for each HFE program element. Where separate implementation plans are written, the implementation plan shall describe the process used to implement that program element and the content of the results summary report required to document completion. All results summary reports or results reports completed as part of the US-APWR DCD and all implementation plans which define post certification HFE processes shall be submitted to the NRC for approval as part of the design certification program. Results summary reports completed after the design certification fulfill Inspection, Test and Analysis Acceptance Criteria and therefore shall be available for NRC inspection.
Table 1 identifies the reference documentation created within the US-APWR DCD (Refrence 11-2) for each HFE program element and the future documentation required to close ITAAC.

Table 1 HFE Implementation Plans, Results Reports, and Results Summary Reports

DCD sub section	Title	Reference Document	Reference Document contents	ITAAC Closed by:
18.1	HFE Program Management	Part 1 HFE Program Plan, MUAP-09019	• HFE program management plan	No ITAAC Required
18.2	Operating Experience Review	Part 2, OER Report, MUAP-08014	• Results summary report, which also contains the program element methodology	No ITAAC Required
18.3	Functional Requirement Analysis &	Part 2, Section 1 FRA/FA Report, MUAP-	• Results summary report, which also contains the program	No ITAAC Required

DCD sub section	Title	Reference Document	Reference Document contents	ITAAC Closed by:
	Functional Allocation	09019	element methodology	
18.4	Task Analysis	Part 2, Section 3 TA Report, MUAP-09019	• Results report for RIHA, which also contains the methodology • Implementation plan for the remaining tasks	Result s summary report for remaining tasks including result report for RIHAs with confirmation of its update
18.5	Staffing and Qualifications	Staffing and Qualifications Implementation Plan, MUAP-10008	• Implementation plan	Results summary report
18.6	Human Reliability Analysis	Part 2, Section 2 HRA report, MUAP-09019	• Results report, which also contains the program element methodology	No ITAAC Required
18.7	Human System Interface Design	HSIS Description and HFE Process, MUAP-07007	• US-Basic HSIS design report	No ITAAC required
		HSI Design Implementation Plan, MUAP-10009	• Implementation plan for the US-APWR HSI inventory	Results summary report
18.10	Verification and Validation	Verification and Validation Implementation Plan, MUAP-10012	• Implementation plan	Results summary report
18.11	Design Implementation	Design Implementation Plan, MUAP-10013	• Implementation plan	Results summary report
18.12	Human Performance Monitoring	Human Performance Monitoring Implementation Plan, MUAP-10014	• Implementation plan	Inspection of HPM program documentation

2.2 Scope

This Program Plan covers the development of the HSI for the Main Control Room (MCR), Remote Shutdown Room (RSR), Technical Support Center (TSC) and safety significant Local Control Stations (LCS).

Safety significant LCS are defined as those LCSs that support:

- Technical specification activities for surveillance testing, radiological protection, and chemical monitoring
- Operability restoration (after maintenance or testing) for equipment controlled by technical specifications
- Emergency and abnormal conditions response

The US-APWR HFE team determines the information that must be transmitted from the plant to the Emergency Offsite Facility (EOF), in accordance with regulatory requirements and guidance, and based on the TA process. The EOF itself, including the detailed design of EOF displays and corresponding V&V, training and procedures, is outside the scope of the US-APWR HFE implementation plans.

This US-APWR HFE program also encompasses the communication interfaces between the MCR and the plant physical security facilities defined as the Central Alarm Station and Secondary Alarm Station (CAS/SAS). The actual design of these facilities is outside the scope of this program plan.

In addition to normal plant operation, the HSIS within this program supports:

- Technical specification surveillance testing
- Radiological protection to support technical specification activities
- Required chemical monitoring supporting technical specifications
- Maintenance and manual testing required by technical specifications
- Emergency and abnormal conditions response

The HSIS includes the displays, alarms, and controls for these facilities as well as the procedures and training that support the tasks conducted at these facilities.

2.3 Excluded Human Factor Engineering Elements

This HFE Program Plan is applicable to all HFE program elements, as defined in DCD Chapter 18, with the exception of Human Performance Monitoring (HPM). HPM is the responsibility of the license holder and is, therefore, governed by the license holder's own HPM implementing procedures. It is noted that most US-APWR COL applicants are expected to reference the US-APWR HPM plan in MUAP-10014 for the development of their HPM implementation plans but this is not required.

The license holder shall also create Implementation Plans for any HFE program elements that must be re-evaluated due to facility design changes.
The communication and information requirements of the EOF and the communication interface with the CAS/SAS, are within the scope of the US-APWR HFE program. However, because the EOF and CAS/SAS facilities themselves are outside the scope of the US-APWR HFE

Implementation Plans, this HFE Program Plan is not applicable to EOF activities other than communication and information.

3.0 MULTIDISCIPLINE MULTIPLE ORGANIZATION TEAM

As shown in Figure 1, several companies comprise the team formed to execute the US-APWR HFE program. This multidiscipline multiple organization team shall execute the US-APWR HFE program, including the HSI Design and V&V Program elements.

3.1 Human Factor Engineering Team and Organization

The HFE team shall consist of an HSIS design team, an HSIS V&V team and an Expert Panel. Current or former US licensed reactor operators (ROs) and senior reactor operators (SROs) shall be integrated into the HFE team. The organization is composed of team members from:

- MHI and MNES, a wholly owned subsidiary of MHI
- MELCO and MEPPI, a wholly owned subsidiary of MELCO
- Consultants to MHI/MNES and MELCO/MEPPI
- Subcontractors to MHI/MNES
- US-APWR COLA applicants

In order to avoid the need for revision to the Implementation Plan to accommodate personnel changes, the names of specific individuals fulfilling each organizational role are not identified in this plan; rather, they shall be identified in future results summary reports, the results summary reports in this document or tracked as an auditable QA record. The specific team member identified within a results summary report shall comprise the key personnel responsible for the HFE activities governed by that report or record document. The contributions from each organization and the responsibilities of each organizational role shall also be described in that report or record document.

3.2 Organization Roles and Responsibilities

3.2.1 Human Factor Engineering Manager

The HFE Manager is the functional manager of the HFE team. The HFE Manager assigns activities to the HFE team members according to each subject matter organization's responsibilities.
The HFE Manager shall assure that all HFE program elements are appropriately implemented in accordance with the respective HFE implementation plan. The HFE Manager is responsible for organizing the HFE team, oversight of the HFE processes, and controlling HFE resources including those outside of his direct line organization. The HFE Manager is also responsible for the oversight of design and activities from other engineering departments that affect safety significant human performance.

3.2.2 Human Factor Engineering Team

MHI shall be the lead technical organization for the overall US-APWR HFE program, including HFE analysis, HSIS design, V&V and implementation. The HSIS design team shall be independent from the HSIS V&V team. The HFE Manager, the HSIS Design Team Manager (DTM), and the HSIS V&V Team Manager (VTM) shall be from MHI. Subcontractors shall perform work at the direction of MHI.

The HFE team shall conduct HFE activities in accordance with applicable HFE implementation plans with MHI's Quality Assurance (QA) Program. Figure 1 shows the HFE team positions in relationship to the team members from other MHI engineering organizations that are controlled under the MHI QA program. HFE team members are assigned from each engineering organization according to the needs of HFE Manager.

The HFE team also has the responsibility to identify HFE problems in the overall plant design and oversee their correction. The HFE team shall coordinate with other organizations to resolve identified HFE issues using the following approach:

- Organize Expert Panel meetings with plant design and HFE experts to identify and discuss solutions to HFE issues
- Designate a responsible design organization to lead issue resolution. Lead plant design organizations are responsible for resolving HFE design issues
- Monitor the progress of resolution of HFE design issues through their completion.
- Verify the effectiveness of HFE design issue resolution through performance of technical reviews and/or the conduct of verification activities using prototype models or simulators

The plant design organizations are responsible for resolving design issues which are identified by the HFE program. Resolution is achieved through improving plant design specifications. The HFE team is responsible for initiating human engineering discrepancies (HEDs), tracking HEDs, 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 shall be the lead organization for conversion of the HSI functional design, which is the responsibility of MHI, into software and hardware for the US HSIS test facilities, operator training facilities and the actual plants. The US-APWR Implementation Project Manager and the HSIS Test Facility Manager shall be MELCO employees or MHI/MNES subcontractors. Within the context of this HFE Program Plan "HSIS Test Facility" refers to the facility for Phase 1a and 1b testing, which is for development of the US-Basic HSIS. At this time, management of the HSI Test Facility for Phases 2 and 3 testing, which is for the integrated system V&V of the US-APWR HSIS and site specific US-APWR HSIS, respectively, had not yet been determined. Since these are future activities, Phase 2 and 3 test facility management will be described in the V&V results summary report for V&V and Design Implementation, respectively.

There shall be an HSI test facility located in the US to support US-APWR HFE program activities. The US HSI test facility shall include a full-scale MCR simulator. The MEPPI (an US subsidiary of MELCO), located near Pittsburgh, PA, accommodates the first US HSI test facility (See Figure 2). The US HSI Test Facility Manager shall be from MEPPI or be MHI/MNES subcontractors. Although MEPPI is responsible for managing and maintaining the US HSIS Test Facility, the hardware and software design and manufacture for the MEPPI test facility are the responsibility of MELCO or MHI/MNES subcontractors.

3.2.3 Expert Panel

The Expert Panel shall contain HFE experts, I&C experts, nuclear plant process, systems, and operations experts. Experts (Expert Panel members and subject matter experts for each HFE elements), the HSIS DTM and the VTM on the HFE team shall have at least 10 years of nuclear experience in their expert field and an education background that supports their expert credentials.

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

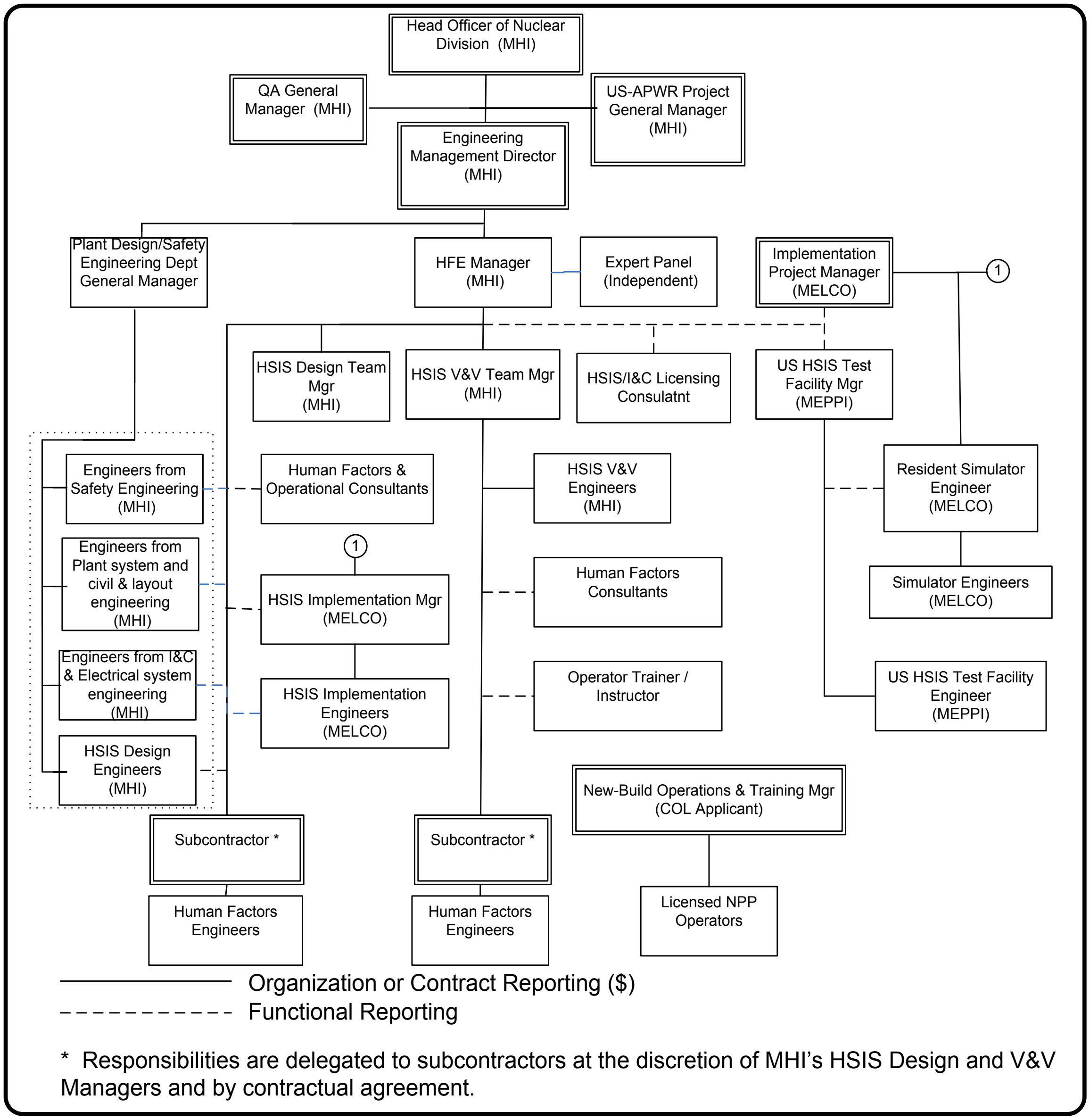


Figure 1 HFE Team Organization

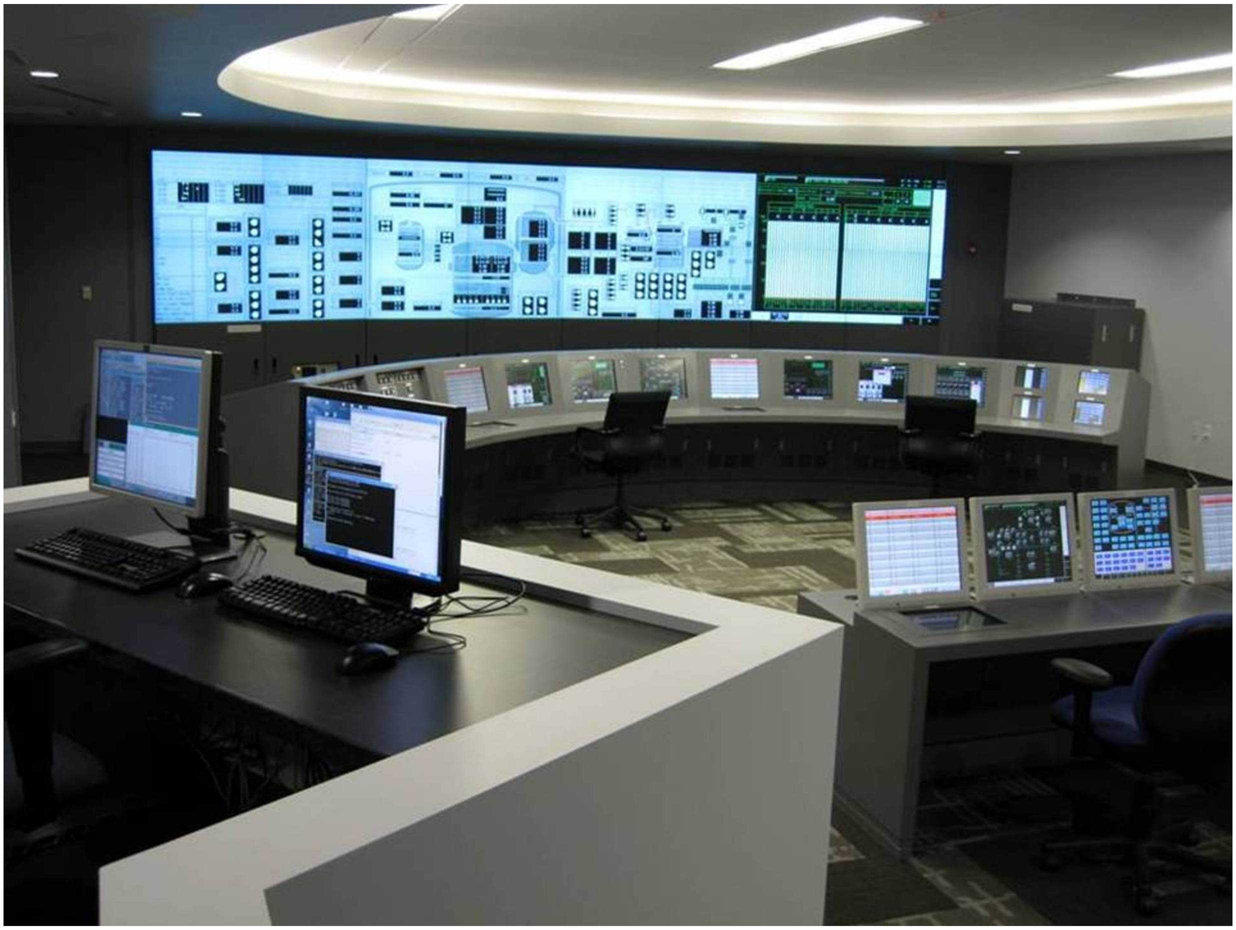


Figure 2 US HSIS Test Facility

3.3 Team Management

3.3.1 Human Factor Engineering Manager

The HFE Manager shall be responsible for management decisions regarding the HFE program. The HFE Manager shall assign work responsibilities to the technical disciplines within the HFE team and within MHI's engineering organization. The technical managers and their staffs shall implement the assigned work responsibilities.

The HFE Manager shall assure that all HFE program elements are appropriately implemented in accordance with the respective HFE implementation plans. The HFE Manager is responsible for making HFE design decisions and controlling HFE design changes. Where a discrepancy exists between HFE requirements and the plant design, an HED is generated. Plant design authorities (i.e., engineering divisions) are engaged in HED resolutions and are required to change the plant design based on HED resolutions.. HFE team members consist of multi-disciplined 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. The HFE manager is responsible for organizing the HFE team, oversight of the HFE processes, and controlling HFE resources including those outside of his direct line organization.

3.3.2 Human System Interface System Design Team Manager

The HSIS DTM is responsible for the HSIS design activities with the exception of HSIS design testing, which is discussed below.
The HSIS DTM shall be responsible for HSI design decisions, including design changes required for resolution of HEDs. The HSIS DTM shall be responsible for the development of US-APWR HSIS design specifications, either directly or indirectly through other engineering disciplines.

The HSIS DTM shall be responsible for the OER.

The HSIS DTM shall be responsible for the US-APWR HFE analyses:

- FRA/FA
- TA
- HRA
- Staffing and qualifications analysis

3.3.3 Human System Interface System Verification & Validation Team Manager

The HSIS VTM shall be responsible for formal design testing of HFE products during the implementation of the HSI Design program element, final V&V testing of the US-APWR HSIS, and site specific HSIS during the V&V program element and Design Implementation program element. The HSIS VTM shall be responsible for defining HFE V&V processes, generation of V&V procedures, and defining and generating V&V data collection forms.

Formal design testing is performed by the V&V team in accordance with a written procedure and a test results report is prepared. The implementation plan "V&V" includes both formal design testing during implementation of the HSI Design program element and testing of the final US-APWR HSIS. This testing is performed in accordance with NUREG-0711 Revision 2, as defined in the V&V program plan of DCD Chapter 18.10 and the V&V Implementation Plan, MUAP-10012. To distinguish HSI Design program element testing from V&V program element testing, this HFE Program Plan will refer to V&V program element testing, as "US-APWR V&V." The VTM is responsible for V&V of changes from the US-APWR HSIS to accommodate site-specific applications. The V&V of these changes will occur in the Phase 3 Design Implementation program element.

Discretion regarding the level of design and verification team member independence rests with the HFE Manager. As a result, V&V team members may contribute to the HSI design, and HSIS design team members may participate in V&V activities with the approval of the HFE Manager.

Licensed nuclear power plant operators (or candidates for an NRC operator's license) shall be the test participants for V&V activities. Licensed Operators or previously Licensed Operators shall also participate in the evaluation of HEDs and the approval of HED resolutions.

The HSIS design team shall be responsible for designing and implementing all HSIS changes that are needed to resolve HEDs. V&V of these HSIS changes shall be made by the V&V team.

HED resolution shall be reached by consensus between the team members and managers. If consensus cannot be reached, then the HFE Manager has the responsibility to be the final arbiter and shall reach a decision. HED resolution shall also be approved by the Expert Panel, as described in Section 6.1.

3.3.4 Human System Interface System Implementation Manager

The HSIS Implementation Manager shall be responsible for implementing the hardware and software of the HSI design. The US HSIS Test Facility Manager shall be responsible for any required changes to the MEPPI US test facility. The HSIS Implementation Manager and the US HSIS Test Facility Manager report to the Implementation Project Manager.

3.4 Quality Assurance

Personnel performing HFE activities shall perform the activities according to the HFE Implementation Plan for that activity. The activities shall be conducted in compliance with each organization's QA program. Subcontractors, who do not have their own QA programs, shall comply with MHI or MNES or COL applicant's QA programs.   Work procedures shall be developed to execute the implementation plans. The names and qualifications of the team members who execute the work procedures shall be recorded directly within the results summary report or as an auditable QA record.

Results for all program element activities shall be documented in result summary reports. Where the result summary report is completed as part of the US-APWR DCD, the results summary report shall contain the program element methodology.

Each HFE program element is conducted by qualified experts having at least 10 years experience in HFE or PWR operations. Experts will be knowledgeable of the differences between the US-APWR and conventional US PWRs. Personnel qualification is managed under the organization's QAP.

US-APWR COL applicants performance of the HPM program and development of any other HFE program element deliverables generated directly by the licensee shall be guided by the applicant's QA program.

4.0 HUMAN SYSTEM INTERFACE MODEL

The US-APWR HSIS development work sequence is based on modeling the HSIS as two components, a generic element and a plant specific element. The generic element is referred to as the "US-Basic HSIS" and the plant specific element is referred to as the "US-APWR HSI Inventory." The US-Basic HSIS is common to any nuclear power plants to which it is applied. (e.g., the US-APWR and US operating plant control board replacements).

4.1 Basic Human System Interface System

The US-Basic HSIS comprises the generic elements of alarm, display and control, and it defines the HSI operation method or technique for each generic element without consideration of the specific alarms, displays or controls for any particular process application. The US-Basic HSIS is defined by MUAP-07007, which includes a design basis and functional design specification that includes specifications for data processing, access, presentation, and a style guide defining the HSI attributes. Examples of HSI attributes are general display guidelines, display element design, display screen format, and display hardware requirements. The US-Basic HSIS also encompasses generic alarm prioritization and presentation methods, generic component, process and system controls, and the generic design of computerized procedures.

4.2 Human System Interface Inventory

The HSI Inventory can be developed for a specific plant design (Plant Specific) or for a specific site (Site Specific). "Plant specific" refers to a specific nuclear unit or a family of units that share the same design.

The HSI Inventory is the specific set or collection of indications, alarms, controls, and procedures implemented using the HSI techniques for a specific nuclear power plant. For example, a plant HSI inventory includes, but is not limited to, the mimic screens, alarm messages, control stations, and procedures for a nuclear power plant design. The HSI inventory is developed from plant specific HFE analyses. For the US-APWR, the generic HSI Inventory is referred to as the "US-APWR HSI Inventory."

When "plant" refers to a family of units that share the same design, there are site specific variations such as interconnection to the grid and to the ultimate heat sink. To ensure completeness, the US-APWR HSI Inventory includes generic assumptions regarding these site specific variations. However, when the actual site specific variations replace these generic assumptions, the result is referred to as the Plant X HSI Inventory (e.g., CPNPP Unit 3 & 4 HSI Inventory).

4.3 Human System Interface System Application

The two elements, Basic HSIS and HSI Inventory are combined to form a plant specific HSIS, as shown in Figure 3. For the US-APWR, the result of combining the US-Basic HSIS with the US-APWR HSI Inventory is referred to as the US-APWR HSIS. When the actual site specific HSI Inventory replaces the generic site specific assumptions, the result is referred as the Plant X HSIS (e.g., CPNPP Unit 3 & 4 HSIS).

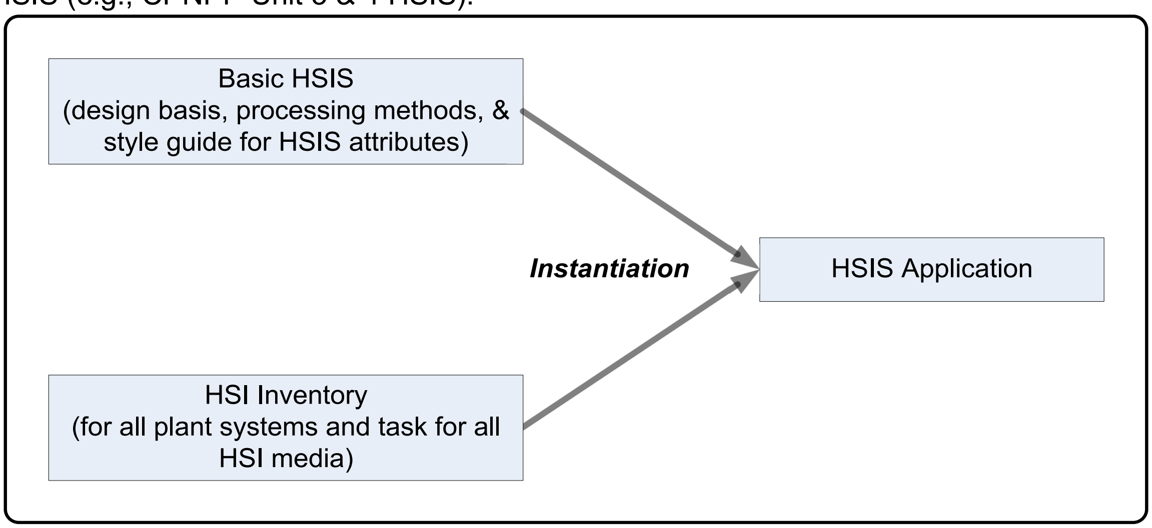


Figure 3 Human System Interface Model

4.4 Relationship of Japanese-Basic HSIS and US-Basic HSIS

The Basic HSI developed by Mitsubishi for application in the US is referred to as the "US-Basic HSIS." The HSIS described in Reference 11-1 Section 4 is what MHI refers to as the US-Basic HSIS.

4.4.1 US-Basic Human System Interface System

The starting point for the US-Basic HSIS shall be the Japanese-Basic HSIS converted for application in the US. These conversions include translation to English and U.S. customary engineering units, and anthropometric changes to the consoles for American body types. Additional changes shall be made only through the US-APWR HFE design and V&V process defined in this HFE Program Plan.

4.4.2 US-APWR Human System Interface Inventory

As described above, the US-APWR HSI Inventory includes the portion of the plant that is common to all US-APWR sites and generic assumptions for the portion of the plant that is site specific (e.g., grid connections and ultimate heat sink).
The design team shall define and specify the US-APWR HSI inventory through an HFE analysis as defined in DCD Chapter 18 and this HFE Program Plan. The analysis shall include an assessment of each element described in NUREG-0711, Revision 2.

5.0 WORK FLOW

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

Figure 4 does not depict a once through process. Like most development processes the US-APWR HSIS development process is an iterative development process with feedback loops. Feedback comes from both HFE analysis and the HSIS V&V. The HSIS V&V is an integrated phased V & V testing process that culminates in a V&V of the final US-APWR HSIS. The V&V of the final US-APWR HSIS shall meet the requirements of NUREG-0711, Revision 2, as defined by the V&V program plan of DCD Chapter 18.10.

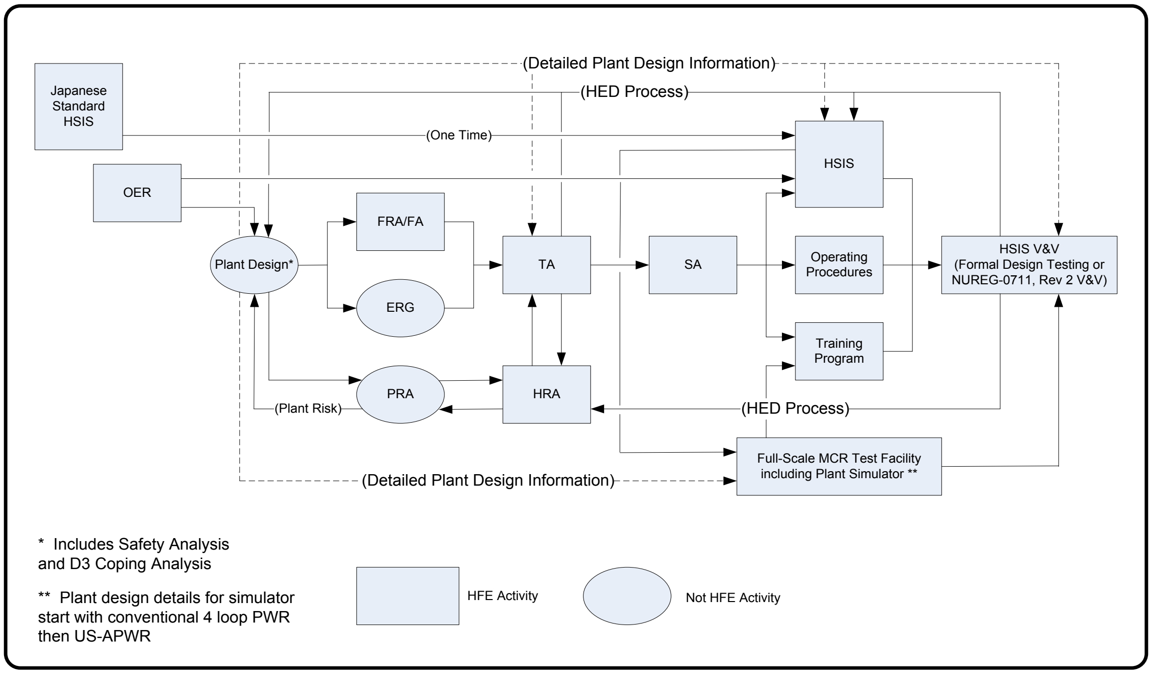


Figure 4 HFE Work Flow

(1) Integration of HFE and Plant Design Activities with Management tool & processes

During HFE activities, if there are any HFE issues identified that impact plant design engineering, HED shall be used to document the item/action and potential solutions. The HED shall be 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. The process of evaluating, tracking, resolving and closing HEDs is described in Section 6.

(2) HFE Program Milestones

Once each HFE program element is completed, the HFE team verifies that the activity meets its Implementation Plan and produces a results summary report. During the implementation of each program element, critical check points are verified to be in compliance with the plant design. Figure 5 shows the HFE milestones embedded in each Plant Phase (System Design, Analysis, Detailed Design and Procurement, Construction and Operation).

	Licensing			ITAAC			
Plant Phase	System Design Analysis		Analysis	Detail Design and Procurement		Construction	Operation
HFE	OER	FRA/FA	TA		V&V	Implementation	HPM
			HRA	Staffing & Qualifications			
				HSI Design			
Plant Design	Safety Analysis		Plant Design	Simulator			
Operating Procedures				Operating & Technical Procedure Development			
Training Programs				Operator & Technical Training Program Development			

Figure 5 HFE Program Milestones Embedded in the Plant Design, Procedure, Construction and Operation

Figure 6 shows engineering work processes and integration with plant design organizations. Arrows show critical checkpoints which indicate milestones for each activity and the relationship to other HFE elements.

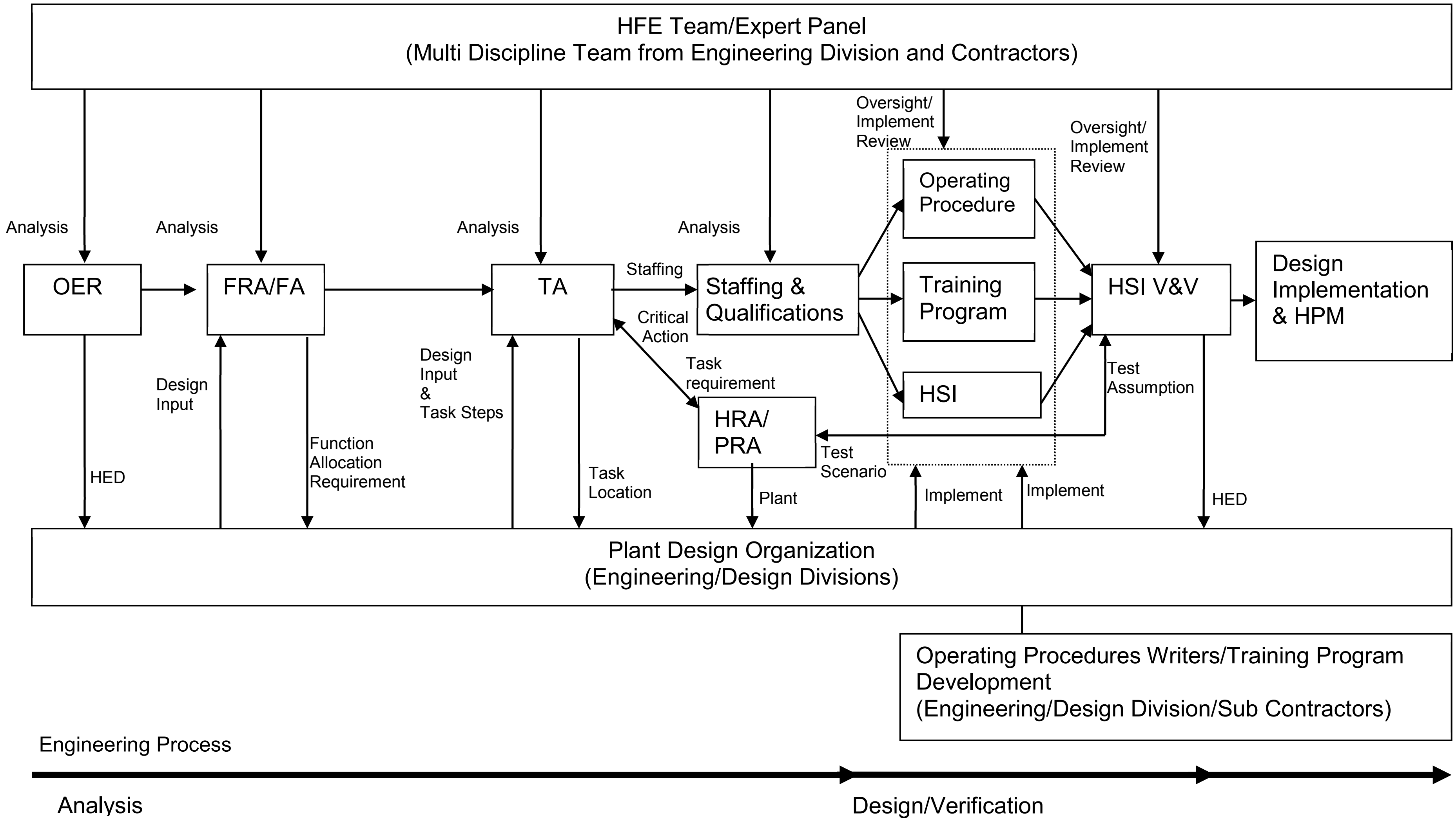


Figure 6 Engineering Work Process and Integrations Between HFE Team and Plant Design Organizations

(3) Subcontractor HFE Efforts - If a subcontractor is involved in HFE activities, the HFE team verifies the subcontractor complies with the US-APWR HFE Implementation Plans and MHI's internal work procedures. The MHI QA organization verifies subcontractors conduct their work in accordance with their QAP, as described in Section 3.4 above.

5.1 Role of the HFE Process in Nuclear Plant Design

The nuclear plant designers design the plant systems including the plant systems that control the critical safety functions (CSFs). The plant designers also define the plant components within those systems. HFE analysis shall check the plant design from the HFE perspective and identify and provide discrepancy information to modify the plant design. This checking shall include all stages of plant design from plant analysis to plant implementation to plant operation. If there are any HFE issues identified that impact plant design engineering, HED shall be used to document the item/action and potential solutions. The HED shall be used to track the issue until the resolutions have been incorporated in US-APWR designs or associated documents. Anyone on the HFE team or anyone who participates in HSI testing can initiate an HED for problems identified during the HFE activities. The process of evaluating, tracking, resolving and closing HEDs is described in Section 6.

5.2 Operating Experience Review

The US-APWR HFE analysis includes an 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 US and Japan. The OER analyzes non-nuclear industrial applications of digital technology which utilize a screen-based HSI. The OER identifies aspects of the US-Basic HSIS, as documented in Topical Report MUAP-07007, 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, a HED has been generated to document the problem and potential solutions. The process of evaluating, tracking, resolving and closing HEDs is described in Section 6.The US-APWR OER Results Summary Report is provided in Part 2 of MUAP-08014. The results summary report describes the OER methodology and results, and identifies HEDs, as described above.

HEDs generated by the OER are evaluated for potential function allocation changes that would impact the FRA/FA program element, and potential HSI design changes that would impact the HSI Design program element. Aspects of the HSI design that are credited to resolve prior human performance issues, as documented in the OER, are considered in the development of the testing conducted during the V&V program element.

5.3 Functional Requirement Analysis/Functional Allocation

The FRA shall determine the plant functions that must be maintained to satisfy the plant safety objectives. The FRA shall also identify the plant power production functions since 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 and abnormal plant conditions, for shutdown, low power and full power operation.

The FA shall allocate the identified success paths for plant safety and plant power production to human resources or to automated resources, or to shared resources. The FA shall consider various success path control characteristics, including time available, control complexity, decision complexity and operator workload. Workload shall be considered for the specific success path under evaluation, as well as the combined workload of maintaining multiple critical functions concurrently.

The FA forms a basis for the operator TA for all functions that are allocated to humans, and for human supervision of automation and human intervention for automation failure.

The US-APWR is an evolutionary design. Therefore, the system designs are based on historical function allocations with few changes. These allocations are reflected in the safety analysis and probabilistic risk assessment (PRA), as noted in Section 5.5.1, below. The FA results shall be compared to the US-APWR system designs. HEDs shall be generated for any discrepancies.

The US-APWR FRA/FA Results Summary Report is provided in Part 2, Section 1 in this document. This Result Summary Report describes the FRA/FA methodology and results, and identifies HEDs, as described above.

The FRA/FA shall be updated, if necessary, to reflect any changes in the final nuclear plant design that have occurred after the FRA/FA was completed.

5.4 Task Analysis

The functions assigned to plant personnel define their roles and responsibilities. Functions are accomplished through 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 which populate the HSI inventory including display screens, alarms, controls, data processing, operating procedures, and training programs that support the accomplishment of the tasks.

TA shall support defining a job and the management of crew members physical and cognitive work load, taking into consideration the number of crew members, crew member skills, and allocation of monitoring and control tasks.

Manual allocations for plant functions that are identified by FRA/FA and RIHAs identified in the HRA shall be available to HFE personnel to support performance of the TA.

The TA Results Report for RIHAs for the US-APWR is provided in Appendix 3.9 to Part 2, Section 3.0 of this report. Appendix 3.9 describes the TA methodology and results for the RIHAs. The main body of Part 2, Section 3.0 provides the TA Implementation Plan (TAIP) for the HAs that were not identified as risk important. This plan also includes confirmation of the TA for the RIHAs based on additional plant design details, as they become available. This IP defines the TA methodology and establishes the basis for the TA results summary report, which is required to close the TA related ITAAC for the US-APWR.

There were no HEDs generated as part of the TA for RIHAs. Therefore, none are identified in the results report.

5.5 Human Reliability Analysis

The HRA program element shall identify RIHAs from the PRA/HRA assumptions. Using operator role considerations, the HRA identifies significant controls and parameters needed to conduct these RIHAs. The HRA provides critical actions and error assumptions to TA. TA provides detailed task requirements to HRA. The PRA/HRA feeds into the HSIS design process. The HSIS design will be assessed for all identified RIHA through the integrated system validation of the V&V program.
The US-APWR HRA Results Summary Report is provided in Part 2 section 2 of this document. This result report describes the HRA methodology and results. There were no HEDs generated as part of the HRA. Therefore, none are identified in the result report.

5.5.1 Probablic Risk Assessment/Human Reliability Analysis

The PRA assumes certain safety actions are performed by the operator. The PRA includes a HRA that assesses and quantifies those operator actions. Within the HRA element of the HFE program, the HFE designers shall confirm the reliability analysis. As a minimum, this shall include validating the HSI design assumptions, input data, and the analysis related to the identification of the applicable types of human performance errors. Consequently, the HSI design shall give special attention to those plant scenarios, RIHAs, and HSIs that have been identified in the PRA/HRA as being important to plant safety and reliability.

5.5.2 Integration Role of HRA

The PRA/HRA defines the RIHAs using appropriate and accepted methods as described in Part 2, section 2 of this document. HFE personnel assess the RIHAs to ensure that they can be carried out within the time required and to evaluate the assumed PRA success probability. The HRA shall be conducted as an integrating activity to support the HFE process and PRA activity, and to risk inform the overall plant design. Although the TA is based on the FA/FRA, the HRA also provides RIHAs as an input to the TA.

5.6 Staffing 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 as described in Reference 11-1. The minimum and maximum MCR staffing levels are constraints for the US-APWR HSI design and plant design. The staffing constraints impact requirements for the HSI design 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 acceptability of the staffing constraints shall be continuously examined as the design proceeds.

In addition, the SA shall determine the number and background of other plant personnel for the full range of plant conditions and tasks in conjunction with the other HFE analyses.

The HFE program shall demonstrate, through V&V activities, that the minimum operator staffing is sufficient for safe plant operation. The staffing and qualifications analysis shall assess the operator staffing constraint described above. HEDs shall be generated were challenges are identified.

The US-APWR SA Implementation Plan is provided in Reference 11-5. This IP defines the SA methodology, and establishes the basis for the SA Results Summary Report, which is required to close the SA related ITAAC for the US-APWR.

5.7 Human System Interface design

The HSI Design program element generates the US-Basic HSIS design, and the plan for translation of the US-APWR HFE analysis outputs into the design of the US-APWR inventory of alarms, displays and controls, through the systematic application of HFE principles and criteria. A key output of the HSI Design program element is a complete US-APWR HSIS that will be implemented in a full scope simulator for subsequent V&V. The simulator will encompass the functions of the MCR, RSR and TSC. This program element will also generate complete HSI designs for safety significant local controls, and detailed communications and information requirements for the EOF, and communication interfaces between the MCR and CAS/SAS.

The process for generating the US-Basic HSIS, which includes Phase 1a and 1b testing, is described in Section 8. The results of Phase 1a and 1b testing are described in MUAP-08014, Part 1, and in Part 3 of this document. The resulting US-Basic HSIS is described in MUAP-07007.

The US-APWR HSI Design Implementation Plan, which will generate US-APWR HSI inventory and integrate that with the US-Basis HSIS to form the complete US-APWR HSIS, is provided in MUAP-10009. This IP defines the HSI design methodology and establishes the basis for the HSI Design Results Summary Report, which is required to close the HSI design related ITAAC for the US-APWR.

5.8 Procedure Development

The US-APWR Procedure Development process is designed to integrate plant operating procedures into the HSIS design by developing computer based procedures (CBPs) with corresponding backup paper based procedures (PBP), as well as stand-alone PBP for which there are no CBP. Normal operating procedures (NOPs), emergency operating procedures (EOPs), other procedures that govern safety-related activities, and maintenance, test, and surveillance activities associated with safety significant tasks are developed. TA output (e.g., HSI inventories, controllers and plant parameter indications) is used as an input to operating procedure development. There is no ITAAC for the procedure development program element, so there is no implementation plan and no results summary report.

5.9 Training Program Development

NEI 06-13A,"Template for an Industry Training Program" is utilized for training program structure and content. Initial and continuing training for Operations, Maintenance, Chemistry, Radiological Protection, and Engineering personnel encompasses all phases of plant operation including preoperational testing and low-power operation. OER review results are incorporated into all initial and continuing training programs.

There is no ITAAC for the procedure development program element, so there is no implementation plan and no results summary report.

5.10 Verification and Validation

V&V evaluations comprehensively determine that the US-APWR HSIS conforms to HFE design principles and that it enables plant personnel to successfully perform their tasks to achieve plant safety and other operational goals. Successful completion of integrated system validation is a critical design acceptance milestone for the US-APWR HSIS. The scope of the V&V activity encompasses the MCR, RSR, TSC, EOF (information requirements and communications), CAS/SAS (communications) and LCS as defined in Section 2.2. V&V of the EOF is outside the scope of the US-APWR V&V program; V&V will be conducted in accordance with the site specific HFE program to confirm compliance to NUREG-0696. V&V of the CAS/SAS is outside the scope of the HFE program.

The US-APWR V&V Implementation Plan is provided in Reference 11-7. This IP defines the V&V methodology and establishes the basis for the V&V Results Summary Report, which is required to close the V&V related ITAAC for the US-APWR.

5.11 Design Implementation

The Design Implementation program element will demonstrate that the design that is implemented (i.e., the “as-built” design) accurately reflects the design that has been verified and validated in the V&V program element. In addition, the design implementation program element will identify and evaluate aspects of the design that were not addressed in the V&V program. These may be site-specific aspects that were not included in V&V or design changes that occur after V&V.

While successful integrated system validation (ISV) marks the end of the V&V program element, the HSI design will continue to be challenged during Phase 3 of the HFE program, which includes operator training. Any HEDs generated during the V&V program that do not affect the ISV acceptance criteria or conclusions, and any HEDs generated after completion of the V&V program element, will be resolved during the Design Implementation program element.

The US-APWR Design Implementation Plan is provided in Reference 11-8. This IP defines the Design Implementation methodology and establishes the basis for the Design Implementation Results Summary Report, which is required to close the Design Implementation related ITAAC for the US-APWR.

5.12 Human Performance Monitoring

HPM will be applied and continue after the Design Implementation Plan (Reference 11-8) is completed. Human performance during the ISV of the V&V program element is a key factor in determining the acceptance of the US-APWR HSIS. 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 HSI design itself. The HPM program is a catalyst for corrective actions, but it does not direct the corrective actions program.

The US-APWR HPM Implementation Plan is provided in MUAP-10014 (Reference 11-9). This IP defines the basis of the HPM program which must be implemented to close the HPM related ITAAC for the US-APWR. Closure of the HPM ITAAC does not require creation of a results summary report.

5.13 Role of the US Nuclear Plant License Holders

US nuclear plant license holders operate the nuclear power plants (NPP) and develops procedures and training programs.

5.13.1 Integration into the Main Control Room Design and Testing Process

US nuclear plant licensed operators are the users of the US-APWR HSIS. In order to have direct specialist feedback licensed NPP operators shall be integrated into the design and testing of the US-APWR HSIS. This is a core concept of the US-APWR HSIS development program.

5.13.2 Protocols and Procedures

The COL holder is responsible for developing protocols and procedures for operating the NPP. The US-Basic HSIS shall inform the US NPP operation protocols and procedures. This does not mean that US NPP operation protocols and procedures shall be used literally for application to the US-Basic HSIS. It is anticipated that there will be some adjustment necessary to the current US NPP protocols and procedures so as to make them appropriate for application to the US-Basic HSIS. For example, adjustments are expected to accommodate navigational display links, embedded data and screen based place keeping, in computerized procedures. Special procedures are also expected for degraded HSI conditions. US NPP protocols and procedures shall be incorporated into the US-Basic HSIS V&V and the US-APWR HSIS V&V.

5.13.3 Supplementary Activities

US nuclear plant operators perform activities in the MCR, and other locations, related to the operation of the nuclear plant apart from direct monitoring and control of the NPP processes. An example of this type of activity is the generation of plant maintenance work orders and support of those maintenance activities. The nuclear plant license holder shall work closely with the US-APWR HFE team to ensure the US-APWR HSI design shall accommodate these supplementary activities in a manner consistent with US practices. The accommodation of these supplementary activities shall not interfere with the safe operation of the NPP.

6.0 HUMAN ENGINEERING DISCREPANCIES

HEDs are the means by which deficiencies in the HSIS are identified.

6.1 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.

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 as described in NUREG-0711, Revision 2.

The HFE team shall evaluate each HED and formulate aproposed discrepancy resolution. Some HEDs may be resolved by improved operating training and/or procedures. If the discrepancy requires an HSI design change, the HSIS Design Team shall generate the functional requirements for the HSI design change. The design change shall be developed and implemented by the HSIS Design Team. Some HEDs may require simple changes to the HSI Inventory. Others may require changes to the US-Basic HSI features. Depending on the complexity or significance of the needed change, HED resolutions may require only documentation of the change; others may also require development and implementation of a documented test plan.

Each HED shall be assessed by an “Expert Panel”, comprised of HFE experts, I&C experts, and nuclear operations experts, that is independent of the HSIS Design Team. Experts shall have at least 10 years of nuclear experience in their expert field of expertise and an education background that supports their expert credentials. The Expert Panel shall have available technical consultants from the US-APWR HFE team, including the HSI Implementation Team, as well as US-APWR plant process and systems experts.

For HEDs where a resolution has been developed by the HSIS Design Team, the Expert Panel shall assess that resolution. For HEDs that have no proposed resolution, the Expert Panel shall recommend a resolution. If the recommended resolution requires an HSI design change, the Expert Panel shall generate the functional requirements for the HSI design change to a level of detail that can be understood by the HSIS design team. The HSIS Design Team shall assess the resolutions proposed by the Expert Panel, and may propose alternative design solutions.

The HSIS Design team and Expert Panel can work independently or together to evaluate HEDs and define HED resolutions. Ultimately, the Expert Panel and the HSIS Design Team shall reach agreement on the HED resolution. After resolution agreement is reached, the HSI Design Team will implement the resolution. HED resolutions that impact US-APWR plant system designs will be implemented by the plant system designers.

The HED resolution shall also define the HED closure requirements. HED closure shall occur when the requirements of the HED closure requirements are considered satisfied by the HFE

Team and by an independent documented review by the Expert Panel. Closure for some HEDs may be based on updated documentation. Other HEDs may require testing. The HSIS Design Team and Expert Panel shall agree on the closure requirements. The HSIS Design Team and Expert Panel shall document their basis for considering the HED closed or for considering the HED closure requirements unsatisfied. The closure requirements establish the Acceptance Criteria for HED closure. It is important to note that some HED resolutions may require retesting. However, where completion of the testing is not specified as a closure requirement, HED closure can occur once the test plan is documented. Actual test execution is typically not a prerequisite for HED closure, because if the HED resolution proves to be inadequate, new HEDs will be generated during that testing.

6.2 Human Engineering Discrepancy Identification

There can be many sources of HEDs, for example:

- HEDs may be generated during any HFE program activity, such as the OER.
- HEDs may be generated directly by licensed NPP operators during the HSI verification and validation.
- HEDs may be 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.
- HEDs may be generated from observer surveys completed during the HSI validation test scenarios and at the end of the validation test week.
- HEDs may be generated from the observers' consensus survey completed at the end of the validation test week.
- HEDs may be generated by HFE and NPP process control experts from operator performance data.
- HEDs may be generated by miscellaneous visitors to the V&V facility (e.g., potential US-APWR customers, visiting HFE and NPP process experts, visiting representatives from the NRC, etc.).

6.3 Human Engineering Discrepancy Evaluation

Outstanding HEDs shall be evaluated periodically and prior to completing any of the HFE phases. At a minimum, HEDs shall be reviewed every six months for what has been closed, design decisions, and progress of design changes.

One consideration in evaluating an HED shall be the number of people who have identified a specific problem. This is referred to as the frequency count.

To support efficient examination, like HEDs may be grouped together. However, this is not necessary. If preferred, each HED may be evaluated individually. HEDs that address unique issues are expected to be 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 HFE and operations experts using engineering judgment. Grouping is not required if each HED is evaluated and closed individually.

6.3.1 NUREG-0711 Grouping

To assist HED evaluation, resolution, and explanation it may be constructive to associate HEDs with NRC grouping guidance. NUREG-0711, Revision 2 suggests potential grouping by:

- Scope

- HSI Component
- Plant System
- Personnel Tasks

However, as noted above, HEDs are grouped only to facilitate evaluation efficiency. Therefore, other groupings may be defined by the HSIS Design Team and/or the Expert Panel. Grouping is not required if each HED is evaluated and closed individually.

6.3.2 Human Factors Engineering Grouping

To assist HED evaluation, resolution, and explanation it may be constructive to group HEDs by HFE classifications. Typical HFE classifications are HFE basic generic categories used for classifying discrepancies. The HFE Basic Generic Categories are:

- Situation Awareness
    - Ability to maintain the 'big picture' with respect to current plant state and direction of process variables
    - Ability to anticipate / forecast what is going to happen next with respect to the plant's processes, automatic systems and abnormalities
    - Ability to maintain awareness of the critical plant safety functions (e.g., based on the information provided on the wall panel)
    - Ability to monitor trends and detect problems pre-alarm
- Control
    - Ability to take control actions in pace with plant process dynamics
- Following Procedures
    - Ability to access and follow required procedures
    - Ability to monitor effectiveness of the procedures (e.g., is it the right procedure for the event? Are there additional problems that are not being addressed)
- Error-tolerance
    - Ability to catch and correct errors
- Mental workload
    - How much mental and perceptual activity is required to respond to emergency events - e.g., thinking, deciding, calculating, remembering, looking, searching, etc
- Physical workload
    - How much physical activity is required to respond to emergency events -- e.g., pushing, pulling, turning, controlling, activating, etc.)
- Teamwork
    - Ability to maintain awareness of what other crew members are thinking and doing
    - Ability to communicate and coordinate actions
    - Ability to catch and correct misunderstandings or errors
    - Ability to maintain shared situation awareness of the state of the plant and procedures
- Supervising Automated Systems
    - Ability to maintain awareness of the status and actions of automated systems
    - Ability to take-over manual control when needed
- Shift staffing
    - Ability of Basic HSI System to support two-person operation

However, as noted above, HEDs are grouped only to facilitate evaluation efficiency. Therefore, other groupings may be defined by the HSIS Design Team and/or the Expert Panel. Grouping is not required if each HED is evaluated and closed individually.

6.4 Human Engineering Discrepancy Classification

There are two types of significance classification, Mitsubishi Significance and NRC Priority. At least one significance classification shall be applied to each HED or to a group of HEDs.

6.4.1 Mitsubishi Significance Category

HEDs may be placed into one or more of the following Mitsubishi Significance categories.

1. The HEDs represent a mean score of less that 3 out of 5, or a weighted score of 3 or lower by 20% of the operators on the V&V Questionnaire.
2. The HEDs have a significant frequency of independent repeat occurrences.
3. The HEDs reflect a violation of regulatory guidance.
4. The HEDs reflect a violation of standard human factors good practice as related to other industries or current NPPs.
5. The HEDs are likely to lead to human error with safety consequences.
6. The HEDs do not necessarily have safety consequences, but are likely to negatively impact efficiency of operations, and the ability to produce power cost effectively.
7. The HEDs do not necessarily have a safety consequence, but are likely to impact minimum staffing requirements.
8. The HEDs do not necessarily have a safety consequence, but are likely to have a Tech-Spec implication.
9. HED represents a potential human performance issue without significant consequences.

6.4.2 NRC Priority

The Mitsubishi set of significance measures results from the Expert Panel review and as such is used for discussions on design change requirements. These can then be converted into NRC measures as described in NUREG-0711, Revision 2 for significance ranking and disposition management. NRC priority risk categories are:

- Priority 1 - direct or indirect consequences to safety
- Priority 2 - consequences to plant or personnel performance
- Priority 3 – other

The Mitsubishi significance category 5 is equivalent to NRC priority 1. Therefore, designating an HED as Mitsubishi significant category 5 is equivalent to a ranking of NRC Priority 1.

6.5 Human Engineering Discrepancy Closure Requirement

All HEDs shall be processed to closure. Each HED shall include clear unambiguous closure requirements. Typical closure requirements are listed below. Other closure criteria may be added as necessary.

1. HED is expected to be resolved by a correction in the simulator or a modification to the simulator to reflect the US-Basic HSI design documented in the HSI Topical Report. HED can be closed when correction/modification is implemented in the simulator and testing is reflected in a V&V program activity (either Phase 1, 2 or 3 as appropriate).
2. HED is expected to be resolved by additional operator training. HED can be closed when training material is updated.
3. HED refers to an HSI design feature which correctly reflects the plant specific design. HED can be closed when the plant specific design is evaluated and resolved.

4. HED is expected to be resolved through a future plant specific HSI design element, or a change to a currently documented plant specific HSI design element. HED can be closed when the plant specific design is documented and reflected in a V&V program activity (either Phase 1, 2 or 3 as appropriate).
5. HED requires updating Basic HSI documentation. HED can be closed when documentation is updated and the subject of the HED is reflected in a V&V program activity (either Phase 1, 2 or 3 as appropriate).
6. HED is expected to be resolved through a Basic HSI design change. The design change must be developed, documented and implemented. HED can be closed when V&V of this design change is reflected in a V&V program activity (either Phase 1, 2 or 3 as appropriate).
7. HED is resolved through an operating procedure change. HED can be closed when the procedure change is documented and reflected in a V&V program activity (either Phase 1, 2 or 3 as appropriate).
8. HED requires no corrective action. The HED can be closed immediately. The HED record shall include 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 shall ensure 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.

6.6 Human Engineering Discrepancy Closure

Some HED closure requirements may require only updated documentation, others may require a documented plan for testing, others may 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, since 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 all testing is completed with no significant (i.e., no priority 1) HEDs generated.

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

7.0 HUMAN ENGINEERING DISCREPANCY DATABASE

There shall be a database to manage the HEDs. All HEDs shall be entered into the database.

7.1 Human Engineering Discrepancy Database Basic Requirements

In order to manage the HED investigation process, the HED database shall contain fields to track the HED status through the entire investigation process to closure.
The database shall have security measures. The database shall have a system administrator. Only predefined users shall have access to the database. Only the system administrator shall be able to delete an HED from the database. The system administrator shall not delete an HED from the database without agreement of the Expert Panel.

7.2 Human Engineering Discrepancy Database Description

The HEDs are managed and tracked using an issue tracking software application, or issue tracker. The issue tracker is a portal into the HED database. The issue tracker provides the user interface through which data is 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 meta-data that further describes or categorizes the HED issue. This meta-data is 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. The workflow steps and associated issue status are show in the table below. Much of the meta-data associated with each HED is 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 pre-defined data fields, a 'Comment' may be added to an issue by any user to add additional information to an issue.

Table 2 HED Workflow Steps

Workflow Step	Issue Status	Workflow Description
Create	Open	Reporter enters an HED
Evaluate	Evaluated	Expert Panel or HFE team completes its evaluation of the issue.
Resolve	Resolved	Expert Panel and HFE team agree on the resolution and closure requirement.
Close	Closed	Expert Panel and HFE team agree that the resolution and closure requirement has been implemented.

7.2.1 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 the Table 3 below.

Table 3 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 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 Originators company of employment.
Origination Date	The date the HED was originated.
Originators Background	The originators primary area of expertise or training as applicable to the V&V process.
Originators Role	The originators 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 to 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 related information to the HED.
Significance	The Significance is the Originator or Observers opinion of the significance of the HED.
Recommended Resolution	The Recommended Resolution is the Originator or Observers opinion of the resolution to this HED.

7.2.2 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 the Table 4 below.

Table 4 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.

7.2.3 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 the Table 5 below.

Table 5 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 needed to close the HED (e.g., design specification, test plan, training plan, procedures, etc.)
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)

7.2.4 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 below.

Table 6 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

8.0 US-APWR MAIN CONTROL ROOM DEVELOPMENT

The US-APWR HSIS encompasses the MCR the RSR and the TSC. Because the RSR and TSC are derivatives of the MCR, all three facilities are developed using the same HFE process. The HFE process for the US-APWR is tailored to address the unique aspects of the communications and information requirements of the EOF, CAS/SAS and local stations.

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 site specific HSIS (e.g., CPNPP Unit 3 & 4 HSIS).

Major development activities and products for each phase are shown in Figure 7 and 8 below. The phases are divided into two steps, a) and b). The activities associated with each step for each phase are different. The phases and steps are activities performed at overlapping times. The development schedule shows the overlap.

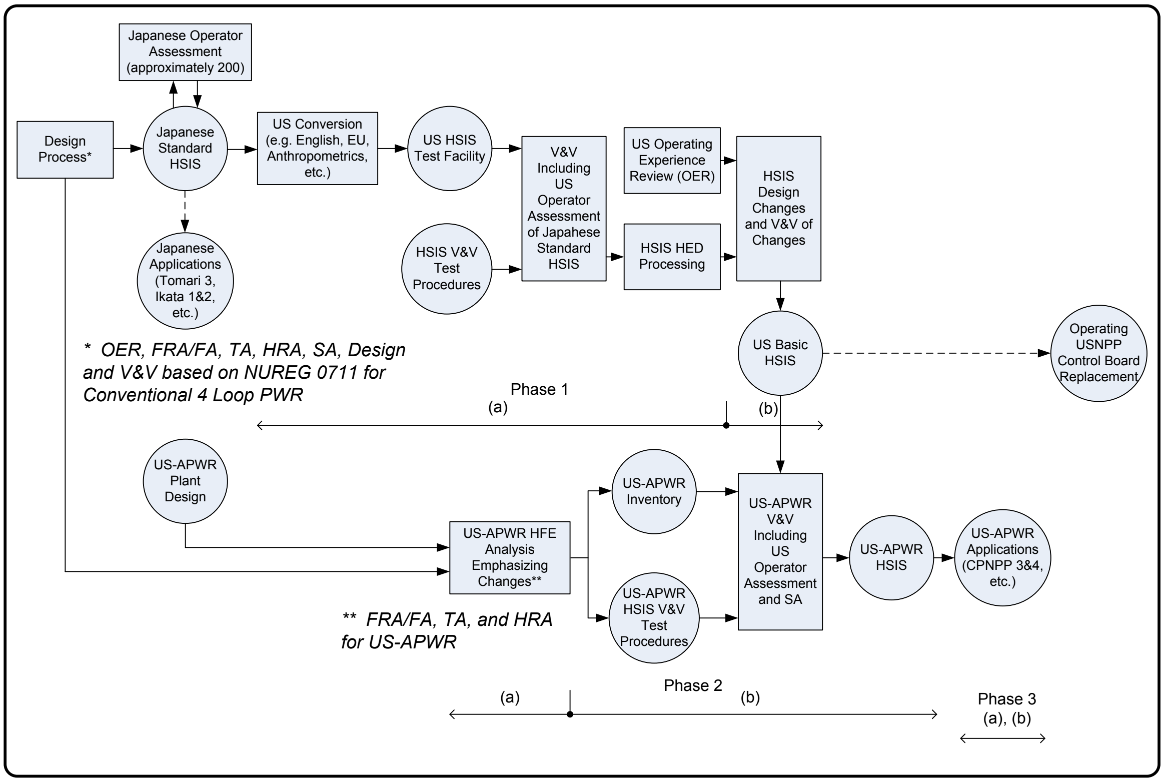


Figure 7 US-APWR Main Control Room Development High Level Logic

Phase 1 and Phase 2

ID	Task Name	Start	Finish
1	Phase 1a	4/1/2008	12/31/2008
2	Phase 1b	10/1/2008	6/30/2009
3	Phase 2a	10/1/2008	6/30/2009
4	Phase 2b	7/1/2009	Prior to Fuel Load

Figure 8 US-APWR Main Control Room Development High Level Schedule

The development phases can be correlated to the US-APWR licensing steps of the DCD (Phase 1a, 1b and 2a), the DCD ITAAC (Phase 2b), and the COLA ITAAC (Phase 3a and 3b). Note that while Phase 1 is correlated in time to the US-APWR DCD review process, this phase generates the US-Basic HSIS. Therefore, Phase 1 is applicable to the US-APWR and to operating nuclear power plant control board replacements.

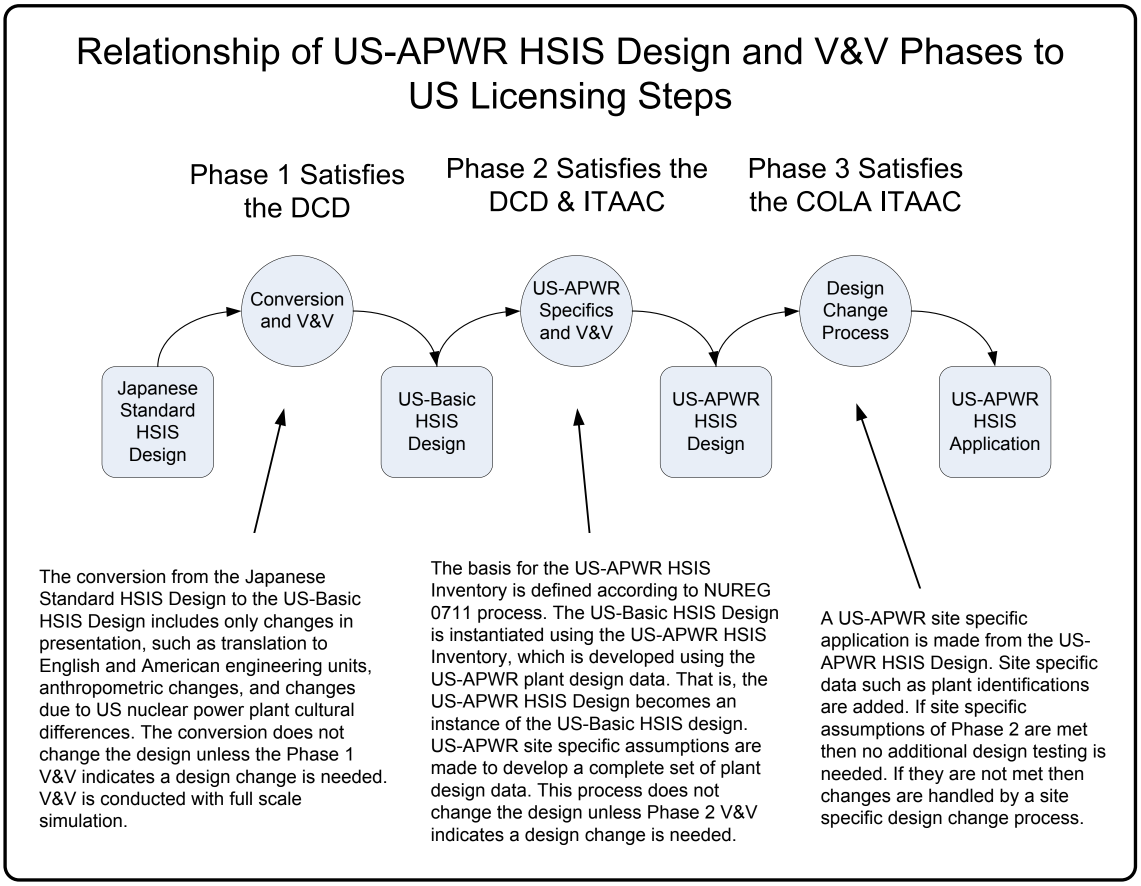


Figure 9 Design and Verification & Validation Phases and Licensing Correlation

8.1 Phase 1

The objective of the US-APWR HSIS development Phase1 is to define the US-Basic HSIS. The Phase 1 design and V&V activities shall be conducted by licensed nuclear plant operators, HFE experts, nuclear plant process operation experts, and I&C experts. Phase 1 is divided into two parts, Phase 1a and Phase 1b. The objective of Phase 1a is to assess the Japanese-Basic HSIS and identify any changes needed. The assessment is based on analysis of HEDs generated from various sources. The objective of Phase 1b is to design and V&V any changes to the Japanese-Basic HSIS needed from the Phase 1a HED analysis. The result of Phase 1b is the US-Basic HSIS.

It should be noted that the Phase 1 formal design testing is part of an integrated V&V program that will include follow on V&V activities. That is, Phase 1 formal design testing is not a V&V of a specific application whether that application is a US-APWR application or an operating plant application. The formal design testing performed for Phase 1 is not focused on HSI Inventory details, but rather it is focused on the suitability of the design concepts for application to US nuclear power plants. A typical 4 loop PWR HSI Inventory used in Phase 1 is a vehicle for evaluating the US-Basic HSI design. An application specific HSI Inventory must be developed for all MCR applications. As defined in US-APWR DCD Section 18.10, all MCR applications shall have an application specific V&V that meets the requirements specified in NUREG-0711, Revision 2.

8.1.1 Phase 1a

The first step of Phase 1a is the conversion of the Japanese-Basic HSIS to an HSIS that is useable by US nuclear power plant operators. This is referred to as the initial US-Basic HSIS. The displays are converted to English and to American engineering units. US step-by-step operating procedures are adopted in lieu of Japanese guidance style procedures. Changes are made to the Standard Japanese HSIS for US ergonomic and cultural differences. This conversion does not change the design. That is, the conversion does not change the HSIS functionality. For example, it does not change the layout of the large display panel (LDP) and the LDP data processing; it does not change the alarm prioritization, presentation, and management; it does not change the mimic display structure and display navigation; it does not change the soft control operation.

The Phase 1a V&V shall consist of both static verification analysis using a portable HSIS analysis tool and dynamic validation tests using a full-scale control room driven by a nuclear plant simulator computer. The Style Guide for the US-Basic HSI and changes to the Style Guide shall be verified against NUREG-0700.

Detailed US-APWR plant design data is neither available nor required for Phase 1 since Phase 1 is intended to develop the US-Basic HSIS. Therefore, in Phase 1 the HSI Inventory and the plant simulator model can use a conventional four-loop two-train PWR. The V&V activities shall be conducted with licensed nuclear plant operators and HFE experts. For validation at least eight operating crews of licensed nuclear power plant operators (six crews of one RO and one SRO and two crews of two ROs and one SRO) shall execute dynamic validation test scenarios that cover normal plant operation, anticipated operational occurrences (AOO), and postulated accidents (PA) under both normal HSI and degraded HSI conditions. At a minimum, observations shall be made by operations and HFE experts. Operators and observers shall have the opportunity to generate HEDs for any aspects of the HSI design they believe should be evaluated for improvement.

Phase 1a HEDs have been evaluated by an Expert Panel. The Expert Panel shall document their evaluation. The evaluation documentation shall include the HED significance defined in this Implementation Plan.

HSI design solutions for HEDs requiring HSI design assessments and possible changes shall be produced in Phase 1b.

8.1.1.1 Operating Experience Review

Phase 1a activities shall include updating the HSIS design OER which was originally conducted to generate the Japanese-Basic HSIS. The updated OER shall include US nuclear power plant operating experiences and recent technology related operational experiences from other industries. The OER shall justify the adequacy of the US-Basic HSIS or identify HEDs that must be resolved, either within the US-Basic HSIS or through future US-APWR plant design or US-APWR HSI Inventory design activities. For completeness, significant issues from the original Japanese OER that impact aspects of the Japanese-Basic HSIS that are carried into the US-Basic HSI shall be included in the OER report.

8.1.1.2 Phase 1a Procedures

There shall be a procedure for each V&V activity. Each V&V procedure shall contain configuration control information to define what HSI design version is under analysis and/or test. There shall be a procedure for:

- Phase 1a verification
- Phase 1a validation testing

8.1.1.3 Phase 1a Report

A report of the Phase 1a V&V activities and the updated OER shall be submitted to the NRC. The report shall summarize the results of Phase 1a. The Phase 1a completion date is 12/31/08.

8.1.2 Phase 1b

Phase 1b shall develop and test the HSIS changes required by Phase 1a. These changes shall be made on the test facility before the start of the Phase 1b testing program.

Phase 1b shall also include features of the basic HSIS that were not available for testing in Phase 1a. For example, as a minimum, Phase 1b shall include testing of the Diverse Actuation System Human Systems Interface Panel (DHP).

Modifications made to the interface as a result of the resolution of Phase 1a HEDs shall be evaluated through dynamic testing in Phase 1b.

Phase 1a HEDs not addressed and new HEDs from Phase 1b will be tested at a later time using the test facility. The test facility need only be modified to the extent necessary to design, verify, and validate the changes. For example, the change may be only partially implemented within the plant systems, but the implementation shall be sufficient to allow a thorough HFE evaluation.

The scope of the Phase 1b dynamic testing shall be based on the extent of changes from Phase 1a. Additional tests may be added to Phase 1b for other reasons, if this testing is determined to be necessary based on the evaluation of the Phase 1a results. Phase 1b validation shall be conducted using the same full-scale simulator as in Phase 1a with a sampling of test scenarios that cover normal plant operation, AOOs, and PAs under both normal HSI and degraded HSI conditions including common cause failures (CCFs). Phase 1b shall include a preliminary assessment of computer based procedures.

Operators, HFE experts, and operations experts shall have the opportunity to generate HEDs for any aspects of the HSI design that they believe should be further evaluated for improvement.

8.1.2.1 Phase 1b Procedures

There shall be a procedure for each V & V activity. Each V&V procedure shall contain configuration control information to define what HSI design version is under analysis and/or test.

8.1.2.2 Phase 1b Report

A report that summarizes the results of Phase 1b has been submitted to the NRC. An updated topical report, Reference 11-1, which reflects the updated US-Basic HSIS, shall also be submitted to the NRC. The updated US-Basic HSIS shall include the resolution of key HEDs identified in Phase 1b validation testing. The Phase 1b completion date is 06/30/09.

8.1.3 Incremental HSI Improvement Process

After the report submittal the Expert Panel shall evaluate the remaining HEDs from Phase 1b validation testing. The Expert Panel shall perform and document the HED evaluation. The evaluation documentation shall include the HED significances defined in this plan. HEDs shall be tracked to closure.

The Expert Panel shall also review the Phase 1a HEDs to either close the HED or decide that additional HSI design and testing is required.

Open HEDs shall be addressed in Phase 2, including additional V&V testing in Phase 2b. Any adjustments to the US-Basic HSI design during Phase 2 shall be handled by regression analysis and testing of the design change.

8.1.4 US-Basic Human System Interface Design Documents

Reference 11-1 Section 4 “Design Description” defines:

- US-Basic HSI design basis
- US-Basic HSI functional specification that includes specifications for data processing

The following design documents complete the US-Basic HSI design specification:

- The US-Basic HSI Style Guide defining the HSI features and operation in sufficient detail to assure consistency throughout the entire HSI.
- The US-Basic HSI Nomenclature defining the standard acronyms and abbreviations and equipment description guidelines used in the HSI design.
- The US-Basic Component Control Design Guide that reflects generic control logic and information processing logic to support the US-Basic HSI. This document is required because the operation of the controlled component must be reflected in the HSI operator control face plate operation including associated indications and alarms.

The US-Basic HSIS description provided in Reference 11-1 provides the design basis for the details documented in the three documents above. All US-Basic HSI design documents shall be updated as required by Phase 1 V&V activities.

8.1.5 Generic Approval

Mitsubishi has requested generic approval by the NRC of the US-Basic HSIS design as defined by Reference 11-1. Reference 11-1 is referenced by the US-APWR DCD and will be referenced by any License Amendment Requests (LARs) from operating plants. It is expected that when the US-Basic HSIS is approved, future licensing submittals will only need to address the plant/site specific HSI Inventory, the HFE process that generates that HSI Inventory and the V&V of the fully integrated plant specific HSIS.

8.1.5.1 US Operating Environment

The goal of Phase 1 is to develop the US-Basic HSIS based on the Japanese-Basic HSIS. A significant portion of Phase 1 is devoted to testing the converted Japanese-Basic HSIS design in a simulated US operating environment. The most significant part of the simulated US environment is the use of licensed US NPP operators. They are used primarily for validation testing.

8.1.5.2 Application to an Operating NPP

For application to an operating US NPP, applicable point will be selected from the US-APWR design and test regime to proceed to an application specific V&V for that plant. The branch point selected will depend on the commonality between that application and the US-APWR application. For example, will the entire control room be replaced at one time or will the replacement be phased. The justification for the selected branch point and the HFE Program Plan for the plant specific HSI Inventory development and HSIS V&V for the operating plant shall be presented in the LAR for the plant. The V&V of the final operating plant HSIS shall meet the requirements specified in NUREG-0711, Revision 2, as documented in DCD Section 18.10.

8.2 Phase 2

The objective of Phase 2 is to analyze, design and V&V the HSI inventory and HSIS of the US-APWR. Phase 2 is divided into two parts, Phase 2a and Phase 2b.

8.2.1 Phase 2a

The objective of Phase 2a is to generate the HFE analysis results necessary to produce the HSI Inventory.

Phase 2a satisfies the commitments of the US-APWR DCD, which includes performing the analysis according to NUREG-0711, Revision 2, as defined in DCD Sections 18.3, 18.4, and 18.6. These activities include the US-APWR HSIS FRA/FA, TA for RIHA, and the human reliability analysis (HRA).

8.2.1.1 Phase 2a Implementation Plans

There shall be a documented methodology for each major HFE program activity. The methodology document describes the process to execute the program element. There shall be documented methodology for:

- Phase 2a FRA/FA
- Phase 2a HRA
- Phase 2a TA for RIHAs

The methodology may be integrated with the result summary report described below by describing the program element process within the results summary report.

8.2.1.2 Phase 2a Result Summary Reports

Part 2 of this document provides the results summary reports for the following program elements:

- FRA/FA results summary report in Part 2, Section 1 of this document. This section includes the FRA/FA methodology which precludes the need for a separate FRA/FA implementation plan.
- TA results report for RIHAs in Part 2, Section 3 of this document. This section includes the TA methodology for RIHAs, which precludes the need for a separate TA

implementation plan for RIHAs.HRA results summary report in Part 2, Section 2 of this document. This section includes the HRA methodology which precludes the need for a separate HRA implementation plan.

8.2.2 Phase 2b

The objective of Phase 2b is to determine the generic US-APWR HSI Inventory, combine that inventory with the US-Basic HSIS to form the US-APWR HSIS, and perform V&V of the US-APWR HSIS.

8.2.2.1 US-APWR Human System Interface Inventory

The Phase 2a HFE analysis results and the Phase 2b analysis results, which are both based on the US-APWR plant design data, shall be used to generate the US-APWR HSI Inventory for the alarms, displays, procedures, and controls. The US-APWR HSI Inventory development is iterative with the HFE products being refined as more detailed plant design data becomes available. Site specific assumptions shall be included in the US-APWR HSI Inventory to complete the total plant design data set. As Phase 2a and 2b HFE products are generated, they shall be checked against each other for consistency.

8.2.2.2 Development of Operating Procedures

Operating procedures are a key component of the US-APWR HSI Inventory. CBP, with backup PBP, shall be developed for all operating conditions. Unique paper procedures shall also be developed for degraded HSI conditions.

The US-APWR Emergency Response Guidelines (ERGs), which establish the basis of the US-APWR EOPs, are being developed by MHI in two phases.
These phases should not be confused with the HSI development phases; they are different. ERG/EOP Phase 1 will develop a draft ERG that reflects the US-APWR design, and will include US industry input. MHI will add detailed design specific bases and add equipment details such as MHI component IDs to complete the ERGs during Phase 2. During ERG/EOP Phase 2 MHI will also develop US-APWR EOPs for use by US-APWR COL applicants when creating plant specific EOPs.

A similar process will be used to develop other US-APWR operating procedures which will be used by the US-APWR COL applicants when creating plant specific operating procedures. The process of V & V of EOPs and operating procedures shall be conducted as follows:

1. Plant designers provide operating procedure guidelines.
2. Operation procedure writers (who have to have conventional PWR operation experience and knowledge of the differences between US-APWR and conventional PWR) complete operation procedures with above operating procedure guidelines and US-APWR design information
3. Plant designers, including plant safety analysis engineers, verify those procedures from a US-APWR design point of view and plant safety
4. Paper procedures are converted to CBPs by the HSIS Design Team.
5. The Phase 2b HSI V&V will be conducted by the HSIS V&V Team using US-APWR CBPs and PBPs. Static task support verification will confirm the procedures and displays have the necessary information and controls. Dynamic validation confirms the procedures and displays using the full scale plant simulator test facility. Through these V&V activities, procedure

problems will be extracted as HEDs and will be tracked to closure using the HED database.

6. In Phase 3, plant specific procedures are developed, verified and validated, and then used for operator training (see Section 8.3).

8.2.2.3 US-APWR HSIS

The US-APWR Inventory is combined with the US-Basic HSIS to produce the US-APWR HSIS. The Phase 2b V&V shall consist of both static verification analysis and dynamic validation tests.

Phase 2b static verification shall be completed prior to dynamic validation testing. Phase 2b static verification shall verify:

- the display details against the Style Guide which was previously verified against NUREG-0700
- the operating procedures technical content and execution order by the plant design and safety engineers
- the operating procedures details against the Writer's Guide
- the operating procedures against the TA
- the displays contents information and controls necessary to execute the procedures

A test facility consisting of a full-scale US-APWR MCR and US-APWR plant and I&C simulator models shall be developed to support the US-APWR HSIS dynamic validation testing. Failure modes of the plant components and I&C equipment shall be included in the simulator models. The simulator shall be adaptable to encompass V&V for the RSC and the information displays used at the TSC. It is noted that the HSIS Design Team defines the information display requirements and communication requirements for the EOF and the communication interface requirements for the CAS/SAS, in accordance with the US-APWR HFE Implementation Plans. But the design and V&V of the EOF and CAS/SAS are outside the scope of the US-APWR HFE Implementation Plans.

The Phase 2b V&V activities shall be conducted by licensed nuclear plant operators, HFE experts, and operations experts. The Phase 2b V&V of the final US-APWR HSIS shall meet the requirements specified in NUREG-0711, Revision 2, as defined in DCD Section 18.10. There shall be a sampling of dynamic validation test scenarios that cover normal plant operation, AOOs, and PAs under both normal HSI and degraded HSI conditions. There shall be validation tests for detection of failed plant components and I&C equipment and taking corrective action. Phase 2b shall include validation of time critical manual actions credited in the US-APWR DCD Chapter 15 safety analysis and the US-APWR Defense-in-Depth and Diversity (D3) Coping Analysis, MUAP-07014. Phase 2b shall include complete validation of the use of CBPs and the transition between CBPs and PBPs. The verification analysis shall be most rigorous for HSI that supports tasks shown by the HRA to be risk significant. This shall include operating procedures and training material. In addition, the validation scenarios shall encompass all HAs shown by the HRA to be risk significant. The validation shall encompass issues identified by the OER where the HSI is credited to prevent human performance errors.

At a minimum, observations shall be made by operations and HFE experts. Operators and observers shall have the opportunity to generate HEDs for any aspects of the HSI design that they believe should be further evaluated for improvement.

As for all HEDs, Phase 2b HEDs shall be evaluated by the HSIS Design Team and the Expert Panel, as described in Section 6. The evaluation, resolution and HED closure requirements shall be documented in the HED database. The evaluation documentation shall include the HED significances defined in this plan. The Expert Panel shall approve the HED closure requirements and shall approve closure of the HED when they are satisfied the closure requirements have been met.

HEDs shall be tracked to closure. HEDs that cannot be completely closed in Phase 2b shall be closed in Phase 3.

8.2.2.4 Phase 2b Implementation Plans

There shall be an Implementation Plan for each Phase 2b HFE program element, as defined in DCD Chapter 18. There shall be an Implementation Plan for:

- TA for actions not identified as risk important), Part 2, Section 3 in this document
- HSI Design Implementation Plan, MUAP-10009
- Staffing and Qualification Analysis Implementation Plan, MUAP-10008
- V & V Implementation, MUAP-10012

These implementation plans shall be submitted to the NRC as part of the US-APWR DCD process.
Phase 2b Results Summary Reports

8.2.2.5 Phase 2b shall satisfy the requirements of the US-APWR DCD ITAAC.

Results summary reports shall be generated which document the results of each Phase 2b program element (with the exceptions of program and training development), including a summary of the HEDs and their resolution. The V&V RSR shall contain configuration control information to define what HSI design version has been analyzed and tested. The results summary reports for each of these activities shall be made available for NRC inspection as part of US-APWR ITAAC closure.

HEDs from ISV that affect conformance of the US-APWR HSIS to the ISV acceptance criteria shall be resolved prior to completion of the Phase 2b V&V program element. Other HEDs may be resolved during Phase 3.

8.2.3 US-APWR Documents

In addition to the update to the US-APWR DCD and the design documents listed for Phase 1, the following documents shall be generated during Phase 2b:

- The US-APWR operating procedures sufficient for validation testing shall be generated and used during the Phase 2b validation testing. Other generic US-APWR operating procedures are also expected to be developed during Phase 2b, but these additional procedures are not required to support Phase 2b validation testing. These additional procedures will be validated separately.
- US-APWR training material sufficient to train the operators for validation testing shall be generated and used during the Phase 2b validation testing. Other generic US-APWR training material is also expected to be developed during Phase 2b, but this additional training material is not required to support Phase 2b validation testing.

8.2.4 Phase 2 Simulator

The simulator used for Integrated System Validation shall have been demonstrated consistent with the validation testbed criteria specified in NUREG 0711, Rev. 2, section 11-4.3.2.2, Validation Testbeds, using ANSI/ANS 3.5-1998 as a guide. However, the simulator does not require features needed for operator training, such as freeze, fast forward rewind and snap shots, unless these features are specifically identified in the ISV test procedure.

8.3 Phase 3

The objective of Phase 3 is to design, verify, and validate the HSIS for a US-APWR site specific application (e.g., CPNPP 3&4) and to train the operators for that site. Phase 3 satisfies the commitments of the COLA ITAAC. Phase 3 is divided into two parts, Phase 3a and Phase 3b. Phase 3 will also resolve HEDs from Phase 2 that do not impact conformance of the US-APWR HSIS to the V&V acceptance criteria.

8.3.1 Phase 3a

The objective of Phase 3a shall be to design, V&V the site specific HSIS. If the site specific assumptions of the US-APWR HSIS, for which a V&V is performed in Phase 2b, are applicable to the actual site specific application, then no additional design or V&V is needed. If the site specific assumptions of the US-APWR HSIS are not applicable to the actual site specific application, then a design change process shall be conducted. The scope of rework for the FRA/FA, HRA, TA, SA, HSI design and V&V, training and operating procedures shall be based on the extent of changes for the site specific application. For most US-APWR applications, very few site specific changes are expected.

If additional HSI validation testing is required in Phase 3a, that testing is conducted using a site specific simulator meeting the requirements of 8.2.4 above.

As for Phase 2b, the scope of required training material is limited to that needed for Phase 3a validation testing. However, all site specific training material is expected to be developed during Phase 3a.

Phase 3b, Site Specific Operator Training, conducted by the site training organization, will begin upon completion of Phase 3a.

The scope of the Phase 3a site-specific activities includes all facilities addressed in Phase 2, including the information and communication requirements for the EOF and communication interfaces with the CAS/SAS. The site specific design and V&V of the EOF is outside the scope of the US-APWR HFE Implementation Plans.

8.3.2 Phase 3b

The objective of Phase 3b is operator training, using the site specific plant referenced simulator. Since Phase 3b includes additional operating crews and additional plant scenarios, which may not have been conducted during Phase 1 or 2, it is anticipated that additional HEDs may be identified by operators participating in the training program. HEDs shall be evaluated as part of the Phase 3b training program. HEDs shall be tracked to closure using the same process as described in Section 6. Any required HSI design changes after Phase 3a shall be managed in accordance with the design change process defined in US-APWR Design

Implementation Plan, MUAP-10013. All outstanding HEDs from all phases shall be closed in Phase 3b.

8.3.3 Phase 3 Implementation Plans

Any rework conducted during Phase 3a for the FRA/FA, HRA, TA, Staffing and Qualifications Analysis, HSI design and V&V, training or operating procedures shall be conducted in accordance with the Implementation Plans used for the corresponding activities in Phase 2. In addition, there shall implementation plans for the following Phase 3 program elements.

- Design Implementation Plan, MUAP-10013
- HPM Implementation Plan, MUAP-10014

9.0 US-APWR LOCAL CONTROLS

Other departments and groups provide plant design outputs with HSI, such as local controls on motor control centers and skid mounted equipment.

9.1 Inclusion in Human Factors Engineering Program

Design outputs that have HSI safety significance shall be included in the US-APWR HFE Program. In order to assure HSI across the nuclear plant systems and components conform to industry accepted HFE practices and do not represent conflicts with the US-APWR HSI System or with one another, the HFE team shall interact with the rest of the plant design teams to review and control design products that contain information related to safety significant HSI. This HFE review and control of the HSI shall apply to both internal and external suppliers of unique systems or systems with local controls. For example, HFE review and control shall apply to local skid mounted HSI and local controls that may be supplied as part of a pump or valve, if those components are safety related and the local HSI will be used to support safety significant testing or maintenance activities, as follows:

- On-line testing, radiological protection activities, and required chemical monitoring supporting technical specifications
- Maintenance required by technical specifications
- Emergency and abnormal conditions response

9.2 Human Factors Engineering Guidance and Review

For HFE control the HSIS V&V Team shall review the HSI designs from other departments to assure conformance to the guidance in NUREG-0700 and to ensure there are no conflicts with US-APWR HSIS. The review shall ensure local controls conform to industry accepted HFE practice. The review shall also ensure that local controls do not have inconsistencies that are likely to lead to human performance error. However, since local equipments will be procured from numerous suppliers, the review shall not try to define HSI standards to the same level as would be expected within an HSI design style guide.

9.3 Quality Assurance Supervision

This process of interaction between the HSIS Design/V&V Teams and other plant design organizations shall be included in the QA procedures governing plant design activities that involve the specification of safety significant human system interfaces. HFE comments that cannot be resolved through mutual agreement between the HFE organization and the plant design organization shall be brought to management attention for resolution.

10.0 US-APWR AS-BUILT HSIS

Any aspects of the US-APWR plant design that would affect the final HSIS V&V program results, but that could not be V&V'ed as part of the V&V using test facilities (e.g., lighting and noise), shall be evaluated for consistency with the assumptions of the V&V program. Any HSIS design modifications that may occur after completion of the Phase 3a V&V program shall be managed in accordance with the design change process described in US-APWR Design Implementation Plan, MUAP-10013 (Reference 11-8). As described, this process includes a reassessment of some or all of the previous HFE program elements, depending on the risk significance of the change.

11.0 REFERENCES

11-1 HSI System Description and HFE Process, MUAP-07007, Revision 5, November 2011.

11-2 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP-DC018, Revision 3, March 2011.

11-3 U.S. Nuclear Regulatory Commission, Human Factor Engineering Program Review Model, NUREG-0711, Revision 2.

11-4 Task analysis, Part 2, Section 3 in this document.

11-5 Staffing and qualification analysis Implementation Plan, MUAP-10008, Revision 2, October 2012.

11-6 HSI design Implementation Plan, MUAP-10009, Revision 2, October 2012.

11-7 Verification and validation Implementation Plan, MUAP-10012, Revision 2, October 2012.

11-8 Design Implementation Plan, MUAP-10013, Revision 2, October 2012.

11-9 Human performance monitoring Implementation Plan, MUAP-10014, Revision 2, October 2012.

Part 2 HFE Analysis (Phase 2a)

1.0 FUNCTIONAL REQUIREMENTS ANALYSIS AND FUNCTION ALLOCATION

1.1 Purpose

The goal of the US-APWR HFE FRA/FA is to identify the plants Critical Functions that must be maintained to meet plant safety and power production goals, and to ensure that the Success Paths that are used to control those Critical Functions are assigned properly as either HAs or to automated systems.

The purpose of this document is to provide both the process for performance of the FRA/FA and also the results summary report documenting the HFE FRA/FA results for the US-APWR that reflects Human Factors principles using the structured and documented methodology contained herein.

The FRA identifies high level plant goals, critical functions, and Success Paths to ensure that the goals are maintained or, if challenged, consequences are mitigated.

The FA allocates control of actions, identified in the FRA, which are categorized as either Machine (automatic), Human (manual) or Shared based on HFE principles.

1.2 Scope and General Description

(1) This process and the associated results summary report are developed to comply with NUREG- 0711.

(2) This FRA/FA process is developed by a Subject Matter Expert (SME) team having experience and knowledge in HFE, integrated nuclear plant operations, and engineering controls. The experience and qualifications of the SMEs are documented in Appendix 1.8.5 of this procedure.

(3) The FRA/FA relies on the joint knowledge and experience of SMEs and reviewers. To control the bias of past experiences in conventional MCRs and staffing levels that may be introduced into the FRA/FA, the SMEs are specifically instructed to not consider current operating reactor practices (allocations) in their final US-APWR allocations. These final allocations get reviewed by the designers and any differences are identified as HEDs. The FRA/FA is revisited as the design matures.

(4) The TA takes the FA results and explicitly assesses at the task level both the US-APWR's MCR digital HSI design and the minimum staffing level constraint via input of operating procedures and specific consideration of the impact of only one RO. Whenever the TA concludes that the design or staffing levels are not sufficient to support the manual tasks and therefore may be impacted, an HED is initiated.

(5) The HSI Design includes a comprehensive design testing program for the MCR that uses human-in-the-loop tests based on the US-APWR MCR design and the one RO crew. Tests results are reported in Part 3 of MUAP-09019 and also in reference 1.7.1.5. One output of the testing program is the identification of HEDs.

- Staffing and Qualification analyzes the design constraint of one RO interfacing with the US-APWR HSI as one of its inputs.
- As the TA, Design, and Staffing and Qualification progress, they feed back all functional requirement and allocation issues found, including the impacts of the HSI design and the staffing constraint, into the FRA and FA for reassessment.
- As a final evaluation, the V & V Program will test the final HSI design in the Integrated System Validation program with the minimum staffing constraint.
- As described in Part 1 of MUAP-09019, all elements of the HFE program feed into the HED program and undergo detailed evaluations to identify resolutions. These documented evaluations include the impacts of the digital highly-integrated MCR, and the one RO staffing constraint.

(6) The FRA/FA is first performed by three SMEs having integrated nuclear plant operational experience on conventional 4-loop Westinghouse PWRs. The FRA/FA then undergoes subsequent review by other SMEs possessing HFE and control engineering experience. The FRA/FA review organization consists of team members from Mitsubishi Heavy Industries (MHI) and Mitsubishi Nuclear Energy Systems (MNES), consultants to MHI/MNES, subcontractors to MHI/MNES, and operations experts from US-APWR COLA applicants.

(7) FRA is performed by identifying plant goals and Critical Functions then identifying Success Paths in the US-APWR plant design to maintain the Critical Function or mitigate the loss of the Critical Function under various plant Modes and operating Conditions. (IEC 60964 Reference 1.7.1.4)

(8) For Power Production Critical Functions the FRA/FA evaluates the preferred Success Path(s) used to maintain or control each Critical Function. For safety Critical Functions, the FRA/FA evaluates the preferred normal Success Path and the preferred emergency Success Path used to maintain or control each Critical Function. The FRA/FA does not identify contingency Success Paths that may be deployed in the event of failure of the preferred Success Path(s). These are considered backup actions, which are analyzed as manual actions during the TA. Preferred Success Paths may be adversely affected by failures in components that are an integral part of the Success Path (e.g. Key Components, as identified in Table 1.8-1) or by failures in auxiliary systems such as electrical power sources, component cooling water or heating, ventilation, and air conditioning (HVAC). Contingency actions for auxiliary system failures are also analyzed during the TA.

(9) The following events and HAs are reviewed, against the plant goals to ensure that applicable Success Paths exist:

- DCD Chapter 15, Table 15.0-1 PA and AOO
- DCD Credited HAs contained in DCD Table 7.5-5 *List of Accidents and Credited Manual Actions*.

(10) FA is performed by considering the aggregate of the following characteristics which are described in detail later in this procedure (IEC 60964 Reference 1.7.1.4):

- Load

- Time Margin
- Rate
- Complexity of Action Logic
- Decision Types and Complexity

(11) Significant HFE considerations based on the differences between the US-APWR and its predecessor US 4-loop PWRs includes:
- The application of a digital highly integrated MCR with soft controls, a large overview display and a CBP and
- The staffing constraint of one RO present in the MCR at all times.

These differences are evaluated throughout the HFE program, and integrated into the HSI design process, by assuring that elements of the HFE program specifically address the impacts of these differences. The elements of the HFE program are integrated together as discussed in Part 1 of MUAP 09019, Human Factors Engineering Overall Implementation Plan, and illustrated in figure 4 of that Plan.

(12) The FRA/FA is strictly an HFE evaluation. It does not consider other factors that may affect the ultimate allocation, such as technical feasibility, regulatory design compliance issues (e.g. separation and independence) or cost of automation. Where the FRA/FA identifies allocations that are different than that of the US-APWR system designs, HED are documented. HEDs are resolved and tracked to closure using a multi-disciplined team with oversight and final approval by the HFE Expert Panel described in MUAP-09019 Part 1 Section 3.0. HED resolution is an ongoing process that is outside the scope of the FRA/FA HFE program element. The final Success Path allocations, which reflect the HFE allocation results as documented in this FRA/FA report, and subsequent HED resolutions where necessary, are reflected in the plant system design and the TA HFE program element.

(13) The US-APWR is an evolutionary plant, similar to operating 4-loop PWRs in both the US and Japan. The plant system designs, as documented in many system design chapters of the US-APWR DCD, reflect historical Critical Functions and Success Paths. The US-APWR has the same high level Critical Functions and Success Paths as previous designs.

The only allocation changes identified in the plant system designs from the conventional PWR plant's functions are:
- Addition of automatic isolation of Emergency Feedwater for a faulted steam generator.
- Elimination of manual or automatic Emergency Core Cooling System (ECCS) sump switching. Refueling Water Storage Pit (RWSP) is located inside containment and replaces the containment sump.

The following are changes to the plant system designs, but these changes do not change the high level functions:
- Four train safety system configuration
- No safety related Low Head Injection Pumps (function is replaced by the advanced accumulators)
- Safety related Gas Turbine Generators (replace diesel generators)

(14) FRA/FA is performed considering human performance related operating experience. The performance of FRA/FA does not consider other system design constraints such as component performance limitations, separation and independence requirements, and economic constraints. Where HEDs are generated, these other factors are considered during the HED resolution process.

1.3 Definitions

Complexity of Action Logic – Complexity of Action Logic identifies potential error likely situations. Where multiple parameters and complex analysis is required to complete actions, human performance may not be consistent due to mental capabilities.

Component – An individual piece of equipment having a unique function such as a pump, valve, or vessel.

Critical Function – A process or group of processes that must be maintained to achieve the ultimate purpose of the plant which is generating electricity (Power Production goal) and prevent uncontrolled release of radiation (Safety goal). The term “High Level Function” from NUREG 0711 is interchangeable with “Critical Function” used in IEC 60694 and the US-APWR FRA/FA.

Decision Types and Complexity – The Decision Types and Complexity function separates those decisions that cannot be performed by machines from those that can. Where parameters monitored or criteria for evaluation are not well defined, requiring human judgment, the Decision Type is considered ill-structured.

Function – A process or activity that is required to achieve a desired goal. For the purpose of this analysis, functions are divided into two categories, Critical Functions which are composed of Sub-functions.

Load – Load analysis identifies mental and physical capacity for humans supervising and/or manually controlling Success Paths to maintain a specific critical function while concurrently supervising or controlling other Success Paths to concurrently maintain all other Critical Functions. Load is evaluated for each Critical Function during three defined plant modes.

Plant Goal – Goals are at the top of the hierarchy for FRA. These goals are taken from IEC 60694 (Reference 1.7.1.4).

Rate – Rate is a relationship between the Load and Time Margin; it relates the time needed to complete the Success Path to the number of actions that must be taken for control of a specific Success Path and the concurrent control/supervision of all Critical Functions in temporal proximity. Due to physical limitations, humans can perform a limited number of functions over a given time period.

Sub-function – Highest level of functional decomposition below Critical Functions that either maintains or mitigates the loss of the Critical Function under the Mode and Condition specified. Sub-function is subsequently the highest level in the definition of the Success Path, which is used to control or maintain the Critical Function.

Success Path – The aggregate of Sub-Functions, Plant Systems, Key Components, and the Actions to be performed to maintain or restore a Critical Function.

System – An integrated collection of plant equipment or components and control elements that operate alone or with other plant systems to perform a Sub-function.

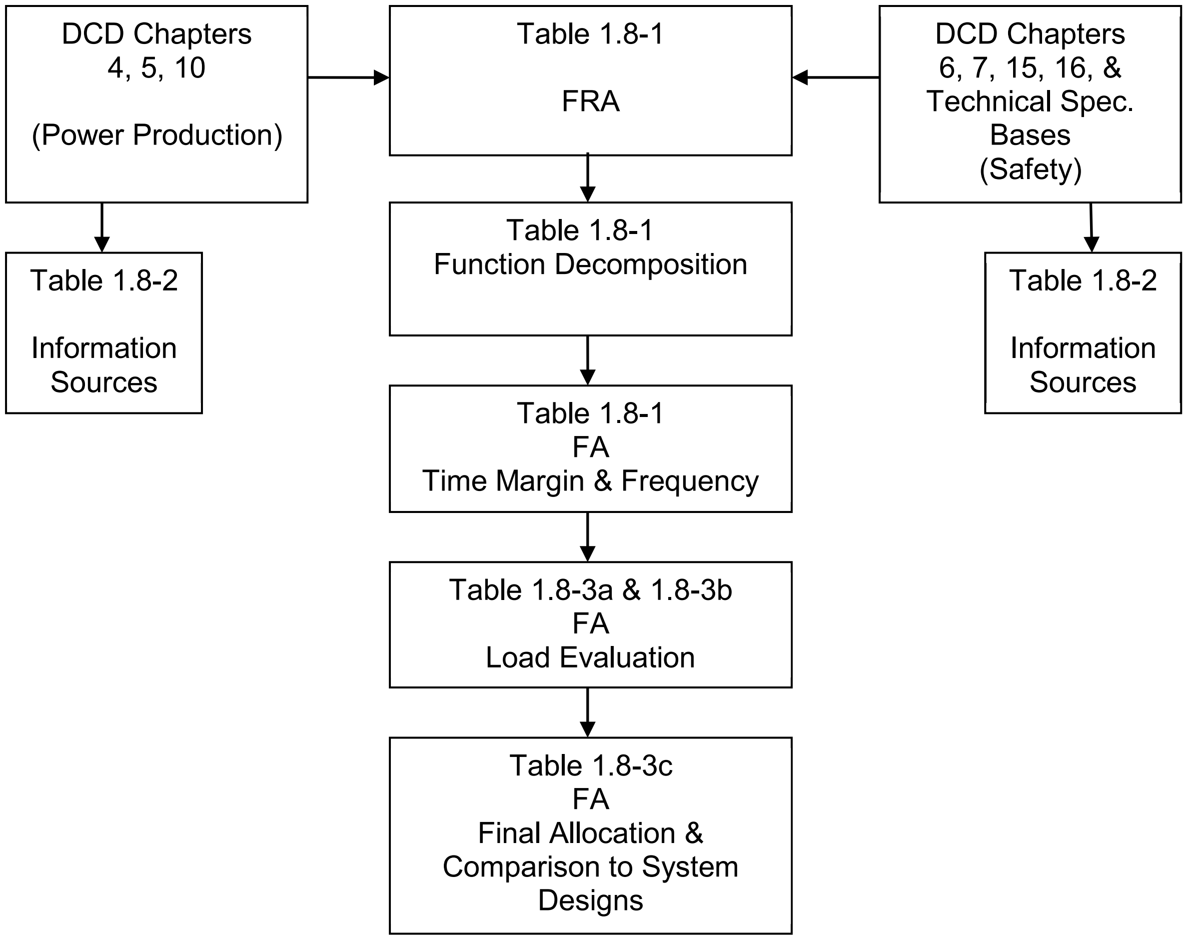
Time Margin – The elapsed time (seconds, minutes, hours, or days) from when a parameter deviates from its preferred value to when a Success Path Action must be completed to protect the Critical Power Production or Critical Safety function. Typically this is a minimum time (shortest); however, if the range of the value is large this information is included in the comments because of the potential impact on FA.

1.4 Methodology

The methodology used to perform the FRA/FA and the documentation supporting the HFE analyses are described in this section. This methodology uses guidance provided in NUREG/CR 3331, Reference 1.7.1.3, and IEC 60964, Reference 1.7.1.4. The FRA/FA methodology fully meets the objectives and review criteria in NUREG 0711, Revision 2, Part 4, Reference 1.7.1.1.

Figure 1.4-1 represents the analytical data flow within the US-APWR FRA/FA process. Note that this only depicts the internal logic of the FRA/FA analysis; the FRA/FA will be reentered as part of the iterative overall HFE process if needed, based on plant design changes or HEDs identified in subsequent HFE program elements.

Figure 1.4-1 FRA/FA Analytical Data Flow



1.4.1 The FRA identifies and documents the following:

- The top hierarchical goals:
  - Safety (prevent uncontrolled release of radiation)
  - Power Production (Availability)
- The high level Critical Functions that must be accomplished to meet the Plant Goals.
- The plant Modes for FRA (i.e., Full Power, Low Power and Shutdown)
- The Conditions for FRA/FA (i.e., Normal and Abnormal).
- The Success Path(s) used to control each Critical Function during each Mode and Condition.
- The decomposition of each Success Path (ie. Sub-Function, System, Key Components, Action)
- The parameters used to monitor each Success Path

1.5 Records (Result Summary Report)

The results summary report from the HFE FRA/FA analysis (Tables 1.8-1 thru 3c) is documented herein as Appendix 1.8-4. Where issues are identified during the FRA/FA, HEDs are created and entered into the HED Database for tracking and resolution.

1.6 Responsibilities

1.6.1 FRA/FA Team

The FRA/FA Team has the following functions and responsibilities:

- Review and approve the FRA/ FA process and results including Figure and Table format and content
- Conduct FRA/FA including data entry in all tables
- Complete the FRA/ FA results summary report including disposition of any comments from internal departments, customers, and NRC reviewers

1.6.2 HSIS Design Team Manager

The HSI system DTM described in MUAP-09019 Part 1 Section 3.0 organizes the FRA/FA team. The DTM is responsible for issuing the FRA/FA results.
Additionally, the DTM:

- Ensures that the FRA/FA is kept current over the life cycle of the US-APWR design (for use as a design basis when modifications are considered)
- Ensures that the FRA/FA is kept within the QA program
- Determines if control functions should be re-allocated in response to developing design specifics, industry operating experience, and outcomes of subsequent HFE program elements (e.g., TA, V&V)

1.6.3 Additional Guidance

MUAP-09019 Part 1 Section 3.0 provides additional guidance on organizational requirements in the area of people, roles, responsibilities, and qualifications for work performed under this procedure

1.7 References

1.7.1 Developmental References

1.7.1-1 Human Factors Engineering Program Review Model, NUREG-0711, Revision 2, February 2004

1.7.1-2 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP-DC018 , Revision 3, March 2011.

1.7.1-3 Pulliam, et al., A Methodology for Allocation if Nuclear Power Plant Control Functions to Human and Automated Control, NUREG/CR-3331, June, 1983.

1.7.1-4 IEC 60964, Design for Control Rooms of Nuclear Power Plants, International Electrochemical Commission, 1989.

1.7.1-5 Human System Interface Verification and Validation (Phase 1a), MUAP-08014, Revision 1, part 2, May 2011.

1.7.1-6 Defense in Depth and Diversity, MUAP-07006, Revision 2, June 2008.

1.7.1-7 HSI System Description and HFE Process, MUAP-07007, Revision 5, November 2011.

1.7.1-8 Quality Assurance Program (QAP) Description for Design Certification of the US-APWR, PQD-HD-19005, Revision 4, Part II, Document Control, Section VI, April 2011.

1.7.1-9 IEC 60964, Design for Control Rooms of Nuclear Power Plants, International Electrochemical Commission, 2009

1.7.1-10 IEC 61839 Nuclear power plants – Design of control rooms – Functional analysis and assignment, International Electrochemical Commission, 2000

1.7.2 Analytical References

1.7.2-1 Design Control Document for the US-APWR, Chapter 4, Reactor, MUAP-DC004, Revision 3, March 2011.

1.7.2-2 Design Control Document for the US-APWR, Chapter 5, Reactor Coolant and Connecting Systems, MUAP-DC005, Revision 3, March 2011.

1.7.2-3 Design Control Document for the US-APWR, Chapter 10, Steam and Power Conversion System, MUAP-DC010, Revision 3, March 2011.

1.7.2-4 Design Control Document for the US-APWR, Chapter 6, Engineered Safety Features, MUAP-DC006, Revision 3, March 2011.

1.7.2-5 Design Control Document for the US-APWR, Chapter 15, Transient and Accident Analysis, MUAP-DC015, Revision 3, March 2011.

1.7.2-6 Design Control Document for the US-APWR, Chapter 16, Technical Specifications, MUAP-DC016, Revision 3, March 2011.

1.8 Appendices

Appendix 1.8-1 Instructions for Functional Requirements Analysis

Table 1.8-1 Function Requirements Analysis

Functional Requirements Analysis															Function Allocation	
Function Description				Success Path												
				Function Decomposition					Success Path Description						Time Factors	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plant Goal	Critical Function	Plant Mode (Full Power Low Power Shutdown)	Condition (Normal Abnormal)	Purpose of the Success Path	Sub-Function	System	Key Components	Actions	Condition Indicating function is needed	Parameter Indicating function is Available	Parameter Indicating function is Operating	Parameter Indicating function is Achieving Purpose	Parameter Indicating Operation of function Can/Should be Terminated	Reference	Time Margin	Frequency

Note: The Critical Function, Sub-Function, Systems, Key Components, and Action represent the “Success Path”.

Appendix 1.8-2 FRA/FA Information Sources

Appendix 1.8-3 Instructions for Function Allocation

Appendix 1.8-4 FRA/FA Results Summary Report

Appendix 1.8-5
FRA/FA Team Member Qualifications and Experience

2.0 HUMAN RELIABILITY ANALYSIS

2.1 Purpose

The purpose of the HRA program element is to (1) ensure that the assumptions of the HRA/PRA, as documented in DCD Chapter 19 regarding RIHAs, are consistent with the US-APWR HSI and are consistent with expected human performance, and (2) document the HRA/PRA results that must be thoroughly incorporated into the HFE analysis and HSI design. The HFE analysis and HSI design process interacts iteratively with the HRA/PRA. The proper interaction of HFE design and HRA/PRA most effectively contributes to minimizing personnel errors, allowing human error detection, and providing human error recovery capability.

2.2 Scope

The scope of the HRA/PRA incorporation into the HFE effort encompasses risk-important HAs as described in Reference 2.9-7. The iterative nature of the interaction of HFE design and the HRA/PRA continues as the design progresses. Although this process continues throughout the design, and as such is not considered to be complete as reported in this section of MUAP-09019, it is complete enough to consider this section in place of a separate implementation plan or result summary report. The primary influence of the HRA/PRA on the HFE process manifests itself in the TA where accurate estimates of workload and task completion times for RIHAs are developed. TA results confirm the HRA/PRA assumptions at a more detailed level than initially performed during the HRA. The TA results for RIHAs are described in Part 2 Section 3.9. The influence of the HRA/PRA on the HFE design manifests itself as input to the TA, and changes to the TA, by developing estimates of workload and task completion times. The human performance assumptions, based on the HFE design influence on the HRA/PRA, are confirmed as part of the task analysis and the continuing control room HSI design test and evaluation program that lead to the final V&V as per Reference 2.9-8 section 11.
MHI will validate, as described in the US-APWR V&V Implementation Plan (MUAP-10012), all HRA assumptions for dominant sequences identified and validated using the process as described in MUAP-09019 Part 2 Section 2.4. In the early design stage they are, through the ongoing control room HSI design test and evaluation program, assessed using a static display navigation system with walk through and display selection analysis. In the final design stage, they will be validated through operability testing using a US-APWR simulator with licensed plant operations personnel. These evaluations will be conducted before the final quantification stage of the PRA and HRA, as part of the HFE V&V process. All aspects of the HRA/PRA integration evaluation and integration into the HFE design process shall be conducted as described in Reference 2.9-1, Section 18.6, and meet the criteria described in Reference 2.9-8 Section 7.

2.3 Definitions and Abbreviations

2.3.1 Definitions

<u>Initiating Event</u> - An initiating event is a disturbance which causes an upset condition of the reactor plant, challenging reactor systems and requiring operator performance of safety functions that are necessary and sufficient to prevent core damage. Initiating events result in challenges to plant safety functions, and postulated failures in these systems, equipment,

and operator response and could lead to an end state involving core damage and/or radionuclide release.

Performance Shaping Factors (PSF) - Factors that influence human reliability through their effects on performance. PSFs include factors such as environmental conditions, human-system interface (HSI) design, procedures, training, and supervision.

RIHAs - Actions that must be performed successfully by operators to ensure plant safety. There are both absolute and relative criteria for defining RIHAs. From an absolute standpoint, a RIHA is one whose successful performance is needed to ensure that predefined risk criteria are met. From a relative standpoint, the RIHA constitute the most risk-significant human activities identified in the HRA/PRA.

2.4 Methodology

The methodology for conducting the HRA program element (i.e. integrating the HRA/PRA into the HFE analyses) is described in this section. Incorporating HRA/PRA results into the HFE design process involves identifying RIHAs, analyzing these HAs to characterize the components (HA types and PSFs) and documenting the analysis results.

HRA/PRA results, including the RIHAs, will be reviewed by each organization involved in the design of the US-APWR HSI. This includes the HFE organizations responsible for the FRA/FA, TA, staffing and qualifications analysis, HFE test and evaluation, procedure design, training design, HSI design, and V&V. Each organization assures these results are considered in their respective design, analysis or testing programs, such that the HSI design minimizes the likelihood of human error, and provides the opportunity for error and fault detection and error recovery.

The HRA provides human error probabilities (HEPs) and the analysis for Type A (pre-initiating event) and Type C (post-initiating event) human interactions is based on the NUREG/CR-4772 “Accident Sequence Evaluation Program HRA Procedure” (ASEP), and the HEP analysis for Type B (Errors that cause an initiating event) human interactions is based on NUREG/CR-1278 “Technique for Human Error Rate Prediction” (THERP).

The analysis of type C HEPs at the design certification stage is conservatively assessed by the ASEP approach because the plant specific information is not fully available. Also, the time available to complete actions is not estimated at the design certification stage in detail, but an evaluation is performed to assure that identified operator actions are possible to perform in the time available. If it is difficult to judge whether the actions can be completed in the time available, those actions were not modeled in the PRA as described in this section of MUAP-09019, but will be addressed in future revisions to the PRA. The evaluations of the identified operator actions and HEPs will be updated as more specific US-APWR design and updated thermal-hydraulic analyses become available.

2.4.1 HRA/PRA Data Acquisition

RIHAs are identified from the HRA/PRA (Reference 2.9-2, Chapter 19) and used as input to the HFE design effort. These actions are extracted from the Level 1 (core damage) PRA and Level 2 (release from containment) PRA and include both internal and external events. The HRA methodology is described in Subsection 19.1.4.1.1, “Description of the Level 1 PRA for Operations at Power” and Subsection 19.1.6.1, “Description of Low-Power and Shutdown Operations PRA.” The categorization of the risk-importance of HAs is described in

Subsections 19.1.4.1.1 and 19.1.6.1. The US-APWR DCD, Chapter 19 references provide the sole source of input for this analysis.

2.4.2 HRA/PRA Data Evaluation

An evaluation is conducted to identify the RIHAs and their associated tasks, scenarios, interactions, PSF, and assumptions. The primary focus of the HFE analyses are the 1) general HSI, 2) operating staff, and 3) procedures associated with the HAs. These parameters will be explicitly stated or inferred in the HRA/PRA, Reference 2.9-2. This information will be contained in the text, tables, or figures in Reference 2.9-2, Subsections 19.1.4.1.1 or 19.1.6.1 or may be obtained from another Chapter 19 Subsection or Chapter 19 references (technical documents or other DCD chapters) if there is a formal reference provided.

2.4.2.1 Identification of Initiating Event Scenario Model

The HRA/PRA integration evaluation identifies the initiating event scenario modeled from the Chapter 19 description. The model includes the operator actions that either respond to the initiating events or mitigate failure of other systems. The HRA modeling addresses three types of human interactions, including actions before and after an initiating event, and actions that may cause or lead to an initiating event:

- Type A: Pre initiating event human interactions -
  These actions take place before an initiating event and are usually routine activities (e.g., tests, maintenance, or calibration). If these actions are not completed correctly, the error may impact the availability of equipment necessary to perform a system function modeled in the PRA. Typically Type A HAs are composed of component misalignment or miscalibration. Misalignments of components can, in many cases, be easily detected by the plant personnel in the control room during plant operation. In the HRA, these kinds of Type A human failure events are screened out, and not explicitly modeled in the PRA (Reference 2.9-2, section 19.1.4.11 (HRA)).
- Type B: Initiating event related human interaction -
  These actions take place before an initiating event (including type A) and if not completed correctly may cause an initiating event. In many cases these contributors to initiating event frequency are included in the data base and are therefore included in the quantification of the PRA.
- Type C: Post initiating event human interaction -
  These actions take place after an initiating event and are evaluated to determine the likelihood of error or conversely task completion. The operator responses required for each of the accident sequences are modeled when they are risk significant and evaluated probabilistically in the HRA. Type C human interactions are categorized into type Cp and type Cr. Type Cp are the actions required to operate the mitigation system, and type Cr represents the recovery actions for failed equipment, or realignment of systems.

The methodology to identify RIHAs, based on the Level 1 and Level 2 PRA for the US-APWR DCD is as follows:
Risk importance measures of the Risk Achievement Worth (RAW) and Fussell-Vesely (FV) importance measures, which can be derived from the PRA, are used to measure risk importance of HAs. RAW represents the factor of increment in core damage frequency (CDF)

or large release frequency (LRF) when the probability of an event (e.g., failure of function, human error or structural failure) is set to the value of 1. Events with RAW values greater than or equal to 2 are considered as risk important events. The FV importance measure value indicates the contribution of an event to CDF or LRF. Events with FV values greater than or equal to 0.005 are also considered as risk important events. RIHAs are identified by the two risk importance measures and the criteria for risk important events discussed above.

Additionally, HAs that will cause an initiating event are considered to be risk important from the perspective of impact on initiating events. Such HAs are also candidates to become RIHAs. The criteria applied to identify RIHAs are summarized below.

- RIHAs to mitigate initiating events:
  - HAs that meet the importance criteria shown below are risk important: FV ≥ 0.005 or RAW ≥2.
  - HA failures that are considered to have large contributions to CDF or LRF, based on engineering judgment, are risk important.

- RIHAs that are potentially incipient of an initiating event:
  - During at-power operation, HAs that can result in reactor trip by a single human error are risk important.
  - During low-power and shutdown operation, HAs that can result in re-criticality or loss of decay heat removal are risk important.

In the low-power and shutdown (LPSD) PRA for the US-APWR DCD, a detailed PRA has been carried out only for the mid-loop operation state. For other plant operational states (POS), a simplified risk assessment method has been applied to evaluate the bounding value of CDF and LRF. Since the simplified risk assessment method does not calculate the risk importance of HAs, for POSs other than mid-loop, RIHAs were identified based on engineering judgment. RIHAs for LPSD are identified based on the criteria shown below.

- RIHAs during mid-loop state
  - HAs that meet the importance criteria shown below are risk important: FV ≥ 0.005 or RAW ≥2.

- RIHA during POSs other than mid-loop state
  - HAs that are risk important during mid-loop are also risk important during other POSs.
  - HAs that are not credited in the PRA for the mid-loop state are all considered to be risk important.

2.4.2.2 HFE Characteristics Evaluation

The HFE characteristics (US-APWR general HSI, operating staff, and procedures) that influence the HRA/PRA and their integrated relationship are evaluated. The following detailed HFE parameters, discussed in 2.4.2.2.1, 2 and 3, are identified from the HRA/PRA and are recorded on the form presented in Appendix 2.10.2.

2.4.2.2.1 General HSI

The general HSI parameters of interest include the ergonomics parameters (facility location and workstation details), environmental influences, communications considerations, and HSI description.

A. Ergonomics Parameters

The ergonomics parameters include the location and physical layout of the facility and the workstation.

- Facility Location - The facility location determination involves identifying the location where the HA described in the HRA/PRA is performed. This is normally interpreted as a room within the facility or an outside area. However, if the HA specifies or implies movement between locations involving more than one room or outside area, then the travel path is determined. The start and end locations and length of travel should be specified (as a minimum level of detail) along with significant associated actions (e.g., don protective clothing, put on a respirator, or obtain equipment), if known.

- Control Panel/Console/Workstation - This HFE parameter involves identifying the specific location within a facility room or outside area where the HA is performed. This usually involves a clearly specified control panel, console, or workstation (e.g., operator console, supervisor console, remote shutdown panel or specific field location equipment panel).

B. Environmental Influences

Environmental influences refer to ambient conditions that could have a negative influence on successful performance of the HA (e.g., contribute to PSF that reduce the probability of success). The range of situational factors that are known to challenge human performance are specified, including adverse or inhospitable environmental conditions such as poor lighting, extreme temperatures, high noise, and radiological issues (dose rate or contamination). When evaluating performance associated with the use of HSI components located remotely from the main control room, the specific effects on crew performance due to potentially harsh environments (i.e., high radiation) are considered (i.e., additional time to don protective clothing and access radiologically controlled areas).

C. Communications

When communication between personnel is required to perform the task, the specifics of the communication is identified. This includes the type of communication (e.g., verbal, written, hand signal), purpose (e.g., coordination, feedback) and equipment used (i.e., telephone, radio, public address, text pager).

D. HSI Description

The HSI description includes specifying the alarms, displays, and controls used by the operators. This description is presented at a high level. For example, the information provided by the alarm should include: visual characteristics (color, text), audible characteristics (buzzer, bell, generated voice), data characteristics (single parameter, table, graph), and/or control characteristics (touch screen, mouse, control switch, other). More detailed information and control interface design details, such as graphic display formats, symbols, dialog design, and input methods are not required by the HRA/PRA. Systematic strategies for organization such as arrangement by importance, frequency of use, and sequence of use are also not required for this analysis. These details are addressed during the TA. Failure events, such as instrumentation and control failures, miscalibration and component restoration errors, or recovery action(s) in response to feedback are defined within the PRA structure and do not need to be specified as part of this parameter.

- Alarm or Display Monitoring - The general purpose of the alarm or display data for determining parameter status or overall automated system performance is provided. Examples are:

  - Parameters that indicate that the high-level function is available
  - Parameters that indicate the high-level function is operating (e.g., flow indication)
  - Parameters that indicate the high-level function is achieving its purpose (e.g., reactor vessel level returning to normal)
  - Parameters that indicate that operation of the high-level function can or should be terminated

- Control Actions - Controls used to conduct manual actions are the primary focus of this analysis. The control action (i.e., open valve, shutdown/trip pump, throttle flow, etc.) should be specified with the following additional information as appropriate:

  - Primary or backup to an automated action or another operator
  - Concern for errors of omission and/or commission
  - Operating precision (specify governing parameter – flow, pressure, temperature) if more complex than on/off activation

2.4.2.2.2 Operating Staff

The facility operating staff (crew) specifications addresses personnel requirements stated or implied in the HRA/PRA. This primarily includes the number of personnel and their skill level. Detailed analysis of staffing levels is conducted in the TA and staffing analyses where minimum, nominal, and high-level staffing are assessed. This level of detail is not provided in the PRA and is beyond the scope of this evaluation.

A. Number of Personnel
The number of personnel required to perform actions as specified in the HRA/PRA is determined. Stated or implied assumptions used in the HRA/PRA are identified and potential issues listed. These include:

- Conflicts between tasks and personnel (simultaneous/parallel tasks or operators using the same controls)
- Workload issues addressing whether tasks can be accomplished within time and performance criteria
- Personnel interactions involving decision making, coordination and feedback within the control room and between the control room and local control stations and support centers.

The HRA/PRA evaluation extracts the number of personnel required to perform the required actions for the task requiring the maximum manpower from the PRA scenario(s). However, for purposes of this integration evaluation, the individual tasks must be evaluated to determine if manpower is available for parallel activities.

B. Personnel Skill Level
Information is extracted from the HRA/PRA relative to stated or implied operator capabilities. This parameter usually is reflected in operator designation/qualifications (i.e., SRO, RO, Auxiliary Operator, fire brigade, Emergency Medical) and is used to support an HA being classified as Skill-of-the-craft or justifying the designation of an HA as a memorized action. Training requirements are implicitly reflected in personnel job titles.

All results of the staffing level analysis will be documented and reviewed to assure that staffing level assumptions are assessed in the HRA. Results from the HRA that apply to staffing that are considered to be discrepancies with staffing assumptions will result in an HED being generated and entered into the HED data base for resolution.

2.4.2.2.3 Procedures

Based on the description, stated or implied in the HRA/PRA, the type of the plant procedures are determined. The procedures that provide guidance to personnel for the affected actions such as failure/error recovery include the following types:

- Emergency Operating Procedures (EOPs)
- Plant and system normal operating procedures (including startup, power, and shutdown operations)
- Abnormal and Emergency Operating Procedures (AOPs)
- Alarm Response Procedures (ARPs)

2.4.2.2.4 Comments

The HRA/PRA evaluation will considered the HFE topic areas described in Subsection 2.4.2.2 of this section of MUAP-09019 during the review. Comments will be provided in Appendix 2.10.2 “US-APWR HRA/PRA Integration Evaluation Table” if any challenge conditions are found as described in Section 2.5.

2.5 Data Documentation

The HRA/PRA integration evaluation data is recorded in a summary table as depicted in Appendix 2.10.2”. Each HRA/PRA evaluation item in section 2.4.2.2 is entered in the form. Challenging HFE characteristics or concerns are identified in the “Comments” section of Appendix 2.10.2. Issues or concerns are resolved through the HFE design process, primarily in the TA and HSI design activities. The issues or concerns are formally dispositioned as Human Engineering Deficiencies (HEDs) and transmitted to the HRA/PRA analysts, the HFE team, and the design team for inclusion in that process as required in the HFE Program.

HRA assumptions identified during the evaluation for Appendix 2.10.2, such as decision-making, diagnosis strategies, and staffing, are validated by walkthrough reviews with personnel with operational experience and the HSI test and evaluation program. These reviews are conducted before the final quantification stage of the PRA as part of the final V&V process.

The HRA/PRA evaluation information obtained from supporting source documents referenced in US-APWR DCD Chapter 19, Reference 2.9-2 are listed and summarized on the HRA/PRA

Information Sources form contained in Appendix 2.10.3. The source document is listed, its unique source document identifier is recorded (for use in the comment section in Appendix 2.10.2), and a brief summary of HFE information from the source document are recorded.

2.6 Records

The results from the HRA/PRA integration evaluation are documented in the Appendix 2.10.2 Appendices. Issues identified during the HRA/PRA integration evaluation are entered into the HED Data base. All documentation activities are conducted as described in Reference 2.9-5.

2.7 Responsibilities

2.7.1 HRA/PRA Evaluation Team

The HRA/PRA Evaluation Team is a multidisciplinary team composed of individuals with a combined experience base in PRA, HRA or human factors, PWR operations and plant design. Each individual member of the team has at least 5 years of experience or education in at least one of the fields of experience. The Team has the following functions and responsibilities:

- Perform a detailed review of Reference 2.9-2, focusing on HRA and related topics
- Identify RIHAs in accordance with Appendix 2.10.1 process
- Populate the RIHAs in Appendix 2.10.2 Table
- Conduct HFE characterized evaluation using the tables in accordance with Appendix 2.10.2
- Write the HRA/PRA evaluation report
- Disposition technical reviewer's comments
- Develop and enter HEDs into the HED database).

2.7.2 HSI System Design Team Manager

The HSI DTM has the following functions and responsibilities:

- Organize the HRA/PRA evaluation team
- Issue the HRA/PRA evaluation in the HSI Design Technical Report
- Disposition HEDs resulting from the HRA/PRA integration process, and tracking the HEDs to closure
- Assign each of the HFE organizations issues related to their area of assignment to assure that the RIHAs are considered throughout the design process.

2.7.3 Additional Guidance

Reference 2.9-1, Section 18.1 provides additional guidance on organizational requirements in the area of people, roles, responsibilities, and qualifications for work performed under this procedure.

2.8 Results

Results of the HRA as specified in HRA/PRA integration evaluation results are shown in Appendix 2.10.2. With these operation step assumptions (i.e. Basic HSI assessment (Indications/Controls allocation, etc.), operating procedure step reflection on corresponding operation procedures and staffing estimation), identified RIHAs are mitigated from HFE aspect. HSI basic design, operating procedure and operator training program, including staffing assumption, shall use the HRA/PRA assumption as input information. All final RIHAs that have resulted from the HRA/PRA will be included in the scenarios used in the Integrated System Validation, Reference 2.9-8 Section 11.

2.9 References

2.9-1 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP- DC018, Revision 3, March 2011.

2.9-2 Design Control Document for the US-APWR, Chapter 19, Probabilistic Risk Assessment and Severe Accident Evaluation, MUAP-DC019, Revision 3, March 2011.

2.9-3 IEEE Guide for Incorporating Human Action Reliability Analysis for Nuclear Power Generating Stations, IEEE Std 1082-1997, Institute of Electrical and Electronics Engineers, NY, September 1997.

2.9-4 Higgins, J.C and O'Hara, J.M., Proposed Approach for Reviewing Changes to Risk Important Human Actions, NUREG/CR-6689, October 2000.

2.9-5 Quality Assurance Program (QAP) Description for Design Certification of the US-APWR, PQD-HD-19005, Revision 4, Part II, Document Control, Section VI, April 2011.

2.9-6 Probabilistic Risk Assessment, MUAP-07030, Revision 3, June 2011.

2.9-7 US-APWR Risk Significant Human Errors, N0-EB40026, Revision 0, December 2011.

2.9-8 Human Factors Engineering Program review Model. NUREG-0711 rev 2, February 2004.

2.9-9 Swain, A. D., Accident Sequence Evaluation program Human Reliability Analysis procedure, NUREG/CR-4772, February 1987.

2.9-10 Swain, A. D. and Guttmann, H.E, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications NUREG/CR-1278, August 1983.

2.9-11 US-APWR Reactor Coolant System Design Package, N0-EE11010, Revision 5, October 2011.

2.10 Appendices

Appendix 2.10.1 Methodology Applied to Identify Risk-Important Human Actions

This attachment describes the methodology applied to identify RIHAs based on the Level 1 and Level 2 PRA for the US-APWR DCD.
Risk importance measures such as the Risk Achievement Worth (RAW) and Fussell-Vesely (FV) importance, which can be derived from the PRA, are used to measure risk importance of HAs. RAW represents the factor of increment in core damage frequency (CDF) or large release frequency (LRF) when the probability of an event (e.g., failure of function, human error or structural failure) is set to value of 1. Events with RAW values greater than or equal to 2 are considered risk important events. FV indicates the contribution of an event to plant CDF or LRF. Events with FV values greater than or equal to 0.005 are also considered as risk important events. RIHA have been identified by the two risk importance measures and the criteria for risk important events discussed above.

Additionally, HAs that will cause an initiating event are considered to be risk important from the perspective of impact on initiating events. Such HAs are also candidates of risk RIHA. The criteria applied to identify RIHA are summarized below.

- RIHA to mitigate initiating events
  - HA that meet the importance criteria shown below are risk important:
    FV≥ 0.005 or RAW ≥2.
  - HA failures that are considered to have large contribution to CDF or LRF base on engineering judgment are risk important.

- RIHA that are potentially incipient of an initiating event
  - During at power operation, HAs that can result in reactor trip by a single human error are risk important.
  - During low-power and shutdown operation, HAs that can result in re-criticality or loss of decay heat removal are risk important.

In the low-power and shutdown (LPSD) PRA for the US-APWR DCD, detailed PRA has been carried out only for mid-loop operation state. For other POSs, a simplified risk assessment method has been applied to evaluate the bounding value of CDF and LRF. Since the simplified risk assessment method does not calculate the risk importance of HAs, for POSs other than mid-loop, RIHAs were identified based on engineering judgment. RIHAs for LPSD are identified based on the criteria shown below.

- RIHA action during mid-loop state
  HAs that meet the importance criteria shown below are risk important:
  FV≥ 0.005 or RAW ≥2.

- RIHA during POSs other than mid-loop state
  - HAs that are risk important during mid-loop are also risk important during other POSs.
  - HAs that are not credited in the PRA for mid-loop state are all considered to be risk important.

Appendix 2.10.2 US-APWR HRA/PRA Integration Evaluation Table

Appendix 2.10.3 HRA/PRA Information Sources*

3.0 TASK ANALYSIS

3.1 Background

During the US-APWR HSIS development Phase 2a, TA was performed for the RIHA which were identified in the PRA and evaluated in the HRA program element, Part 2 Section 2.0 of this report. The Phase 2a TA evaluated the RIHA for topics listed in Table 5-1 of Reference 3.8-1 and confirmed that all RIHAs can be performed within the time available specified in the PRA. The TA for RIHA is documented in Appendix 3.9 of this section which includes the TA methodology and results.

The remaining Section 3.0 describes the implementation plan for the Phase 2b TA. The Phase 2b TA addresses the HAs that were not identified as risk important in Phase 2a. The Phase 2b TA also reassesses the RIHAs to confirm the TA results of Phase 2a, based on additional plant system design detail, as it becomes available. For example, in the Phase 2a TA Results tables (Table 3.9-5 of Appendix 3.9), the “Information Requirements” field for a sub-task states that the necessary indications “are available in the MCR”; this is expanded in the Phase 2b TA to indicate the instrument ID tags, and to confirm the adequacy of the ranges and resolutions of the indications, based on the detailed system design. The Phase 2b TA also expands upon the methodology used in Phase 2a, as necessary. For example, new operational sequence diagram (OSD) patterns are developed for sub-tasks that were not applicable to RIHAs, and therefore were not developed in Phase 2a.

3.2 Purpose

The main purpose of the US-APWR HFE TA is to identify the specific tasks that are needed to accomplish the functions that have been allocated to humans in the FRA/FA.

The TA will encompass the specific tasks that are needed to control the success paths identified in the FRA/FA, for the success path actions that have been allocated to plant operators. The success paths are used to control the critical safety and power production functions. For each task the TA identifies the information, control and task-support requirements. The TA also analyzes the work load for each task to confirm the task can be performed by the normal US-APWR operator staffing that consists of one RO and one SRO in the main control room (MCR) and one additional RO and SRO in the plant. This staffing is a design basis constraint of the US-APWR. Where the TA identifies an excessive task burden for the design basis staff, the TA will generate HED. HEDs are resolved by a multi-disciplined team including an independent Expert Panel, as described in Part 1 Section 6.0. HED resolutions will consider many options to reduce operator task burden, such as improved procedure sequences, additional automation and human-machine shared functions.

The TA will also evaluate representative operator tasks related to maintenance, test, inspection, and surveillance for safety-related plant equipment. This part of the TA is not driven by the FRA/FA.

The output of TA is an input to:

- HRA
- HSI design

- HFE V&V
- Operational Procedures
- Staffing and Qualifications Analysis
- Training Program and Materials

The TAs provides one of the bases for making design decisions, verifies human-performance requirements do not exceed human capabilities, is used as basic input for developing procedures, is used as basic information for developing the staffing, training, and communication requirements of the plant, and forms the basis for specifying the design requirements for the displays, data processing, and controls needed to carry out tasks. The TA also forms the bases for the Task Support Verification part of the final V&V program.

3.3 Scope

In accordance with the Review Criteria 5.4 (1) of NUREG-0711 Revision 2, Phase 2b task analysis includes:

- Selected representative and important tasks from the areas of operations, maintenance, test, inspection, and surveillance.
- Full range of plant operating modes, including startup, normal operations, abnormal and emergency operations, transient conditions, and low-power and shutdown conditions.
- RIHAs, which are HAs that have been found to affect plant risk by means of PRA importance. Internal and external initiating events and actions affecting the PRA Level I and II analyses are considered when identifying risk-important actions.
- Monitoring of the automated system and execution of backup actions if the automation fails.

Tasks identified and analyzed in Phase 2b are derived from:

- RIHA's from the PRA
- Output of the FRA/FA. During the TA, the Success Path actions identified by FRA on the basis of their allocation from FA are analyzed. If the allocation is to machine, the TA is limited to the tasks needed to supervise the automation. If the allocation is to man, the TA breaks down the action to tasks that encompass all required manual control actions. During the TA a separate analysis for manual actions to accommodate automation failure is also performed.
- Emergency Response Guidelines
- Selected representative and important tasks from the areas of maintenance, test, inspection and surveillance

The specific tasks needed to support the items above are derived from US-APWR system design documentation and from SMEs, based on their experience at conventional PWR predecessor plant tasks.

3.4 Definitions

Component – An individual piece of equipment such as a pump, valve, or vessel; usually part of a plant system or instrumentation loop.
Critical Function – A process or activity that is required to achieve the two high level goals defined in the FRA, Safety and Power Production.
Success Path – A system or a subset of components within a system together with the specific action defined for those components (e.g., increase RCS boron concentration) that are used to successfully control a Critical Function.
Task – The activities assigned to plant personnel that define their roles and responsibilities. Plant personnel perform actions HAs, which are grouped into a task to accomplish the activity. A task includes a group of related HAs that have a common objective or goal.
Time Constraint – a pre-determined time for task completion based on the design specifications.

3.5 Responsibilities

The Phase 2b TA is performed by SMEs who are former licensed operators with pressurized water reactor experience. The SMEs perform TA under the supervision of the HFE Manager. Specific resumes are on file for audit purposes. The MNES Engineering organization and HFE team provide a review function of TA results generated by the SMEs. The HFE Manager is ultimately responsible for the oversight and approval of the HFE TA process and results as described in Part 1 Section 3.0, MULTIDISCIPLINE MULTIPLE ORGANIZATION TEAM. These responsibilities are delegated and described in the TA implementation procedures. Any HEDs generated by the SMEs are resolved by a separate multi-disciplined team as defined in Part 1 Section 6.0.

3.6 Phase 2b Task Analysis Methodology

3.6.1 Methodology

Either a detailed or basic TA is performed on each task identified in Phase 2b. A preliminary evaluation will be conducted for each task against the following screening criteria:

- Is the task related to or does it impact any RIHAs identified in the HRA or any ERG credited manual?
- Does the task require more than the defined minimum operator staffing?
- Does the task have an operation time constraint?
- Does task performance require interactions with other personnel or local actions (i.e. impact on staffing and consider different environment)?
- Does the task require a unique operator action?
- Does the task result in excessive operator burden?

- Does the task require long interaction control (manual modulation and/or throttle valve operations)?

If all the screening criteria result in a NO response, a basic TA is performed. The basic TA identifies the required inventory of indications, alarms and controls necessary to perform the task. In addition, a basic TA identifies the qualification level of the personnel who must perform the task and confirms the task can be performed with minimum staffing.

If any of the screening criteria result in a YES response a detailed TA is conducted. Table 3.6-1 identifies the required functions for a human task accomplishment that are used in the detailed TA:

Table 3.6-1 Required Functions for Human Task Accomplishment (Sheet 1 of 2)

No.	Evaluation Items	Acceptance Criteria	Remarks
1	Information Requirements	The plant information, alarms and controls needed to accomplish the task (e.g., flow and pressure indication, pump and valve controls)	
2	Decision-making	The type of decision required. Ab (Absolute information): Prompting information in the MCR (such as an alarm) that notifies the operators of the plant situation. R (Relative information): Plant symptom information (such as changes in plant parameters and/or component status indications caused by plant malfunctions) is presented in the MCR that enables the operators to gain awareness of the plant situation. P (Probabilistic): Information is available locally only (not directly indicated in the MCR), so that operators would only become aware of the plant situation during routine inspections or other activities in the area.	Decision making requirements are specified for the first sub-step of a task sequence. This defines how the decision to initiate the task is determined.
3	Communication Requirements	Type of communication required: V: Verbal communication between operators in the control room	

		R: Remote communication between a person outside the control room and a control room operator.	

Table 3.6-1 Required Functions for Human Task Accomplishment (Sheet 2 of 2)

No.	Evaluation Items	Acceptance Criteria	Remarks
4	Time Required (OSD time)	The Time Required is the time to complete the HA based on the summation of the individual times for each OSD. (See Table 3.9-5).	
5	OSD Pattern	The HA is composed of subtasks which are represented by the standard OSD Patterns.	
6	Task Support Requirements	Specific job aids, tools, or protective clothing needed. D: Support material such as reference documents or calculation sheet for dedicated action. T: Some support apparatus or tool such as valve handling tool if required in the action.	
7	Situational and Performance Shaping Factors	Whether there are any situational factors such as high stress or task complexity that may affect the required actions.	These factors are considered for the difficult and high work load actions.

8	Workplace Factors and Hazard	Whether there is any significant workplace factors or hazards that may affect actions required in a local area. Most actions are taken in the Control Room that is considered a good working environment void of hazards.	Significant workplace factors considered: high or low temperature, radiant heat by high energy piping, noise, radiation, lighting, and roaring sound of turbine rotation. Potential hazards considered: falling materials, actions on a ladder, and actions at high elevations.

In summary, the general steps for TA are:

Basic TA:

- Step 1: Develop task narrative description
- Step 2: Determine required inventory of alarms, controls and indications
- Step 3: Determine if detailed TA is required based on screening criteria

Detailed TA:

- Step 1: Determine decision making requirements
- Step 2: Determine communications requirements
- Step 3: Identify time constraints
- Step 4: Identify human response requirements using OSD patterns
- Step 5: Identify task support requirements
- Step 6: Identify situational and performance shaping factors
- Step 7: Identify workplace factor and hazards
- Step 8: Determine if allocation of monitoring is appropriate
- Step 9: Determine if allocation of control is appropriate
- Step 10: Identify qualification level and number of direct and support personnel

In all of the TA steps, if it is determined that the assumptions or constraints in the current plant design, HRA/PRA, or FRA/FA do not match the outcome of the TA, an HED is written and entered into the HED data base to identify the deficiency/discrepancy and track the resolution. In contrast to the TA performed in Phase 2a, which is documented in Table 3.9-5 of Appendix 3.9, the Phase 2b TA is documented in a HFE TA database.

Phase 2b TA consists of multiple phases as the design cycle progresses. The initial phase of TA follows preliminary design development and is detailed sufficient to identify information and control requirements to enable specification of detailed requirements for the HSI design. The initial phase is followed by a second phase which is conducted after detailed design is complete and ensures the TA and final design is in alignment.
Following the second phase, the TA is maintained current through a process which monitors design changes for impact on the TA and modifies the TA as appropriate.

The following subsection provides each process step in detail.

3.6.2 Task narrative description

Task descriptions are developed from a review of system design information (Design documents, P&ID's, logic diagrams, electrical schematics), RIHAs, Operator Actions credited in the accident analysis, the human and shared actions allocated by the function allocation, and similarities with predecessor plants. Each narrative provides a description of what personnel do to accomplish a task.

3.6.3 Required inventory of alarms, controls and indications

The inventory is determined by reviewing the task narrative and identifying the indications, alarms, and controls required in the HSI to execute the task. The determination of the inventory also identifies the following:

- Measured Parameter and Units
- Display characteristics; instantaneous / historical trend; digital; bar chart; simultaneous multiple parameter monitoring
- Automated Calculations
- Range / Resolution
- Refresh/Update Rate
- Alarms
- Equipment Controls; including interlocks, overrides and blocks that support equipment operation

3.6.4 Decision-making requirements

The decision making requirements are determined by reviewing the task narrative and inventory and identifying how information is presented to personnel. Based on the information requirements, the decision making is classified in one of the following categories:

- Absolute (Ab) – Prompting information in the main control room (such as an alarm) that notifies the operators of the plant situation.
- Relative (R) – Plant symptom information (such as changes in plant parameters and/or component status indications caused by plant malfunctions) is presented in the main control room, enabling operators to gain awareness of the plant situation.
- Probabilistic (P) – Information is available at the local area but is not directly indicated in the main control room, so that operators would only become aware of the plant situation from the local area (e.g., during periodic inspections).

3.6.5 Communications requirements

The communication requirements are determined by reviewing the task narrative and identifying what communications are required and to whom the information must be communicated. Communication requirements are classified in one of the following categories:

- Verbal (V) communication between operators in the control room
- Remote (R) communication between a person outside the control room and a control room operator.

3.6.6 Time Constraints

Design input documents, HRA/PRA, FRA, and Safety Analysis are evaluated to determine identified “Time Available” and if a “Time Constraint” is associated with the performance of a task. If a “Time Available” or “Time Constraint” is identified, the task is evaluated using OSD patterns to verify that the task can be performed within the time constraint. Timeframes for existing OSD patterns were determined during the performance of Phase 2a TA utilizing GOMS analysis supplemented by engineering judgment where appropriate. GOMS analysis is used to determine the times required to perform OSD patterns for HAs that are performed in the main control room, while engineering judgment is used to determine the times required to perform OSD patterns for HAs that are performed locally in the plant (Reference Table 3.9-4).

3.6.7 Human response requirements using OSD patterns

The task narrative is broken down into individual actions, each of which can be represented by a specific OSD pattern. The individual actions are linked using OSD patterns to judge work load (cognitive and physical) of the personnel performing the task.

In the Phase 2a TA, a set of OSD patterns were identified based on operating experience and existing operating procedure review (Reference Appendix 3.9, Table 3.9-2) and are used in Phase 2b TA. The set of operator actions include:

- Verify Parameter(s)
- Energize or de-energize valves (Local action)
- Open or close valves
- Start or stop the pump(s)
- Jumper on/off motor control center terminal block (Local action)
- Set or reset the designated signal
- Place component control switch or controller in Pull-lock/Auto/Manual mode
- Connect or disconnect the load to the bus
- Connect or disconnect the load to the bus (Local action)
- Open or close valves (Local action)
- Start or stop the pump(s) (Local action)
- Unlock or lock the valve (Local action)
- GO TO or REFER TO action[1]
- Adjust the controller/control

Additional OSD patterns may need to be developed during Phase 2b TA. New OSD patterns are evaluated by engineering through the HED process to determine performance times that require GOMS analysis (Reference Appendix 3.9, Sub-section 3.9.6, 2. "Evaluation of Operator's Cognitive Workload" and Table 3.9-4). Performance times requiring engineering judgment are determined by SMEs identified in Sub-section 3.5, "Responsibilities" above.

3.6.8 Task support requirements

Each task is evaluated to determine if support requirements, such as written job aids, calculation sheets, tools, equipment, protective clothing, or other special support equipment are necessary for task performance.

3.6.9 Situational and performance shaping factors

Each task is evaluated for situational and PSF that increase the cognitive work load and may influence human reliability through their effects on performance. Environmental conditions coupled with error tolerance, consequences, time pressure, multiple alarms, potential hazards, task importance, and secondary tasks factor into this determination.

3.6.10 Identify workplace factors and hazards

[1] Included in this OSD set but not used in Phase 2a Task Analysis.

Each task is evaluated to determine if workplace factors and hazards exist at the location where the task is being performed. Typical factors and hazards include, but are not limited to: presence of chemicals, fall and slip hazards, confined spaces, ambient temperature, radiation, and contamination. Under normal main control room conditions, workplace factors and hazards are not present and are not applicable to tasks performed in the control room.

3.6.11 Allocation of monitoring

Each task narrative, inventory of alarms, controls and indications, and human response requirements are reviewed in aggregate to determine if the allocation of monitoring to the operator, as defined by the FRA/FA is appropriate. Additional tasks which are not addressed in the FRA/FA have the allocation of monitoring defined in the TA.

3.6.12 Allocation of control

Each task narrative, inventory of alarms, controls and indications, and human response requirements are reviewed in aggregate to determine if the allocation of control to the operator, as defined by the FRA/FA is appropriate. Additional tasks that are not addressed in the FRA/FA have the allocation of control defined in the TA.

3.6.13 Identify qualification level and number of direct and support personnel

Each task is evaluated to determine the qualification level and number of personnel required to perform the task. If the number of or qualification level of personnel necessary to perform the task does not support the US-APWR minimum staffing design constraint, an HED is generated.

3.6.14 Results

The Phase 2b TA results, for the applicable type of TA (basic or detailed), are recorded and documented in the HFE TA database, including:

- Information Requirement (inventory of alarms, controls and indications)
- Decision making requirements
- Communication requirements
- Time Required (OSD time)
- OSD Pattern
- Task Support Requirements
- Situational and PSF (cognitive work load)
- Workplace Factors & Hazards
- Staffing requirements

The above results are reviewed in aggregate to ensure there is a success path for the specific tasks that are needed to accomplish the functions that have been allocated to humans in the FRA/FA.

The results are utilized as input information to:

- HRA

- HSI design
- The HFE V&V
- Procedure development
- Staffing and Qualifications Analysis
- Training program development

3.6.15 Results Summary Report

Upon completion of TA, a TA Results Summary Report will be generated that includes the following:

- Scope of the TA
- Identification of the TA team members and their qualifications
- Description of the implementation methodology
- Task descriptions and implementation results
    - Task narrative descriptions
    - HED evaluation results
    - SMEs performing the TA and their specific qualifications

3.7 Records

HEDs are initiated, documented, and entered into the HED database when it is identified that the US-APWR plant design or HSI design features do not facilitate effective performance of the analyzed task. All documentation activities are conducted as described in DCD Section 18.1.4 (Reference 3.8-2).

3.8 References

3.8-1 U.S. Nuclear Regulatory Commission, Human Factor Engineering Program Review Model, NUREG-0711, Revision 2.

3.8-2 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP-DC018, Revision 3, March 2011.

3.8-3 Defense in Depth and Diversity, MUAP-07006, Revision 2, September 2009.

3.8-4 HSI System Description and HFE Process, MUAP-07007, Revision 5, November 2011.

3.8-5 U.S. Nuclear Regulatory Commission, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800.

3.8-6 Quality Assurance Program (QAP) Description for Design Certification of the US-APWR, PQD-HD-19005, Revision 4, Part II, Document Control, Section VI, April 2011.

3.8-7 The Psychology of Human-Computer Interaction, Stuart K. Card, Thomas P. Moran, and Allen Newell, Lawrence Erlbaum Associates, 1983.

3.9 Appendix
Phase 2a Task Analysis Methodology and Results for Risk Important Human Actions

3.9.1 Scope

The TA performed in Phase 2a included US-APWR RIHAs from the PRA results that cover a full range of plant operations. These HAs are documented in HRA report (MUAP-09019 Part 2 Section 2).

3.9.2 Purpose

The purpose of the TA includes confirming the time response assumptions for the risk important HAs. The list of HAs that have been analyzed are presented in Table 3.9-6.

3.9.3 Definitions

Component – An individual piece of equipment such as a pump, valve, or vessel; usually part of a plant system or instrumentation loop.
Function – A process or activity that is required to achieve a desired goal.
Task – A group of activities that have a common purpose, often occurring in temporal proximity and that utilize the same displays and controls.

3.9.4 Responsibilities

The Phase 2a TA was performed by MHI HFE engineers or qualified subcontractors, and is based on input from safety analysis, HRA, plant fluid systems and I&C engineering.

The results were reviewed by two operations experts who were formerly licensed at a U.S. pressurized water reactor nuclear plant possessing over 19 years operations and training experience, familiar with the US-APWR plant design, and the MHI US-Basic HSI as implemented in the MEPPI simulator.

The HSI system DTM organized the TA team. The DTM is responsible for issuing the TA results within the HSI Design Technical Report.

3.9.5 Methodology

Each HA is broken down into sub-steps that are either cognitive tasks (e.g., detection, confirming a parameter value) or action steps (e.g., opening or closing a valve).
These sub-steps are then evaluated with respect to a number of characteristics that can influence the quality or timeliness of performance. Table 3.9-1 presents the list of required functions for human task accomplishment that are derived from Table 5, NUREG-CR 0711, Revision 2. These items are correlated to the columns shown in Table 3.9-5 for each risk important HA.

For each sub-task, answers to these items are determined based on analysis of the APWR plant design and general PWR NPP operational knowledge, and documented in summary table form. (See Table 3.9-5).

One item in Table 3.9-5 relates to Response Time requirements when the OSD response time is compared to the time required assumptions from Table 3.9-6. This item examines whether a task can be accomplished in the time available specified by PRA and Safety Analyses. The time available within a HA needs to be completed as well as the time required to complete the actions are presented in Table 3.9-6.

Operator tasks are broken down into sub-tasks that can be evaluated by OSD patterns. The OSD is utilized to identify simplified operator action patterns and break down complicated or integrated operator's actions into OSD patterns in order to evaluate operator's physical and cognitive work load. The OSD patterns are also utilized for breaking down operator's task to sub tasks that can be evaluated by the OSD pattern template.

OSD pattern development is summarized in Sub-section 3.9.6," Task Linking and Cognitive Workload Analysis, 1. OSD Pattern. HA symbols are represented using single a single line layer and machine reaction's (HSIS reaction's) are represented using a double line layer.

Both actions are represented with shape codes that consist of geometric configurations. Supplemental task information represent actions, such as visual, touch etc., are added inside the shape code using letter codes (i.e. S, V, W, and T). A flow diagram is made by connecting each task symbol in chronological order as in Table 3.9-2. Graphical task flows with interactions of humans (i.e. RO, SRO and other personnel) and systems/component (i.e. Displays/Controls) are shown. GOMS, described in Sub-section 3.9.6, "Task Linking and Cognitive Workload Analysis", 2. Evaluation of Operators Cognitive Workload, or engineering judgment were utilized in supporting operator's action time and cognitive work load to evaluate how long (what time order- second, tens of seconds, or minutes) an action time the operator requires to perform each OSD pattern. A set of OSDs used in the Phase 2a TA is shown in Table 3.9-2.

A second, table-top method was used as an independent check that each HA can be accomplished within the time available specified by the PRA and safety analyses, as well as the following objectives:

- Accuracy of the English translation
- Accuracy of the task sub-steps
- Other evaluation aspects of Table 3.9-1 criterion

Technical documents referenced for the review, where available, consisted of P&ID drawings of the applicable nuclear plant systems found in the Tiers 1 and 2 DCD for the US-APWR and PRA/HRA results in DCD Chapter 19.

This table top analysis was performed by the two operations experts referenced in Sub-section 3.9.4 above. The experts evaluated whether the tasks could be completed within the required time available, assuming one RO and one SRO in the control room, and a local operator (in cases where local operation is required).

All discrepancies from the stated objectives identified by the table-top reviewers were annotated and forwarded to MHI engineers for incorporation into the TA results table.

Table 3.9-1 Required Functions for Human Task Accomplishment (Sheet 1 of 2)

No.	Evaluation Items	Acceptance Criteria	Remarks
1	Information Requirements	The plant information needed to accomplish the task(e.g., flow and pressure indication)	
2	Decision-making	The type of decision required. Ab (Absolute information): Prompting information in the MCR (such as an alarm) that notifies the operators of the plant situation. R (Relative information): Plant symptom information (such as changes in plant parameters and/or component status indications caused by plant malfunctions) is presented in the MCR that enables the operators to gain awareness of the plant situation. P (Probabilistic): Information is available at the local area but is not directly indicated in the MCR, so that operators would only become aware of the plant situation from the local area (e.g., during periodic inspections). “Ab”, “P”, and “R” appear in this column of Table 3.9-5 to indicate the type of decision required for the action.	Decision making requirements are specified for the first sub-step of a task sequence. This defines how the decision to initiate the task is determined.
3	Communication Requirements	Type of communication required V: Verbal communication between RO and SRO in the control room R: Remote communication between RO (AO) and SRO can be performed. “V” and “R” are listed in this column of Table 3.9-5 to indicate the type of communication required for the action.	
4	Time Required (OSD time)	The time in this column of Table 3.9-5 is the time required to complete the HA based only on the summation of the individual times for each OSD pattern (see Table 3.9-4). The total Time Required, which includes additional considerations for qualitative factors (Columns 8-10), is shown in Note 1	

		of the table. An ‘A’ in this column of Table 3.9-5 indicates that the total Time Required to complete the HA is acceptable.	

Table 3.9-1 Required Functions for Human Task Accomplishment (Sheet 2 of 2)

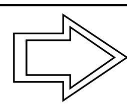
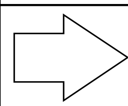
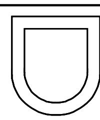
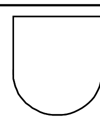
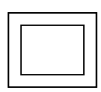
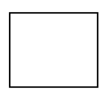
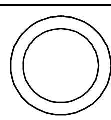
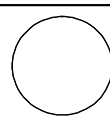
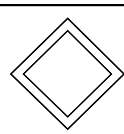
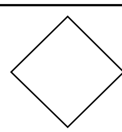
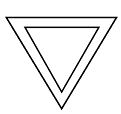
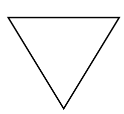
No.	Evaluation Items	Acceptance Criteria	Remarks
5	OSD Pattern	The HA is composed of sub-tasks which are represented by the standard OSD Patterns. The numbers in this column of Table 3.9-5 indicate the specific OSD Pattern used from Table 3.9-2.	
6	Task Support Requirements	Specific job aids, tools, or protective clothing needed. D: Support material such as some reference document or calculation sheet for sub-task action. T: Some support apparatus such as valve handling tool if required in the action. "D" or "T" appear in this column of Table 3.9-5 if either is required to support the action.	
7	Situational and Performance Shaping Factors	Whether there are any situational factors such as high stress or reduced staffing that may affect the required action. An 'A' in this column of Table 3.9-5 indicates that no factors exist that influence performance of the action; otherwise the factors are listed.	These factors are considered for the difficult and high work load actions.

8	Workplace Factors and Hazard	Whether there is any significant workplace factors or hazards that may affect actions required in the local area. Most actions are taken in the Control Room that is considered a good working environment void of hazards. .	Significant workplace factors considered: high or low temperature, radiant heat by high energy piping, noise, radiation, lighting, and roaring sound of turbine rotation. Potential hazards considered: falling materials, actions on a ladder, and actions at high elevations.

3.9.6 Task Linking and Cognitive Workload Analysis

1. OSD Pattern

The OSD represents operator and computer tasks (Automated tasks) in graphical scheme sequentially. The symbols for OSD are shown in Figure 3.9-1. Through the use of symbols to indicate actions, data transmitted or received, inspections, operations, decisions and data storage, the OSD shows the flow of information through a task. The information flow is shown in relation to both time and space. If detailed information on a given action is needed, code letters (S, V, W, T) may be used to indicate the mode of actions. The OSD is used to develop and present the system reaction to specified inputs.
In the OSD, the interrelationships between operators and equipment (including computers for human-machine interfaces) are easily displayed. Operator activities are sequentially categorized. Decision and action functions are clearly identified, and task frequency and load become obvious.

SHAPE			CODE	
MACHINE	HUMAN	ACTION	LETTER	MEANING
		Transmit	S	Sound
		Receipt	V	Visual
		Inspect	W	Walking
		Operate	T	Touch
		Decision		
		Storage		

* A code letter may indicate Mode of shapes

Figure 3.9-1 Symbols Used in Operational Sequence Diagram (OSD)

The OSD corresponding to each task is constructed by the following steps:

Step 1: Description of task scenario
- Represent elements of task in simple linguistic form
- Select appropriate detail level in design phase

Step 2: Break down job task into individual activities

Step 3: Activity assignment to human and machine
- Use the result of Function Allocation
- Assign each activity to operator or machine

Step 4: Description of activity sequence for functions assigned to the operator

Table 3.9-2 shows an OSD table which is used to record the analysis results. Fields in this table are described below:

- Operating Procedure Field: Task sub-steps are described sequentially.
- OSD Description Field: Human and machine (Automation) actions are represented using OSD symbols. The contents of task are described as activities in simple form. Activity description is broken down into individual actions (OSD symbols) such as ‘Transmit’, ‘Receipt’, ‘Inspect’ as shown in Figure 3.9-1. Each action is located in appropriate column (Human: SRO or RO, Machine: displays and controls) according to the output of the Function Allocation process. Finally all actions are connected to each other to represent the temporal sequence of the elements of the task
- Task Description Field: Key information of task execution such as reading plant parameters and identification of plant status.
- Example Steps Field: Specifies the detailed steps necessary for task execution.

Each task is categorized into following representative patterns;

1. Verify Parameter
2. Energize/de-energize the valves (Local action)Power on the valves at local
3. Open or close the valves
4. Start or stop the pump

4A. Jumper on/off motor control center terminal block (local action)

5. Set or reset the plant demand signal

5A. Place component control switch or controller in Pull-lock/Auto/Manual mode

6. Connect or disconnect the load to the electrical bus
7. Connect or disconnect the load to the bus (local action)
8. Open or close the valve (local action)

8A. Start or stop the pump(s) (local action)

9. Lock/Unlock the valve/component (local action)

10. GO TO or REFER TO action
11. Adjust the controller/control

In TA evaluation, response time for each task is evaluated using above template.

Table 3.9-2 OSD Pattern Sheet

Table 3.9-3 Extended Human Information Processing Model

Table 3.9-4 Time Required to Perform OSD Pattern Tasks

3.9.7 Results

The results of the TA for risk-important HA are presented in Table 3.9-5. There is a separate sheet for each of the risk-important HA identified in the HRA/PRA:

- Column 1 numbers the HA sub-steps.
- Column 2 describes the HA sub-steps

Required functions for human task accomplishment:

- Column 3 provides the information requirements for the sub-step and whether the information is available in the main control room (MCR) or locally
- Columns 4 and 5 specify the decision-making and communication requirements as defined in Table 3.9-1.
- Column 6 indicates the Time Required to complete the HA based on the summation of times for each OSD pattern.
- Column 7 indicates which OSD pattern this sub-step corresponds to. See Sub-section 3.9.6 and Table 3.9-2 for an explanation of OSD patterns and the OSD pattern corresponding to each number.
- Columns 8, 9, and 10 are used to document any task support requirements, situational and PSF, and workplace factors and hazards associated with the sub-step.

Results:

- Columns 11 and 12 specify whether the sub-step is a monitoring or control task and provides additional descriptive details.
- Column 13 specifies the number of operators involved in performing that sub-step.
- Column 14 indicates the type of operator that is required to perform that sub-step.

As shown in TA and Evaluation Tables, the results of the TA indicated that the risk-important HA can be completed within the time available specified by the PRA and safety analyses. This analysis assumes one SRO and one RO in the MCR and one local operator (if applicable)

The time required for HAs for events in Table 3.9-6 are based on both engineering judgment and GOMS evaluations. Column 7 of each TA and Evaluation Table (Table 3.9-5) specifies an OSD for each sub-step of a RIHA. As specified in Sub-section 3.9.6, OSD patterns clearly identify operator decision and action functions required to perform that sub-step. GOMS is then used to assess the work load and evaluate time requirements for each OSD pattern specified for each sub-step of the RIHA performed in the main control room. For example, OSD pattern 1 in Table 3.9-2 would be appropriate to analyze a sub-step of a task that requires the operator to verify a single plant parameter in the main control room as illustrated below.

GOMS applies the Model of Human Information Processor by Card, et al. as specified in Figure 3.9-2 to determine time requirements for OSD patterns. Basic HAs specified in Table 3.9-3 are assigned to each sub-step of each OSD pattern and evaluated for response time requirements using the Card et al. approach in the “Internal Processing” and “Work load” columns in Table 3.9-4 of this Appendix. The OSD pattern sub-step response times are then summed and the total time required to perform each OSD pattern is specified in the applicable Table 3.9-4.

For example, the total time required to verify a plant parameter (OSD pattern 1) is approximately 2.31 seconds; the total time required to start a pump (OSD pattern 4) from the main control room is approximately 3.48 seconds. Response times for some OSD patterns are based on engineering judgment. For example, OSD pattern 2, “Energize a valve”, OSD pattern 8 (open or close the valve- local action) and OSD pattern 9 (unlock the valve- local action) response times are estimated to require approximately 10 minutes, the basis of which is given in Table 3.9-4 for that OSD pattern. As indicated in Section 3.9.5, “Methodology”, the engineering judgment applied in the Phase 2a TA was verified through a table-top analysis performed by two operations experts (both SRO Instructors with PWR plant experience) who are familiar with U. S. NPP operations and the MHI US-Basic HSI as implemented in the MEPPI simulator.
Engineering judgment and GOMS evaluation are both used in determining the response time for RIHAs specified in Table 3.9-5.

Example 1: In Table 3.9-5 (36/44), “Establish RCS water level recovery and Charging Injection System Operation (LOCA, OVDR, LORH, LOOP, FLML)” is broken down into seven sub-steps with each sub-step assigned an OSD pattern, the time response requirements that have been analyzed by the GOMS approach (for OSD patterns 1, 3, and 4), and engineering judgment (for OSD pattern 8) in Table 3.9-5. The time required to perform each sub-step of this RIHA would be:

Sub-step 1: 2.31 sec	(OSD 1; response time based on GOMS)
Sub-step 2: 3.48 sec	(OSD 4; response time based on GOMS)
Sub-step 3: 2.31 sec	(OSD 1; response time based on GOMS)
Sub-step 4: 3.48 sec	(OSD 3; response time based on GOMS)
Sub-step 5: 10 min	(OSD 8; response time based on engineering judgment)
Sub-step 6: 10 min	(OSD 8; response time based on engineering judgment)
Sub-step 7: 3.48 sec	(OSD 4; response time based on GOMS)

Total time: 20 min.,15.06 sec.

Based on the time summary above, it has been shown that the time required to perform this RIHA is “Approx. 30 minutes” as indicated in column 6 of Table 3.9-5 (36/44), “Time required (OSD time)”. This time is also specified in Table 3.9-6 “Response Time Criteria for Risk significant human actions” in the “Time Required” column, which is less than the time of one hour specified in the “Time Available” column, indicating that there is sufficient margin between the Time Available (as defined in the safety analysis or PRA) and the Time Required (as determined by the HFE TA).

Example 2: In Table 3.9-5, (3/44), “Standby Charging Pump Start Operation (PLOCW, ATWS)” is broken down into two sub-steps with each sub-step assigned an OSD pattern, the time response requirements that have been analyzed by the GOMS approach only (for OSD patterns 1 and 4). The time required to perform each sub-step of this RIHA is:

Sub-step 1: 2.31 sec	(OSD 1; response time based on GOMS)
Sub-step 2: 3.48 sec	(OSD 4; response time based on GOMS)

Total time: 5.79 sec

Again, it is shown that the time required to perform this RIHA is “Within a few minutes” as indicated in column 6 of Table 3.9-5 (3/44), “Time required (OSD time)”. This time is also specified in Table 3.9-6 “Response Time Criteria for Risk significant human actions” in the “Time Required” column, which is less than the time of one hour specified in the “Time Available” column, indicating that there is sufficient margin between the Time Available (as defined in the safety analysis or PRA) and the Time Required (as determined by the HFE task analysis). The methodologies are based on the Japanese HFE program.

The “Time Required to complete actions” in Examples 1 and 2 above are merely a summation of the times required to perform each OSD as specified in Table 3.9-5 because the sub-steps for these RIHAs are not influenced by any other qualitative factors, such as Task Support Requirements, Situational and PSF, or Workplace Factors & Hazards.

Table 3.9-5 Task Analysis and Evaluation Table

Table 3.9-6 Response Time Criteria for Risk Significant Human Actions

Part 3 HSI System Verification and Validation (Phase 1b)

1.0 INTRODUCTION

This report discusses the second set, Phase 1b, of HSI tests in support of the HSI design process of the US-APWR and the Mitsubishi US operating plant modernization program, as described in section 1 of this report, US-APWR Overall Implementation Procedure. As such it represents the continuation of the test and evaluation program which has the goal of determining the changes needed to safely introduce the Japanese-Basic HSI into US operation as reported in December 2008, as Phase 1a Technical Report, MUAP-08014-P (R0).

In general, the tests described here in follow the same methodology as Phase 1a and continued the assessment of the full main control room HSI, with the two exceptions. First, the Phase 1b tests used the dynamic simulator with human in the loop scenarios focusing on the evaluation of HSI design changes that were proposed in response to the Human Engineering Discrepancies, HEDs. Second, they began the process of integrating HFE analysis and HSI testing by reviewing the risk important human actions and including a sub set of these actions into the test scenarios. Results of this program are captured and transferred to other elements of the overall HFE program through the HED process, Part1 of this report, and through this and a follow up the detailed-level documents. Where this report is only a summary of methodology and results, the detailed-level documents, will be a complete document including data, analysis and robust conclusions and recommendations for use by the HSI designers, and analysis's and developers of the other HFE elements, such as function and task analysis, HRA/PRA/ procedures and training. The detailed-level documents will be an internal Mitsubishi document meant to be used within the design process and auditable, upon request, by the NRC. This summary report finds its bases primarily on the subjective data collect, the detailed analysis and analysis of the objective performance data was not completed at the time of publication and will be reported on in the detailed-level documents.

The iterative process of analysis, design and test will continue over the next 2 years as the HSI for the US-APWR is refined, leading up the full Verification and Validation as recommended by NUREG-0711 Rev.2, in Phase 2 as described earlier in this report

The test results as reported here, fully support the above process. Changes made to the HSI, as assessed in Phase 1a, have been convincingly demonstrated to not only have better acceptance by US operators, but also measurably enhanced their performance. This, however, did not result in absolute, a number of HFE issues were identified through the test data and or new HEDs that will now be evaluated for next round HSI design changes.

2.0 HUMAN ENGINEERING DISCREPANCIES (HED)

2.1 Description of the HED Process

As a result of the Phase 1a testing, over 700 HEDs were documented in the formal project HED data base. These represent un reviewed, raw HEDs from all the operating crews that supported the 1a testing, the V&V team and all qualified observers to the test facility, including representatives of the industry and the NRC, The test facility, located at MEPPI head quarters, is made up of a full scope dynamic main control room simulator representative of the, at that time, current HSI design. These Phase 1a HED were then binned by the V&V team, using results from the test data analysis, into higher level HFE issues termed "Parents." The Parents as well as the raw HEDs were then evaluated one by one by the designers and independently by the HFE Expert Panel in committee session, resulting in a set of design changes that were considered to give reasonable assurance of HED and parent resolution. The expert panel alone represented a senior manpower intensive exercise using the equivalent of approximately 2000 person hours.

The design changes that reasonable could be made in the simulator HSI, were then considered for inclusion in the Phase 1b tests, as described in this report. As design changes were completed, the test scenarios were developed to include multiple independent failures which would stress the new designs along with the full HSI.

A procedure that used a two step process, described later in the report, to document the HEDs resulting from this series of tests was developed and applied which resulted in a comprehensive binning of the new and old HEDs for evaluation as before. At the time of writing this report, this evaluation is in the planning stage.

2.2 Summary of HEDs Resulting from Phase 1a Testing

As a result of the HED process from Phase 1a verification and validation testing during 2008, a set of HSI design changes were arrived at. Those that could be implemented on the MEPPI simulator prior to the start of the Phase 1b were and became part of the test scenarios to allow their testing in a dynamic human in the loop setting. Appendix 8.1 presents these HEDs, their parents and how they were incorporated into the scenarios. Appendix 8.2 presents the order in which the scenarios containing the HEDs were run and Appendix 8.3 shows the 8 scenarios along with which HED s were included and how. It is the intent of the detailed-level documents, which will be available to the NRC for audit, to address each HED tested in a level of detail that is suitable for HED resolution by the HSI Expert Panel or feed back to the HSI designers.

2.3 Description of Changes to the MEPPI Simulator

In order to incorporate many of the Phase 1a proposed HSI design change, that were agreed to by the designers and the Expert Panel, into the tests for Phase 1b, the MEPPI simulator underwent changes to the Japanese-Basic HSI. In some cases the change was implemented in full and in some cases, due to schedule constraints, it was partially implemented and in still others only static demonstrations were used to complete the testing. These changes, along with several additional new automation functions are described in Appendix 8.5.

2.4 Description of Scenario Selection

Dynamic simulator scenarios were developed to exercise human system interface design changes that were implemented as a result of HEDs that were generated in Phase 1a testing and evaluation activities. The specific identification of HED-to-scenario assignments are described in Appendix 8.1 and 8.3. A total of eight scenarios were developed by the V&V team nuclear plant systems engineer and nuclear training instructor, and reviewed by the teams HFE and HRA/PRA experts, to encompass all HED design changes made for Phase 1b.

In addition, the US-APWR Risk Significant Human Errors, defined in Part 2 Chapter 2 HRA, was reviewed to select a subset of risk important human actions that could be incorporated into the test scenarios. This was not intended to be an exhaustive test of these human actions but instead the beginning of the needed assessment of the Phase 1b HSIs ability to limit these important human errors. As the testing program continues this subset of risk important human actions will be expanded to eventually include all risk important human actions in the final Phase 1b full V&V tests for the US-APWR HSI. Results of the Phase 1b tests and all future tests will be shared, through the HED data base, reports and face to face meetings as needed, with the HRA/PRA team so that the insights gained will be incorporated into future analyses updates.

Static part task tests were integrated in Phase 1b testing to solicit operator feedback from the test crews on human system interface design features that could not be incorporated into the simulator for dynamic testing in a timely manner, reference section 4.2.2 of this report.

3.0 NEW HSI FEATURES TESTED

3.1 Diverse Actuation System (DAS) Diverse HSI Panel (DHP)

The installation of the DHP for Phase 1b testing allowed for the evaluation of operator response in coping with a beyond design basis common cause failure in the main control room digital human system interface. Detailed descriptions of DAS and the DHP are located in MUAP-07006 Defense in Depth and Diversity, Section 6, MUAP-07007 HSI System Description and HFE Process, Section 4.11.4, and the DCD Section 7.8 Instrumentation and Controls.

3.2 Computer Based Procedures

Operating crew response to scenario events with the normal full complement of human system interface was in accordance with scenario related procedures that were developed and installed in the computer based procedure visual display units (paperless procedures). Some examples of the types of procedures in the available compliment include normal station operating procedures, alarm response, abnormal, and emergency procedures. A more detailed description of computer based procedures, as tested, is found in MUAP-07007 HSI System Description and HFE Process, Section 4.8.

4.0 METHODOLOGY

4.1 Overview of Approach for Achieving Test Objectives

Phase 1b utilized a similar test methodology as was used in Phase 1a testing. The methodology was slightly modified to address the specific goals of Phase 1b:

- test Phase 1a HED resolutions implemented on the MEPPI simulator,
- test new HSI features not tested in Phase 1a,
- continue to test the full HSI.

Among the major HSI changes that were implemented in response to Phase 1a HED and tested in Phase 1b, a number were found to be notable due to their direct measurable effect on human performance and are listed below :

- An additional VDU screen at the SRO’s desk that allowed the SRO to monitor the ROs detailed control actions;
- Modifications to the LDP including:
  - Use of up/down arrows to indicate trend information
  - Areas devoted to critical safety function
- Automated auxiliary feedwater control

Among the new US-APWR HSI features tested in Phase 1b included:

- OK and BISI panel added to the LDP
- computer based procedures
- Diverse Actuation System/Diverse HSI Panel (DAS/DHP)
- Mode-dependent LDP
- Ability to create user-defined trend displays and to display them on the variable area LDP
- Ability to enter and display Tag-outs on the LDP

In addition to testing new US-APWR HSI elements, Phase 1b attempted to expand the scope and complexity of the test scenarios to include:

- Inclusion of scenarios that sampled risk significant human actions
- Inclusion of scenarios where more than one critical safety function was challenged requiring the crews to utilize function restoration guidelines
- Inclusion of instances where automated systems failed enabling testing the ability of the crews to detect automation failures and manually take-over automated functions.
- Inclusion of scenarios that included multiple independent failures.

A summary of the test methods used is provided below. Supportive details can be found in the detailed-level documents.

4.2 Test Methods

As in the case of Phase 1a, Phase 1b testing employed:

- experienced plant crews as test participants (5 two-person crews)
- realistic normal and emergency scenarios (8 scenarios, plus crews 3 and 5 performed an additional SGTR)
- Collection of objective data of operator performance as well as subjective operator feedback collected via questionnaires and verbal debrief sessions.

As in Phase 1a crews were tested over a four day period. They arrived on Monday afternoon. They were provided approximately 6.5 - 8 hours of training (4 hours on Monday afternoon, and 2.5 - 4 hours on Tuesday morning). As most of the operators in the Phase 1b test had also participated in Phase 1a, training primarily focused on HSI changes from Phase 1a.
All two person crews then participated in 8 test scenarios (5 with the non-safety VDU referred to as the O-VDU; 1 with the DAS, and 2 with the S-VDUs), reference Appendix 8.4 and Appendix 8.5, scenarios and test success criteria, respectively:

- Manual load run-back with failed instrument channel, controller mode malfunction, etc. (O−VDUs)
- Large Break LOCA with failed Aux. feedwater automation and circ water pump trip (O−VDUs)
- Small break LOCA with violation of two critical safety functions (O-VDUs)
- SGTR with operation from O-VDUs and with Aux. F/W automation (O-VDUs)
- DAS/DHP operation due to common cause failure (DAS/DHP)
- SGTR with operation from the S-VDUs and with Aux. F/W automation (S-VDUs)
- Small break LOCA from S-VDUs with Violation of two critical safety functions (S-VDUs)

- High pressure feedwater heater tube leak (O-VDUs)

As noted above, if time permitted they also were presented the SGTR scenario a second time, as the last scenario of the week, in order to assess the impact of training on the speed and facility with which they could perform the SGTR. Two of the five crews tested were able to run in a second SGTR. In this scenario the crews were given the additional guidance to gain control of the event as quickly as possible without having the effected steam generator going solid.

Following each scenario operators filled out a short questionnaire followed by a short (15 minute to 30 minute) verbal debrief where the operators were given the opportunity to mention any HEDs of particular concern.

After the DAS scenario operators filled out a final DAS questionnaire. It included likert- ratings questions of the primary features of the DAS as well as space to write in HEDs. This final written questionnaire served as the primary source for operator input on HEDs for the DAS HSI. Since only one scenario was conducted with the DAS, a post-scenario form was not filled out after the DAS scenario.

After the two safety VDU scenarios operators filled out a final safety VDU questionnaire. It included likert- ratings questions of the primary features of the safety VDUs as well as space to write in HEDs. This final written questionnaire served as the primary source for operator input on HEDs for the safety VDU HSI.

At the completion of the week, participants were given a final written feedback questionnaire on the non-safety VDU HSI to fill out. This questionnaire included questions on all features of the non-safety VDU HSI and provided the operators the opportunity to list HEDs of particular concern. This final written questionnaire served as the primary source for operator input on HEDs for the non-safety VDU HSI. Operators took approximately an hour to an hour and a half to fill out this questionnaire.

Following the written final feedback questionnaire, a final verbal debrief session was conducted where operators were provided the opportunity to explain and discuss the HEDs they listed. This final verbal debrief took approximately one hour.

All sessions were videotaped and the video tapes reviewed as in the Phase 1a tests..

4.2.1 Major Changes from Phase 1a to Accommodate Phase 1b Objectives

While Phase 1b primarily followed the test logic and procedure used in Phase 1a, a number of changes were made to address specific Phase 1b objectives as well as to streamline the data collection and analysis process based on Phase 1a lessons-learned.
Primary changes included:

- The scenarios were developed to include specific events/malfunctions intended to exercise HSI modifications that resulted from Phase 1a HEDs.
- The test questionnaires were modified to include questions that addressed the HSI modifications as well as the new HSI features that were not tested in Phase 1a
- A section was added to the final non-safety VDU HSI feedback questionnaire and safety VDU HSI feedback questionnaire asking operators to indicate whether the HSI changes provided in Phase 1b were an improvement over the HSI in Phase 1a.

- Part-task and static demonstrations were conducted to address HSI features that were not fully implemented in the simulator but could be demonstrated for purposes of eliciting operator feedback
- The final feedback questionnaires (one for DAS, one for safety VDU, one for Non-safety VDUs) were used as the primary means of collecting HEDs from the operators participating in the test.

4.2.2 Use of Part-Task and Static Demonstrations

Several static and part-task demonstrations were conducted to obtain operator feedback on aspects of the HSI that were not fully implemented in the simulator to allow dynamic scenario testing. These static and part-task demonstrations were conducted in an interspersed fashion around the scenarios, to take advantage of available time that arose.
Part-task and static demonstrations included:

1. Main Control Room, MCR, Ergonomics- show with tape on the floor, the possible limits if positioning the shift managers control consol with respect to the operators control console. Discuss with the RO and SRO the noise level in the CPNPP MCR Ask the crew if the two consoles should be moved closer. Also document any other console relationship layout changes that are recommended, i.e. elevation of the shift manager console.

2. Computer Based Procedures, CBP, Display Screen Ergonomics- after the crew has had a chance to use the CBPs in several scenarios, discuss the mock up of the raised display on the STA console. Discuss readability, glare and loss of table top lay down surface area.

3. Mode Dependent LDP- after several scenarios change the LDP to the prototype of the Mode #6 DISPLAY. Discuss the plan to have the ability to switch the LDP display for different plant modes. Solicit crew input on the general concept and the specific content for Mode #6

5. Task Displays- demonstrate the prototypes of task specific displays on the VDUs. This should include task displays for Rx trip and SI. Also discuss with the crew specific content and navigation to displays GD 6.1, 2, 3 and EM 4, 5.

6. Pull to Lock- demonstrates the pull to lock permissive requirement on the SVDUs to lock out automatic activation of safety components on the O-VDUs for activities such as maintenance activities. Discuss the design requirement, specific actions and specific control displays on the VDUs and the LDP.

7. Tag Out- allow the RO to exercise, during and outside of the scenarios, the tag out system from the maintenance PC, tag out request, and the O-VDUs, tag out acceptance and implementation. Record their debrief comments.

8. Custom Trends- allow the RO to set up and the RO and SRO to use trends they set up using the prototype of the Customized Trend System. This should be during a scenario and independent from the scenario tests. The latter will take at 15 minutes. Show them how to select the parameters and scales, the fact that they can put up to 5 parameters on each trend plot and up to 4 plots on the VDU or LDP. Demonstrate the zoom feature on the VDU. Ask about usability, scales and dynamic scaling, specific custom trends that they would save.

4.2.3 Test Crews

Five two-person crews made up of experienced Comanche Peak plant operators (one SRO and one RO) participated in the evaluation. In the case of three of the crews, both crew members had participated in Phase1a testing. In the case of the remaining two crews, one of the crew members had participated before and one had not (in one case the RO was new, in the other case the SRO was new). Training of the test crews was based on the assumption that most had participated in the Phase 1a tests and were therefore familiar with the HSI and the test process. The 2 crew members that did not were treated as the exception and given remedial training. The training is briefly described in Appendix 8.3.

Operating crew training for Phase 1b validation activities was supplemental to previously administered initial training during Phase 1a V&V activities for repeat crew members. The initial training description is explained in the Phase 1a Final Report. Two crew members (one RO and one SRO) did not participate in Phase 1a activities and thus were given accelerated initial control room HSI training prior to commencing testing activities. Phase 1b training was then administered to all crew members and consisted exclusively of a training handout which concatenated descriptions of the HEDs that were chosen to be implemented as a result of being generated in Phase 1a. This training was approximately 4 hours in duration and discussed major HSI changes including:

1. Operational VDU custom trending
2. Audio alarm reduction
3. Computer based procedures
4. OK monitor
5. Bypass and Inoperable Systems Indication
6. System auto status monitor
7. Critical Safety Function monitor
8. Trending on the LDP
9. Diverse HSI Panel
10. Safety VDU HSI changes

HSI changes that were implemented on the MEPPI simulator were demonstrated by a dynamic means where practical. Minor verification type HSI changes such as labeling enhancements were also listed in the training.

4.2.4 Observers

The test procedure was developed, administered and analyzed by a team made up of three HFE experts, one of which also had HRA/PRA experience, and one plant operations/ training expert. The same team developed and conducted the Phase1a evaluation.

The four team members served as test observers during the test scenarios, and were responsible for documenting any problems in operator performance that they observed during the scenarios on post-scenario observer forms. The plant operations expert and one of the three HFE experts were present during all eight weeks of testing. The other two HFE experts switched off so that on any given test week there were at least three expert observers – two HFE observers and one plant operations expert. The observer team for the Phase 1b testing were responsible for test procedure design, scenario developement, modification of the data collection tools from Phase 1a, and data analysis. They are members of the 8 person Expert Panel involved in the evaluation of the HEDs and performed the same roles for the Phase 1a testing. The joint experience of the observors includes; HFE,HF test design and assessment, nuclear power plant operations, HSI control room design, and HRA/PRA.

In addition to the primary observer team, other observers were routinely present during the test scenarios and debrief sessions. Additional observers included MHI and MELCO designers, simulator experts, instrumentation and control engineers and a manager from Luminant power. All individules were encouraged to document HSI concerns through the HED process and take part in the verbal debriefing sessions described.

4.2.5 Data Collection Instruments

A number of objective and subjective data collection instruments were used. The objective was to obtain multiple converging measures to assess the impact of the HSI on individual and crew team performance.
Formal questionnaire instruments included:

- Post-scenario operator forms – This form included 5-point likert rating questions (where 1 was poor; 3 was acceptable; and 5 was very good) that asked operators to rate their technical performance, teamwork, situation awareness, and mental and physical workload. It also asked them to indicate whether they felt the crew size was sufficient for the scenario. The form also included space for the operators to list HEDs that they felt contributed to performance problems.
- Post-scenario observer form – This form was used by the primary test observers (the operations expert and the two or three HFE experts) to document any technical performance problems they observed during the scenario (e.g., errors of omission; errors of commission; delays in taking appropriate action) as well as any problems in monitoring/detection; situation awareness, teamwork, or work-load. Observers were also asked to rate crew technical and team performance on a 5 point scale. A consensus post-scenario observer form was then filled out jointly by all the expert observers that documented observer consensus on each item on the post-scenario observer form.
- Final operator feedback forms. Specific final operator feedback forms were developed for the non-safety VDU HSI; the safety VDU HSI; and the DAS respectively. These forms included summary 5-point likert-rating questions (1 = very poor; 3 = acceptable, and 5 = very good) that asked for operator self-ratings of the impact of that HSI on their situation awareness, ability to take control actions in pace with plant process dynamics; ability to follow procedures; ability to catch and correct own errors, mental workload and physical workload; teamwork and ability of the SRO to supervise the operator activities and control actions of the RO. It also asked about the ability of the HSI to support two-person operation. The final questionnaires also included 5-point likert rating questions intended to evaluate different aspects of the primary features of the HSI. Space was provided for operators to write in HEDs.
- Unlike the Phase 1a tests, where all HEDs from all sources were directly entered, unaltered or reviewed, into the HED data base, the Phase 1b tests applied a two step procedure. All potential HEDs generated by the test crews were reviewed by at least two of the expert observers at the end of each week's testing and a consensus based evaluation made to determine if:
    1. the HED represented a repeat of an HED already in the HED data base,
    2. the HED represented a new HED,
    3. the HED represented an HED based on the HSI design changes made for 1b,
    4. the HED was not an HED.

  The results of the evaluation were then documented and entered into the HED data base for formal tracking and resolution.

In addition to these formal questionnaires a number of data collection guidance forms were developed to support the expert observers in following the scenarios and recording operator actions and timing. Check-lists were also developed to support structured verbal debrief sessions.

Time-stamped plant parameter data were also collected directly off of the simulator to provide objective operator performance data with respect to their ability to maintain plant parameters within required tolerance bands, ref Appendix 8.4 for the acceptance criteria used in each scenario, and to take timely action to avoid excessive plant process perturbations/excursions.

5.0 SUMMARY OF RESULTS AND OPEN ITEMS

5.1 Conclusions from Final Operator Feedback Data

As noted in section 4, above, the basic approach to analyzing the Phase 1b test used the same ‘converging methods’ approach that was used in the Phase 1a test. Both objective crew performance measures and subjective operator feedback measures were collected and analyzed.

Due to scheduling constraints on the part of the utility, the last crew had to be rescheduled several weeks later than originally planned. As a consequence the results summarized in this report are based on the first four crews. The final results based on all five crews will be fully documented in the detailed-level documents.

A summary of major results is provided below. A more complete description of results is provided in the detailed-level documents.

The results reported in this section include operator ratings provided on the final feedback questionnaires as well as ratings and observations provided by the expert observer team.

5.2 Open Items

6.0 CONCLUSIONS

7.0 REFERENCES

7-1 U.S. Nuclear Regulatory Commission, Human Factor Engineering Program Review Model, NUREG-0711, Revision 2.

7-2 Design Control Document for the US-APWR, Chapter 18, Human Factors Engineering, MUAP DC018, Revision 3, March 2011.

7-3 Design Control Document for the US-APWR, Chapter 19, Probabilistic Risk Assessment and Severe Accident Evaluation, MUAP DC019, Revision 3, March 2011.

7-4 Defense in Depth and Diversity, MUAP-07006, Revision 2, September 2009.

7-5 HSI System Description and HFE Process, MUAP-07007, Revision 5, November 2011.

7-6 U.S. Nuclear Regulatory Commission, Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants, NUREG-0800.

8.0 APPENDICES

Appendix 8.1 Phase 1a Generated and Expert Panel Reviewed HEDs Included in Phase 1b Testing

Appendix 8.2 Weekly Test Schedule

Appendix 8.3 Scenarios

- Operators successfully ESTABLISH SI flow in ONE (1) Train. Acceptance criteria: Crew has ESTABLISHED SI flow to the core AND Aux. F/W to the SGs

- TERMINATE scenario 8 **(HED #62-1;2)**

Appendix 8.4 Scenario Acceptance Criteria

Appendix 8.5 Simulator HSI Modifications Made from Phase 1a to Phase 1b as a Result of Phase 1a HEDs