## 18 HUMAN FACTORS ENGINEERING

The U.S. Nuclear Regulatory Commission (the NRC or staff) staff reviewed Chapter 18, "Human Factors Engineering," of the AP1000 Design Control Document (DCD) Tier 2 on the basis of current regulatory requirements and NRC guidance, including the criteria of the NRC technical report designation (NUREG)-0711, “Human Factors Engineering Program Review Model,” which provides additional guidance for reviewing aspects of the AP1000 Human Factors Engineering (HFE) Program not fully addressed by previously available documents. The staff’s review also included aspects of the organizational structure of the applicant, training and plant procedures, contained in DCD Tier 2 Sections 13.1, “Organizational Structure of the Applicant,” 13.2, "Training," and 13.5, "Plant Procedures," and additional human factors engineering materials submitted by the applicant.

In Section 18.1 of this report, the staff provides an overview of the general methodology and review criteria used in this evaluation, including the HFE program review model. Sections 18.2 through 18.13 describe the results of the staff’s review of the following HFE topics, the first 12 of which are the elements of NUREG-0711. The last requirement, minimum inventory, addresses the challenges posed by the lack of control room detail provided in applications for advanced reactor designs:

- HFE Program Management (Section 18.2)
- Operating Experience Review (OER) (Section 18.3)
- Functional Requirements Analysis and Allocation (Section 18.4)
- Task Analysis (Section 18.5)
- Staffing and Qualification (Section 18.6)
- Human Reliability Analysis (HRA) (Section 18.7)
- Human-System Interface (HSI) Design (Section 18.8)
- Procedure Development (Section 18.9)
- Training Program Development (Section 18.10)
- Human Factors Verification & Validation (V&V) (Section 18.11)
- Design Implementation (Section 18.12)
- Human Performance Monitoring (Section 18.13)
- Minimum Inventory (Section 18.14)

In Section 18.15, the staff provides a summary of the review findings and overall conclusions and Section 18.16 identifies Chapter 18 related Tier 2* information items.

## 18.1 Review Methodology

### 18.1.1 HFE Review Objective

The overall purpose of the HFE review is to ensure the following:

- HFE has been satisfactorily integrated into the AP1000 development, design and evaluation.

- The AP1000 HFE products (e.g., HSIs, procedures, and training) reflect "state-of-the-art human factors principles" [10 CFR 50.34(f) (2), as required by 10 CFR 52.47(a) (1) (ii)] and satisfy all other appropriate regulatory requirements as stated in Title 10 of the Code of Federal Regulations (CFR).

- The AP1000 HSIs, procedures, and training make possible safe, efficient, and reliable performance of operation, maintenance, test, inspection, and surveillance tasks.

### 18.1.2 Review Criteria

The review criteria used to assess Westinghouse's AP1000 HFE program were primarily based on the criteria of NUREG-0711. In addition, the review criteria included current regulatory requirements established in 10 CFR 50.34(f), 10 CFR 50.34(g), 10 CFR 52.47, and the HFE review guidance contained in NUREG-0800, "Standard Review Plan," and NUREG-0700, "Human System Interface Design Review Guideline." For selected review topics, the staff used guidance from other NRC documents as well. These documents are identified in the appropriate review sections of this report.

### 18.1.3 Procedure for Reviewing AP1000 Human Factors Engineering

HFE for the Westinghouse AP1000 design is described in the DCD Tier 2 in responses to the staff's requests for additional information (RAI), and in several related Westinghouse topical reports (WCAPs). These materials describe a design and implementation process for an AP1000 HFE program, and some preliminary products of that process. With regard to RAIs, the staff issued 50 HFE-related RAIs, the majority of which were of a clarifying nature, satisfactorily responded to by the applicant, and do not require reiteration in this report. The applicant responses to two substantive RAIs which are included in this report and an additional seven RAIs were not responded to at the completion of this report and are therefore identified as Open Items.

At the time the staff completed this report for design certification, the applicant had not completed the final AP1000 HFE design. The review criteria identified in Section 18.1.2 of this report are the basis for the AP1000 HFE review. The design certification evaluation is based on a design and implementation process plan that describes the HFE program elements required

to develop the detailed design, and on partial completion of NUREG-0711 criteria. Generally, NUREG-0711 can be used to conduct three types of reviews of applicant submittals:

(1) programmatic review,

(2) implementation plan review, and

(3) complete element review.

All three types of reviews were used for the AP1000 design. For a programmatic review, the DCD Tier 2 does not include appropriate detailed methodologies; therefore, detailed evaluations using NUREG-0711 acceptance criteria are beyond the scope of the staff's review for design certification. At a programmatic review level, NUREG-0711 criteria are used to determine whether the program provides a top-level identification of the substance of each review criterion that, after design certification, will be developed by the Combined License (COL) applicant into a detailed implementation plan. The value of the programmatic review is that it provides assurance that the implementation plan will address all NUREG-0711 review criteria. The commitment to develop such a detailed implementation plan is described in the AP1000 Tier 1 information, which includes the inspections, tests, analyses and acceptance criteria (ITAAC). The staff will review this plan in the context of specific applications. The ITAAC are also needed for completing the implementation plan and providing the results to the staff for review. The staff evaluates the AP1000 ITAAC for HFE in Section 14.3 of this report.

For the staff to perform an implementation plan review, the applicant's submittals should describe the proposed methodology in sufficient detail for the staff to determine if the methodology will lead to products that meet NUREG-0711 acceptance criteria for the element. An implementation plan review affords the design certification applicant the opportunity to obtain staff review and concurrence on the full method before design certification. The actual completion of the plan will then likely take place after design certification. Such a review is desirable from the staff's perspective because it presents the opportunity to resolve methodological issues and provide input early in the analysis or design process. The staff's concerns can be addressed more easily at that time when the applicant's effort is completed. While some implementation plans can be reviewed on their own merits, the staff may request a sample analysis that demonstrates the application of the methodology and its results. The ITAAC are needed for completing the implementation plan and providing the results to the staff for review.

A complete element review can only be performed when the finished products (e.g., main control room (MCR) design) are available for the staff to evaluate. This means that the design certification applicant has submitted the results summary report(s). A results summary report provides the results of the design certification applicant's efforts to complete an element of NUREG-0711 with respect to the review criteria. Reviewers will use the report as the main source of information for assessing compliance with the review criteria.

In addition to NUREG-0711, the staff reviewed the applicant's minimum inventory (Section 18.14) of controls, displays, and alarms required to adequately implement emergency

operating procedures (EOPs) and address critical and risk-important operator actions identified from the AP1000 probabilistic risk assessment (PRA). The staff also reviewed applicant's emergency response guidelines (ERGs) applicable to the AP1000 design.

The remaining sections of this chapter present a review of each topic using the following four subheadings:

(1) Objectives — This section describes the overall review objectives for the topic.

(2) Methodology — While the general review methodology is described in this section, specific review topics sometimes have unique aspects to the review methodology. Such details are provided in the methodology section on that topic. This section identifies the specific Westinghouse material used in the safety determination (e.g., DCD sections or RAI responses) and the materials used to support the technical basis of the evaluation (e.g., NUREG-0711 or NUREG-0700).

(3) Results — The results section is divided into the following two components:

a. Criterion — This states the criterion being evaluated, usually based on NUREG-0711 or a similar document issued by the NRC.

b. Evaluation — This describes the staff's evaluation of the applicant material for its acceptability with respect to the review criterion. The basis for the assessment is documented, including documented materials and discussions with the applicant that may have resulted in modifications or clarifications to Westinghouse material that led to the assessment. Any questions, additional information, or discrepancies that were identified are documented in the evaluation.

(4) *Conclusions* — This section summarizes the staff's findings for the review topic.

## 18.2 Element 1: Human Factors Engineering Program Management

### 18.2.1 Objectives

The objective of the staff's review of the AP1000 HFE program management is to ensure that the design certification applicant has described an adequate HFE program, and that it will be implemented by a qualified HFE design team. The HFE design team should have the responsibility, authority, placement within the organization, and composition to ensure that the design commitment to HFE is achieved. Also, the team should be guided by an HFE program plan to ensure the proper development, execution, oversight, and documentation of the HFE program. This plan should describe the technical program elements, ensuring that all aspects

of the HSI are developed, designed, and evaluated based upon a structured, top-down, systems analysis using accepted HFE principles.

18.2.2 Methodology

18.2.2.1 Material Reviewed

The following Westinghouse documents were used in this review:

- AP1000 Design Control Document (DCD)
- WCAP-13793 dated June 21, 1994, “The AP600 System/Event Matrix.”
- WCAP-13957, dated, January 31, 1994, “AP600 Reactor Coolant Mass Inventory: Function-Based Task Analysis.”
- WCAP-14075 dated May 20, 1994, “AP600 design Differences Document for the Development of Emergency Operating Guidelines Report.”
- WCAP-14396 (Revision 2) dated January 27, 1997, “Man-In-The-Loop Test Plan Description.”
- WCAP-14396 (Revision 3) dated November 27, 2002, “Man-In-The-Loop Test Plan Description.”
- WCAP-14401 (Revision 3) dated May 8, 1997, “Programmatic Level Description of the AP600 Verification and Validation Plan.”
- WCAP-14644 dated October 9, 1996, “AP600 Functional Requirements Analysis and Function Allocation.”
- WCAP-14645 (Revision 2) dated January 1, 1997, “Human Factors Engineering Operating Experience Review Report for the AP600 Nuclear Power Plant.”
- WCAP-14651 (Revision 2) dated May 3, 1997, “Integration of Human Reliability Analysis With Human Factors Engineering Design Implementation Plan.”
- WCAP-14655 (Revision 1) dated August 8, 1996, “Designer’s Input for the Training of Human Factors Engineering Verification and Validation Personnel.”
- WCAP-14690 (Revision 1) dated June 27, 1997, “Designer’s Input to Procedure Development for the AP600.”
- WCAP-14694 dated July 31, 1996, “Designer’s Input to Determination of the AP600 Main Control Room Staffing Level.”
- WCAP-14695 dated July 31, 1996, “Description of the Westinghouse Operator Decision-Making Model and Function-Based Task Analysis Methodology.”
- WCAP-15847 (Revision 1) dated January 9, 2003, “AP1000 Quality Assurance Procedures Supporting NRC Review of AP1000 DCD Sections 18.2 and 18.8.”
- WCAP-15800 dated April 10, 2002, “Operational Assessment for AP1000.”
- WCAP-15860 dated April 10, 2002, “Programmatic Level Description of the AP1000 Human Factors Verification and Validation Plan.”
- Westinghouse Procedure AP-3.1, AP600 System Specification Documents (SSDs) (Revision 2), June 1, 1995).
- Westinghouse Procedure AP-3.2, Change Control for the AP600 Program (Revision 8), June 1, 1999.
- Westinghouse Procedure AP-3.5, Design Reviews (Revision 2), February, 18, 1997

- Westinghouse Procedure AP-3.6, AP600 Design Criteria Documents (Revision 2), March 11, 1994.
- Westinghouse Procedure AP-3.7, Interface Control Document, February 8, 1991.
- Westinghouse Procedure AP-3.12, AP600 Engineering Data Base (EDB) Access and Control, (Revision 1), February 20, 1997.
- Westinghouse Procedure AP-3.14, AP1000 Plant I&C Systems (PI&CS), October 31, 1991.
- Westinghouse Procedure AP-7.2, Control of Subcontractor Submittals, March 1, 2002.
- NUREG-1512, Final Safety Evaluation Report Related to Certification of the AP600 Standard Design."

18.2.2.2 Technical Basis

The staff focused its review on an evaluation of the applicant documents with respect to the topics and general criteria of Element 2, "HFE Program Management," of NUREG-0711. The staff reviewed Westinghouse's HFE program management at a complete element review level. Finished products from the element are available for review using NUREG-0711 criteria.

18.2.3 Results

18.2.3.1 General HFE Program Goals and Scope

Criterion 1: HFE Program Goals

Criterion:

The general objectives of this program should be stated in human-centered terms. As the HFE program develops, the terms should be objectively defined and serve as criteria for test and evaluation activities. Generic human-centered HFE design goals are listed in General Criterion 1 of NUREG-0711.

Evaluation:

The human-centered description is supported throughout DCD Tier 2 Chapter 18 for all phases of the HFE program as indicated in the following examples:

- DCD Tier 2 Section 18.2 identified the goal of the human factors engineering program "to provide the users of the plant operation and control centers effective means for acquiring and understanding plant data and executing actions to control the plant's processes and equipment."

- The process described in DCD Tier 2 Sections 18.4 and 18.8.2.1.2 for functional task analysis emphasized the identification of detection, monitoring, decision, and control requirements for crew task performance to support HSI development.

- The verification and validation process described in DCD Tier 2 Section 18.11 focused on the evaluation of user-centered issues (see DCD Tier 2 Table 18.11-1) that are consistent with NUREG-0711-identified goals, such as crew awareness of plant condition.

  The DCD Tier 2 Section 18.2, “Human Factors Engineering Program Management,” acceptably incorporates the HFE Program Goals of this NUREG-0711 criterion.

  Based on this information, the NUREG-0711 criterion is satisfied.

Criterion 2: Assumptions and Constraints

Criterion:

The design assumptions (or constraints) should be clearly identified. An assumption or constraint is an aspect of the design, such as a specific staffing plan or the use of specific HSI technology, which is an input to the HFE program rather than the result of HFE analyses and evaluations. For example, if a design constraint imposed by a utility requirement (rather than by design analysis) is that the entire plant operation, including emergencies, is to be accomplished by a single operator, that constraint will impact all other human factors analyses, such as allocation of function (much greater automation than is typical in commercial nuclear power plants would be required) and workstation design (a single operations console containing all plant monitoring and control function would be required). The staffing design constraint may drive the design without an acceptable HFE rationale, and may negatively impact the integration of plant personnel into the overall plant design. The purpose of this criterion is to make such "design drivers" explicit.

Evaluation:

The DCD Tier 2 addresses the assumptions and constraints of the design by identifying them as inputs to the HFE program. The overall HFE design and implementation process is described in DCD Tier 2 Section 18.8. This section presents the inputs to the program (e.g., specific system details such as those represented by piping and instrumentation diagrams). Also, see DCD Tier 2 Figure 18.11-1. Assumptions and constraints stem from regulatory guidance, utility groups, and AP1000 plant system design specifications. The DCD Tier 2 provides an overview of the types of requirements associated with each. For example, it is a utility requirement that a single reactor operator control major plant functions performed from the main control room during normal plant operations. The process of function allocation was briefly discussed in DCD Tier 2 Section 18.2.1.2 and further clarified in WCAP-14644. Initial allocations are made by system engineers based on operating experience of previous designs.

With respect to control room resources, the inclusion of a wall panel display is an approach to meeting a utility requirement for an integrating overview and mimic display. While alternative approaches are possible, the wall panel approach will be designed and evaluated as part of the AP1000 HFE program.

Appropriately, the applicant indicates that while all assumptions and constraints are provisionally treated as requirements, they are ultimately evaluated as part of the HFE design process for their appropriateness.

Based on this information, the NUREG-0711 criterion is satisfied.

Criterion 3: Applicable Facilities

Criterion:

The HFE program should address the MCR, remote shutdown facility, technical support center (TSC), emergency operations facility (EOF), and local control stations (LCSs).

Evaluation:

DCD Tier 2 Section 18.2.1.3, “Applicable Facilities,” indicated that the following facilities are included in the AP1000 human factors engineering program: main control room, technical support center, remote shutdown room, operational support center, emergency operations facility, and local control stations. The COL applicant is responsible for designing the EOF, including specification of a location, in accordance with the AP1000 human factors engineering program. DCD Tier 2 Section 18.8 indicated that the scope of the HFE program encompasses the facilities identified in this criterion. The applicant will define the EOF information systems and communications necessary for the plant to interface to the EOF. The design of the facility will be the responsibility of the COL applicant. This is acceptable because the site-specific requirements on the EOF necessitate final design by the COL applicant. However, the presentation of the plant data should be consistent with the HSI design, and the applicant approach will achieve this compatibility and consistency. This is COL Action Item 18.2.3.1-1.

Based on this information, the DCD Tier 2 acceptably addressed this NUREG-0711 criterion.

Criterion 4: Applicable HSIs, Procedures and Training

Criterion:

The applicable HSIs, procedures, and training included in the HFE program should encompass all operations, accident management, maintenance, test, inspection, and surveillance interfaces (including procedures).

Evaluation:

DCD Tier 2 Section 18.2.1.4, “Applicable Human System Interfaces,” stated that the scope of human systems interfaces covered by the AP1000 human factors engineering program includes instrumentation and control systems, that perform the monitoring, control, and protection functions associated with all modes of plant operation, as well as off-normal, emergency, and accident conditions. Physical and cognitive requirements of plant personnel involved in the use,

control, maintenance, test, inspection, and surveillance of plant systems, including training and procedures, are addressed by Westinghouse's HFE program.

Based on this information, the DCD Tier 2 acceptably addressed this NUREG-0711 criterion.

Criterion 5: Applicable Plant Personnel

Criterion:

Plant personnel who should be included in the HFE program include licensed control room operators, as defined in 10 CFR Part 55, and the following categories of personnel defined in 10 CFR 50.120:

- nonlicensed operator
- shift supervisor
- shift technical advisor
- instrument and control technician
- electrical maintenance personnel
- mechanical maintenance personnel
- radiological protection technician
- chemistry technician
- engineering support personnel

In addition, other plant personnel who perform tasks that are directly related to plant safety should also be included.

Evaluation:

In addition to operations personnel, the following personnel types are identified to be within the mission and scope of the HFE program: management, engineering, maintenance, health physics, and chemistry. DCD Tier 2 Section 18.2.1.5, "Applicable Plant Personnel," acceptably incorporates the applicable plant personnel that should be addressed by the HFE program.

Based on this information, the NUREG-0711 criterion is satisfied.

18.2.3.2 HFE Design Team and Organization

The staff reviewed the responsibility, organizational placement and authority, composition, and staffing of the HFE design team addressed in DCD Tier 2 to determine whether it acceptably addresses these topics as defined by NUREG-0711. NUREG-0711 refers to an HFE design team, while the equivalent Westinghouse organizational unit is called the Human System Interface (HSI) Design Team. The two terms are used interchangeably in this report.

Criterion 1: Responsibility

Criterion:

The team should be responsible (with respect to the scope of the HFE program) for the following activities:

- developing all HFE plans and procedures
- overseeing and reviewing all HFE design
- development, test, and evaluation activities
- initiating, recommending, and providing solutions through designated channels for problems identified in the implementation of the HFE activities
- verifying implementation of team recommendations
- ensuring that all HFE activities comply with the HFE plans and procedures
- scheduling activities and milestones

Evaluation:

In DCD Tier 2 Section 18.2.2, “Human System Interface Design Team and Organization,” the function of the human system interfaces design team is described as being part of the AP1000 systems engineering function and having similar responsibilities, authority, and accountability as other segments of the design team. The responsibilities of the human system interfaces design team (18.2.2.1) address the responsibilities identified by NUREG-0711 criterion.

Based on this information, the NUREG-0711 criterion is satisfied.

Criterion 2: Organizational Placement and Authority

Criterion:

The primary HFE organization(s) or function(s) within the organization of the total program should be identified, described, and illustrated (e.g., charts to show organizational and functional relationships, reporting relationships, and lines of communication). When more than one organization is responsible for HFE, the lead organizational unit responsible for the HFE program plan should be identified. The team should have the authority and organizational placement to ensure that all of its areas of responsibility are accomplished, and to identify problems in the implementation of the HSI design.

Evaluation:

Section 18.2.2.2, “Organizational Placement and Authority,” of DCD Tier 2 discusses the organization of the human system interface design team and its relationship to the AP1000 design organization. The organization of the HSI team and its relation to the AP1000 design organization is provided in Figure 18.2-2. The team comprises seven design and analysis functions and an Advisors/Reviewers Team. These groups report to an Instrumentation and Controls Systems manager, who is responsible for the overall HSI design and its integration with the rest of the plant design.

Based on this information, the NUREG-0711 criterion is satisfied.

Criterion 3: Composition

Criterion:

NUREG-0711 specifies that the HFE design team should have specific expertise in the following areas:

- technical project management
- systems engineering
- nuclear engineering
- control and instrumentation engineering
- architect engineering
- human factors
- plant operations
- computer system engineering
- plant procedure development
- personnel training
- systems safety engineering
- reliability, availability, maintainability, and inspectability engineering

Evaluation:

In DCD Tier 2 Section 18.2.2.3, the applicant provided the disciplines of a multi-disciplinary human system interface design team which met the criteria identified in Appendix A of NUREG-0711.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: Team Staffing

Criterion:

Team staffing should be described in terms of job descriptions and assignments of team personnel.

Evaluation:

DCD Tier 2 Section 18.2.2.4, "Team Staffing Qualifications," identified the organization of the HSI design team in terms of functional engineering areas. Greater emphasis is placed on the individual's relevant experience to the specific area rather than on formal education. The professional experience of the HSI design team as whole addresses the experience qualifications.

Based on this information, this NUREG-0711 criterion is satisfied.

18.2.3.3 HFE Process and Procedures

Criterion 1: General Process Procedures

Criterion:

The process should be identified through which the team will execute its responsibilities, including procedures for the following:

- assigning HFE activities to individual team members
- governing the internal management of the team
- making management decisions regarding HFE
- making HFE design decisions
- governing equipment design changes
- conducting design team review of HFE products

Evaluation:

Section 18.8.2 of the DCD Tier 2 describes the programmatic aspects of the design process. The instrumentation and control systems function group is responsible for developing the AP1000 instrumentation and control (I&C), including human system interfaces, coordinating and integrating the interfaces with other plant design activities. Design reviews are an integral part of the design process.

Regarding items 1a and 1b of the NUREG-0711 criterion, procedures address the assignment of HFE activities to individual team members and the internal management of the team. DCD Tier 2 Section 18.2.2.2, "Organizational Placement and Authority," discussed the organization of the team (Figure 18.2-2) and its relationship to the overall AP1000 organization. The internal workings of the organization were also described. The key people of the HSI design team

consist of an I&C manager, an HSI design function manager, the HSI technical lead, a review team, and the core HSI design team. The technical lead works on the HSI design function and reports to the manager of the HSI design function, who in turn reports to the I&C manager, who reports to the AP1000 project manager. Responsibilities are defined in Section 18.2.2.1. The organization is depicted on DCD Tier 2 Figure 18.2-2, which lists individual technical skills that are related to the project and coordinated by the technical lead. These disciplines include: Systems Engineering, Nuclear Engineering, I&C Engineering, Human Factors, Plant Operations, Computer Systems, Systems Engineering, and Maintainability. NUREG-0711 Items 1c and 1d address management and design decisions relative to HFE. These topics are addressed in DCD Tier 2 Section 18.2.2.2, "Organizational Placement and Authority," which covers the roles of the various managers associated with the project.

The DCD Tier 2 indicates that SSDs document human factors and HSI requirements by including task requirements, information requirements, and operations requirements. They provide a mechanism to document and track HFE requirements. A functional requirements document is developed for each HSI resource, e.g., alarm system and wall panel information system. Design specification documents document design specifications and integration. This information acceptably provided an indication of how HFE information is documented and coordinated. Relevant procedures related to the human factors engineering process are contained in WCAP-15847, (Revision 1), "AP1000 Quality Assurance Procedures Supporting NRC Review of DCD Tier 2 Sections 18.2.1 and 18.8."

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Process Management Tools

Criterion:

Tools and techniques (e.g., review forms) to be used by the team to ensure they fulfill their responsibilities should be identified by the applicant.

Evaluation:

DCD Tier 2 Section 18.2.3.1 indicated that design change proposals are tracked to closure through the design issues tracking database. DCD Tier 2 Section 18.2.4, "Human Factors Engineering Issues Tracking," indicated that the database receives issues to track from several sources, including design reviews. The responsibility for entering design review action items into the database and tracking them is with the manager responsible for the system reviewed. This method is an acceptable approach to tracking the design review action items. HFE checklists are included in the design review package, provided for each design review. An action item is defined for each issue identified through use of the checklist.

Relevant information related to the human factors engineering process management tools is contained in WCAP-15847, (Revision 1), "AP1000 Quality Assurance Procedures Supporting NRC Review of DCD Tier 2 Section 18.2 and 18.8." The staff reviewed the WCAP and finds it acceptably incorporates the items required by this criterion.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Integration of HFE and Other Plant Design Activities

Criterion:

The integration of design activities should be identified, including inputs from other plant design activities to the HFE program, and outputs from the HFE program to other plant design activities. The iterative nature of the HFE design process should also be addressed.

Evaluation:

DCD Tier 2 Section 18.2.3.3, describes how the AP1000 human factors engineering design process provides for the integration of human factors engineering activities with other design groups. DCD Tier 2 Figure 18.2-3, "Overview of the AP1000 Human Factors Engineering Process," depicts organization and design process flows that include iterative and feedback features. DCD Tier 2 Section 18.8 discusses the integration of the applicant designed components of the HSI with those portions that are site-specific and the responsibility of the COL applicant. This includes areas such as the operations support center and the emergency operations facility (EOF). The staff concludes that the applicant has acceptably addressed the integration of HFE and other plant design activities.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: HFE Program Milestones

Criterion:

HFE program milestones should be identified so that the effectiveness of the HFE effort can be evaluated at critical check points, and to show the relationship to the integrated plant sequence of events. A relative schedule should be available for NRC staff review of the HFE program tasks showing the relationships among HFE elements and activities, products, and reviews.

Evaluation:

DCD Tier 2 Section 18.2.5 addresses HFE program milestones, with Figure 18.2-3 providing a program milestone schedule of human factors engineering tasks showing relationships between the human factors engineering elements, activities, products and reviews. Internal design reviews are performed by the applicant design team at various points throughout the design process.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 5: HFE Documentation

Criterion:

HFE documentation items should be identified and briefly described along with the procedures for retention and access.

Evaluation:

DCD Tier 2 Section 18.2.3.4 addresses the criterion for human factors engineering documentation. DCD Tier 2 Sections 18.3 through 18.12 provide information on the types of documents that are generated as part of the AP1000 human factors engineering program. Additional documentation addressing this criterion is provided in WCAP-15847, (Revision 1), “AP1000 Quality Assurance Procedures Supporting NRC Review of AP1000 DCD Section 18.2 1 and 18.8.”

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 6: Subcontractor HFE Efforts

Criterion:

HFE requirements should be included in each subcontract and the subcontractor's compliance with HFE requirements should be periodically verified.

Evaluation:

DCD Tier 2 Section 18.2.3.5, “Human Factors Engineering in Subcontractor Efforts,” indicates that human factors engineering and human system interface requirements are provided to subcontractors through the applicant engineering documents including design criteria and system specification documents. WCAP-15847(Revision 1), “AP1000 Quality Assurance Procedures Supporting NRC Review of AP1000 DCD Section 18.2 1 and 18.8,” contains the AP1000 program procedure matrix which identifies the procedures that apply to subcontractor design organizations. In addition, DCD Tier 2 Section 17.3 specifies quality assurance requirements that are associated with subcontractor human factors engineering design efforts.

Based on this information, this NUREG-0711 criterion is satisfied.

18.2.3.4 HFE Issues Tracking

Criterion 1: Availability

Criterion:

A tracking system should be available to address human factors issues that are known to the industry (defined in Element 3, "Operating Experience Review," of NUREG-0711) and identified

throughout the life cycle of the HFE/HSI design, development, and evaluation. Issues are those items that need to be addressed at some later date, and thus need to be tracked to ensure that they are not overlooked. An existing tracking system may be adapted to serve this purpose.

Evaluation:

DCD Tier 2 Section 18 2.4 discusses the applicant human factors engineering issues tracking system. Tracking of human factors engineering issues is accomplished within the framework of the overall plant design process. The design issues tracking system database is used to track AP1000 design issues to resolution, including human factors engineering issues. The design review process also provides input into the design issues tracking system. Human factors engineering design issues directly associated with AP1000 human system interfaces and the operation and control centers (e.g., main control room, remote shutdown workstation, and the technical support center) are also entered into the design issues tracking system database. The AP1000 project manager is responsible for the maintenance and documentation of the design issues tracking system and for each issue entered into the database, a “responsible engineer” is assigned to resolve the issue.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Method

Criterion:

The method should document and track HFE issues from identification until elimination or reduction to an acceptable level.

Evaluation:

DCD Tier 2 Section 18.2.4, “Human Factors Engineering Issues Tracking,” described a database for tracking issues. The tracking system enables the documentation and tracking of issues that need to be addressed at some later date. For each design issue entered into the database, the actions taken to address the issue and the final resolution are documented.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Documentation

Criterion:

Each issue or concern that meets or exceeds the threshold established by the design team should be entered into the system when first identified, and each action taken to eliminate or reduce the issue or concern should be thoroughly documented. The final resolution of each issue or concern should be documented in detail, along with information regarding design team acceptance.

Evaluation:

DCD Tier 2 Section 18.2.3.4 discusses the human factors engineering documentation for the AP1000 design. The AP1000 human factors engineering design process has procedures to address documentation for AP1000, including procedures for document preparation, review, retention, access, and configuration control. A design configuration control process is used to control and implement proposed design changes. The design change proposals are maintained in a database that is used to track the status of each design change proposal from initiation through implementation and closure.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: Responsibility

Criterion:

When an issue is identified, the tracking procedures should describe individual responsibilities for issue logging, tracking, and resolution, as well as resolution acceptance.

Evaluation:

DCD Tier 2 Section 18.2.2.2., "Organizational Placement and Authority," identified the HSI technical lead as the one central person responsible for tracking HFE issues to resolution, and indicated that the engineer responsible for each issue is identified in the database. Design review issues, for example, are the responsibility of the manager who is responsible for the system under review. It is the AP1000 project manager who is responsible for the overall maintenance and documentation of the tracking system.

Based on this information, this NUREG-0711 criterion is satisfied.

18.2.3.5 HFE Technical Program

The evaluation of the HFE technical program, as part of Element 1 of NUREG-0711, addresses scoping, resources, and management details. Actual technical details are addressed in the respective element reviews.

Criterion 1: Plans and Analyses

Criterion:

The general development of implementation plans, analyses, and evaluation for each of the following areas should be identified and described:

- operating experience review
- functional requirements analysis and function allocation
- task analysis

- staffing and qualifications
- HRA
- HSI design
- procedure design
- training design
- human factors verification and validation
- design implementation
- human performance monitoring

Evaluation:

The applicant's technical program, as presented in DCD Tier 2 Chapters 13 and 18, incorporates all of the identified NUREG-0711 elements. DCD Tier 2 Figures 18.2-1, 18.2-2, and 18.2-3 identify the inputs and outputs (documentation) for the major activities of the HFE program. DCD Tier 2 Section 18.2.5, “Human Factors Engineering Technical Program and Milestones,” details the applicant commitment to perform the AP1000 human factors engineering program in accordance with the human factors engineering process specified in NUREG -0711.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: HFE Requirements

Criterion:

The HFE requirements imposed on the design process should be identified and described. List the standards and specifications that are sources of HFE requirements.

Evaluation:

HFE requirements are addressed in numerous places in DCD Tier 2, and the definition of HFE requirements is a major activity of the HFE program. DCD Tier 2 Section 18.8.6 lists the requirements to be identified in the HFE program. DCD Tier 2 Section 18.8.1.2, states that guidance documents are provided to designers of the alarm systems, anthropometrics, displays, controls, and computerized procedures. Guidelines for the human system interface design are developed for each of the human system interface resources to facilitate the standard and consistent application of human factors engineering principles to the AP1000 design. The guidance is contained in a set of standards and conventions guidelines documents that tailor generic human factors engineering guidance to the AP1000 human system interface design and define how those human factors engineering principles are applied.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Facilities and Tools

Criterion:

HFE facilities, equipment, tools, and techniques (such as laboratories, simulators, and rapid prototyping software) to be used in the HFE program should be specified.

Evaluation:

DCD Tier 2 Section 18.2.3.2, “Process Management Tools,” provides a description of a design database and tracking system that are used to facilitate communications across AP1000 design disciplines and organizations. In WCAP-15860, “Programmatic Level Description of the AP1000 Human Factors Verification and Validation Plan,” Westinghouse identifies the use of various tools to evaluate dynamic task performance, supported by further detailed descriptions in WCAP-14396 (Revision 3), “Man-in-the-Loop Test Plan Description.”

Based on this information, this NUREG-0711 criterion is satisfied.

18.2.4 Conclusions

The objective of the HFE program management review is to ensure that the applicant has described an adequate HFE program plan and a qualified HFE design team to implement the plan. The plan should describe the technical program elements, ensuring that all aspects of the HSI are developed, designed, and evaluated based on a structured, top-down systems analysis using accepted HFE principles. The staff reviewed the applicant's HFE program management at a complete element review level. That is, finished products from the element are available for review. The DCD Tier 2 provides an acceptable basis for a human factors program plan. The applicant has acceptably completed this NUREG-0711 element. The COL applicant referencing the AP1000 certified design is responsible for the execution of the NRC approved human factors engineering program. This is COL Action Item 18.2.4-1.

18.3 Element 2: Operating Experience Review

18.3.1 Objectives

The objective of the staff's review of the AP1000 OER is to ensure that the applicant has identified and analyzed HFE-related problems and issues encountered in previous designs that are similar to the design under review, so that they are not repeated in the development of the current design or, in the case of positive features, to ensure their retention.

18.3.2 Methodology

18.3.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD - (through Revision 3)
- WCAP-14645 (Revision 2) dated January 6, 1997

18.3.2.2 Technical Basis

The staff evaluated the applicant documents with respect to the topics and general criteria of Element 3, "Operating Experience Review," of NUREG-0711. The staff reviewed Westinghouse's OER at a complete element review level. That is, finished products from the element were available for review using NUREG-0711 criteria.

18.3.3 Results

18.3.3.1 Scope

Criterion 1: Predecessor Plant and Systems

Criterion:

The OER should include information pertaining to the human factors issues related to the predecessor plant(s) or highly similar plants and plant systems.

Evaluation:

In Section 1.4.2 of WCAP-14644, applicant identified the predecessor plant for the AP600 as "the generic PWR [pressurize-water reactor] design for currently licensed Westinghouse nuclear power plants." Table 1 illustrates in detail how the critical safety functions for the AP600 are the same as for current Westinghouse PWR plants. The other portions of this WCAP illustrate the differences between the predecessor plants and the AP600. Thus, current Westinghouse PWRs, in general, serve as the predecessor for the AP600 nuclear power plant. Since the AP1000 is similar to the AP600 in its operation, WCAP-14644 is applicable to AP1000.

In the AP1000 OER, the applicant addressed current Westinghouse PWRs. This is illustrated in WCAP-15800. Further, WCAP-14645 (Revision 2), as noted in Section 2.0 of that WCAP, includes both Westinghouse and non-Westinghouse PWRs. It also addresses pertinent boiling-water reactor (BWR) issues and a pressurized heavy-water reactor, where applicable to the new design. Thus, the applicant has included information in their OER pertaining to the human factors issues related to both the predecessor plant(s) and highly similar plants and plant systems. Therefore, WCAP-14645 (Revision 2) is also applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Recognized Industry HFE Issues

Criterion:

Recognized nuclear power industry issues, organized into the following categories, should be addressed:

- unresolved safety issues (USIs)
- generic safety issues (GSIs)
- Three Mile Island (TMI) issues
- NRC generic letters (GLs) and information notices
- studies by the NRC Office of Analysis and Evaluation of Operational Data (AEOD)
- low power and shutdown issues
- operating plant event reports

In addition, TMI Item I.C.5 of NUREG-0737 was included as an HFE issue.

Evaluation:

The applicant performed a thorough review of various industry issues that would have pertinent operating experience to the AP1000. They performed extensive literature reviews and maintain an up-to-date knowledge of advanced systems and HSI research and experience, as illustrated by their reference lists contained in WCAP-14645 (Revision 2) and WCAP-15800. In addition, DCD Tier 2 Section 1.9 provides a detailed summary of the results of the applicant OER relative to the industry operating experience issues. WCAP-15800 addresses USIs/GSIs, TMI Issues, NRC Generic Letters and Information Notices. Additional information related to the staff's evaluation of generic issues pertaining to human factors engineering can be found in Chapter 20 of this report.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Related HFE Technology

Criterion:

The OER should address related HFE technology. For example, if touch screen interfaces are planned, HFE issues associated with their use should be reviewed.

Evaluation:

The staff determined through review of specific attributes that WCAP-14645 is applicable to AP1000. WCAP-14645 (Revision 2) addresses this criterion in Section 4.0, "Related Human System Interface (HSI) Technologies Where Little or No Nuclear Plant Experience Exists," and in Table 2. The WCAP identifies three such HSI technologies used in the AP1000 design which are soft controls, computerized procedures, and large screen (wall panel) displays. The applicant reviewed the operating experience of soft controls and large overview type displays to identify human factors issues. There are 38 identified issues from these 2 areas listed in Table 2 of the WCAP, including a discussion in Section 4.0 about the AP1000 computerized procedure system. This states that the computerized procedure system is dynamic and interactive with the remaining HSI. The applicant committed to reviewing and identifying any human factors found in published comparable systems with relevant operating experience found in other industries. Also, in Section 4.0 of WCAP-14645 (Revision 2), Westinghouse summarized the seven items that are the responsibility of the COL applicant. With regard to using proposed HFE technology, WCAP-14645 (Revision 2) is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: Issues Identified by Plant Personnel

Criterion:

Personnel interviews should be conducted to determine operating experience related to predecessor plants or systems. The following topics should be included in the operator interviews:

- plant operations
    - normal plant evolutions (e.g., startup, full power, and shutdown)
    - instrument failures (e.g., safety-related system logic and control unit, fault tolerant controller for nuclear steam supply system (NSSS), local "field unit" for multiplexer (MUX) system, MUX controller for balance of plant, and break in MUX line)

HSI equipment and processing failure (e.g., loss of video display units, loss of data processing, and loss of large overview display)

- transients (e.g., turbine trip, loss of offsite power, station blackout, loss of all feed water, loss of service water, loss of power to selected buses and control room power supplies, and safety/relief valve transients)
- accidents (e.g., main steamline break, positive reactivity addition, control rod insertion at power, control rod ejection, anticipated transient without scram, and loss-of-coolant accidents of various sizes)
- reactor shutdown and cooldown using the remote shutdown system

- HFE/HSI design topics
    - alarm/annunciation
    - display
    - control and automation
    - information processing and job aids
    - real-time communications with plant personnel and other organizations
    - procedures, training, staffing, and job design

Evaluation:

WCAP-14645 (Revision 2) addresses operator interviews in Section 5.0 and Table 3. The applicant states that interviews have been conducted during plant operations and after events. Eight specific reports are cited that document the operator interviews. These reports are two NUREG/CRs, two Westinghouse proprietary reports, one Westinghouse non-proprietary WCAP, one Electric Power Research Institute (EPRI) report, one utility letter, and one Canadian report. The staff reviewed these reports to determine the scope of the operator interviews. All of the topics above were addressed to some extent in the eight reports, with the exception of remote shutdown and staffing. A number of issues were identified based on the interviews, as documented in Table 3 of the WCAP. The issues cover many areas including emergency situations, cognitively demanding situations, procedures, soft controls, alarms and alarm systems, safety parameter display system (SPDS), plant startup, and feedwater control.

The applicant submitted a letter on December 16, 1996, with Enclosure 1, "AP600 Open Item Tracking System: Design Issues Tracking," Item No. 4179, which acceptably addressed the staff's previous concerns related to the scope of operator interviews. Specifically, WCAP-14645 (Revision 2) provided an explanation of how the operator interview issues were selected and Item No. 4179 of the letter dated December 6, 1996, provided a commitment to address operator interviews on the topics of remote shutdown and staffing. Since the AP1000 is like the AP600 with regard to obtaining information through personnel interviews regarding operating experience related to predecessor designs, WCAP-14645 (Revision 2) is directly applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 5: Risk-important human actions

Criterion:

The OER should identify risk-important human actions that have been identified as different or where errors have occurred. The human actions should be identified as requiring special attention during the design process to lessen their probability.

Evaluation:

The applicant does not address this item in discussing developing the OER. This is Open Item 18.3.3.1-1.

18.3.3.2 Issue Analysis, Tracking, and Review

Criterion 1: Analysis Content

Criterion:

Issues should be analyzed with regard to the identification of the following:

- human performance issues, problems, and sources of human error
- design elements that support and enhance human performance

Evaluation:

In WCAP-14645 (Revision 2), Westinghouse identified human performance issues and problems, and sources of human error. They also identified the various aspects of the design and design process that will address these problems by supporting and enhancing human performance. Additionally, in Section 1 of WCAP-14645 (Revision 2), Westinghouse stated that they will continue to review current plant operating experience and as new HFE issues are identified, they will address and track to resolution those issues.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Documentation

Criterion:

The analysis of operating experience should be documented in an evaluation report.

Evaluation:

The applicant consolidated their operating experience review work into a single document, WCAP-14645 (Revision 2), "Human Factors Engineering Operating Experience Review Report for the AP1000 Nuclear Power Plant." This report addresses all of the areas and issues identified in NUREG-0711, as well as the additional related industry issues in BNL Technical Report E2090-T4-3-1/95, "HFE Insights for Advanced Reactors Based Upon Operating Experience." The staff has concluded that with regard to documenting issues related to human performance, WCAP-14645 (Revision 2) is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Incorporation into the Tracking System

Criterion:

Each operating experience issue determined to be appropriate for incorporation into the design (but not already addressed in the design) should be documented in the HFE issue tracking system.

Evaluation:

The applicant submitted a letter on December 16, 1996, and WCAP-14645 (Revision 2) on January 6, 1997, to address the open issues that remained from the staff's review of WCAP-14645 (Revision 1). In their December 16, 1996, letter, the applicant acceptably addressed the staff's request for entries of HFE issues that have been included in the HFE Issues Tracking System as evidenced by Enclosures 1 through 3. Enclosure 1 provided a copy of the design issues tracking system database report for HFE issues identified as a result of the operating experience review. Enclosure 2 was a copy of the tracking system database report for HFE issues which resulted from design reviews. Enclosure 3 provided the database report for HFE issues identified by the human systems interface designers as important HSI design issues.

The staff has concluded that with regard to documenting issues related to human performance in the tracking system, WCAP-14645 (Revision 2) and the December 16, 1996, letter are applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

18.3.4 Conclusions

The objective of the AP1000 OER review is to ensure that the applicant has identified and analyzed HFE-related problems and issues encountered in previous designs that are similar to the current design under review so that they are not repeated in the development of the current design or, in the case of positive features, to ensure their retention. The staff reviewed the applicant's OER at a complete element review level. That is, finished products from the element were available for review. Overall, the applicant has discussed a comprehensive approach to operating experience review. The applicant has also completed fairly extensive reviews, both in the general nuclear power experience area and in the particular area of HSI technology. With the exception of satisfactorily addressing Criterion 5, "Risk-important human actions," which is Open Item 18.3.3.1-1, the applicant acceptably completed this NUREG-0711 element.

## 18.4 Element 3: Functional Requirements Analysis and Function Allocation

### 18.4.1 Objectives

The objective of the functional requirements analysis and function allocation review for the AP1000 is to ensure that the applicant has defined the plant's safety functional requirements, and that the function allocations take advantage of human strengths and avoid allocating functions that would be negatively influenced by human limitations.

The functional requirements and function allocations of a new design are typically based on one or more predecessor designs. Many of the functional requirements and function allocations for the new plant may be the same as those of the predecessor. This reflects the evolutionary nature of technology development in complex, high-reliability systems like nuclear power plants. In such cases, operating experience becomes an essential component of the technical basis and rationale for the functional requirements and function allocations. Functions and their allocations are described in NUREG-0711 as "modified," in comparison to the predecessor design. It is acceptable for functions and allocations that are not modified to be justified based upon the successful operating experience of predecessor designs. The review criteria below reference the concepts of unmodified and modified functions and function allocations.

### 18.4.2 Methodology

#### 18.4.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD
- WCAP-14644 dated October 9, 1996

#### 18.4.2.2 Technical Basis

The staff focused its review on an evaluation of the applicant documents with respect to the topics and general criteria of Element 4, "Functional Requirements Analysis and Function Allocation," of NUREG-0711. The staff reviewed this element at a complete element review level.

### 18.4.3 Results

Criterion 1: Process

Criterion:

Functional requirements analysis and allocation should be performed using a structured, documented process reflecting HFE principles.

Evaluation:

The applicant's approach to the AP1000 functional requirements analysis is based on a decision sets model that involves decomposition of plant functions from global, abstract functions, such as "prevent radiation release", to lower level decision sets, such as "control reactor coolant system (RCS) boron concentration." For each decision set, questions are addressed that provide information for accomplishing the goal of the decision set, such as what information is needed, what decisions need to be made, and where the results must go. The results are presented in both graphic and tabular form with the aid of a computer-aided software engineering tool. At the lower levels, cognitive task analysis is performed to provide the requirements for the HSI design. The applicant used a structured approach based on the methodology developed by the International Atomic Energy Agency (IAEA) that is described in IAEA-TECDOC-668. This document is based on the methodology developed in NUREG/CR-3331. These documents are described as appropriate sources of function allocation methodology in NUREG-0711.

Applying the methodology, the applicant first identified those function assignments that are mandatory (required by regulation) and assessed human performance requirements based on task characteristics. For many functions, a combination of human and automated systems is identified. A seven-level categorization scheme developed by Billings (1991) is used, and the initial set of allocations is documented. The allocations are reevaluated as the design becomes more detailed

For tasks assigned to personnel, the applicant considers approaches to support the crew's task performance by reducing the workload. When a task is automated, the applicant defines human task requirements in order for plant personnel to properly monitor the automated activities. In addition, the applicant provided high-level principles for making the automation "human-centered." Consideration of the requirements associated with the task of monitoring automation is an especially positive aspect of the described approach.

In summary, the staff concludes that the applicant's general approach to functional requirements analysis and allocation is acceptable.

Criterion 2: Updating Requirements

Criterion:

The functional analysis should be kept current over the life-cycle of design development and held until decommissioning so that it can be used for design when modifications are considered.

Evaluation:

WCAP-14644, Section 2.3, discusses the verification and updating of functional requirements analyses. Several different analyses contribute to the evaluation of functional requirements including DCD Tier 2 Chapter 15 safety analyses, PRA analyses, and function-based task

analyses. DCD Tier 2 safety analyses address the ability of the plant functions, systems, and processes to cope with design-basis events. PRA analyses address the acceptability of plant functions, systems, and processes for coping with beyond-design-basis accidents. The function-based task analyses performed by the HSI design team provide verification of the detailed sensor, and control specifications for critical safety function (CSF)-related requirements.

WCAP-14644, Section 2.3 also describes the mechanisms for modifying functional requirements if the analyses described above identify a need to do so. Modifications would be accomplished through the formal procedures described in the design configuration change control process (discussed in the Element 1 review). The procedures assure that the change is properly implemented, documented, and verified. This information provides an acceptable explanation of the process by which functional requirements will be verified and the requirements can be changed, if required. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Predecessor Plant and Systems

Criterion:

A description should be provided of the plant functions, processes, and systems and a comparison made to the reference plants/systems so that one can identify areas of difference that exist. The description should also address how the results of functional requirements analysis are verified and how the results are updated as the design process proceeds.

Evaluation:

Information addressing this criterion is in Section 2 of WCAP-14644. The CSFs are identified in Table 1 of WCAP-14644, and include subcriticality, core cooling, heat sink, RCS integrity, containment, and RCS inventory. Table 2 provides a comparison of the CSFs and their success paths with those of the reference plant. The reference plant is the generic PWR design for currently licensed Westinghouse nuclear power plants. Section 2.1.3 and Table 3 provide a comparison of the design of the structures, systems, and components (SSCs) and their function allocation between the new design and the reference plants. The table indicates whether each of the success paths for each CSF is unchanged, modified, or new. The CSFs for the new design are the same as those for the reference plants, but the success paths and SSCs are different. The major differences are (1) the use of safety-related, passive systems for safety injection and decay heat removal, (2) the use of advanced digital I&C, (3) automation of certain SSC actuation and control functions that help reduce operator workload, and (4) design changes that were identified through a review of operating experience. WCAP-14644 provides a detailed and acceptable description of the functions, processes, and systems as well as a comparison to the reference plants/systems so that one can identify areas of difference that exist. This information provides an acceptable explanation of the process for comparing plant

functions and systems with reference plants/systems. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: High-level function descriptions

Criterion:

A description of the functions and systems should be provided along with a comparison to the reference plants/systems, i.e., the previous plants or plant systems on which the new system is based. Function decomposition should be done at several levels, starting at "top level" functions, where a very general picture of major functions is described, and continuing through the plant process level to lower levels until a specific critical end-item requirement emerges (e.g., a piece of equipment, software, or an operator). The functional decomposition should address the following levels:

- high-level functions (e.g., maintain RCS integrity) and critical safety functions (e.g., maintain RCS pressure control)
- specific plant systems and components

Evaluation:

High-level safety functions have been defined and include the functions required to prevent or mitigate the consequences of postulated accidents that could cause undue risk to the health and safety of the public. The safety processes themselves will be defined at the next level when the function-based task analyses (FBTAs) are completed. A method for doing this has been established and implemented as illustrated by the sample case in WCAP-13957. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 5: Technical basis for modifying high-level functions

Criterion:

The technical basis for modifying high-level functions in the new design (compared to the predecessor design) should be documented.

Evaluation:

WCAP-14644, Section 2.3 describes the mechanisms for modifying functional requirements if the analyses described above identify a need to do so. Modifications would be accomplished

through the formal procedures described in the design configuration change control process. The procedures assure that the change is properly implemented, documented, and verified. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 6: A technical basis should be documented for all function allocations

Criterion:

A technical basis should be documented for all function allocations, including the allocation criteria, rationale, and analyses methods.

Evaluation:

WCAP-14644, Sections 1.4, 1.5, and 3.0, provide the technical basis, including criteria, rationale and analyses methods for function allocations. In section 4.3, the applicant also describes the mechanisms for modifying function allocations. If problems with respect to allocation are identified, a process is in place to address the problem. Options include modifications to the HSI to better support the operators tasks, modifications to system design to change the level of automation, or modifications to the staffing assumptions.

Once the problem has been addressed, modifications would be accomplished through the formal procedures described in the design configuration change control process (discussed in the Element 1 review). The procedures assure that the change is properly implemented, documented, and verified. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644, is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 7: OER should be used to identify modifications to function allocations

Criterion:

The OER should be used to address the case of modified processes. Problematic OER issues should be considered during the function allocation analyses for modified functions.

Evaluation:

The role of operating experience in the identification of acceptable allocations, or for allocations that need to be addressed, is an essential part of initial allocations (as identified in the basis for the Westinghouse approach, IAEA-TECDOC-668). In WCAP-14644, Section 4.2, Westinghouse describes the evaluation of the integrated role of the operator using task and workload analysis, HSI design and evaluation, and verification and validation. In WCAP-14644,

Westinghouse indicates that because of the dynamic and interactive aspects of human performance, the allocations are evaluated through subsequent HFE analyses throughout the design process. Following the initial allocations by system designers, the integrated role of operators is assessed during task analyses when workload evaluations are conducted. Because the task analyses will address a full range of operating modes, they provide an opportunity to identify operational phases in which workload can be expected to be high. The HSI will be specifically designed to support the operator's functional role in the plant (through the support of the functional decomposition analyses), which will be evaluated in verification activities. The final allocation will be evaluated as part of integrated system. In WCAP-14644, Section 4.3, Westinghouse describes the mechanisms for modifying function allocations. If problems with respect to allocation are identified, a process is in place to address the problem. Options include modifications to the HSI to better support the operators tasks, modifications to system design to change the level of automation, or modifications to the staffing assumptions. Once the problem has been addressed, modifications would be accomplished through the formal procedures described in the design configuration change control process (discussed in the Element 1 review). The procedures assure that the change is properly implemented, documented, and verified.

The applicant described an acceptable approach to evaluating the functional role of the operator and to developing design changes to modify the function allocations, should it become necessary as the design develops. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 8: Allocation analysis considers primary allocations and emergency functions

Criterion:

The allocation analysis should consider not only the primary allocations to personnel but also their responsibilities to monitor automatic functions and to assume manual controls when automatic systems fail.

Evaluation:

In addition to the information presented in the previous evaluation of Criterion 7, WCAP-14644, Section 4.2, specifically indicates that the allocation analysis will consider the need for manual backup, manual intervention or manual override as part of Westinghouse's function based task analysis process, which is integrated with function allocation. The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 9: Integrated personnel role across functions

Criterion:

A description of the integrated personnel role across functions and systems should be provided in terms of personnel responsibility and level of automation.

Evaluation:

In WCAP-14644, Section 4.2, Westinghouse describes the evaluation of the integrated role of the operator using task and workload analysis, HSI design and evaluation, and verification and validation. Additional detail is provided in the previous evaluation of Criterion 7.

The staff has concluded that with regard to performing this activity of functional requirements analysis and function allocation, WCAP-14644 is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 10: Verification of the functional requirements analysis and function allocation

Criterion:

The functional requirements analysis and function allocation should be verified for high level, safety-related functions.

Evaluation:

See evaluation for previous Criterion 2 for updating and verification of the functional requirements analyses.

18.4.4 Conclusions

The objective of this review is to ensure that the applicant has defined the plant's safety functional requirements, and that the functional allocations take advantage of human strengths and avoid allocating functions that would be negatively influenced by human limitations. Functional requirements analysis and function allocation analysis were reviewed at a complete element review level. The applicant discussed a detailed analysis of functional requirements and allocation, and has identified a process to further evaluate allocation if necessary. The applicant has acceptably completed this NUREG-0711 element.

## 18.5 Element 4: Task Analysis

### 18.5.1 Objectives

The objective of this review is to ensure that the applicant's task analysis identifies the specific tasks that are needed for function accomplishment and their information, control, and task-support requirements.

### 18.5.2 Methodology

#### 18.5.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD (through Revision 3)
- WCAP-14651 (Revision 2) dated May 8, 1997
- WCAP-14690 (Revision 1) dated June, 1997
- WCAP-14655 (Revision 1) dated August 8, 1996
- WCAP-14695 dated July 23, 1996

#### 18.5.2.2 Technical Basis

The staff focused its review on an evaluation of the applicant documents with respect to the topics and general criteria of Element 5, "Task Analysis," of NUREG-0711. The staff reviewed the applicant's task analysis at an implementation plan review level because the work will not be completed in this area until after design certification.

### 18.5.3 Results

Criterion 1: Scope of the Task Analysis

Criterion:

The scope of the task analysis should include selected representative and important tasks from the areas of operations, maintenance, test, inspection, and surveillance. The analyses should be directed to the full range of plant operating modes, including startup, normal operations, abnormal and emergency operations, transient conditions, low power, and shutdown conditions.

Evaluation:

The applicant approach to task analysis is to evaluate tasks from two perspectives (1) function-based task analysis and (2) operational sequence analysis (OSA). FBTA is described in DCD Tier 2 Section 18.5.2.1, "Function-Based Task Analyses," and in WCAP-14695, "Description of the Westinghouse Operator Decision-Making Model and Function-Based Task Analysis Methodology." The scope of the FBTA is on decomposition of the higher level functions (as described in Level 4 in DCD Tier 2 Figure 18.5-1). This approach is an

appropriate and acceptable means of assuring that function-based requirements are identified that are not dependent on specific operator tasks. The scope of the OSA is identified as including the full range of plant operating modes, including startup, normal operations, abnormal and emergency operations, transient conditions, low power and shutdown conditions. These will include tasks representing the full range of activities in the AP1000 ERGs, and tasks identified as critical or risk-significant. DCD Tier 2 Section 18.5.1, “Task Analysis Scope,” further indicated that the traditional task analyses will include tasks that involve maintenance, test, inspection, and surveillance. The tasks selected will involve activities involving "risk-significant" systems, structures, and components (SSCs). The staff has concluded that with regard to performing this task analysis activity, WCAP-14695 and the description provided in DCD Tier 2 related to task analysis scope are applicable to AP1000.

Based on the information provided, this NUREG-0711 criterion is satisfied.

Criterion 2: Task Linking

Criterion:

Tasks should be linked using a technique such as using operational sequence diagrams. Task analyses should begin on a gross level and involve the development of detailed narrative descriptions of personnel tasks. The analyses should define the nature of the input, process, and output needed by and of personnel.

Evaluation:

The applicant functional task analysis methodology begins with the high-level functional goals and decomposes them. A goal-means structure will be used to map the cognitive and physical tasks that define the operational space of the plant to each plant function. The goal-means structure representation is based on the concept of describing the plant's functional processes in terms of the goals to be achieved and the means or mechanisms available for achieving them.

Cognitive task analysis methodology is used to identify the monitoring and feedback, planning, and control requirements. Because the emphasis of the task analysis is on cognitive requirements, the methodology described will acceptably provide the necessary information to support the definition of requirements for information gathering, decision making, response, and feedback.

The applicant provided a discussion and clarification of the integration of both FBTA and OSA approaches to the task analysis in the AP1000 design process. While the focus of FBTA is on decomposition of the higher level AP1000 functions, the focus of the OSA will be the analysis of the operational tasks as defined within the scope of task analysis activities.

The OSA will be performed in two phases. First, (OSA-1) tasks will be developed to include plant state data, data source, actions, criteria/reference values, feedback, time, sequencing requirements, support requirements, and work environment considerations. These results will

provide the operational requirements for task performance. These requirements and constraints provide input into HSI design development.

The resulting designs are tested in concept tests, which enable further refinement of the analysis results. To accomplish this, a second OSA (OSA-2) is performed on a representative subset of the tasks analyzed in the first phase of OSA, which include those which are risk important and those where there are performance concerns. These analyses address the completeness of available information, time to perform tasks, operator workload, and staffing. In summary, the combination of FBTA and OSA provides a particularly strong technical basis for identifying operational requirements to be addressed in the detailed HSI design. The staff has concluded that with regard to performing this task analysis activity, WCAP-14695 and the description provided in DCD Tier 2 related to linking tasks, developing descriptions, and defining inputs, processes, and output of the tasks analyses, are applicable to AP1000.

Based on the information provided, this NUREG-0711 criterion is satisfied.

Criterion 3: Task Analysis Iterations

Criterion:

The task analysis should be iterative and become progressively more detailed over the design cycle.

Evaluation:

DCD Tier 2 and WCAP-14695 describe a task analysis process that is iterative, the contents of which are developed and refined as it is performed over the design cycle. The applicant's task analysis process is based on functional decomposition and combines traditional task analysis, with cognitive task analysis methods. The use of these two task analytic techniques attempts to (1) ensure that a complete set of operator tasks is selected for evaluation, (2) determine the process plant data needed to support operator decisions, and (3) make the plant equipment achieve their designed purposes. The staff has concluded that with regard to performing this task analysis activity, WCAP-14695 and the description provided in DCD Tier 2 related to task analysis iteration are applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: Job Design Issues

Criterion:

The task analysis should incorporate job design issues such as the following:

- the number of crew members
- crew member skills

- allocation of monitoring and control tasks to the formation of a meaningful job and management of a crew member's physical and cognitive workload

Evaluation:

The applicant indicates in the DCD Tier 2 that the second set of OSA evaluations will incorporate crew staffing considerations. The workload assessment as part of these analyses will provide "an indication of the adequacy of staffing assumptions" (p.18.5-4). Where high workload or time limits occur, alternative staffing assumptions, task allocations, or design changes will be evaluated. With respect to skills, the applicant indicated that skill requirements addressed by NRC requirements for training are assumed (i.e., no special skills are assumed for AP1000 operators). This is an acceptable approach.

In DCD Tier 2, the applicant also stated that a COL applicant referencing the AP1000 certified design will document the scope and responsibilities of each main control room position, considering the assumptions and results of the task analysis. This is COL Action Item 18.5.3-1. The staff has concluded that with regard to performing this task analysis activity, WCAP-14695 and the description provided in DCD Tier 2 related to job design issues are applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 5: Minimum Inventory

Criterion:

The task analysis results should be used to define a minimum inventory of alarms, displays, and controls necessary to perform crew tasks based upon both task and I&C requirements.

Evaluation:

DCD Tier 2 Section 18.5.2.1, "Function-based Task Analysis," indicates that the FBTA is used as a completeness check on the availability of needed indications, parameters, and controls. The DCD Tier 2 also indicates that the OSAs will provide information on the inventory of alarms, controls, and parameters needed to perform sequences selected for analysis, which include those addressed in the discussion of Criterion 1, Scope of the Task Analysis. The applicant described a minimum inventory of alarms, displays, and controls for the AP1000 (the staff performed a complete review of the inventory for the AP1000 design certification with the evaluation details provided in Section 18.12 this report). The staff has concluded that with regard to performing this task analysis activity, WCAP-14695 and the description provided in DCD Tier 2 related to task analysis and minimum inventory are applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 6: Input to HSI Design, Procedures, and Training

Criterion:

The task analysis results should provide input to the HSI design, procedure development, and personnel training programs.

Evaluation:

DCD Tier 2 Sections 18.9, “Procedure Development,” and 18.5.2, “Task Analysis Implementation Plan,” do not identify the relationship between task analysis and procedures or training development. Further, DCD Tier 2 Figure 18.2-3, “Overview of the AP1000 Human Factors Engineering Process,” did not show a task analysis as an input to either procedure or training development. However, the relationship between procedure development and task analysis is addressed in WCAP-14690 (Revision 1). The WCAP states that the "plant operating procedures' technical bases... shall be consistent with ... task analyses" (p 2-1) and that the EOP technical content should be developed from the ERGs with additional input from the task analysis, among other things. Also, both these items are COL items. The staff considers these statements to be appropriate and acceptable.

The relationship between training program development and task analysis is addressed in WCAP-14655 (Revision 1), “Designer's Input for the Training of HFE V&V [verification and validation] Personnel.” The WCAP indicates that the results of the task analysis will serve as input to the training of V&V personnel. Following V&V, a "Training Insights Report" will be developed and provided to the COL applicant. The report will provide, among other things, the task analysis that is completed for the HFE V&V, as well as the knowledge, skills, and abilities analysis associated with those tasks (p. 4-1). Thus, while procedures and training program development are COL activities, the applicant will provide the COL with the input from task analyses. The staff understands this to mean that the COL applicant will utilize the AP1000-specific task analysis information, in the development of procedures and training programs. This is COL Action Item 18.5.3-2. Further, the staff expects that the COL applicant will utilize task analysis information, for all training and procedure efforts that involve tasks for which task analyses were performed, even if those go beyond the scope of the V&V activities. The staff has concluded that with regard to performing this task analysis activity, WCAP-14695 and the description provided in DCD Tier 2, related to task analysis input to HSI design, procedures and training are applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

18.5.4 Conclusions

The objective of the task analysis review is to ensure that the applicant’s task analysis identifies the requirements of the tasks that plant personnel are required to perform. Task analysis was reviewed at an implementation plan level of detail; that is, finished products from the element were not available for review but the methodology for conducting a complete task analysis was evaluated. The methodology will be used by the COL applicant to conduct a complete task

analysis after design certification. This is COL Action Item 18.5.3-3. The applicant has acceptably developed a task analysis implementation plan and has satisfied this NUREG-0711 element.

18.6 Element 5: Staffing and Qualifications

18.6.1 Objectives

The objective of this review is to ensure that the applicant has analyzed the requirements for the number and qualifications of personnel in a systematic manner, that includes a thorough understanding of task requirements and applicable regulatory requirements.

18.6.2 Methodology

18.6.2.1 Material Reviewed

The following Westinghouse documents were used in this review:

- DCD (through Revision 3)
- WCAP-14075 dated May 20, 1994
- WCAP-14694 dated July 31, 1996

18.6.2.2 Technical Basis

The staff focused its review on an evaluation of the Westinghouse documents with respect to the general criteria and topics of NUREG-0711, Element 6, "Staffing and Qualifications." Also requirements of 10 CFR 50.54, "Conditions of Licenses," were used to develop this report.

18.6.3 Results

Criterion 1: Applicable Requirements

Criterion:

Staffing and qualifications should address applicable requirements of 10 CFR 50.54 and associated guidance in NUREG-0800, Section 13.1.

Evaluation:

The applicant, in DCD Tier 2 Section 18.6.1, “Combined License Information Item,” states that the staffing requirements of 10 CFR 50.54(m), will be addressed by COL applicants referencing the AP1000 design.

The NRC staff finds that this is an acceptable commitment for addressing this criterion.

Criterion 2: Number and Qualifications of Personnel

Criterion:

The staffing analysis should determine the number and background (qualifications) of personnel required during the full range of plant conditions and tasks, including operational tasks (normal, abnormal, and emergency), plant maintenance, and plant surveillance/testing. The scope of personnel that should be considered is identified in Element 1 of NUREG-0711.

Evaluation:

DCD Tier 2 Section 18.6.1, "Combined License Information Item," states that the COL applicant will address staffing levels and qualifications of plant personnel, including operations, maintenance, engineering, I&C, radiological protection, security, and chemistry.

While this description is acceptable, the staff determined that it is necessary for the COL applicant to (1) address the staffing considerations in NUREG-0711and (2) to identify the minimum documentation that the COL applicant will provide to the staff to complete its review. This is COL Action Item 18.6.3-1.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Staffing Analysis Iteration

Criterion:

The staffing analysis should be iterative; that is, the initial staffing goals should be reviewed and modified as the analyses associated with other NUREG-0711 elements are completed.

Evaluation:

See discussion under staffing Criterion 2, "Number and Qualifications of Personnel," above.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: Basis for Staffing

Criterion:

The staffing analysis should consider the issues associated with the following NUREG-0711 elements and then compare these issues to staffing assumptions, regarding the number and qualifications of operations personnel. The basis for staffing should be modified to address these elements:

- operating experience review
    - operational problems and strengths that resulted from staffing levels in predecessor systems

- function analysis and allocation
    - mismatches between functions allocated to the operator and the qualifications of anticipated operators
- task analysis
    - the knowledge, skills, and abilities required for operator tasks addressed by the task analysis
    - requirements for operator response time and workload
    - requirements for operator communication and coordination
    - the job requirements that result from the sum of all tasks allocated to each individual operator both inside and outside the control room
- human reliability assessment
    - the effect of overall staffing levels on plant safety and reliability
    - the effect of overall staffing levels and the coordination of individual operator roles on critical human actions
    - the effect of overall staffing levels and the coordination of individual operator roles on human errors associated with the use of advanced technology
- HSI design
    - staffing demands resulting from the locations and use (especially concurrent use) of controls and displays
    - the requirements for coordinated actions between individual operators
- procedures
    - staffing demands resulting from requirements for concurrent use of multiple procedures
    - skills, knowledge, abilities, and authority required of operators by the procedures
- training
    - crew coordination concerns that are identified during the development of training
- verification and validation
    - ability of minimum size operating crew to control plant during validation scenarios
    - ability of operators to effectively communicate and coordinate actions during all validation scenarios
    - ability of operators to maintain awareness of plant conditions and operator actions throughout all validation scenarios

Evaluation:

See discussion under staffing Criterion 2, “Number and Qualifications of Personnel,” above.

Based on this information, this NUREG-0711 criterion is satisfied.

18.6.4 Conclusions

The objective of this review is to ensure that the applicant has analyzed the requirements for the number and qualifications of personnel in a systematic manner that includes a thorough understanding of task requirements and applicable regulatory requirements.

The applicant identified staffing and qualifications as a COL action item with applicable issues to be addressed by the COL. This is COL Action Item 18.6.4-1. In addition, WCAP-14694 provides additional information related to this element and available for the COL. The staff has concluded that with regard to performing this staffing and qualifications activity, WCAP-14694 and the description provided in DCD Tier 2 related to staffing and qualifications are applicable to AP1000.

18.7 Element 6: Human Reliability Analysis

18.7.1 Objectives

The objectives of the HRA reviews are to ensure that:

- the applicant has addressed human error mechanisms in the design of the plant HFE (i.e., the HSIs, procedures, shift staffing, and training in order to minimize the likelihood of personnel error and to provide for error detection and recovery capability)

- the HRA activity effectively integrates the HFE program activities, as well as the PRA and risk analysis activities.

18.7.2 Methodology

18.7.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD Tier 2 (through Revision 3)
- WCAP-14651 (Revision 2) dated May 8, 1997
- Chapter 30 of the AP1000 PRA (Revision 1) dated February 6, 2003

18.7.2.2 Technical Basis

The staff focused its review on an evaluation of the applicant documents with respect to the topics and general criteria of Element 7, "Human Reliability Analysis," of NUREG-0711. Section 7.1 of NUREG-0711 addresses the technical review of HRA methodology. These criteria were not applied by the staff as part of the HFE review, because this part of the HRA review is being conducted as part of the staff's PRA review, addressed in Section 19 of this report. Instead, the HFE review focused on the integration of the HRA with HFE design.

The applicant indicated that the HRA implementation plan, the PRA, and HRA are within the scope of design certification. However, the analysis results report for this HRA element of NUREG-0711, requires a completed function-based task analysis report, and is not within the scope of design certification. Therefore, the staff reviewed the applicant's HRA at an implementation plan review level, because the applicant will not complete work in this area until after design certification.

18.7.3 Results

General Criterion: Implementation Plan

Criterion:

While NUREG-0711 criterion for this element does not explicitly include an implementation plan, such a plan is needed to address the NUREG-0711 criterion-based review to follow. This criterion addresses the availability of an implementation plan in DCD Tier 2.

Evaluation:

In WCAP-14651 (Revision 2), dated May 1997, the various items associated with proper integration of the PRA/HRA and the HFE processes are discussed in detail, including use of HRA/PRA insights to guide HFE design, identification of critical human actions and risk important tasks, task analyses for critical human actions and risk important tasks, reexamination of critical human actions and risk important tasks, and validation of HRA performance assumptions. Thus, the applicant developed an implementation plan with appropriate scope. Further, Section 18.7 references this implementation plan. The acceptability of the individual items is discussed under the evaluations of the following individual criteria.

In Sections 3.2 and 5.0 of WCAP-14651 (Revision 2), Westinghouse addressed the issue of whether there is a need to reevaluate and possibly requantify the HRA/PRA after the HFE design is complete. The applicant stated that performance assumptions will be confirmed as part of both the task analyses and the control room validation. The applicant will perform an evaluation as to whether any of the assumptions of the HRA must be changed. If necessary, the HRA will be modified and the impact on the PRA will be assessed. Reports will be generated documenting the results, which will be submitted to the NRC for review.

Based on the above information, this NUREG-0711 criterion is satisfied.

Criterion 1: Risk-important Human Actions

Criterion:

Risk-important human actions should be identified from the HRA and PRA, and used as input to the HFE design effort. These critical actions should be developed from the Level 1 (core damage) and Level 2 (release from containment) portions of the PRA, including both internal and external events. They should be developed using selected (more than one) importance measures and HRA sensitivity analyses to ensure that an important action is not overlooked because of the selection of the measure or the use of a particular assumption in the analysis.

Evaluation:

Westinghouse submitted WCAP-14651, "Integration of Human Reliability Analysis with Human Factors Engineering Design Implementation Plan," Revision 2 on May 8, 1997.

The risk-important (critical human actions) are defined as "tasks that must be accomplished in order for personnel to perform their functions. In the context of PRA, critical tasks are those that are determined to be significant contributors to plant risk." In its Integration Plan, the applicant chose to subdivide the NUREG-0711 critical human actions into two categories, critical human actions and risk-important tasks. However, the applicant indicated that both of these types of actions will be addressed through their HFE design program.

The threshold for defining a Westinghouse critical human action is high. It is any action that, if failed, would result in total core damage frequency (CDF) greater than or equal to 1E-4 events/Rx-year or a severe release frequency greater than or equal to 1E-5 events/Rx-year. With these thresholds AP1000 design has no critical human actions. This is because of the low overall CDF, the passive nature, and the high value of the threshold selected for AP1000. The staff has accepted the applicant's high thresholds for defining critical human actions because the applicant also defines risk-important tasks in the paragraphs that follow (in a manner acceptable to the staff) and uses them appropriately for other portions of the control room design where critical actions were intended. Also, as indicated in Section 18.2 of this report, because of the high threshold for defining critical human actions, the staff considered an additional task (manual actuation of the ADS) as critical and, as such, a necessary task to be included in the Minimum Inventory of Control Room Controls, Displays, and Alarms. The applicant agreed and added this action to the Inventory. The staff understands that, although the applicant has not identified any critical human actions based on preliminary results from the PRA studies completed in 1996, as PRA studies are updated, critical human actions may be identified.

The thresholds for defining a risk-important task are detailed in the integration plan and consist of both quantitative and qualitative criteria. For the determination of risk important tasks, the applicant will use the following PRA studies:

- the internal events at-power PRA
- the shutdown events PRA
- the focused PRA for regulatory treatment of non-safety-related systems (RTNSS) analysis
- the external events PRA (for fire and flood events)
- the seismic margins PRA

For the quantitative criteria, the applicant will use two importance measures, risk achievement (or risk-increase) worth and risk reduction (or risk-decrease) worth. The threshold for risk-increase importance, for at-power internal events and shutdown events, is 200 percent or a risk achievement worth of 3.0. This will be applied to both the Level 1 (core damage frequency) and the Level 2 (severe release from containment) PRAs.

WCAP-14651 (Revision 2) specifies that all of the PRAs that will be used in the determination of risk important tasks, defines the quantitative thresholds, adds five well-specified qualitative criteria, and provides example results of risk-important tasks in Appendix A. The latest baseline values of the various PRA studies, as referenced in the integration plan, were determined to range from 6.5E-7 events/Rx-year down to about 2E-10 events/Rx-year. These are low values compared to the PRAs for current day plants. Thus, the AP1000 can accept a somewhat higher percentage increase than would be acceptable for current plants. Further, using only the quantitative criteria, the integration plan in Appendix A provides examples of risk-important tasks. Depending on how one converts human action basic events to tasks, there are about 13 to 15 risk-important tasks. This appears to be a reasonable number of risk-defined operator tasks to address in the task analysis portion of the HSI design.

Thus, the applicant developed an acceptable approach to define critical human actions and risk-important tasks from the PRA/HRA to be used as input to the HFE design effort. They are developed from Level 1 and Level 2 PRAs and include consideration of both internal and external events. They will be selected using multiple measures and criteria to ensure that important actions are not overlooked. The staff has concluded that with regard to performing this human reliability analysis integration activity, WCAP-14651 (Revision 2) and the description provided in DCD Tier 2 related to developing risk-important human actions are applicable to AP1000.

Based on the above information, this NUREG-0711 criterion is satisfied.

Criterion 2: Detailed Examination of Risk-important Human Actions

Criterion:

Critical human actions that are identified in the HRA/PRA as posing serious challenges to plant safety and reliability should be re-examined by function analysis, task analysis, HSI design, or procedure development to either change the operator task or the control or display environment to reduce or eliminate undesirable sources of error.

Evaluation:

Section 4.0 of WCAP-14651 (Revision 2) states that any critical human action or risk important task, that is determined to be a potentially significant contributor to risk, will be re-examined by task analysis, HSI design, and procedure development. These evaluations will be used to identify changes to the operator task or the HSI to reduce the likelihood of operator error and provide for error detection and recovery capability.

Section 3.2 of the WCAP discusses how the task analyses will be used to address the assumptions used in the HRA by developing more accurate estimates of workload and task completion times. This information will be provided to the Westinghouse HRA/PRA group. The staff has concluded that with regard to performing this human reliability analysis integration activity, WCAP-14651 (Revision 2) is applicable to AP1000.

Based on the above information, this NUREG-0711 criterion is satisfied.

Criterion 3: Using HRA/PRA Insights

Criterion:

The use of the HRA/PRA results by the HFE design team should be specifically addressed (i.e., how the HFE program addressed critical personnel tasks through HSI design, procedural development, and training to minimize the likelihood of operator error and provide for error detection and recovery capability).

Evaluation:

The applicant designed the AP1000 taking into account lessons learned from existing plant experience, and the results of past HRAs and PRAs. This allowed the applicant to reduce the potential for human error. The applicant states that this simplifies the plant and reduces the number of human actions required. For example, no human actions are required to maintain core cooling following design-basis events.

Further, Section 1.2 of WCAP-14651 (Revision 2) provides a discussion of how the HRA/PRA results will be used in task analysis, HSI design, procedure development, and V&V to identify changes to operator tasks, procedures, or the HSI to minimize the likelihood of operator error and provide for error detection and recovery capability.

Regarding training, the applicant stated that training program development is a COL responsibility. Section 1.2 of the Westinghouse implementation plan discusses how Westinghouse will provide the COL applicant with documentation that includes a description of HRA assumptions, PRA results relevant to training, and insights relevant to training based upon the V&V. This will include a list of critical human actions (if any), risk important tasks, performance requirements for those actions (e.g., response time). The staff has concluded that with regard to performing this human reliability analysis integration activity, WCAP-14651 (Revision 2) is applicable to AP1000.

Based on the above information, this NUREG-0711 criterion is satisfied.

Criterion 4: HRA Validation

Criterion:

HRA assumptions such as decision-making and diagnosis strategies for dominant sequences should be validated via walk-through analyses with personnel with operational experience using a plant-specific control room mockup, prototype, or simulator. Reviews should be conducted before the final quantification stage of the PRA.

Evaluation:

Section 5.0 of WCAP-14651 (Revision 2) discusses the validation of HRA performance assumptions. It states that validation of the HRA operator performance assumptions will be performed as part of the integrated HFE system validation. This will include scenarios that include critical or risk-important human actions, as well as specific performance assumptions that the HRA/PRA group identifies for confirmation. The applicant will not validate the quantitative HRA probabilities. The qualifications of personnel involved in the analyses are identified in WCAP-14651. Although walk-throughs are not specifically identified in the WCAP, exercises using scenarios are mentioned as part of the validation effort, which is conducted as part of the overall integrated HFE system validation which incorporates control room walk-throughs and extensive simulator exercises. After review of the results of the validation, the HRA/PRA group will determine whether any changes need to be made to the HRA assumptions or HRA quantification. If changes are needed, the HRA will be modified and the impact on the PRA will be assessed. A report will be generated, documenting the results of the exercises intended to validate the HRA performance assumptions, and submitted to the NRC for review as part of the COL application information provided in COL Action Item 18.7.3-1.

The staff has concluded that with regard to performing this human reliability analysis integration activity, WCAP-14651 (Revision 2) is applicable to AP1000.

Based on the above information, this NUREG-0711 criterion is satisfied.

18.7.4 Conclusions

The objectives of this review are to ensure that (a) the HRA activity effectively integrates the HFE program activities and PRA/risk analysis activities, and (b) the applicant has addressed human error mechanisms in the design of the plant HFE (i.e., the HSIs, procedures, shift staffing, and training in order to minimize the likelihood of personnel error and to provide for error detection and recovery capability). HRA integration was reviewed at an implementation plan level of detail.

The applicant developed an acceptable implementation plan for integrating HRA with HFE for the AP1000 design. The COL applicant referencing the AP1000 certified design is responsible

for the execution and documentation of the human reliability analysis/human factors engineering integration implementation plan. This is COL Action Item 18.7.4-1.

## 18.8 Element 7: Human-System Interface Design

This section discusses the results of the staff's review of the applicant's process for HSI design. A detailed review of the specific features of the HSI (such as the alarms, displays, and controls of the control room and the remote shutdown station) was beyond the scope of this review because the HSI design features will not be completely developed by the applicant for the AP1000 design by the time of design certification. Therefore, the staff's review addressed the HSI design process methodology and was conducted at an implementation plan review level. Included in the HSI review was the safety parameter display system (SPDS). Although the MCR is not fully designed, the staff evaluated the applicant's approach to meeting the functional requirements for the SPDS (see Section 18.8.2 of this report).

### 18.8.1 HSI Design Process

#### 18.8.1.1 Objectives

The objective of this review is to evaluate the process by which HSI design requirements are developed, and HSI designs are selected and refined. The review should ensure that the applicant has appropriately translated function and task requirements to the controls, displays, and alarms that are available to the crew. The applicant should have systematically applied HFE principles and criteria (along with all other function, system, and task design requirements) to identify HSI requirements, select and design HSIs, and resolve HFE/HSI design problems and issues. The process and rationale for the HSI design (including the results of trade-off studies, other types of analyses and evaluations, and the rationale for selection of design and evaluation tools) should be documented for review.

#### 18.8.1.2 Methodology

##### 18.8.1.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD
- WCAP-14396 (Revision 3) dated November 27, 2002
- WCAP-14401 (Revision 3) dated May 8, 1997
- WCAP-15847 dated January 9, 2003
- WCAP-14695 dated July 23, 1996

##### 18.8.1.2.2 Technical Basis

The staff focused its review on an evaluation of the applicant documents with respect to the topics and general criteria of Element 8, "Human-System Interface Design," of NUREG-0711. The staff reviewed the applicant's HSI design at an implementation plan review level, because the applicant will not complete work in this area until after design certification.

18.8.1.3 Results

Criterion 1: Sources of Input to the HSI Design Process

Criterion:

The analyses performed in earlier stages of the design process should be used to identify HSI requirements. These sources include, 1) analysis of personnel task requirements (i.e., input from OER, functional requirement analysis and function allocation, task analysis, staffing/qualifications and job analyses); 2) systems requirements (constraints imposed by the overall I & C design); 3) applicable regulatory requirements; and 4) other applicant-identified inputs that are applicable to the HSI design.

Evaluation:

DCD Tier 2 Section 18.8, "Human System Interface Design," addresses the design of the HSI based on task analysis and other design inputs. It provides a general description of the translation of task requirements to HSI resource requirements, the procedures for development and documentation of the detailed design, and design tests and evaluations. DCD Tier 2 Section 18.8.1.7, "Task-Related Human System Interface Requirements," describes how various AP1000 human factors engineering program elements such as staffing assumptions, task analyses results, functional requirements analysis and allocations, are used as input to the design of HSI. Figure 18.2-3, further illustrates how various sources of information provide input to the AP1000 HSI design process.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Concept of Operations

Criterion:

A concept of operations should be developed indicating crew composition and the roles and responsibilities of individual crew members based on anticipated staffing levels. The concept of operations should consider factors such as, specifying the crew responsibilities for overriding automatic equipment and interacting with computerized support systems; location of personnel at a single, large workstation or individual workstations; and addressing the coordination of crew member activities.

Evaluation:

DCD Tier 2 Section 18.8.1.1, “Functional Design,” provides a description of the AP1000 system specification document for the operation and control centers system. This document is described as an “umbrella document for capturing human factors requirements and providing a uniform operational philosophy and design consistency among the individual human systems interface resources.” The system specification document for the operation and control centers system (and individual human system functional requirements documents that are developed for each human system interface resource) provide mission statements and performance requirements. The mission statements provide high-level goals and main tasks to be supported by the control center or human system interface resource. The functional requirements document for each human system interface resource includes a specification of the cognitive activities associated with the operators’ use of the HSIs.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Functional Requirements Specification

Criterion:

Functional requirements should be developed to address: 1) concept of operations, 2) personnel functions and tasks that support the role in the plant as derived from task, functional requirements, and staffing analyses; 3) personnel requirements for a safe, comfortable working environment. Requirements should be established for various types of HSIs, e.g., alarms, displays, and controls.

Evaluation:

See response to criterion 2 above. In addition, the Westinghouse design process provides for the development of comprehensive detailed design guidance and provides sufficient information to support its standard and consistent application. The application of the process to AP1000 guidance is addressed in DCD Tier 2 Section 18.8.1.2, “Design Guidelines.” The specific commitment to develop HSI design guidance for each HSI resource is identified. A general description of the content of the guidance documents is provided and includes: intended scope, references to sources, instructions for use, design conventions and guidelines, and provisions for guideline deviations based on a documented rationale.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: HSI Concept Design

Criterion:

The functional requirement specification should serve as an initial source of input to the HSI design effort. Operating experience from predecessor designs should be considered if applicable. Alternative approaches for addressing HSI functional requirements should be considered. Alternative concept designs should be evaluated with one selected for further

development. HSI design performance requirements should be identified for components of the selected HSI concept design.

Evaluation:

The HSI design process proposed for the AP1000 design is presented an implementation plan which is described in DCD Tier 2 Section 18.8, “Human System Interface Design.” As such, the central elements of the AP1000 HSI design processes are based on a "comprehensive model of operator performance" that incorporates information from a variety of sources (e.g., reports of problems with current control technology, studies of human performance, Westinghouse expertise, and industry experience as discussed in the EPRI ALWR URD).

The staff has reviewed the "rationale for each M-MIS feature" (that is, the wall panel information station, functionally organized alarm system, compact workstations, functionally and physically organized workstation displays, computer-based procedures, and plant communication system). For each operator activity identified by the applicant (detection and monitoring, interpretation and planning, and controlling plant state), the staff reviewed the ways in which the relevant features support the activity. Detailed guidelines were reviewed as products of the applicant design process. These documents were reviewed in terms of statements of their intended scope, references to source materials, instructions for their proper use, and procedures to be followed. One of these document provides guidance on display design. The document contains numerous graphics and illustrations providing examples of the design principles that will further support its use by the design team. References to numerous appropriate source documents are also included such as the Boff, Human Engineering Compendium; Smith and Mosier; Tufte, 1983; Helendar, 1988; and NUREG-0700.

The staff also reviewed an alarm system design guideline which was a very comprehensive document that addresses alarms from the perspective of their role in plant operations and not simply the end-point design. The technical basis for the alarm guidance included references to numerous appropriate sources such as EPRI 3448, ALWR URD (1989); Van Cott and Kinkade; IEEE 1023-1988; NUREGs-0737, -0696, -0800, -1342; and RG 1.97. In addition, the applicant has tested several of the HSI concepts earlier proposed for the AP1000 design such as soft controls; the wall panel information system, computer-based alarms and procedures (see the applicant response to AP1000 RAI 620.008), providing evidence that alternative approaches for HSI concept designs have been employed in the HSI design process for the AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 5: HSI Detailed Design and Integration

Criterion:

Design-specific HFE design guidance (style guide) should be developed. The HSI detailed design should support personnel in their primary role of monitoring and controlling the plant while minimizing personnel demands associated with the use of HSIs. The HSI detailed design should adequately address such factors as minimizing errors associated with risk-important

HSIs, supporting personnel performance during minimal, nominal, and high-level staffing, effects of fatigue on the use of the HSIs, the ability of the HSIs to be used under a full range of environmental conditions, and the ability of the HSIs to support inspection, maintenance, test and repair.

Evaluation:

DCD Tier 2 Section 18.8.1.2, "Design Guidelines," provides a description of a set of standards and convention guideline documents that tailor generic human factors engineering guidance to the AP1000 human system interface design and define how to apply the principles. The applicant indicates that the guidelines become a tool that enables groups of people to simultaneously develop the HSI in a consistent manner in accordance with the human factors engineering principles established for the design. These guideline documents include: Anthropometric guidelines; Alarm guidelines; Display guidelines; Control guidelines; and Computerized procedures guidelines. In addition, the applicant has proposed the use of design specifications for the operation and control centers system and human system interface resources. They provide for the design of each human system interface resource, including the integration of the hardware and software to satisfy the human system interface functional design requirements. To further address this criterion of HSI detailed design and integration, the applicant proposes the use of engineering tests to support the HSI design process described in DCD Tier 2. WCAP-14396 (Revision 3), "Man-in-the-Loop Test Plan Description," provides additional means for addressing this criterion through the use of engineering tests to obtain empirical results about HSI design questions that could affect the final design of the HSI.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 6: HSI Tests and Evaluations

Criterion:

Testing and evaluation of the HSI designs should be conducted throughout the HSI development process and the evaluations should be performed.

Evaluation:

WCAP-14396 (Revision 3), "Man-in-the-Loop Test Plan Description," provides a description of the use of engineering tests to support the detailed HSI design process. The engineering tests proposed by the applicant for the AP1000 HSI design are preliminary tests to address the design of HSIs as compared to validation tests that are performed as part of the validation of the final HSI design to test the acceptability of the HSIs during verification and validation of the plant design. The tests reflect an iterative design process with the intent of identifying and correcting HSI design deficiencies before the validation of the final HSI design.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 7: Trade-Off Evaluations

Criterion:

The selection of the HSI design approaches should consider the effects of the following criteria: personnel task requirements; human performance capabilities and limits; HSI system performance requirements; inspection and testing requirements; maintenance requirements; and the use of proven technology and operating experience of predecessor designs. The HSI design selection process should indicate the relative benefits of design alternatives and the basis for their selection.

Evaluation:

DCD Tier 2 Section 18.8.1.8 addressed this item. DCD Tier 2 states that the HSI resources identified were selected as a starting point for meeting the information and control needs for general human activities (such as detection, planning, and control) identified in the operator decision making model (described in WCAP-14695). The relationship between the human activities and the control room resources are described in DCD Tier 2 Figure 18.8-3. For example, detection and monitoring are supported by the alarm system, the wall panel information system, the qualified data processing system (QDPS) and the plant information system. The principal source for the initial selection was utility requirements and operating experience review. The basis of all resource design decisions will be documented in the functional design documentation. The acceptability of each resource and the evaluation of design alternatives for the detailed implementation of each resource are accomplished through the test and evaluations that are performed during concept testing, engineering tests and final V&V. The results of testing will be used to refine the design.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 8: Performance-based Tests

Criterion:

Various criteria constitute the development of appropriate performance-based tests. These criteria include, testing that should be based on specific test objectives; selection of test-beds should be based upon the requirements of the test hypotheses and maturity of the designs; selection of appropriate test participants; selection of appropriate performance measurements; selection of an appropriate test environment; selection of appropriate test data analysis techniques, etc.

Evaluation:

Details of the various engineering tests planned to support the detailed design of the AP1000 human system interfaces are provided by Westinghouse in WCAP-14396 (Revision 3). WCAP-14396 (Revision 3) Section 2.4, “General Test Plan,” discusses the issues identified in this criterion such as overall test design, use of test subjects, use of performance measures and data analysis and, use of test results. This topic is also covered, to a lesser extent, in

WCAP-15860, “Programmatic Level Description of the AP1000 Human Factors Verification and Validation Plan,” which will be addressed later in this report.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 9: HSI Design Documentation

Criterion:

The HSI design should be documented to include the following features:

- the detailed HSI description, including the format and performance characteristics
- the basis for the HSI design characteristics with respect to operating experience and literature analyses, trade-off studies, engineering evaluations and experiments, and benchmark evaluations
- records of the basis of the design changes

The outcomes of tests and evaluations performed in support of HSI design should be documented.

Evaluation:

A full documentation of the AP1000 HSI is not currently available because the design is not yet completed. DCD Tier 2 Sections 18.8, “Human System Interface Design,” and 18.13, “Inventory,” document the current status of the MCR resources, including HSI requirements, description, and technical basis.

The complete documentation process for the final design is described and controlled under WCAP-15847 (Revision 1), “AP1000 Quality Assurance Procedures Supporting NRC Review of AP1000 DCD Tier 2 Sections 18.2 and 18.8,” which provides a description of the HSI documentation process. Procedure AP-3.1 on System Specification Documents (SSDs) establishes requirements for SSDs. SSDs identify specific system design requirements and show how the design satisfies the requirements. They provide a vehicle for documenting the design and its basis. General Step C states that the SSDs provide for the control room HSI design. Step E and Appendix C provide a list of systems for which SSDs are required, which includes the operation and control centers (OCS). Appendix A provides a table of contents by section for each SSD and Appendix B provides a summary description of what should go into sections of the SSD.

WCAP-15847, Procedure AP-3.2 on Change Control Program provides the required process and actions to implement a design change in a document that is under configuration control. The scope of the procedure includes SSDs, drawings, and so forth. It has considerable information on responsibilities, procedures, documentation, and approvals.

WCAP-15847, Procedure AP-3.6 on Design Criteria Documents specifies requirements for the preparation, review, approval, and revision of design criteria documents, which define the requirements for specific aspects of the AP1000 design, typically in a single discipline or subdiscipline. In addition, DCD Tier 2 Section 18.8.1.2, "Design Guidelines," provides a commitment from the applicant that the HFE program will be developed using accepted industry standards, guidelines, and practices. Section 18.8.6, "References," provides numerous citations of applicable standards, guidelines, and practices used to develop the AP1000 HSI design.

In conclusion, the Westinghouse design process defined in WCAP-15847, documented and illustrated in the DCD for the current state of the AP1000 HSI design completion, will provide an acceptable documentation of the detailed HSI design. Based on the review the staff has concluded that WCAP-15847 (Revision 1) is applicable to AP1000.

Based on this information, this NUREG-0711 criterion is satisfied.

18.8.1.4 Conclusions

The objective of this review is to evaluate the process by which HSI design requirements will be developed and HSI designs will be selected and refined. The staff reviewed HSI development at an implementation plan level of detail. The review addressed the process by which function and task requirements will be translated to the displays and controls that will be available to the crew. The applicant should have a process for systematically applying HFE principles and criteria (along with all other function, system, and task design requirements) to the identification of HSI requirements, the selection and design of HSIs, and the resolution of HFE/HSI design problems and issues. The process and rationale for the HSI design (including the results of trade-off studies, other types of analyses and evaluations, and the rationale for selection of design and evaluation tools) should be documented for review.

The HSI design process presented in DCD Tier 2 has many positive features, including a systematic identification of information and control requirements, and the systematic testing of concepts and designs. This process includes developing functional requirements and functional specifications for key components of the HSI design. This is followed by the development of physical implementation documents that guide the detailed design of software and hardware.

The review of the AP1000 HSI focuses strongly on the process by which the final design will be developed. Details of the guidance documents and the process by which they will be completed are important considerations in this review because the full details of the actual HSI design were not available before design certification.

The applicant has provided an acceptable Human-System Interface Design implementation plan for the AP1000 design. The COL applicant referencing the AP1000 certified design is responsible for the execution and documentation of the human system interface design implementation plan. This is COL Action Item 18.8.1.4-1.

18.8.2 Safety Parameter Display System

18.8.2.1 Objectives

The objective of this review is to evaluate the way in which SPDS functions will be provided in the AP1000 control room. The review will ensure that the applicant has appropriately translated SPDS functional requirements to the displays that are available to the crew.

18.8.2.2 Methodology

18.8.2.2.1 Material Reviewed

The review focused on an evaluation of the applicant material pertinent to the SPDS. The staff used the following Westinghouse documents in this review:

- DCD
- WCAP-14396 (Revision 3) dated November 27, 2002

18.8.2.2.2 Technical Basis

The staff focused its review on an evaluation of information provided by the applicant pertaining to the SPDS with respect to the criteria contained in 10 CFR 50.34 (f)(2)(iv), Supplement 1 of NUREG-0737, and NUREG-1342. This review considered the extent to which the applicant's design will support the functions required for the SPDS, because the applicant has not completed the detailed design of the control room displays.

18.8.2.3 Results

Criterion 1: General SPDS Requirements

Criterion:

The top-level requirements for SPDS are contained in 10 CFR 50.34 (f)(2)(iv). The detailed NRC criteria that follow were derived from Supplement 1 of NUREG-0737.

Evaluation:

The discussion of plant safety parameters in 10 CFR 50.34 (f)(2)(iv) indicates that the design should provide a plant safety parameter display console that will (a) display to operators a minimum set of parameters defining the safety status of the plant, (b) be capable of displaying a full range of important parameters and data trends on demand, and (c) be capable of indicating when process limits are being approached or exceeded.

As described in DCD Tier 2 Section 18.8.2, “Safety Parameter Display System,” the applicant addresses the SPDS concerns and criteria via an integrated design rather than a stand-alone, add-on system, as is used at most current operating plants. The regulatory requirements will

be addressed by integrating the SPDS requirements into the design requirements for the alarm and display systems. In NUREG-0800, the staff indicated that, for applicants who are in the early stages of the control room design, the “function of a separate SPDS may be integrated into the overall control room design.”

Therefore, the staff has determined that the special circumstances described in10 CFR 50.12(a)(2)(ii) exist. The applicant has provided an acceptable alternative that accomplishes the intent of the regulation. The requirement for an SPDS console need not be applied in this particular circumstance to achieve the underlying purpose for an SPDS, which is to provide a control room improvement that enhances operator ability to comprehend plant conditions and interact in situations that require human intervention. The SPDS should provide a concise display of critical plant variables to control room operators to aid them in rapidly and reliably determining the safety status of the plant.

On this basis, the Commission concludes that an exemption from the requirements of 10 CFR 50.34(f)(2)(iv) for an SPDS console is authorized by law, will not present an undue risk to public health and safety, and is consistent with the common defense and security. However, for the implementation of an integrated SPDS to be acceptable, it must meet the detailed SPDS requirements reflected in this item. A discussion of these requirements is given below:

> The SPDS will display to operators a minimum set of parameters defining the safety status of the plant. The SPDS will be capable of displaying a full range of important parameters and data trends on demand.
>
> The minimum set of parameters defining safety status is reviewed in Criterion 8. With respect to other "important parameters," the applicant's integrated HSI design provides parameter display to operators via the wall panel information display and the workstation displays. A complete specification of the individual parameters to be displayed will be developed as the MCR design and its supporting analyses, such as FBTA and HRA, continue. The status of the functions of reactivity control, reactor core cooling and heat removal, reactor coolant system integrity, radioactivity control, and containment will be provided. Most of the parameters used to monitor these functions are continuously displayed. Those that are not will be available in one navigation step. DCD Tier 2 Chapter 7, identifies parameters for postaccident monitoring (PAM) which includes those needed to monitor the critical safety functions (CSFs).
>
> The ability of operators to call up data trends on demand is addressed in Section 18.9.5.
>
> The SPDS will be capable of indicating when process limits are being approached or exceeded.
>
> This SPDS function will be satisfied by the AP1000 alarm management system.
>
> Another set of top-level requirements for the SPDS is contained in NUREG-0737-Supplement Number 1, 3.8.a, Items (1), (2), and (3). These are expressed in terms of one acceptable way of implementation, with other proposals to be reviewed as necessary.

Item (1) states that the licensee/applicant should review the functions of the nuclear power plant operating staff that are necessary to recognize and cope with rare events that pose significant contributions to risk, could cause operators to make cognitive errors in diagnosing them, and are not included in routine operator training programs.

Item (2) states that the licensee/applicant should combine the results of this review with accepted human factors principles to select parameters, data display, and functions to be incorporated into the SPDS.

Item (3) states they should then design, build, and install the SPDS in the control room and train its users.

The applicant committed to design, build, and install the SPDS in accordance with accepted human factors principles as discussed in DCD Tier 2 Section 18.8.2.5, "Human Factors Engineering." The applicant discussed the training of users in DCD Tier 2 Section 18.8.2.7, "Procedures and Training." However, training has been defined as a COL item (see DCD Tier 2 Section 18.10, "Training Program Development"). Thus, the SPDS training issue will not be addressed as part of the design certification review.

Based on this information, this SPDS criterion is satisfied.

Criterion 2: Rapid and Concise Display of Safety Parameters

Criterion:

The SPDS should provide a rapid and concise display of critical plant variables to control room operators.

Evaluation:

The basis for the requirement for a concise display stems from the lack of centralized display capability in the Three Mile Island Nuclear Station, Unit 2 (TMI-2) control room. TMI-2 control room personnel could not easily develop an overview of plant conditions, which contributed to the severity of the accident. The applicant alarm management system is organized around the concept of plant process functions, which include the five safety functions defined by the NRC for the SPDS. The layout of these functions ensures that they are always visible.

For the AP1000, a similar design will be used for the wall panel information system. The individual parameters that support the safety functions will be grouped by those safety functions in both the AP1000 alarm system and the plant information system displays. The status of all five safety functions will always be displayed via the alarm system overviews that will be displayed to the operators through the wall panel information system. Thus, a concise display will be available which acceptably addresses this aspect of the SPDS criterion.

Regarding the criterion of a rapid display, judgment of a rapid display is dependent on sample rate, update rate, system response times, and a display format that is easy to understand and rapidly comprehended.

In DCD Tier 2 Section 18.8.2.2, “Display of Safety Parameters,” the applicant stated that the design goal for the graphical display response time is 2 seconds; the design goal for AP1000 HSI is to update the displays every 1 to 2 seconds; and, the process data sampling is 1 second or less. The SPDS design met the criterion with the exception of response time, as explained below.

The acceptability of a display response time of 2 seconds (and as stated in DCD Tier 2 Section 18.8.2.2, as long as 10 seconds) for operator support during transient operations may be problematic for operators. The staff recognizes that this value is within the response time originally developed for SPDS. However, such SPDS consoles were supplemental to the available indications and controls. It is also recognized that a 2 second response time is within the time range recommended by most current HFE guidelines. However, this value is based on general literature and, therefore, may not be fully adequate for emergency operations in a process control environment such as a nuclear power plant. Delays have the potential to create frustration in operators who are accustom to having information instantly available through continuously displayed analog instruments. The staff, therefore, recommended that the applicant verify the acceptability of the 2 second criterion and if found unacceptable, to determine the appropriate display response time.

DCD Tier 2 indicates that most of the safety parameters used to monitor SPDS functions will be continuously displayed on the wall panel information system. Those that are not continuously displayed will be accessible from the operator's workstation with one navigation action. In addition, the applicant agreed to include the issue of response time as a Design Issues Tracking System item and examine it in their “Man-In-The-Loop Test Program,” (WCAP-14396, Revision 2). The tracking system item references the NRC letter dated September 28, 1995, in which the staff's concerns are documented. The item indicates that, "The acceptability of a display response time of 2 seconds for operator support during transient operations is determined during Man-in-the-Loop testing. If 2 seconds is determined to be unacceptable, then a revised display response time is determined."

Based on this information, this SPDS criterion is satisfied.

Criterion 3: Convenient Display of Safety Parameters

Criterion: The location of the SPDS should be convenient to the control room operators.

Evaluation:

To meet this criterion, the SPDS should be convenient to all operators/users of the SPDS. In DCD Tier 2 Section 18.8.2, “Safety Parameter Display System,” the applicant indicated that the SPDS would utilize the main control alarm system and display system in order to fully integrate the SPDS into the AP1000 HSI. All process displays and controls (including the SPDS) will be

available at each of the redundant operator workstations. The control room supervisor has another console that contains all of the same displays. The Shift-Technical Advisor (STA) also has a console with all displays. Finally, the wall panel information system is a parallel display device that also contains the SPDS information, and is available and viewable by all in the control room.

Thus, the status of critical safety functions is conveniently located where it can be monitored from anywhere in the control room and is continuously displayed by the overview alarms presented on the wall panel information system and, in addition, in the computerized emergency operating procedures system when in use.

Based on this information, this SPDS criterion is satisfied.

Criterion 4: Continuous Display of Safety Parameters

Criterion:

The SPDS should continuously display plant safety status information.

Evaluation:

In DCD Tier 2 Section 18.8.2, the applicant indicated that the status of all five safety functions is always displayed via the alarm management system. The alarm system is organized on the dark board concept for all plant modes. Thus, when no alarms are displayed, it indicates that the status of all safety functions is acceptable. The alarm system also will have failure indicators to ensure the operability of the alarm system itself. Further, the AP1000 computerized procedures for EOPs will provide a continuous display of the overall state of each of the safety functions as part of the EOP requirement to monitor the status of the Critical Safety Function Status Trees. The computerized procedures system proposed by the applicant was not reviewed for design certification.

Thus, the status of critical safety functions is conveniently located where it can be monitored from anywhere in the control room and is continuously displayed by the overview alarms presented on the wall panel information system.

Based on this information, this SPDS criterion is satisfied.

Criterion 5: High reliability

Criterion:

The SPDS should have a high degree of reliability.

Evaluation:

The SPDS is to be incorporated into the AP1000 control room; however, the control room is not yet designed. In DCD Tier 2 Section 18.8.2, the applicant indicated that availability and reliability criteria will be included in the design process as is standard for Westinghouse I&C systems. The applicant response to this criterion that the design process will ensure that a high degree of reliability will be achieved for all I&C systems including the SPDS, has been determined acceptable by the staff.

Based on this information, this SPDS criterion is satisfied.

Criterion 6: Isolation

Criterion:

The SPDS should be suitably isolated from electrical or electronic interference with safety systems.

Evaluation:

In DCD Tier 2 Section 18.8.2.4, "Isolation," the applicant stated that a discussion of the electrical isolation for the control room is in DCD Tier 2 Chapter 7. The staff reviewed the applicant response to this criterion (i.e., that data links are fiber-optic isolated and transmit only to the monitor bus) and determined that it acceptably addresses suitable isolation of the SPDS.

Based on this information, this SPDS criterion is satisfied.

Criterion 7: Human Factors Engineering

Criterion:

The SPDS should be designed incorporating accepted human factors principles.

Evaluation:

In DCD Tier 2 Section 18.8.2.5, "Human Factors Engineering," the applicant stated that the SPDS will be incorporated in the control room alarm and display systems. In accordance with the NUREG-0711 element on HSI design (evaluated herein), the staff considered the HSI design acceptable at the program plan level. The detailed implementation of SPDS displays, controls, and interface management (e.g., navigation) characteristics will not be complete until after design certification.

Based on this information, this SPDS criterion is satisfied.

Criterion 8: Minimum Information

Criterion:

The SPDS should display sufficient information to determine plant safety status with respect to safety functions as described in Table 2 of NUREG-1342.

The safety functions and parameters of Table 2 NUREG-1342, were developed for conventional PWRs. They are still generally applicable for the AP1000, but will need to be revised slightly to address the passive plant differences.

Evaluation:

In discussing the minimum parameters for display, NUREG-1342 states that the minimum information to be provided shall be sufficient to provide information about the following safety functions:

- reactivity control
- reactor core cooling and heat removal from the primary system
- RCS integrity
- radioactivity control
- containment conditions

The specific parameters to be displayed are to be determined by licensees and applicants. Sample acceptable parameters for BWRs and PWRs are contained in Tables 2 and 3 of NUREG-1342.

In DCD Tier 2, the applicant indicates that the AP1000 human system interface resources used to address the SPDS requirements are the alarm system, plant information system, and the computerized procedures system. The AP1000 human system interface displays sufficient information to determine plant safety status with respect to the SPDS safety functions. Safety functions and respective parameters that are presented in Table 2 of NUREG-1342 are used as a starting point for developing the AP1000 SPDS. The applicant also commits to track the design issue of SPDS “minimum information” in the human factors engineering issues tracking system.

Based on this information, this SPDS criterion is satisfied.

Criterion 9: Procedures and Training

Criterion:

Procedures and operator training, addressing actions with and without the SPDS, should be implemented.

Evaluation:

DCD Tier 2 addresses procedures and training in Section 18.8.2.7, “Procedures and Training.” This section indicates that procedures and training are the responsibility of the COL applicant. Thus, review of this SPDS criterion is a postdesign certification activity.

Based on this information, this SPDS criterion is satisfied.

18.8.2.4 Conclusions

The objective of this review is to evaluate the way in which the functions of the SPDS will be provided in the AP1000 control room. The staff has completed its review of the SPDS component of Element 7 of NUREG-0711. The applicant has acceptably addressed all criteria for SPDS.

18.9 Element 8: Procedure Development

18.9.1 Objectives

The objective of this review is to ensure that the applicant's procedure development program will result in procedures that support and guide human interaction with plant systems and control plant-related events and activities. Human engineering principles and criteria should be applied along with all other design requirements to develop procedures that are technically accurate, comprehensive, explicit, easy to use, and validated.

18.9.2 Methodology

18.9.2.1 Material Reviewed

The review focused on an evaluation of the applicant documents with respect to the topics and general criteria of NUREG-0711. The following Westinghouse documents were used in this review:

- DCD
- WCAP-14690 (Revision 1) dated June 27, 1997
- NUREG- 1512
- "Westinghouse AP600 Emergency Response Guidelines (ERGs)"

18.9.2.2 Technical Basis

The focus of the staff’s review was to determine the acceptability of the COL action item description and evaluation of applicant’s existing ERGs (developed for AP600) to the AP1000 design.

18.9.3 Results

Procedure development is a COL action item for AP1000.

DCD Tier 2 Section 18.9.1, “Combined License Information,” refers to DCD Tier 2 Section 13.5, “Plant Procedures,” for a description of the item. The item states that procedure development is the responsibility of the COL applicant. Westinghouse will provide the COL applicant with WCAP-14690 (Revision 1), “Designer's Input to Procedure Development for the AP600.” It should be noted that, although Westinghouse submitted this document in support of the COL’s procedure development program, the staff has not evaluated the computerized procedure system identified by Westinghouse as the interface to plant procedures.

The NRC neither endorses nor rejects using the computer as a platform for presenting procedures. In the NRC's review of the EPRI URD guidance on computer-based procedures (CBPs), questions were raised concerning the basis for the computerized procedure requirement. EPRI (1991) indicated that CBP guidance is lacking and that it will have to be developed by the designer using simulation. The response noted that "Since both the 'soft' and 'hard' procedures are subject to the test of active simulation, there will inherently be a direct comparison between the 'soft' and the 'hard' procedures as part of the design process. Differences in operator performance with the computer-presented procedures compared to the conventional printed procedures should be evident from these evaluations". Further, EPRI indicated that "If the soft procedures are not concluded to represent an improvement when active simulation is attempted, there is a clear fall-back to hardcopy procedures".

In consideration of the EPRI URD and the subsequent response to the RAI, the staff noted that:

> the development of electronically displayed procedures is a desirable goal for the overall integration of operator information needs. The staff position is that the M-MIS designer should consider the use of electronically displayed procedures early in the design process to resolve any issues concerning their development, operability, maintainability, and reliability. If electronically displayed procedures are determined to be an improvement over hard-copy procedures and the M-MIS designer has integrated electronically displayed procedures into the overall M-MIS design, they should be provided as part of the design.

The staff position reflected in the URD review is applicable to the AP1000 use of computerized procedures. That is, the acceptance of them will be based, in part, on the type of evaluations described above.

Evaluation of the applicant computerized procedure system was not included in design certification for the AP1000. The WCAP provides information on the computer-based procedure system which will serve as the interface to the plant procedures.

While this description is acceptable, the staff has determined that it is necessary for the COL applicant to (1) address the procedure development considerations in NUREG-0711and (2) to identify the minimum documentation that the COL applicant will provide to the staff to complete its review. This is COL Action Item 18.9.3-1.

In addition to the information provided in DCD Tier 2 Section 18.9.1, “Combined License Information,” and DCD Tier 2 Section 13.5, “Plant Procedures,” the staff assessed the

applicability of applicant's existing ERGs to the AP1000 design. The ERGs (or generic technical guidelines) are evaluated in the following paragraphs as an important input to procedure development. The acceptability of other bases for the development of AP1000 procedures (e.g, task analysis results, risk-important human actions) is addressed in other elements of the design review.

Section 18.9 of the DCD Tier 2 states that WCAP-14690 provides input to the Combined License applicant for the development of plant operating procedures, including information on development and design of the emergency response guidelines (ERGs) and emergency operating procedures which applies to AP1000. Also, Sections 19E.1.2 and 19E.3.3 reference applicant's existing ERGs to address the shutdown operations issues for the AP1000 design, and states that applicant's existing ERGs are applicable to AP1000 for the purpose of developing emergency operating procedures.

In response to the staff requests for technical justification of the applicability of applicant's existing ERGs to AP1000 design, the applicant provides the following technical reasons:

1) The existing ERGs (developed for the AP600) are suitable for the AP1000 for the purposes for which they are intended. Namely, to provide the starting point for the development of the EOPs as part of the HFE process. The ERGs provide symptom-based, as opposed to event-based guidance to operator. For that reason, the ERGs do not immediately instruct the operator to attempt to diagnose an event. The ERGs guide the operator to assess the plant parameters and operability of the available systems, and provides the most straightforward director to the operator.

2) The AP600 and AP1000 employ the same passive safety-related systems that significantly reduces the burden on the operator in and accident scenario when compare with the operating reactors. The design of the AP600 and AP1000 are functionally the same with respect to the role of the passive safety systems and active systems provided for defense-in-depth. The symptom-based approach contained in applicant's existing ERGs allow for them to be used as the starting point to develop the detailed EOPs as part of the HFE design process for the AP1000.

3) The use of existing ERGs for the AP1000 is similar to the implementation of the Standard ERGs for Westinghouse Operating Plants. Because the ERGs are symptom-based, the functional guidance they provide is applicable to a range of plant designs that functionally perform in a similar manner. For example, the Westinghouse Standard ERGs can apply to 2-loop, 3-loop or 4-loop plants that contain a range of nuclear steam supply system (NSSS) and balance of plant system design features. Therefore, it is reasonable to expect that applicant's existing ERGs can be used as the starting point for the development of the AP1000 EOPs.

4) The analysis provided in the ERGs Background documentation is suitable, as it provides an example of the role of the operator in performing actions outlined in the ERGs. The timing of the specific accidents analyzed may be slightly different for two plants; however, the response of the operator of any particular plant symptom or system will be similar.

The staff has reviewed the above technical justifications and agreed with the Westinghouse assessment that existing ERGs could be applied to AP1000 design for developing adequate EOPs using proper HFE procedures.

18.9.4 Conclusions

The objective of this review is to ensure that the applicant's procedure development program will result in procedures that support and guide human interaction with plant systems, and control plant-related events and activities. Human engineering principles and criteria should be applied along with all of the other design requirements to develop procedures that are technically accurate, comprehensive, explicit, easy to use, and validated.

Procedure development is a combined license action item and will be addressed by the COL applicant as part of postdesign certification issues. This is COL Action Item 18.9.4-1.

18.10 Element 9: Training Program Development

18.10.1 Objectives

A systems approach to training, as defined in 10 CFR 55.4, is required of plant personnel by 10 CFR 52.78 and 50.120. Training design is to be based on the systematic analysis of job and task requirements. The HFE analyses associated with the HSI design process provide a valuable understanding of the task requirements of operations personnel. Therefore, training program development should be coordinated with the other elements of the HFE design process. The objective of this review is to ensure that the COL applicant establishes an approach for the development of personnel training that incorporates the elements of a systems approach to training, as well as the following:

- a systematic analysis of tasks and jobs performed
- development of learning objectives derived from an analysis of desired performance following training
- design and implementation of training based on the learning objectives
- evaluation of trainee mastery of the objectives during training
- evaluation and revision of the training based on the performance of trained personnel in the job setting.

18.10.2 Methodology

18.10.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD
- WCAP-14655 (Revision 1) dated August 8, 1996

8.10.2.2 Technical Basis

The focus of the staff's review was to determining the acceptability of the COL action item description with respect to the topics and review criteria of Element 10, "Training Program Development," of NUREG 0711.

18.10.3 Results

DCD Tier 2, Section 18.10.1, "Combined License Information," refers to DCD Tier 2 Section 13.2, "Training," for a description of the item. The item states that training program development is the responsibility of the COL applicant. Westinghouse will provide the applicant with WCAP-14655 (Revision 1), "Designer's Input to Training of the Human Factors Engineering Verification and Validation Personnel." The WCAP provides information on how insights are passed from the designer to the COL applicant. While this description is acceptable, the staff has determined that it is necessary for the COL applicant to (1) address the training program development considerations in NUREG-0711, (2) address relevant concerns identified in this report, and (3) to identify the minimum documentation that the COL applicant will provide to the staff to complete its review. Based on the review, the staff has concluded that, WCAP-14655 (Revision 1) and the associated COL action item are applicable to AP1000. This is COL Action Item 18.10.3-1.

18.10.4 Conclusion

The objective of the training program review is to ensure that the applicant establishes an approach for developing personnel training that incorporates the elements of a systems approach to training, evaluates the knowledge and skill requirements of personnel, coordinates training program development with the other elements of the HFE design process, and implements the training in an effective manner that is consistent with human factors principles and practices.

Training Program Development is a combined license action item and will be addressed by the COL applicant as part of postdesign certification issues. COL Action Item 18.10.4-1.

18.11 Element 10: Human Factors Verification & Validation

18.11.1 Objective

The objective of this review is to ensure that the:

- HFE/HSI design provides all necessary alarms, displays, and controls to support plant personnel tasks

- HFE/HSI design conforms to HFE principles, guidelines, and standards

- HFE/HSI design can be effectively operated by personnel within all performance requirements

- HFE/HSI design resolves all of the identified HFE issues (HEDs)

18.11.2 Methodology

18.11.2.1 Material Reviewed

The staff used the following Westinghouse documents in this review:

- DCD
- WCAP-14396 (Revision 3) dated November 27, 2002
- WCAP-15860 dated April 10, 2002
- WCAP-15847 (Revision 1) dated January 9, 2003

18.11.2.2 Technical Basis

The staff focused its review on an evaluation of the applicant documents with respect to the topics and general criteria of Element 11, "Human Factors Verification & Validation," of NUREG-0711.

A detailed V&V implementation plan was not submitted for design certification. Detailed verification and validation procedures were not developed for design certification. The staff reviewed the applicant's V&V description at a programmatic review level, because completion of an implementation plan is a COL action item and will not be completed until after design certification.

Element 10 was reviewed at a programmatic review level; therefore, detailed evaluations using NUREG-0711 acceptance criteria are beyond the scope of the staff review for design certification. At a programmatic level review, NUREG-0711 criteria are used to determine whether the applicant program provides a top-level identification of the substance of each criterion which, after design certification, will be developed (by Westinghouse) into a detailed implementation plan. ITAAC exist for completing the implementation plan and the commitment to the development of such a detailed implementation plan is described in the ITAAC.

18.11.3 Results

The staff reviewed the general criteria for V&V, Operational Condition Sampling; Design Verification (HSI Task Support Verification and HFE Design Verification); Integrated System Validation; and Human Engineering Discrepancies Resolution.

18.11.3.1 Operational Conditions Sampling

Criterion 1: Sampling Dimensions

The sampling methodology will identify a range of operational conditions to guide V&V activities. The sample of operational conditions should, 1) include conditions that are representative of the range of events that could be encountered during operation of the plant, 2) reflect the characteristics that are expected to contribute to system performance variation, 3) and consider the safety significance of HSI components.

Criterion 1-1:

The following plant conditions should be included: normal events including plant startup, plant shutdown or refueling, and significant changes in operating power; failure events; transients and accidents; and reasonable risk-significant, beyond-design basis events.

Evaluation:

In WCAP-15860, Section 1.2, "General Scope of AP1000 V&V," Westinghouse indicates that the operational sequences that will be included in V&V will cover a full range of activities including, startup; normal operations; abnormal and emergency operations; transient conditions; low power; and shutdown conditions. The V&V scope will include those tasks determined to be risk-important as determined by the probabilistic risk assessment (PRA) threshold criteria specified in the implementation plan for the integration of human reliability analysis (HRA) and HFE Design. Section 4.6, "Criteria for Evaluation of Test Scenarios for Dynamic Evaluations," contains further detail related to addressing this criterion.
Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 1-2:

The following types of personnel tasks should be included as part of an HFE V&V program: risk-significant human actions, systems, and accident sequences; OER-identified difficult tasks; range of procedure-guide tasks; range of knowledge-based tasks; range of human cognitive activities; range of human interactions.

Evaluation:

See description in the previous evaluation. In addition, WCAP-15860, Section 4.6, "Criteria for Evaluation of Test Scenarios for Dynamic Evaluations," contains further detail related to addressing this criterion such as using scenarios that produce cognitive challenges; using scenarios that are sufficient to validate the EOPs, and key HRA modeling assumptions. WCAP-14396 (Revision 3) provides additional information in Section 2.4, "General Test Plan."

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 1-3:

The sample should reflect a range of situational factors that are known to challenge human performance such as, operationally difficult tasks; error-forcing contexts; high workload

conditions; varying workload situations; varying fatigue and circadian factors; environmental factors.

Evaluation:

See description in the previous evaluation. In addition, WCAP-15860, Section 4.6, “Criteria for Evaluation of Test Scenarios for Dynamic Evaluations,” contains further detail related to addressing this criterion, specifically addressing factors such as high workload. Section 4.7, “Realistic Validation Scenarios,” further addresses issues such as environmental factors.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Scenario Identification

Criterion 2-1:

The results of sampling should be combined to identify a set of scenarios to guide subsequent analyses.

Evaluation:

WCAP-15860, Section 4.6, “Criteria for Evaluation of Test Scenarios for Dynamic Evaluations,” indicates that a multidimensional set of criteria will be used to define a set of test scenarios to be included in the AP1000 integrated system validation.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2-2:

Scenarios should not be biased in the direction of factors such as scenarios where only positive outcomes can be expected, scenarios that are relatively easy to conduct administratively, and scenarios that focus on “textbook” design accidents.

Evaluation:

WCAP-15860, Section 4.6, “Criteria for Evaluation of Test Scenarios for Dynamic Evaluations,” indicates that the set of test scenarios included in the integrated system validation will be defined by a multi disciplinary team that includes input from EOP developers, HSI designers, human factors specialists, and human reliability analysis/PRA analysts. Section 4.7, “Realistic Validation Scenarios,” and Section 4.8, “Performance Measures and Acceptance Criteria,” provide further explanation to address this criterion.

Based on this information, this NUREG-0711 criterion is satisfied

18.11.3.2 Inventory and Characterization

Criterion 1: Scope

Criterion 1-1:
The applicant should develop and inventory all HSI components associated with the personnel tasks that are required based on the identified operational conditions.

Evaluation:

In DCD Tier 2 Section 18.8.1.7, "Task-Related Human System Interface Requirements," the applicant discusses the process of operational sequence analysis (OSA) which is comparable to a traditional task analysis. One type of information provided by the operational sequence analysis is an inventory of alarms, controls, and parameters needed to perform the task sequences.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: HSI Characterization

Criterion:

The inventory should describe the characteristics of each HSI component within the scope of the review with the following information for each component: unique identification code number or name; associated plant system and subsystem; associated personnel function/subsystem; type of HSI component; display characteristics and functionality; control characteristics and functionality; user-system interaction and dialog type; location in the data management system; physical location of the HSI if applicable. Photos, copies of Video Display Unit screens, and samples of HSI components should be included.

Evaluation:

Although the applicant does not address the specific characteristics of each HSI component identified in the inventory of HSIs developed as part of the design process, the set of documents that the applicant describes in DCD Tier 2 Section 18.8.1, "Implementation Plan for the Human System Interface Design," as an output of the functional design, provide assurance that characteristics needed for a satisfactory description of an HSI inventory are present. The applicant has a comprehensive set of HSI design documents that specify the mission, design bases, performance requirements, and functional requirements for each HSI.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Information Sources

Criterion:

The HSI inventory should be based on the best available sources (e.g., equipment lists, design specifications and drawings).

Evaluation:

In DCD Tier 2 Section 18.8.6, “References,” the applicant provides an acceptable listing of contemporary sources that will be used in compiling human factors engineering guidelines, standards, and principles to be included in the AP1000 design guidance.

Based on this information, this NUREG-0711 criterion is satisfied.

18.11.3.3 HSI Task Support Verification

Criterion 1: Criteria Identification

Criterion:

The criteria for task support verification come from task analyses of HSI requirements for performance of personnel tasks.

Evaluation:

WCAP-15860, Section 2, “HSI Task Support Verification,” indicates that the AP1000 HSI task support verification implementation plan will include checking against information and control requirements identified by the function-based task analysis and operational sequence tasks analysis.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: General Methodology

Criterion:

HSIs and their characteristics should be compared to the personnel task requirements identified in the task analysis.

Evaluation:

In WCAP-15860, Westinghouse described their approach to HSI task support verification. Section 2 of WCAP-15860 identified the objective and high-level methodology for conducting the evaluation. The analysis will address the availability of HSI features for accomplishing

personnel tasks and actions as defined by the task analyses, the EOPs, and the risk-important human tasks identified by the PRA.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Task Requirements Deficiencies

Criterion:

HEDs should be identified when an HSI needed for task performance is not available, or when HSI characteristics do not match personnel task requirements.

Evaluation:

WCAP-15860, Section 5, “Issue Resolution Verification,” indicates that an implementation plan will be developed to ensure that all human factors issues are adequately addressed in the final HSI design.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 4: Unnecessary HSI Components

Criterion:

The applicant should verify that the HSI does not include information, displays, controls, and so forth, that do not support operator tasks. This includes non-functional, decorative details, such as borders and shadowing on graphical displays.

Evaluation:

In WCAP-15860, Westinghouse described their approach to HSI task support verification. Section 2 of WCAP-15860 identified the objective and high-level methodology for conducting the evaluation. The plan also indicated that the methodology shall describe how, in each case, the HSI design will be verified to ensure that the HSI does not include information, controls, and displays that do not support operator tasks. A process for checking such HSI features will include an analysis before any information is removed from the HSI.

Based on this information, this NUREG-0711 criterion is satisfied.

18.11.3.4 HFE Design Verification

Criterion 1: Criteria Identification

Criterion:

Review criteria are the HFE guidelines. Selection of specific guidelines depends on the characteristics of the HSI components included in the scope of review and whether the applicant has developed a design-specific guideline document. NUREG-0700 may be used for HFE design verification.

Evaluation:

In WCAP-15860, Westinghouse described the general approach to HFE design verification. Section 3 of WCAP-15860 identifies the objective and high-level methodology for conducting the evaluation. The analysis will address the verification that all aspects of the HSI are consistent with accepted HFE guidelines, standards, and principles. The verification will utilize AP1000-specific guidance documents and will cover alarms, displays, controls, data processing, navigation, computerized procedures, workstation and console configurations, and anthropometric considerations and their integration. The document identifies an illustrative subset of the documents that will be used in the development of the AP1000-specific guidance. It includes the most recent control room design guidance including IEC 964 and NUREG-0700 (Revision 2). The plan also identified the process through which guideline deviations will be addressed and their technical basis documented.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: General Methodology

Criterion:

Characteristics of HSI components should be compared with the HFE guidelines to determine whether the HSI is acceptable or discrepant (i.e., an HED). Discrepancies should be evaluated as potential indicators of additional issues.

Evaluation:

In WCAP-15860, Westinghouse described the general approach to HFE design verification. Section 3 of WCAP-15860 identifies the objective and high-level methodology for conducting the evaluation. The applicant indicated that the design implementation plan will specify a process by which deviations from accepted HFE guidelines, standards, and principles will be identified and acceptably justified based on a documented rationale. AP1000-specific HSI standards and convention guidelines will provide documentation of any deviations from accepted HFE guidelines, standards and principles.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: HED Documentation

Criterion:

HEDs should be documented in terms of the HSI component involved and how the characteristics depart from a particular guideline.

Evaluation:

See Open Item for 18.11.3.6 Human Engineering Discrepancy Resolution

Based on this information, the NUREG-0711 criterion is identified as Open Item 18.11.3.4-1.

18.11.3.5 Integrated System Validation

Criterion 1: Test Objectives

Criterion:

The methodology for integrated system validation should address the following items:

- general objectives
- test objectives
- validation testbeds
- plant personnel
- scenario definition
- performance measurement
- test design
- data analysis and interpretation
- validation conclusions

Evaluation:

In WCAP-15860, Westinghouse described the general approach to integrated system validation. Section 4 of WCAP-15860 identifies the objective and high-level methodology for conducting the evaluation. Section 4.1 identifies the aspects to the methodology that will be addressed in the implementation plan. The topics identified in the NUREG-0711 are included. In addition, the plan addresses the process by which results will be used to evaluate potential design changes and, where made, their subsequent verification.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 2: Validation Testbeds

Criterion:

Validation should be performed by evaluating dynamic task performance using tools that are appropriate to the accomplishment of this objective. The primary tool for this purpose is a simulator (i.e., a facility that physically represents the HSI configuration and that dynamically represents the operating characteristics and responses of the plant design in real time).

The requirement to validate performance at plant HSIs outside the CR will depend on the applicant's design. Human actions at non-CR facilities, such as remote shutdown panels and LCSs, may be evaluated using mockups, prototypes, or similar tools.

Evaluation:

In WCAP-15860, Westinghouse described the general approach to integrated system validation. Section 4.2 of WCAP-15860 addressed the tools for evaluating dynamic task performance. A "near full-scope," high-fidelity simulator that satisfies the general requirements of Sections 3 and 4 of ANSI/ANS-3.5-1998, will be used. "Near" means features of the simulation that are not relevant to the tests being performed may not be high-fidelity. Personnel actions that are performed at non-control room facilities, such as remote shutdown panels and the TSC may be evaluated using static mock-ups or prototypes.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 3: Plant Personnel

Criterion:

Participants in validation tests should represent an unbiased sample; be representative of actual plant personnel; reflect characteristics of the population of plant personnel; include shift supervisors, reactor operators, shift technical advisors, etc., and minimum and normal crew configurations.

Evaluation:

In support of the AP1000 design, Westinghouse submitted WCAP-14396 (Revision 3), "Man-In-The-Loop Test Plan Description." Section 2.4.3, "Subjects," addresses the composition of the "target user population," the test subject population. While this WCAP addresses preliminary or "engineering" tests, rather than final or "validation" tests, with validation tests addressed by WCAP-15860, the test subject selection criteria are applicable to test subjects for both test types. The applicant should amplify/clarify or explain how validation tests address this NUREG-0711 item. This is Open Item 18.11.3.5-1.

Based on this information, this NUREG-0711 criterion is identified as Open Item 18.11.3.5-1.

Criterion 4: Scenario Definition

Criterion:

The validation scenarios should be realistic. Selected scenarios should include environmental conditions, such as noise and distractions, which may affect human performance in an actual nuclear power plant. For actions outside of the control room, the performance impacts of potentially harsh environments (i.e., high radiation) that require additional time should be realistically simulated (i.e., time to don protective clothing and access hot areas). Dynamic evaluations should evaluate the HSI under a range of operational conditions and upsets, and should include the following events:

- normal plant evolutions (e.g., startup, full power, and shutdown operations)
- instrument failures (e.g., the solid state logic control unit, fault tolerant controller, local "field unit" for the multiplexes system, or a break in a MUX line)
- HSI equipment and processing failure (e.g., loss of VDUs, data processing, or the large overview display)
- transients (e.g., turbine trip, loss of offsite power, station blackout, loss of all feedwater, loss of service water, loss of power to selected buses or main control room power supplies, or safety relief valve transients)
- accidents (e.g., main steamline break, positive reactivity addition, control rod insertion at power, control rod ejection, anticipated transient without scram and various sized loss-of-coolant accidents
- reactor shutdown and cooldown from the remote shutdown panel

Evaluation:

In WCAP-15860, Westinghouse described their general approach to integrated system validation. Section 4.7 of WCAP-15860 addresses how the scenarios selected for validation will be made realistic. Considerations regarding the incorporation of environmental conditions, communication demands, and the number of personnel in the control room are identified in the program description. In WCAP-15860, Westinghouse described their general approach to integrated system validation. Section 4.6 discusses the selection of test scenarios. Test scenarios will be defined using a multi-dimensional set of criteria. The dimensions are identified and include all of the types of scenarios identified on NUREG-0711. In addition, the applicant identified design features that are specific to the AP1000 such as ADS, situations that are cognitively challenging to the crew such as complicated situation assessment under conflicting plant state information, and scenarios that would enable validation of key HRA assumptions

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 5: Performance Measurement

Criterion:

Performance measures should exhibit a number of characteristics to ensure that the measures are of good quality such as: construct validity, diagnosticity, objectivity, impartiality, reliability, resolution, sensitivity, simplicity, unintrusiveness. A hierarchical set of performance measures should be selected which includes measures of the performance of the plant and personnel. Performance measures for dynamic evaluations should be adequate to test whether all objectives, design goals, and performance requirements were achieved, and should include as a minimum the following items:

- system performance measures relevant to plant safety
- crew primary task performance (e.g., task times and procedure violations)
- crew errors
- situation awareness
- workload
- crew communications and coordination
- dynamic anthropometry evaluations
- physical positioning and interactions

Evaluation:

In WCAP-15860, Westinghouse described their general approach to integrated system validation. Section 4.8 of WCAP-15860 discusses performance measurement, and the aspects of integrated system performance identified in NUREG-0711 are included. The applicant indicated that the process by which objective acceptance criteria is developed for each measure will be defined in the implementation plan.

Based on this information, this NUREG-0711 criterion is satisfied.

Criterion 6: Test Design

Criterion:

Tests used for V&V should address such characteristics as ensuring that important characteristics of scenarios are balanced across crews; detailed, clear, and objective procedures are available to conduct the tests; testing administration personnel are appropriately trained; participant training should be “high-fidelity,” and not focused on training to perform validation scenarios; level of training should result in performance that is at/near the level of performance expected of actual plant personnel; and pilot testing should be conducted to assess the adequacy of the test design before conducting integrated testing.

Evaluation:

WCAP-15860, in combination with WCAP-14396 (Revision 3), “Man-In-The-Loop Test Plan Description,” Section 2.4, “General Test Plan,” address the aspects of this criterion. While WCAP-14396 (Revision 3) addresses preliminary or “engineering” tests, rather than final or “validation” tests, with validation tests addressed by WCAP-15860, elements of the general test plan should be applicable for both test types. The applicant should indicate the applicability of the general test plan to validation tests or provide further detail on this criterion in DCD Tier 2 Section 18.8.11 or in WCAP-15860. This is Open Item 18.11.3.5-2.

Based on this information, this NUREG-0711 criterion is identified as Open Item 18.11.3.5-2.

Criterion 7: Data Analysis and Interpretation

Criterion:

Validation test data should be analyzed through a combination of quantitative and qualitative methods; for pass/fail performance measures, failed indicators must be resolved before the design can be validated; the degree of convergent validity should be evaluated; data analyses should be independently validated for correctness; inference from observed performance to estimated real-world performance should allow for margins of error (i.e., allow that actual performance may be more variable than observed test performance).

Evaluation:

WCAP-15860, in combination with WCAP-14396 (Revision 3), “Man-In-The-Loop Test Plan Description,” Section 2.4, “General Test Plan,” address the aspects of this criterion. While WCAP-14396 (Revision 3) addresses preliminary or “engineering” tests, rather than final or “validation” tests, with validation tests addressed by WCAP-15860, elements of the general test plan should be applicable for both test types. The applicant should indicate the applicability of the general test plan (e.g., Section 2.4.2, “Measures and Analysis,”) to validation tests or provide further detail on this criterion in DCD Tier 2 Section 18.8.11 or in WCAP-15860. This is Open Item 18.11.3.5-3.

Based on this information, this NUREG-0711 criterion is identified as Open Item 18.11.3.5-3.

Criterion 8: Validation Conclusions

Criterion:

The statistical and logical bases for determining that performance of the integrated system is and will be acceptable should be clearly documented. Limitations of validation tests and their potential effects on validation conclusions should be clearly documented.

Evaluation:

WCAP-15860, in combination with WCAP-14396 (Revision 3), “Man-In-The-Loop Test Plan Description,” Section 2.4, “General Test Plan,” address the aspects of this criterion. While WCAP-14396 (Revision 3) addresses preliminary or “engineering” tests, rather than final or “validation” tests, with validation tests addressed by WCAP-15860, elements of the general test plan (e.g., 2.4.6, “Use of Results,” 2.4.8, “Documentation,”) should be applicable for both test types. The applicant should indicate the applicability of the general test plan (e.g., DCD Tier 2 Section 2.4.2, “Measures and Analysis,” to validation tests or provide further detail on this criterion in DCD Tier 2, Section 18.8.11 or in WCAP-15860. This is Open Item 18.11.3.5-4.

Based on this information, this NUREG-0711 criterion is identified as Open Item 18.11.3.5-4.

18.11.3.6 Human Engineering Discrepancy Resolution

In WCAP-15860, Westinghouse described their general approach to human engineering discrepancy (HED) resolution. Section 5 of WCAP-15860 provides a commitment to develop a procedure to ensure that all issues documented in the HFE issue tracking system are verified to be completely addressed in the final HSI. However, the staff believes that further detail is needed related to the process the applicant will use to identify, analyze, prioritize, evaluate, document, determine and evaluate design solutions for HEDs using the HED resolution review criteria in NUREG-0711 as a template. This is Open Item 18.11.3.6-1.

Based on this information, this NUREG-0711 criterion is identified as Open Item 18.11.3.6-1.

18.11.4 Conclusion

The V&V review was conducted at a program plan level of detail, and was directed toward determining whether the program plan addressed NUREG-0711 criteria at a high level. The staff expects the V&V program to be developed in greater detail in the implementation plan. The COL applicant referencing the AP1000 certified design has the responsibility for developing, documenting, and executing the implementation plan for the verification and validation of the AP1000 human factors engineering program. This is COL Action Item 18.11.4-1.

In addition, the applicant has not addressed the following items in their V&V program description and hence these items remain as the following Open Items: Criterion No. 3, “HED Documentation,” (Open Item 18.11.3.4-1); Criterion No. 3, “Plant Personnel,” (Open Item 18.11.3.5-1); Criterion No. 6, “Test Design,” (Open Item 18.11.3.5-2); Criterion No. 7, “Data Analysis and Interpretation,” (Open Item 18.11.3.5-3); Criterion No. 8, "Validation Conclusions," (Open Item 18.11.3.5-4); “Human Engineering Discrepancy Resolution,” (Open Item 18.11.3.6-1).

## 18.12 Element 11: Design Implementation

### 18.12.1 Objectives

The objective of this review is to ensure that:

- the applicant's implementation of plant changes considers the effect on personnel performance and provides the necessary support to ensure safe operations
- the applicant's as built design conforms to the verified and validated design that resulted from the HFE design process.

### 18.12.2 Methodology

#### 18.12.2.1 Material Reviewed

The staff reviewed the following material:

- DCD

#### 18.12.2.2 Technical Basis

The staff focused its review on an evaluation of the Westinghouse DCD Tier 2 with respect to the general criteria and topics of NUREG-0711, Element 12, "Design Implementation."

### 18.12.3 Results

The applicant indicated in DCD Tier 2 Section 18.13, that those portions of this element that apply to new plant designs, rather than issues of plant modernization, are addressed in Section 18.11 of DCD Tier 2 as "Issue Resolution Verification" and "Final Plant HFE Verification." This is acceptable to the staff. The staff's evaluation of these criteria is provided in the previous element, "Human Factors Verification and Validation."

### 18.12.4 Conclusions

The objective of this review is to ensure that: the applicant's implementation of plant changes considers the effect on personnel performance, provides the necessary support to ensure safe operations, and that the applicant's design conforms to the verified and validated design that resulted from the HFE design process. The applicant acceptably addressed this review element as part of the previous element, "Human Factors Verification and Validation."

## 18.13 Element 12: Human Performance Monitoring

The objective of this review is to assure that the applicant has prepared a human performance monitoring strategy for ensuring that no significant safety degradation occurs because of any changes that are made in the plant and to provide adequate assurance that the conclusions

that have been drawn from the evaluation remain valid over time. This element of NUREG-0711 is the responsibility of the COL applicant. The performance monitoring strategy and program are developed after design certification. This is COL Action Item 18.13-1.

## 18.14 Element 13: Minimum Inventory

As part of the general resolution of the lack of control room detail, the staff requested that applicants for design certification identify the minimum group of fixed-position controls, displays, and alarms that are required for transient and accident mitigation. The information regarding the minimum inventory for AP1000 is contained in DCD Tier 1 Tables 2.5.2-5 and 2.5.4-1, and in Table 18.12. It should be noted that the inventory is described as a “minimum” inventory to indicate that an applicant can add to it but cannot delete from it without a significant rulemaking effort.

### 18.14.1 Objective

The objective of this review is to ensure that analysis of the ERGs and operator actions, that are determined to be significant contributors to plant risk by PRA analyses, result in an acceptable minimum inventory of fixed-position controls, displays, and alarms for transient and accident mitigation.

### 18.14.2 Methodology

#### 18.14.2.1 Material Reviewed

The staff reviewed the following material:

- DCD
- WCAP-14651 (Revision 2)
- AP600 Emergency Response Guidelines (Revision 2), December 31, 1996
- AP600 Emergency Response Guidelines Background Documents (Revision 2), December 31, 1996
- List of AP600 critical actions contained in WCAP-14651 (Revision 2), "Integration of Human Reliability Analysis with Human Factors Engineering Design Implementation Plan"

#### 18.14.2.2 Technical Basis

The review was focused on evaluating the applicant’s submitted material to ensure that proposed methodology met the overall intent of the staff request for a minimum inventory and that it was properly carried out by the applicant. RG 1.97, (Revision 3, May 1983), was used to support the identification of minimum inventory instrumentation.

18.14.3 Results

Criterion 1: Scope of Minimum Inventory

Criterion:

The inventory should provide criteria that define a reasonable minimum set of fixed-position controls, displays, and alarms to adequately implement the ERGs for the AP1000 design, account for the critical operator actions identified in the AP1000 PRA, and mitigate transients and accidents associated with the ERGs and the PRA sensitivity study results.

Evaluation:

In DCD Tier 2, the applicant submitted their methodology for the determination of the minimum inventory, as well as the results of the method. This is contained in DCD Tier 2 Section 18.12.2. The AP1000 is designed such that the primary controls, displays, and alarms are computer-based and "soft." Soft controls and displays are software-defined and can be changed to perform different functions. Their locations are not dedicated like hard controls and displays. The basis for this design choice is described and justified in DCD Tier 2 Chapter 18. It is based upon a combination of operating experience, research, and testing.

In addition to the soft controls and displays, the applicant has committed to providing a minimum set or inventory of dedicated or fixed-position instrumentation. Per DCD Tier 2 Section 18.12.2, this minimum inventory is used (1) to monitor the status of CSF, (2) to manually actuate the safety-related systems that achieve these CSFs, and (3) to establish and maintain safe-shutdown conditions. These fixed-position controls, displays, and alarms are available at a fixed location. They are continuously available, but not necessarily continuously displayed to the operator. This is an acceptable approach.

In DCD Tier 2 Section 18.12.2, the applicant described the characteristics or selection criteria which they used to develop the minimum inventory. The five criteria are as follows:

(1) RG 1.97 Types A, B, and C, Category 1 instrumentation

(2) dedicated controls for manual safety-related system actuation (reactor trip, turbine trip, and engineered safety feature actuation)

(3) controls, displays, and alarms required to perform critical manual actions as identified from the PRA analysis

(4) alarms provided for operator use in performing safety functions to respond to design-basis events for which there is no automatically-actuated safety function

(5) controls, displays, and alarms necessary to maintain the [EOP] CSF and safe-shutdown conditions

These characteristics or criteria address a reasonable minimum set of fixed-position controls, displays, and alarms for the minimum inventory. In developing the minimum inventory for the AP1000, the applicant employed the process approved earlier by the NRC.

However, for AP1000, the applicant removed the "Containment Hydrogen Igniter" display from the minimum inventory (DCD Tier 2 Tables 2.5.2-5; 2.5.4-1; and 18.12.2-1). In response to the staff's AP1000 RAI 620.005, the applicant explained that removal of the display was justified because there is a long time available before excessive hydrogen can be generated (72 hours after fuel meltdown) and the corresponding operator response to fuel failure (starting the igniters) is required. Because hydrogen igniters are discrete-state devices and are not adjusted in response to hydrogen levels, the ERGs do not use containment hydrogen concentration as a cue to either initiate or control hydrogen igniters. Instead, indication to start the hydrogen igniters is based on Core Exit Temperature, which remains in the minimum inventory. Since fixed position display of hydrogen concentration is not required for emergency operation, it was removed from the inventory. This is acceptable to the staff.

The process used to develop the AP1000 minimum inventory and the resulting minimum inventory, as described in DCD Tier 2 and the applicant's response to the staff's AP1000 RAI 620.005, acceptably addresses the staff's review criteria for minimum inventory.

Each of these characteristics is discussed in more detail in the DCD Tier 2 and is evaluated under subitem 2 below.

Criterion 2: Development of Actual Items in the Minimum Inventory

Criterion:

The development of actual items in the minimum inventory should include an acceptable set of controls, displays, and alarms developed from the defined scope and criteria of the above Criterion 1. It should appropriately address required operator actions in the emergency procedures or procedure guidelines.

Evaluation:

As noted above, the applicant described five characteristics or criteria for defining the minimum inventory. These five characteristics are evaluated here.

(1) RG 1.97 Types A, B, and C, Category 1 instrumentation

RG 1.97 defines a method for the determination of plant variables to be monitored by control room operators, and for the definition of the appropriate instrumentation to be used for those variables. The criteria of the RG are separated into three categories that provide a graded approach to requirements depending on the importance of the measurement of a specific variable to safety. Category 1 provides the most stringent requirements and is intended for key variables. Thus, the limitation to Category 1 here is appropriate.

Type A variables provide primary information needed to permit the operators to take specified manual actions for which there are no automatic controls and that are required for safety systems to perform their safety function for design-basis events. Due to the passive nature of the AP1000 and the specific systems design, there are no specific, preplanned, manual actions of this nature. Thus, there are no Type A variables for AP1000.

Type B variables are defined in DCD Tier 2 Section 7.5.3.2, Table 7.5.5, and DCD Tier 2 Section 18.12.2. They are variables that provide information to the MCR operators to assess the process of accomplishing or maintaining the six CSFs in the ERGs. Table 7.5-5 lists the Type B variables for AP1000. DCD Tier 2 Table 18.12.2.1 lists the minimum inventory. The six CFS status trees of the ERGs (AF-0.1 through AF-0.6) were reviewed, as part of the design certification review, to ensure that all Type B variables needed by the operators were included in Tables 7.5-5 and 18.12.2-1. RG 1.97, Table 3, provides a list of PWR Type B variables, which was compared to the Type B variables of AP1000. The staff also compared Table 7.5-5 with Table 18.12.2-1 to ensure that all identified Category 1 Type B variables had been transferred over to the minimum inventory list. With the exception of the items noted below, no discrepancies were identified.

- ERG AF-0.1 contains power range power percent, intermediate range startup rate (SUR), and source range SUR. RG 1.97 calls for monitoring neutron flux from 1E-6 percent to 100 percent. The tables in Chapters 7 and 18 only mentioned neutron flux and did not address the range or include SUR. The applicant clarified that Table 7.5-1 contains the ranges for all instruments and that only the instrument name is carried forward to the other tables. Table 7.5-1 indicates that neutron flux will be monitored from 1E-6 to 200 percent power. The applicant states that SUR is calculated from the same neutron flux instrument and also modified Table 18.12.2-1 to include startup rate. This is acceptable.

- AF-0.3 contains SG narrow range level, SG pressure, and total feedwater flow, that are not in the tables in DCD Tier 2 Sections 7.5 or 18.2. The applicant stated that per the analyses, the design-basis cases only require passive residual heat removal (PRHR) as a heat sink and not the SGs. AP1000 is different from current generation PWRs in that it uses PRHR in place of auxiliary feed water (AFW) and the SGs for the safety-related heat sink. Thus, the SGs and SG parameters are not required variables to indicate whether the heat sink CSF is satisfied, and, as a result, do not have to be classified as Type B variables or included on the minimum inventory. Thus, for AP1000 the SG parameters are classified as Category D variables. It is noteworthy that the SG parameters are in Table 7.5-1 as safety-related parameters, are included in the ITAAC, and hence are included on the QDPS. This is acceptable.

Additionally, SG wide range level, appears to have been classified as a Category 2 variable, in the DCD Tier 2 Section 7.5, and not Category 1 as recommended in RG 1.97, without adequate justification. The staff also noted that only one channel is required per SG rather than the usual two per SG. The staff also asked if the indication channel is fed from the trip channel. The applicant stated that the AP1000 design has no Category D1 variables, which is consistent with the general statement on page 3 of RG 1.97. Table 7.5-7 of the AP1000 DCD Tier 2 also shows no Category D1 variables.

The applicant further stated that this treatment of SG parameters was previously accepted by NRC for Vogtle and South Texas. In the AP1000, the SGs are less important than at these two plants because, for the AP1000, the PRHR is used as a safety-related heat sink instead of the AFW system and the SGs. Nonetheless, both narrow range and wide range SG level are qualified as PAMS instruments for harsh environments per DCD Tier 2 Section 3.11. Also, the indication channel is fed from the same instrument as the trip channel. The staff's question concerning SG wide range level being classified as a Category 2 variable rather than as Category 1 is being addressed by the applicant in their response to Chapter 7, "Instrumentation and Controls," issues.

- AF-0.4 contains RCS cooldown rate and $T_C$ compared to a limit, based on RCS pressure. The tables in DCD Tier 2 Sections 7.5 and 18.2 did not contain any provision for determining the rate or the comparison to the varying temperature/pressure limit. These parameters can very easily be developed into integrated displays with the computer-based instrumentation system of the AP1000. The applicant added these two parameters to Table 18.12.2-1. This is acceptable.

- AF-0.5 lists containment radiation level. This variable is not included in Table 7.5-5, but is listed in Table 18.12.2-1. The applicant indicated that it is included in Table 7.5-6 under RCS boundary, which is acceptable.

- AF-0.6 contains a requirement to monitor pressurizer (PZR) level and PZR level behavior. Both tables contain PZR level, but neither had any mention of instrumentation related to the time-dependent behavior of PZR level. The applicant added PZR level trend to Table 18.12.2-1. This is acceptable.

- RG 1.97 lists containment isolation valve (CIV) position. However, CIV position is limited to remotely operated CIVs. The applicant justified this position by stating that all manual CIVs would be normally locked, under administrative controls, and would have local vapor phase inhibitor as determined via the OER.

In summary, the coverage in the DCD is satisfactory with respect to the Type B variables.

Type C variables are defined in DCD Tier 2 Section 7.5.3.3, Table 7.5-6, and DCD Tier 2 Section 18.12.2. They are variables that provide the control room operators with information to monitor the potential for breach or actual gross breach of (1) incore fuel cladding, (2) RCS boundary, or (3) containment boundary. Type C variables are listed in DCD Tier 2 Table 7.5-6.

DCD Tier 2 Table 18.12.2-1 lists the minimum inventory and has a column that identifies if the instrument was based upon a Type B or Type C variable. The staff reviewed the six CSF status trees of the ERGs (AF-0.1 through AF-0.6) to ensure that all Type C variables needed by the operators were included in Tables 7.5-5 and 18.12.2-1. RG 1.97, Table 3 provides a list of PWR Type C variables, which the staff compared to the Type C variables of the AP1000 design. Also, the staff compared Table 7.5-6 with Table 18.12.2-1 to ensure that all identified Category 1, Type C variables had been transferred over to the minimum inventory list.

(2) dedicated controls for manual safety-related system actuation (reactor trip, turbine trip, and engineered safety feature actuation)

DCD Tier 2 Section 18.12.2 states that the selection criteria for AP1000 minimum inventory include dedicated, fixed position controls to manually initiate system-level actuation signals for the safety-related systems and components that are used to achieve CSFs. Table 18.12.2-1 contains an acceptable identification of dedicated, fixed position controls to manually initiate system-level actuation signals for the safety-related systems and components that are used to achieve CSFs. This is acceptable.

(3) controls, displays, and alarms required to perform critical manual actions as identified from the PRA analysis

The applicant noted in DCD Tier 2 Section 18.12.2 that fixed position controls, displays and alarms to support the critical actions will be included in the minimum inventory. DCD Tier 2 Section 18.8 references WCAP-14651 (Revision 2), “Integration of Human Reliability Analysis with Human Factors Engineering Design Implementation Plan,” Revision 2, which notes that there are no critical actions. The staff has concluded that WCAP-14651 is applicable to AP1000. The staff evaluations of DCD Tier 2 Section 18.8 and WCAP-14651 discuss the issue of the selection of critical human actions based upon the PRA studies and notes that the threshold criteria for selection is high. However, because the applicant also defines risk-important tasks and uses them for other portions of the control room design (where critical actions were intended to be used), the staff has accepted the applicant’s position.

It should be noted that it is the staff's understanding that, although the applicant has not identified any critical human actions based on preliminary results from PRA studies completed in 1996, as PRA studies are completed and/or updated, critical human actions may be identified and thus used as input to the minimum inventory. It should also be noted that the applicant’s approach to human system design uses input from task analyses (e.g., see Figures 18.5.2, and Figure 1-1 WCAP-14651) and, critical human actions and risk-important tasks derived from PRA are used as input to task analyses.

Therefore, because task analyses are used to verify the minimum inventory (DCD Tier 2 page 18.12.1) both critical human actions and risk-important tasks are used in determining the AP1000 minimum inventory. Thus, the staff believes that all operator

actions that are determined to be significant contributors to plant risk by PRA analyses are addressed by the AP1000 minimum inventory.

Although the staff has accepted the applicant criteria for defining critical human actions and risk-important tasks, the high threshold used by the applicant to define critical action selection has eliminated any entries to the minimum inventory that may be judged important based on operating experience and engineering judgment. In particular, the staff considers the manual actuation of ADS a very important action, and notes that it is also classified as a risk-important task by the applicant. Manual actuation of the ADS is based on level in the CMT reaching 67 percent and the ADS not actuating automatically. Consequently, CMT level is a key parameter needed to judge the necessity for an operator to manually actuate ADS. The staff thus believed that CMT level should be included in the minimum inventory list. The applicant subsequently added CMT level to Table 18.12.2-1. This is acceptable.

(4) alarms provided for operator use in performing safety functions to respond to design-basis events for which there is no automatically-actuated safety function

As noted in the discussion under (1) above, due to the passive nature of the AP1000 and the specific systems design, there are no preplanned, manual actions required for safety systems to perform their safety function for design-basis events. Thus, because there are no operator actions of the type noted in (1), there are no alarms required to alert the operators to take this type of action.

(5) CDAs necessary to maintain the CSF and safe-shutdown conditions

With regard to the CDAs necessary to maintain the CSFs, these are the same as identified in (1) above, based upon the CSF Status Trees of the ERGs.

With regard to CDAs to maintain the CSFs and safe-shutdown conditions, the discussions under (2), (3), and (4) above indicate that the applicant had not included CDAs in the minimum inventory. If one were to go beyond single failure and use the ERG functional restoration guidelines, which are entered from the CSF status trees, then additional controls would be obtained. However, this would add many more dedicated CDAs than appears appropriate in the highly computerized AP1000 control room. If required, this added number of fixed controls may actually be counterproductive to safety, due to creating requirements that are not appropriately integrated into the overall human factors engineering of the control room.

The applicant ERGs also define a CSF associated with shutdown conditions. While the applicant criterion refers to safe-shutdown, the staff considers this criterion applicable to all shutdown conditions. With regard to the controls, displays, and alarms necessary to maintain shutdown conditions, the staff reviewed the ERG shutdown safety status tree to determine if all required items to implement the Tree were on the minimum Inventory list.

In addition, the ability to control the normal RNS appears to be essential to maintain the plant in cold shutdown. RNS is used to assist in achieving the CSF of core cooling, heat sink, and RCS inventory in cold shutdown conditions. The staff earlier requested the applicant to define the minimum RNS CDAs that should be part of the minimum inventory.

The applicant stated that, RNS is not required for the safety case evaluation of safe-shutdown. For the safety case, IRWST is used which has both automatic and manual actuation. The manual actuation and related indications are included in the minimum inventory. Thus, RNS CDAs are not "necessary" to maintain the CSFs or the safe-shutdown conditions. Hence, they are not required to be in the minimum inventory per Criterion 5. This is acceptable.

With respect to alarms on the minimum inventory list, Table 18.12.2-1 includes alarms (alerts) in the minimum inventory and on the QDPS. The staff noted that, when the design is finalized, the alarm acknowledgment scheme should be coordinated between the QDPS and the main alarm system so that operators are not required to acknowledge the same alarm in two different places.

Based on this information, this minimum inventory criterion is satisfied.

Criterion 3: Consideration of Operator Tasks

Criterion:

An inventory of fixed-position controls, displays, and alarms necessary to permit execution of the operator tasks to place and maintain the plant in a safe-shutdown condition should be identified.

Evaluation:

DCD Tier 2 Section 18.12, "Inventory," and Section 7.4.3, "Safe Shutdown from Outside the Main Control Room," discuss the development of the minimum inventory of CDAs needed to place and maintain the plant in a safe-shutdown condition from either the MCR or the remote shutdown workstation (RSW). The applicant has provided a minimum inventory of fixed position CDAs for the MCR. The characteristics for selection of minimum inventory items established by the applicant and satisfactorily reviewed under Subitems 1 and 2 above, address operator actions or tasks needed to maintain CSF and safe-shutdown conditions. DCD Tier 2 Section 18.12.3 states that the CDAs of Table 18.12.2-1 are also retrievable from the RSW.

Based on this information, this minimum inventory criterion is satisfied.

Criterion 4: HFE Input

Criterion:

The inventory contains a list of key minimum displays, controls, and alarms necessary to carry out operator actions associated with the ERGs. The applicant will also need to identify and further define additional detailed characteristics of these controls, displays, and alarms (e.g., ranges, scales, physical dimensions, and actual information presentation) during the detailed task analysis and HSI design efforts. The HFE design process should provide adequate assurance that these detailed characteristics will be defined and implemented.

Evaluation:

The commitments provided in DCD Tier 2 Sections 18.5, 18.8, and 18.11 that address task analysis, HSI design, and the HSI design test program (including verification and validation) provide an acceptable assurance that these additional detailed characteristics of the controls, displays, and alarms will be defined, designed, tested, and implemented. The detailed review of these sections of the DCD Tier 2 is provided elsewhere in this document.

Based on this information, this minimum inventory criterion is satisfied.

Criterion 5: Task Analysis Input Into Minimum Inventory

Criterion:

The task analysis results should be used to define a minimum inventory of controls, displays, and alarms necessary to perform crew tasks based upon both task and I&C requirements.

Evaluation:

The applicant defined a method and criteria that will be used to define the minimum inventory. These are delineated in DCD Tier 2 Section 18.12 and have been previously reviewed. The method does not directly use the task analyses, but provides an acceptable alternative that uses a combination of RG 1.97, the design features of the AP1000, and the emergency response guidelines.

DCD Tier 2 Section 18.5.2.1, “Function-Based Task Analyses (FBTAs), indicates that the FBTAs are used as a completeness check on the availability of needed indications, parameters, and controls. DCD Tier 2 also indicates that the OSAs will provide information on the inventory of alarms, controls, and parameters needed to perform sequences selected for analysis, which include those addressed in the discussion of Task Analysis Criterion 1: Scope, discussed in Section 18.5.

Based on this information, this minimum inventory criterion is satisfied.

Criterion 6: Development of the Remote Work Station Minimum Inventory

Criterion:

In conjunction with the effort by the applicant to develop a MCR minimum inventory of CDAs for use in the mitigation of transient and accidents, the staff requested that the applicant provide a list of CDAs that would be available at the RSW for use in establishing and maintaining shutdown conditions in the event the MCR was uninhabitable. The staff does not consider it necessary that any RSW CDAs be fixed-position. However, a minimum inventory of CDAs accessible from the RSW should be well described.

Evaluation:

In DCD Tier 2 Section 7.4.3.1.1, Remote Shutdown Workstation, and Section 18.12.3, “Remote Shutdown Workstation Displays, Alarms, and Controls,” the applicant indicated that the same CDAs contained in the MCR workstations will be retrievable from the RSW. This acceptably addresses the staff's questions related to establishing a minimum inventory of CDAs for the RSW.

Based on this information, this minimum inventory criterion is satisfied.

18.14.4 Conclusion

The applicant defined a minimum inventory of controls, displays, and alarms for the AP1000 design that satisfies the staff's criteria.

18.15 Summary and Conclusions

The overall purpose of the AP1000 HFE review is to ensure the following:

- The applicant has integrated HFE into plant development and design
- The applicant has provided HSIs that make possible safe, efficient, and reliable performance of operation, maintenance, test, inspection, and surveillance tasks
- The HSI reflects "state-of-the-art human factors principles" [10 CFR 50.34(f) (2) (iii), as required by 10 CFR 52.47(a) (1) (ii)] and satisfies all specific regulatory requirements as stated in Title 10 of the Code of Federal Regulations.

In addition, the review included the applicant's proposed resolutions of unresolved safety issues, generic safety issues, and related human factors considerations addressed in Chapters 6, 7, 9, 13, 14, 16, 19, and 20 of the DCD Tier 2.

In conclusion, the applicant HFE DCD and supporting materials reviewed describe a comprehensive HFE program that will be acceptable and consistent with the staff's review criteria when the applicant successfully addresses the open items identified.

18.16 Tier 2* Information:

As a result of its review of the AP 1000 HFE program, the staff has determined that the following information in Chapter 18 of the AP 1000 DCD Tier 2 must be designated as Tier 2* information in the AP1000 design control document. The rationale for selecting this information is provided in parentheses. This information is similar to Tier 2* HFE information for the evolutionary plants and, as with the evolutionary design certifications, the Tier 2* information identified herein is not subject to expire at first full power. Furthermore, any proposed change to Tier 2* information, by a COL applicant or licensee, will require NRC approval prior to implementation.

DCD Tier 2 Sections:

18.2.1.2 Regulatory Requirements (assures HFE Program meets design requirements)

18.2.1.3 Applicable Facilities (assures scope of HFE Program)

18.2.1.4 Applicable Human System Interfaces (assures scope of HFE Program)

18.2.1.5 Applicable Plant Personnel (assures scope of HFE Program)

18.2.1.6 Technical Basis (assures that HFE Program will be developed in accordance with specified standards, guidelines, and accepted professional practices)

18.2.2.1 Responsibility (assures preservation of HFE Program Design Team integrity)

18.2.2.3 Composition [first paragraph and listing of design team disciplines only] (assures preservation of design team multidisciplinary composition)

18.2.3.1 General Process and Procedures [last paragraph of Design Review of Human Factors Engineering Products only] (assures commitment to design issues tracking system implementation)

18.2.3.5 Human Factors Engineering in Subcontractor Efforts (assures that subcontractors employ accepted human engineering practices)

18.2.4 Human Factors Engineering Issues Tracking (assures commitment to use of design issues tracking system database implementation)

18.2.5 Human Factors Engineering Technical Program and Milestones (assures that the HFE program is performed in accordance with NUREG-0711)

Figure 18.2-1 Human Factors Engineering Program Management, Human System Interface (HSI) Design Team Process (assures commitment to conduct of HFE Process)

18.5 AP100 Task Analysis Implementation Plan (assures task analysis objectives are met)

18.5.1 Task Analysis Scope (assures commitment to Task Analysis scope and process, implementation of which will be verified by ITAAC)

18.5.2 Task Analysis Implementation Plan (assures commitment to scope and methodology for Task Analysis Plan, implementation of which will be verified by ITAAC)

18.5.2.1 Function-Based Task Analysis (assures that the set of questions provided for function-based task analysis is used)

18.7 Integration of Human Reliability Analysis with Human Factors Engineering (assures commitment to details of HRA Integration are preserved, implementation of which will be verified by ITAAC)

18.8 Human System Interface Design (assures that the alarm system supports the crew in accordance with the decision-making model and computerized procedures/backup will be confirmed through the V&V program)

18.8.1.2 Design Guidelines (assures the use of specific guidelines for performing V&V)

18.8.1.7 Task-Related Human System Interface Requirements (assures that the HSI design provides needed alarms, displays, and controls)

18.8.1.8 General Human System Interface Design Feature Selection (assures that decision-making model used to identify operator information and control requirements)

18.8.1.9 Human System Interface Characteristics: Identification of High Workload Situations (assures that critical and risk-important human actions related to local control actions are identified)

18.8.2 Safety Parameter Display System (SPDS) through 18.8.2.7, inclusive (assures function of SPDS will be incorporated as part of overall HSI program, implementation of which will be verified by ITAAC)

18.8.3.2 Main Control Area Mission and Major Tasks (assures commitment to MCR mission, conduct of operation, and major components of MCR covered by HFE Program are preserved)

18.8.3.4 Remote Shutdown Workstation Mission and Major Tasks implemented (assures commitment to RSW mission, conduct of operation, and major components of RSW covered by HFE Program are preserved)

18.8.3.5 Technical Support Center Mission and Major Tasks (assures commitment to TSC mission, conduct of operation, and major components of TSC covered by HFE Program are preserved)

18.11 Human Factors Engineering Verification and Validation (assures commitment to scope and conduct of HSI Engineering Tests are preserved, implementation of which will be verified by ITAAC)

18.12 Inventory [through 18.12.3, Remote Shutdown Workstation Displays, Alarms, and Controls] (assures commitment to scope and development of Minimum Inventory is preserved for future iterations of the AP1000 PRA)

DCD Tier 2 Supporting Documents:

WCAP- 14396 (Revision 3)
Man-In-The-Loop Test Plan Description (principal design document supporting 18.11)

WCAP- 14645 (Revision 2)
Human Factors Engineering Operating Experience Review Report for the AP600 Nuclear Power Plant (principal document supporting 18.3)

WCAP- 14651 (Revision 2)
Integration of Human Reliability Analysis With Human Factors Engineering Design Implementation Plan (principal design document supporting 18.7)

WCAP-14695
Description of the Westinghouse Operator Decision-Making Model and Function-Based Task Analysis Methodology (principal design document supporting 18.5.1)

WCAP- 15847 (Revision 1)
AP1000 Quality Assurance Procedures Supporting NRC Review of AP1000 DCD Sections 18.2 and 18.8 (principal design document supporting 18.2, 18.8.)

WCAP- 15860
Programmatic Level Description of the AP1000 Human Factors Verification and Validation Plan (principal design document supporting 18.11)