18.0 Human Factors Engineering

18.1 Human Factors Engineering Program Management

The human factors engineering (HFE) program management section describes the technical program for the U.S. EPR. The HFE program involves applying human factors principles to the design of the U.S. EPR human system interfaces (HSI) and engineering the incorporation of the HSI with the control and information systems. The program governs HFE design activities and provides guidance for certain aspects of the design of systems which interface with the control rooms via the HSI.

A COL applicant that references the U.S. EPR design will execute the NRC approved HFE program as described in this section.

18.1.1 Human Factors Engineering Program Goals, Assumptions and Constraints, and Scope

18.1.1.1 Goals

The goal of the HFE program is to provide the plant operators with task support and access to the information required to control plant processes and equipment safely and efficiently. The HFE program also establishes the time and performance criteria for required equipment operations via human reliability analyses and recognized guidelines.

18.1.1.2 Assumptions and Constraints

The U.S. EPR is an evolutionary PWR design based on years of operation and design experience from the precursor PWR plants (e.g., based on European N4 and Konvoi plants which are based on Westinghouse-designed PWRs currently operating in the U.S.). The U.S. EPR also uses similar control of system functions and instrumentation and control (I&C) concepts as the predecessor PWRs and the Olkiluoto 3 (OL3) EPR.

The initial main control room (MCR) staffing level is similarly established based on experience with previous four loop PWR plants and takes into account the increased levels of automation and the minimum number of operators required by 10 CFR 50.54(m). For further details on staffing levels, see Section 18.5.

Other assumptions and constraints related to standard features of EPR control rooms, HSI design, and the concept of operations are described in Section 18.7.2 of this FSAR and in Sections 3 and 4 of Reference 2.

The U.S. EPR HFE design process addresses the applicable review criteria specified in NUREG-0711 (Reference 1).

18.1.1.3 Applicable U.S. EPR Facilities

The HFE program scope includes the design of the MCR, the Technical Support Center (TSC), and the remote shutdown station (RSS). The design of local control stations (LCS) is typically accomplished concurrent with the applicable system and follows guidelines established by the HFE and Control Room Design Team (see Section 18.1.2). In addition, the Instrumentation and Control Service Center (I&CSC), the central location for maintaining the digital I&C systems for the plant, is included in the application of the HFE program. A COL applicant that references the U.S. EPR design certification will be responsible for HFE design implementation for a new emergency operations facility (EOF) or changes resulting from the addition of the U.S. EPR to an existing EOF. The HFE and Control Room Design Team provides guidance to that design. Execution of the HFE program guidance described herein provides reasonable assurance that HFE principles are both comprehensively and properly applied for the design of the EOF. This HFE guidance also provides a level of consistency for all HSI facilities in the U.S. EPR.

18.1.1.4 Applicable Human System Interfaces, Procedures, and Training

The scope of the HFE program includes HSIs, procedures, and training associated with monitoring and controlling U.S. EPR plant processes and equipment through the system functions. These system functions include those required during the various normal operating modes as well as those required during tests, inspections, surveillances, and maintenance, and during abnormal, emergency, and accident conditions. HSIs associated with non-I&C systems (e.g., manual valve operators and other LCSs) follow guidelines established by the HFE and Control Room Design Team. See Section 18.1.3.2 for information on implementation of these guidelines.

HSIs for the U.S. EPR design are implemented in the following hardware and software with the following I&C systems:

- Process Information and Control System (PICS).
- Safety Information and Control System (SICS).
- LCSs.

Details of the design and the concept of operations associated with each of these HSIs can be found in Section 18.7 and associated references.

The U.S. EPR HFE program also includes the application of appropriate HFE principals and techniques to support the development of operating procedures for the applicable interfacing facilities (see Section 18.1.1.3) and the operator training program. A generic set of operational guidelines (i.e., not specific to owner and site requirements or constraints), for the U.S. EPR, is provided for use in the development of site-specific

operating procedures. The requisite set of knowledge, skills, and attributes, and training objectives and goals required to operate a U.S. EPR are also provided for use in the development of a site-specific training program based on the Systematic Approach to Training (SAT) development protocol accredited by INPO. The training program and procedure development program are described in Sections 18.9 and 18.8, respectively.

18.1.1.5 Applicable Plant Personnel

The HFE program is tailored allowing licensed control room operators the capability to attain, view, assimilate, and act on process data in order to maintain plant safety. HFE principles are also applied to the tasks which relate to plant safety that are performed by other personnel, including technicians, maintenance personnel, engineering support staff, and management.

18.1.1.6 Effects of Modifications on Personnel Performance

The HFE program applies to the equipment supplied for the original configuration of the U.S. EPR. Modifications to the original interface configuration are required to adhere to the guidelines of Reference 1. Adverse effects caused by modifications on the overall system performance and the performance of personnel who use the equipment are minimized as described in Reference 1 and RG 1.174. Throughout the life of the plant, HFE issues resulting from plant modifications are documented and dispositioned as described in Section 18.12.

18.1.2 Human Factors Engineering and Control Room Design Team Organization

The HFE and Control Room Design Team is the multi-disciplinary team responsible for implementing the HFE program. The HFE and Control Room Design Team is responsible for overseeing certain aspects of the design and construction of the nuclear facility in accordance with 10 CFR 50.34(f)(3)(vii), as described in SRP Section 13.1.1, Management and Technical Support Organization. A description of the responsibilities, organizational placement and authority, and composition and qualifications of the HFE and Control Room Design Team is provided in Section 5.4.2.1 of the Human Factors Topical Report (Reference 2).

The HFE and Control Room Design Team is guided by the HFE program described herein for the proper development, execution, oversight, and documentation. The HFE and Control Room Design Team follows the same design processes as other engineering disciplines and is accountable for the quality of the HSI and control room layout to meet the requirements of the AREVA QAP Topical Report (Reference 3).

18.1.3 Human Factors Engineering Processes and Procedures

The HFE and control room design is performed in accordance with the U.S. EPR QAP described in Reference 3. As described in Section 5.1 of Reference 2, the AREVA NP generic design control process, as described in Section 5.1 of Reference 2, is used to execute the HFE and control room design. HFE-specific processes and procedures are further described in Section 5.3 of Reference 2.

18.1.3.1 Design Process Management Tools

Design adequacy is maintained by measures such as design verification checklists, product upgrade lists (i.e., a method of tracking open items in design documents), and plant-level design freezes. These methods are described in procedures for design control process, design change control, and release of product documentation.

A separate procedure defines the process for controlling design changes. Justification for changes to the design configuration and reviews by organizational functions similar to those which completed the original design are required by this procedure so that quality standards are uniformly applied. Design change proposals are maintained in a database used to track the status of each proposed change to the U.S. EPR design.

A database for I&C system design issues is used to document and track design issues that are identified during the design process. Further details on the HFE and control room design issues tracking system are provided in Section 18.1.4.

18.1.3.2 Integration of HFE with Other Plant Design Activities

The HFE and Control Room Design Team is required to follow the same design processes as other engineering disciplines and is accountable for verifying the quality of the HSI and control room layout per Reference 3.

The I&C engineering organization develops the I&C system designs, which includes defining design requirements, reviewing inputs, producing system documentation, verifying that the design inputs link to the outputs, and outlining expected acceptance testing. The HFE and Control Room Design Team integrates the I&C systems with the HSI and conducts the design and layout of the control rooms. Both functions involve an iterative process.

As previously described, the documentation produced by systems and component engineering organizations include design requirements, system descriptions (e.g., design bases, safety classifications), design system interfaces, drawings, calculations, and ancillary documents. A design verification checklist is required for certain portions of the design to support the evaluation of design adequacy.

For processes not previously defined, writing guides and procedures are produced in accordance with the design control process described in the QAP. System design requirements decompose higher-level (i.e., plant) requirements to define the design inputs for each system. System descriptions for control rooms and HSI platforms are produced as roll-up documents. Documentation produced by the HFE and control room design team includes the system descriptions, equipment specifications, and applicable implementation plans or output reports for the various analyses or design activities. Appendix A of Reference 2 provides a summary and schedule of the documentation associated with the HFE program elements.

The U.S. EPR design process requires cross-discipline reviews of design documentation for systems, structures, or components. System interface documents are produced by system discipline engineers to facilitate communication between disciplines for systems, structures, or components that have boundaries encompassing several engineering disciplines. The design documentation for complex systems is generally rolled up into a governing document (i.e., system description) controlled by the lead discipline engineer. Similarly, the HSI engineering activities are integrated into the overall plant design by use of the cross-discipline review concept and system interface documentation.

18.1.3.3 HFE Program Milestones

HFE milestones are identified to allow evaluations of the effectiveness of the HFE effort to be made at critical checkpoints. Section 18.1.5 also shows the relationship to the integrated plant design sequence. A relative program schedule of HFE tasks showing relationships between HFE elements and activities, products, and reviews and identifying HFE program milestones to allow evaluations of the effectiveness of the HFE effort to be made at critical checkpoints is shown in Figure 18.1-1— HFE Program Milestones.

18.1.3.4 HFE Documentation

Documentation of the HFE and control room design is addressed by procedures that apply to U.S. EPR design activities. The applicable procedures establish requirements, methods, and responsibilities for preparing, reviewing, and approving initial design documents as well as for changing previously released documentation.

System descriptions for control rooms and for HSI platforms contain the bases for how design requirements are met; this includes HFE-related design requirements. The documentation of the HFE and control room design is included in the system descriptions, equipment specifications, and implementation plans for the various analyses, or in reports generated as a result of the analyses. Appendix A of Reference 2 provides a summary and schedule of the documentation associated with the HFE program elements.

18.1.3.5 Subcontractor HFE Efforts

Subcontractors for the HFE portions of the U.S. EPR design are subject to the requirements of the U.S. EPR QAP described in Reference 3. The QAP identifies the procedures that apply to subcontractor design organizations. Effective implementation of a subcontract supplier organization QAP is monitored by respective internal audit programs and by individual supplier audits.

18.1.4 Human Factors Engineering Issues Tracking

Section 5.5 of Reference 2 describes the method used to track HFE issues throughout the life of the design.

HFE issues are tracked in a standard corrective action program database and are generated, verified, and implemented as described in Section 16 of Reference 3.

18.1.5 Technical Program

As described in Section 5.3 of Reference 2, the HFE and control room design program is performed in accordance with the process specified in Reference 1. Figure 18.1-2—HFE Design Control Process illustrates the design control process and how the HFE implementation plans, analyses, and evaluations required as part of the program fit the overall process flow.

18.1.5.1 HFE Program Process Drawing

Figure 18.1-2 illustrates how the HFE aspects of the plant are developed, designed, and evaluated on the basis of a structured analysis using accepted HFE principles. It shows the relationships between:

- The implementation plans for the various analysis and validation activities.
- The HFE design guidelines and the design products.
- The specific design records and output reports or summaries used to document the design.

In conjunction with Reference 2 and Section 18.1 of this FSAR, Figure 18.1-2 illustrates that the HFE and Control Room Design Team is guided by a plan that is properly developed, executed, overseen, and documented. Specific elements of Figure 18.1-2 include:

- The U.S. EPR design stages (i.e., conceptual, basic, detailed, and construction).
- The four HFE program general activities (Figure 1.1 of Reference 1).
- The relationship between the different HFE program elements.

- The input and output documents.
- A general sequence for the different HFE elements.
- The relationship between HFE and other EPR design disciplines.
- The relationship between HFE and COL applicant.

The U.S. EPR HFE design is based on predecessor designs and is revised to accommodate regulatory requirements, industry HFE codes and standards, and customer requirements. The revised predecessor design is used to design a state-of-the-art HFE program which is iterated as the EPR plant design matures. The HFE program culminates in a design which is verified and validated by acceptable HFE methods.

18.1.5.1.1 U.S. EPR Design Phases

The background shading in Figure 18.1-2 illustrates how the U.S. EPR design occurs in four design phases. The milestone schedule shown in Figure 18.1-1 is developed with an understanding of the relationship between design phases.

The conceptual design phase consists of producing high level descriptions (e.g., program plans and the plant technical requirements) and system engineering tasks (e.g., such as design requirements and system descriptions). Initial HSI and control room layout designs are developed during this phase. In Reference 2, conceptual design phase activities are described in Sections 5.3.1 through 5.3.4.

As described in Section 5.3.5 of Reference 2, the basic design phase includes preparation of design specifications to support ordering equipment. The HSI and control room layout designs are iterated with the initial input from procedure developers and the training specialists during this phase.

The detailed design phase involves performing design support and configuration measures. Support measures such as calculations, selection and suitability reviews, and design reviews (as described in Section 5.1 of Reference 2) are used to validate the design and maintain or manage the design configuration. Certain HFE verification and validation (V&V) activities are conducted throughout basic and detailed design, but summary reports for V&V and other HFE program activities are produced late in the detailed design phase.

The construction and operation phase involves acceptance testing before and after installation, verifying configuration management for design documentation (see Section 18.11), and monitoring system and operator performance throughout the life of the plant (see Section 18.12).

18.1.5.1.2 HFE Program General Activities

The four HFE program general activities (see Figure 1.1 of Reference 1) categorize the twelve HFE program elements. These four general activities roughly coincide with U.S. EPR HFE design phases (see Section 18.1.1.5.1). There is significant overlap between general activities and the HFE design process, which often requires iteration or feedback to activities conducted earlier in the sequence.

HFE activities in planning and analysis are a subset of the conceptual design phase. During planning and analysis, the HFE and Control Room Design Team:

- Studies the details of the predecessor plant designs and compares them against the applicable industry codes, standards, regulatory requirements, and customer requirements.
- Conducts analysis of operating experience and formulates the concept of operations including initial staffing and qualification analyses.
- Writes implementation plans for the applicable HFE program activities.
- Determines the applicability of analysis activities conducted on predecessor designs and the best means to convert those analyses into HSI design input.
- Completes initial design documentation (i.e., design requirements and system descriptions for control rooms and HSIs).

As in the basic design phase, HFE design activities involve iteration of the HSI based on input from other elements such as procedure development and analysis activities.

During the HFE V&V program activity (coincides with detailed design phase), the HSI and control room design is substantiated (see Section 18.10). Changes may cause revisions in the functions and documentation that were completed during the planning and analysis or design stages.

The implementation and operation activity coincides with the construction and operation phase. Changes to the design at this phase may cause re-engineering and revision of documentation produced in any of the previous stages.

18.1.5.2 Relationship Between HFE and Other Engineering Disciplines

Reference 3 requires that the HFE and Control Room Design Team follow the same design processes as other engineering disciplines. Section 5 of Reference 2 describes the relationship between HFE program design documentation and general design documentation.

18.1.5.3 HFE Program Element Documentation

The U.S. EPR HFE program is described in Section 18.1. Section 2.2 of Reference 2 describes the general HFE requirements, standards, and specifications utilized in the design of the U.S. EPR. Section 18.10 of this FSAR and Section 6.0 of Reference 2 describe the uses of HFE facilities such as mockups and simulators as well as methods and tools employed for the various testing and validation techniques.

Sections 18.2 through 18.12 provide information on the types of documents generated as part of the U.S. EPR HFE program.

18.1.6 References

1. NUREG-0711, "Human Factors Engineering Program Review Model," Revision 2, 2004.

2. ANP-10279, Revision 0, "U.S. EPR Human Factors Engineering Program," AREVA NP Inc., January 2007.

3. ANP-10266A, Revision 1, "AREVA NP Inc. Quality Assurance Plan (QAP) for Design Certification of the U.S. EPR," AREVA NP Inc., April 2007.

Figure 18.1-1—HFE Program Milestones
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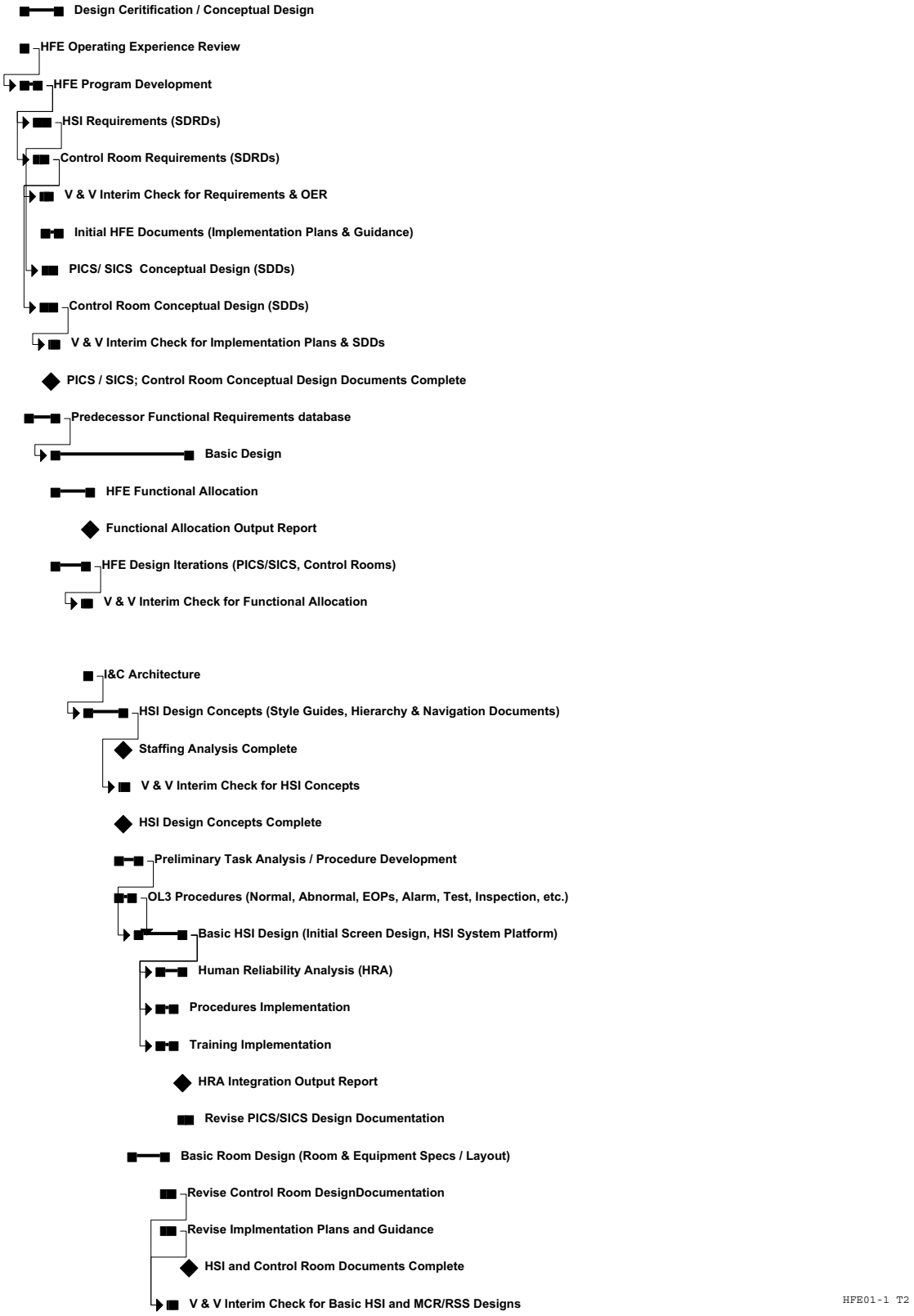

Figure 18.1-1—HFE Program Milestones
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