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Revision 0

March 2006

AP1000 Standard Combined License Technical Report

AP1000 Human Factors Engineering Program and Human System Interface Design

Revision 0

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Nuclear Power Plants
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AP1000 Human Factors Engineering Program and Human System Interface Design Status Report March 2006

1.0 Purpose and Scope

The AP1000 human factors engineering (HFE) design and implementation process is depicted in Figure 18.1.1 of the AP1000 DCD[1] as shown below. Elements have been completed or are currently underway in the Planning, Analysis and Design phases. This technical report briefly describes the HFE work that (a) was completed during AP600 design certification, (b) has been completed during the current AP1000 Human System Interface (HSI) design process, (c) is currently ongoing and (d) is to be completed later during the HFE program.

This report identifies the activities and documentation that complete combined license information item 18.2-1 and the planning, activities, and documentation that complete combined license information item 18.8-1

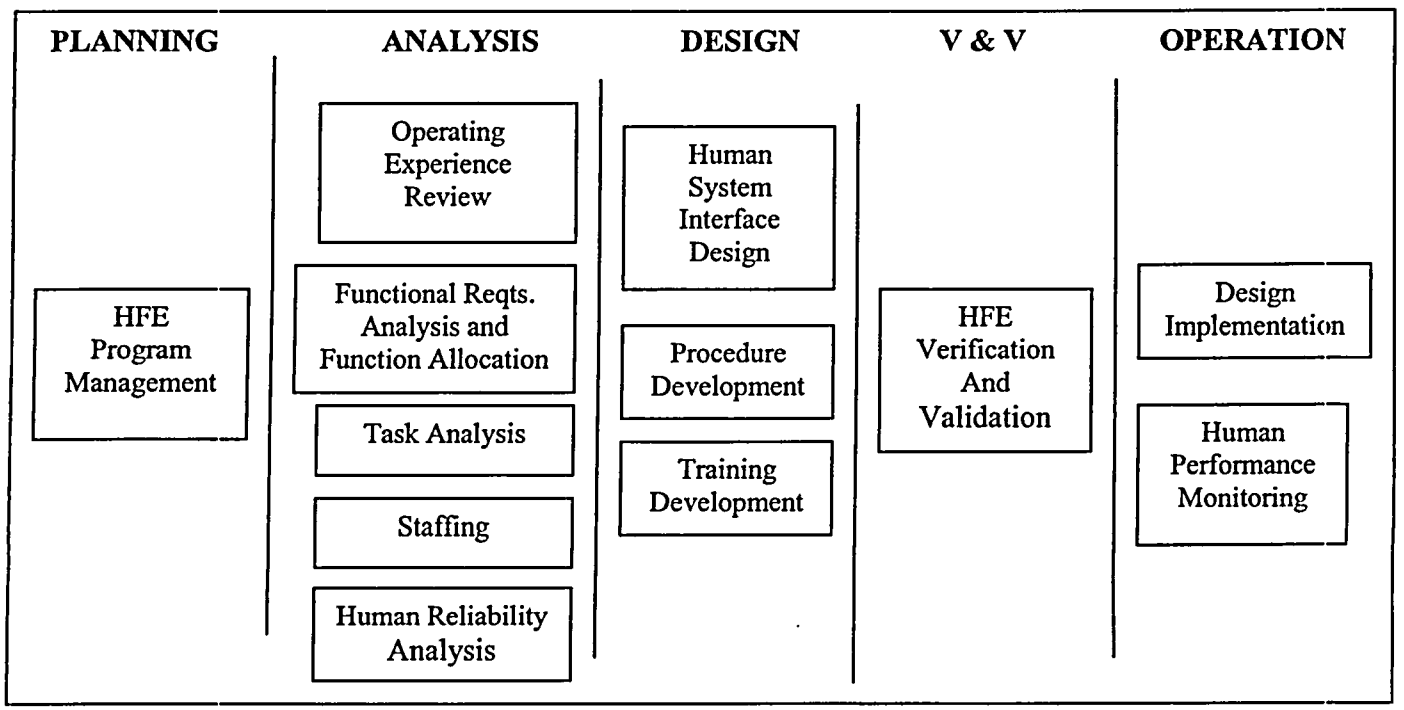

Figure 18.1-1 AP1000 Human Factors Engineering Design and Implementation Process

2.0 BACKGROUND

AP1000 received its Final Design Approval from the USNRC in September 2004 and was granted Design Certification by the NRC on December 30, 2005. During the AP1000 design certification licensing efforts, a control room and HFE/HSI design process was submitted and approved. Realizing that Instrumentation and Control (I&C) and HSI technology changes rapidly, Westinghouse deferred the detailed design of the control room and operator interfaces until the entire HSI design process would be conducted. This allows the latest technology to be used when a plant is actually going to be built.

A key focus of an AP1000 Combined Construction and Operating License (COL) application is to complete Design Certification COL items related to the Main Control Room (MCR) and Human System Interface (HSI) design. To fulfill the COL items for upcoming applications Westinghouse is performing a comprehensive Human Factors Engineering program in conjunction with development of an advanced set of HSI resources for a compact control room.

The Combined License applicant is expected to address the twelve elements of the Human Factors Engineering Program Review Model[2] (NUREG-0711). Document submittals and timelines have been developed to support timely NRC review of COL applications.

Westinghouse expects to generically close design-centered COL items from Chapter 18 of the DCD. The COL items being addressed relate to conducting the HFE program, performing task analysis, defining roles and responsibilities for the MCR staff, integrating results of Human Reliability Analyses in the design process, performing the HSI design, the procedure development program and planning the HFE Verification and Validation implementation. The COL items that remain to be addressed relate to the design of the Emergency Operations Facility, plant staffing levels and staff qualifications, the training program and planning for human performance monitoring. These items are outside the scope of this report.

Some Inspections, Tests, Analyses and Acceptance Criteria (ITAAC) from Tier 1 of the AP1000 DCD design commitments overlap exactly with some of the DCD Chapter 18 HFE program's COL items. The results of the current program will form the basis for ITAAC completion. Other ITAAC commitments will be fulfilled later during the design process (e.g. conducting the HFE V&V) or require inspection of specific characteristics of the as-built MCR and remote shutdown workstation.

The following outlines the completion and status of the elements in the AP1000 HFE program.

3.0 AP1000 HFE PROGRAM STATUS

3.1 HFE Elements Completed during AP600 Design Certification

This section describes HFE program elements of NUREG-0711 that were completed as part of the AP600 Design Certification review.

Operating Experience Review (AP1000 DCD 18.3)

The purpose of the Operating Experience Review (OER) is to capture useful human factors-related feedback and lessons learned obtained at comparable nuclear facilities. This activity was completed during the AP600 design certification with no additional work required for AP1000 COL application.

The OER information has been sorted according to its relevance to specific I&C systems and HSI resources and disseminated to HSI resource engineering leads.

A supplemental OER is being performed to assess operating experience (1) after completion of the AP600 OER and (2) related to specific HSI products being applied in AP1000 that are already in nuclear industry use (e.g., computerized procedures). While there is no AP1000 licensing commitment in this regard, the supplemental OER is being performed because it is prudent from a HSI design perspective.

Functional Requirements Analysis and Functional Allocation (AP1000 DCD 18.4)

The Functional Requirements Analysis and Allocation identified the functions that are required to safely operate and maintain the facility, and identified their allocation to either an automatic control system function, the human operator or a combination of the two. This analysis was completed for AP600 as documented in Section 18.4 of the DCD. The AP600 analysis applies equally to the AP1000 design, as the plant design from an operational perspective is unchanged.

3.2 AP1000 COL Items to be Completed Prior to COL Application

The following activities will be completed prior to COL Application to fulfill design-centered COL items in the AP1000 DCD.

HFE Program Management (AP1000 DCD 18.2)

A HFE Program Plan is described in Section 18.2 of the AP1000 DCD in the context of supporting the design of the AP1000 Human System Interfaces (HSI). One of the first initiatives of the current program was to complete a comprehensive AP1000 HFE Program Plan that details the scope, organization, process, methodologies and deliverables that will be employed by Westinghouse to fulfill the commitments in the DCD. This plan describes the HSI design team's responsibilities, its authority, and its organizational placement within the overall AP1000 design organization. Key human factors specialists and HSI resource designers are identified. Processes and procedures to be used by the design team are identified. An HFE issues tracking system and its intended use is described and has now been implemented for project use. The major activities of the AP1000 HFE process and a timeline for high level milestones are included to support timely execution of the HSI design.

The AP1000 HFE Program Plan[4] has been formally issued and fulfills COL Item 18.2-1 in the DCD.

Task Analysis (AP1000 DCD 18.5)

Two complementary types of Task Analysis activities are performed in the AP1000 HFE Program Plan – Functional Based Task Analysis (FBTA) and Operational Sequence Analysis, including both the OSA-1 and OSA-2, as described in DCD Section 18.5.

The FBTA decomposes functions from two primary plant goals: (1) to generate electricity and (2) to prevent radiation release. At the 4th level of decomposition from these goals 19 functions were identified (Figure 18.5-1 of the DCD). Each of these Level 4 functions have now been analyzed by decomposing them further into systems (Level 5), sub-functions (Level 6), components (Level 7) and support systems (Level 8), eventually identifying information and controls necessary to monitor and control the function.

The FBTA results support development of a functional display set and HFE verification of the HSI. This analysis is now complete and a final report is under internal review.

Operational sequence analysis is a more traditional task analysis methodology that identifies task characteristics for a representative set of tasks to provide input to the HSI design and criteria for Task Support Verification. Tasks have been selected that include: (1) the full range of operating modes including startup, normal operations, abnormal and emergency operations, transient conditions, and low-power and shutdown conditions, (2) risk important tasks, and (3) maintenance, test, inspection and surveillance actions. OSA-1 is well underway with documentation of a detailed methodology, development of a structured database and analysis of initial sequences completed. It is scheduled to be completed later this year. OSA-2 is performed later in the design process as it is more focused on human performance issues in using the HSI resources.

Completion of these task analysis activities will fulfill COL Item 18.5-1 and form the basis for completion of ITAAC Design Commitment 2 in Tier 1 Table 3.2-1.

An AP1000 MCR Staffing Roles and Responsibilities[5] document has been completed defining the AP1000 control room staffing assumptions, the scope and responsibilities of each main control room operational position (considering legally mandated staffing requirements) and expected staffing alternatives. This document serves as a foundation for developing a concept of operations for the AP1000 HSI resources. This document, fulfilling COL Item 18.5-2 in the DCD (actually identified in the task analysis section but pertaining to staffing) will be submitted to NRC as a separate technical report.

Definitions of specific staffing levels, crew structures, and staff qualifications to satisfy COL Item 18.6-1 are outside the scope of this document.

Human Reliability Analysis (AP1000 DCD 18.7)

Two Human Reliability Analysis integration activities have been performed in the early stages of the HSI design process. The first systematically identified critical human actions and risk-important tasks based on Probabilistic Risk Assessment studies. The second identified risk-important Maintenance, Inspection, Test and Surveillance tasks. A report documenting both of these activities has been completed and made available as an input to task analysis, HSI design, training, procedure development and the HFE validation activities. This HRA Integration Report[6], fulfilling COL Item 18.7-1 in the DCD will be submitted to NRC as a separate technical report.

Human System Interface Design (AP1000 DCD 18.8)

The physical facilities from which AP1000's HSI resources are accessed are known as the operations and control centers. These include:

- Main Control Room (MCR),
- Remote Shutdown Room,
- Technical Support Center (TSC)
- Operations Support Center
- Emergency Operations Facility and
- Local control stations.

The AP1000 HSI devices within these centers provide sufficient resources to monitor and operate the plant.

The purpose of the AP1000 MCR is to provide a continuously habitable location that allows operators to monitor and control the plant processes over their entire operating range, including emergency operations. The major tasks performed in the MCR include monitoring, managing, and controlling plant processes under normal, abnormal, and emergency conditions, both to efficiently produce power and to protect the health and safety of the public.

The AP1000 control room employs a set of HSI resources that provides a uniform capability for monitoring, control and procedure execution across plant systems. These HSI resources include:

- Computerized Procedure System (CPS)
- Alarm management system (AMS)
- Non-safety displays and soft controls
- Wall panel information system
- Qualified Data Processing System (QDPS) displays
- Fixed-position controls

To date the AP1000 HSI design program has focused on the main control room and HSI resource designs. A generic compact control room development facility has been converted to a facility reflecting the AP1000 MCR design. The facility includes operator and supervisor consoles and a dedicated safety panel, with the full complement of HSI devices, and a prototype set of WPIS large screen displays. AP1000 simulator models are being developed in parallel with the HSI prototypes and integrated into the facility on a system-by-system basis to support HIS engineering tests. By the end of 2007 it is intended that an AP1000 specific control room simulator will exist with sufficient fidelity of the models and HSI to support HFE integrated system validation.

Planned HIS engineering tests are being conducted early in the HSI design process. The purpose of these simulation tests is to obtain feedback (both positive and negative) from prototype HSI designs early in the design process in order to provide timely identification of issues and insights for design refinement. A cross section of nuclear control room operators and supervisors is used in order to obtain realistic results and to benefit from their operations experience. The tests provide data in the form of verbal feedback from test participants via questionnaires, workload ratings and debriefing sessions, also in the form of recordings of operator actions via a commercial software package. Recordings provide video and data capture of plant and process events, parameter data, use of different screens, and use of individual controllers. The recordings are then analyzed in detail.

The first HIS engineering test addressed the specific design issue of universal soft controls (e.g. controlling both safety and non-safety systems/components from the non-safety workstations). This test was completed in June 2005. The data has now been analyzed, feedback from observations has been provided to the HSI resource design process and a final test report[7] has been completed. The report specifically provides findings related to the soft control issues addressed in the test. It also provides resulting design implementation issues to be implemented in the HSI designs before conducting the second engineering test. A more comprehensive test of "control room HSI integration" will be performed in May 2006 to assess operations in a compact, video-based control room. This test will use all HSI resources and feature a broader range of plant systems to support the selected steam generator tube break scenarios.

In addition to prototype designs to support the engineering tests, the formal design process for each of the HSI resources is proceeding. The HSI design process is depicted in Figure 18.2-3 of the AP1000 DCD within the dashed lines. Interfaces to the other HFE Program elements are shown as interfaces to or from the HSI design box. The Operations and Control Centers System's (OCS) high level functional design is

being captured in an OCS System Specification Document[8]. This document is currently being revised to reflect the current AP1000 MCR and HSI direction.

The HSI Resource functional design block depicted in Figure 18.2-3 is being captured in functional requirements documents being created for each of the HSI resources. Four of these documents (References 9-12) were completed late in 2005, permitting an initial multi-disciplinary design review to be conducted. This review of the functional requirements allowed independent reviewers from different disciplines within Westinghouse and from utility participants to provide feedback on the HSI designs from a wide range of perspectives, including but not limited to plant operations. Issues identified during the design review are in the process of resolution. Functional requirements documents for the other resources (for example wall panel information system and nuclear application system) are currently being completed.

The Design Guidelines Documents block depicted in Figure 18.2-3 is being addressed by a single document, the AP1000 HSI Design Guidelines. This overall HSI design guidelines document will provide a set of human factors standards and guidelines that are tailored for the AP1000 HSI resources. These guidelines are intended to be used directly by designers to ensure consistent application of human factors principles and consistent implementation of interface design. The document will also serve as a basis for the criteria used in HFE Design Verification. Guideline documents have also been generated for (1) development of alarm input from plant system designers and (2) development of displays.

Work will continue on the HSI resource designs to create design specifications for each of the HSI resources addressing the Design Specifications block in Figure 18.2-3. This work is just getting started for some of the HSI resources. Later in the design process system software and test hardware arrangements will be integrated to assure that the resources are prepared sufficiently for the initiation of HFE V&V activities.

Completion of the HSI documentation defined above completes the documentation requirement of COL Item 18.8-1 and ITAAC Design Commitment 3 in Table 3.2-1.

Procedure Development (AP1000 DCD 18.8)

A significant effort is in progress to create AP1000 emergency operating procedures, abnormal operating procedures and normal (general) operating procedures. This is expected to be completed prior to COL application. From an HFE perspective, the results of the HFE analyses and the HSI design will be communicated to the organization developing procedures to effectively allow integration. Of particular importance for AP1000, which uses computerized procedures, are issues of shared concern between the procedure development and HSI design organizations. These include procedure V&V using automated tools, the configuration control of procedures in the electronic environment and the transition from computerized procedures to backup hardcopy procedures.

Completion of the procedure development process fulfills COL Items 18.9-1 and 13.5-1.

3.3 HFE Elements Later in the Design Process (AP1000)

The following HFE program elements will be initiated later in the HFE Program schedule.

Staffing (AP1000 DCD 18.6)

The staffing element is outside the scope of this document and is required for closure of COL item 18.6-1.

Training Program Development (AP1000 DCD 18.10)

The training program element is outside the scope of this document and is required for closure of COL item 18.10-1.

Human Factors Verification and Validation (AP1000 DCD 18.11)

Human Factors Engineering Verification and Validation (HFE V&V) is a fundamental feature of the AP1000 HFE Program. These activities provide the final confirmation that the AP1000 MCR and HSI designs are acceptable. The HFE V&V efforts will include: (1) HSI Task Support Verification, (2) HFE Design Verification, (3) Integrated System Validation and (4) Human Engineering Discrepancy (HED) Resolution as defined in NUREG-0711. These activities are required for closure of COL item 18.11-1.

Design Implementation and Human Performance Monitoring (AP1000 DCD 18.13 & 18.14)

The design implementation and planning for human performance monitoring is outside the scope of this document and is required for closure of COL item 18.14-1.

4.0 SUMMARY

Westinghouse is completing the design of the AP1000 Operations and Control Centers Systems, including the main control room. To fulfill commitments in Chapter 18 of the DCD a comprehensive human factors engineering program is well under way in support of the formal design of AP1000's compact control room and Human System Interface resources. The design and human factors program supports announced COL Applications.

This report provides the documentation to support completion of COL information items 18.2-1 and 18.8-1.

5.0 REGULATORY IMPACT:

The AP1000 FSER (Reference 13) in Subsection 18.2 discusses the AP1000 HFE program management. The AP1000 FSER in Subsection 18.8 discusses the AP1000 Human-System Interface Design. The implementation and documentation of human factors engineering program and the human system interface design implementation plan described in this report do not alter the discussion of objectives, methodology, and results described in 18.2 and 18.8. The conclusions in FSER Subsections 18.2 and 18.8 are not altered.

The implementation and documentation of human factors engineering program and the human system interface design implementation plan does not include any change to:

- a System, Structure, or Component (SSC)
- a procedure
- a DCD-described evaluation methodology
- a test or experiment not described in the DCD where an SSC is utilized or controlled in a manner that is outside the reference bounds of the design for that SSC or is inconsistent with analyses or descriptions in the DCD

As a result, the implementation and documentation of human factors engineering program and the human system interface design implementation plan do not represent an adverse change to the design function or to how design functions are performed or controlled. The implementation and documentation do not involve revising or replacing a DCD-described evaluation methodology nor involve a test or experiment not described in the DCD. The implementation and documentation do not require a license amendment per the criteria of VIII. B. 5.b. of Appendix D to 10 CFR Part 52.

In addition, the implementation and documentation do not affect resolution of a severe accident issue and does not require a license amendment based on the criteria of VIII. B. 5.c of Appendix D to 10 CFR Part 52.

The subject activities will not alter barriers or alarms that control access to protected areas of the plant. The subject activities will not alter requirements for security personnel. Therefore, the subject activities do not have an adverse impact on the security assessment of the AP1000.

6.0 DCD Mark-Up

The following DCD markups identify how COL application FSARs should be prepared to incorporate the subject change.

18.2.6 Combined License Information

The Combined License applicant referencing the AP1000 certified design is responsible for the execution of the NRC approved human factors engineering program as presented by Section 18.2. The AP1000 human factors engineering plan is documented in Reference 8.

Add Reference 8 to subsection 18.2.7 as follows:

8. APP-OCS-GBH-001, AP1000 Human Factors Engineering Program Plan.

Revise the first paragraph of 18.8.5 as follows:

18.8.5 Combined License Information

Combined License applicants referencing AP1000 certified design will address the execution and documentation of the human system interface design implementation plan that is presented by Section 18.8. The execution and documentation of the human system interface design implementation plan is addressed by Reference 47.

Add Reference 47 to subsection 18.8.6 as follows:

47. APP-GW-GLR-012, "AP1000 Human Factors Engineering Program and Human System Interface Design," Revision 0, March, 2006.

REFERENCES

1. Westinghouse Electric Company, "AP1000 Design Control Document," Rev. 14, Chapter 18

2. USNRC, NUREG-0711, Rev. 2, "Human Factors Engineering Program Review Model," February 2004.

3. Nuclear Energy Institute, "Draft Industry Guideline for Combined License Applicants Under 10 CFR Part 52, Revision E, October 5, 2005

4. AP1000 Human Factors Engineering Program Plan, APP-OCS-GBH-001, Rev. A

5. AP1000 Main Control Room Staffing Roles and Responsibilities, APP-GW-GLR-011

6. AP1000 HRA Integration Report, APP-GW-GLR-010, Rev. A

7. AP1000 Engineering Test Reports Phase 1 Test Report, APP-OCS-T2R-020, Rev. A

8. Operations and Controls Centers System System Specification Document, APP-OCS-J7-001, Rev. A

9. AP1000 Alarm System Functional Requirements, APP-OCS-J1-001, Rev A.

10. AP1000 Computerized Procedure System Functional Requirements, APP-OCS-J1-020, Rev A

11. AP1000 Display Functional Requirements, APP-OCS-J1-010, Rev A

12. Post Accident Monitoring System Functional Specification, APP-PMS-J4-001, Rev. D

13 NUREG-1793, Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design, September 2004.

Figure 18.2.-3 Overview of the AP1000 Human Factors Engineering Process