Human Factors Engineering

1. Applicable Codes and Regulations
2. Schedule for HFE Program
3. Topical Report
4. HFE Design Process for APR1400
5. SKN 3&4 Human System Interface Design
6. Summary

1. Applicable Codes and Regulations

- Basic Requirements
  - NUREG-0800, Standard Review Plan, Chapter 18.0 Human Factors Engineering, 2007
  - NUREG-0711, Human Factors Engineering Program Review Model, 2004

- HFE Program Management
  - 10 CFR 50.34(f)(3)(vii), Domestic Licensing of Production and Utilization Facilities - Management and Technical Support Organization
  - RG 1.174, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis, 2002
  - NUREG-0737 and Supplements, Clarification of TMI Action Plan Requirements, 1980

1. Applicable Codes and Regulations

- Operating Experience Review
  - 10 CFR 50.34(f)(3)(i), Domestic Licensing of Production and Utilization Facilities - Contents of applications; technical information
  - NUREG/CR-6400, HFE Insights for Advanced Reactors based upon Operating Experience, 1996
  - NUREG/CR-6749, Integrating Digital and Conventional Human-System Interfaces: Lessons Learned from a Control Room Modernization Program, 2002

- Functional Requirements Analysis and Function Allocation
  - NUREG-3331, A Methodology for Allocation of Nuclear Power Plant Control Functions to Human and Automated Control, 1983

- Task Analysis
  - NUREG-3371, Task Analysis of Nuclear Power Plant Control Room Crews, 1983

1. Applicable Codes and Regulations

- Staffing and Qualifications
  - 10 CFR 50.54(i) ~ (m), Domestic Licensing of Production and Utilization Facilities - Conditions of licenses
  - RG-1.8, Qualification and Training of Personnel for Nuclear Power Plants, 2000
  - NUREG/CR-6400, HFE Insights for Advanced Reactors based upon Operating Experience, 1996
  - NUREG/CR-6838, Technical Basis for Regulatory Guidance for Assessing Exemption Requests from the Nuclear Power Plant Licensed Operator Staffing Requirements Specified in 10 CFR 50.54(m), 2003
  - Information Notice 95-48, Results of Shift Staffing Study
  - Information Notice 97-78, Crediting of Operator Actions in Place of Automatic Actions and Modifications of Operator Actions, Including Response Times

1. Applicable Codes and Regulations

- Human Reliability Analysis
  - 10 CFR 52.47(a)(27), A description of the design specific probabilistic risk assessment (PRA) and its results
  - 10 CFR 52.47(b)(1), Combined Licenses - Contents of applications; technical information
  - 10 CFR 52.79, Combined Licenses - Contents of applications; technical information in final safety analysis report
  - RG 1.200, An Approach for Determining the Technical Adequacy of Probabilistic Risk Assessment Results for Risk-Informed Activities, 2009
  - NUREG/CR-1278, Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications, 1983

1. Applicable Codes and Regulations

- HSI Design
  - 10 CFR 50.34(f)(2), Domestic Licensing of Production and Utilization Facilities - Contents of applications; technical information
  - 10 CFR 50 Appendix A, General Design Criteria for Nuclear Power Plants Criteria 19 Control Room
  - RG 1.22, Periodic Testing of Protection System Actuation Functions, 1972
  - RG 1.47, Bypassed and Inoperable Status Indication for Nuclear Power Plant Safety Systems, 2010
  - RG 1.62, Manual Initiation of Protective Actions, 2010
  - RG 1.97, Criteria for Accident Monitoring Instrumentation for Nuclear Power Plants, 2006
  - DI&C-ISG-04, Highly-Integrated Control Rooms-Communications Issues, 2009
  - DI&C-ISG-05, Highly-Integrated Control Rooms-Human Factors Issues, 2008
  - NUREG-0700, Human-System Interface Design Review Guidelines, 2002
  - NUREG-0696, Functional Criteria for Emergency Response Facilities, 1980

1. Applicable Codes and Regulations

- Procedure Development (*)
  - 10 CFR 50.34(f)(2)(ii), Domestic Licensing of Production and Utilization Facilities - Contents of applications; technical information
  - NUREG-0899, Guidelines for the Preparation of Emergency Operating Procedures, 1982
  - NUREG-1358, Lessons Learned From the Special Inspection Program for Emergency Operating Procedures, 1989
  - NUREG/CR-6634, Computer-Based Procedure Systems: Technical Basis and Human Factors Review Guidance, 2000

(*): COL applicant will develop the procedures and meet the listed codes and regulations

1. Applicable Codes and Regulations

- Training Program Development (*)
  - 10 CFR 50.120, Additional Standards for Licenses, Certifications, and Regulatory Approvals - Training and qualification of nuclear power plant personnel
  - 10 CFR 52.79, Combined Licenses - Contents of applications; technical information in final safety analysis report
  - 10 CFR 55, Operators' Licenses
  - RG 1.149, Nuclear Power Plant Simulation Facilities for Use in Operator Training and License Examinations, 2001
  - RG 1.8, Qualification and Training of Personnel for Nuclear Power Plants, 2000
  - NUREG-1021, Operator Licensing Examination Standards for Power Reactors, 2004
  - NUREG-1122, Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Pressurized Water Reactors, 1998

(*): COL applicant will develop the training program and meet the listed codes and regulations

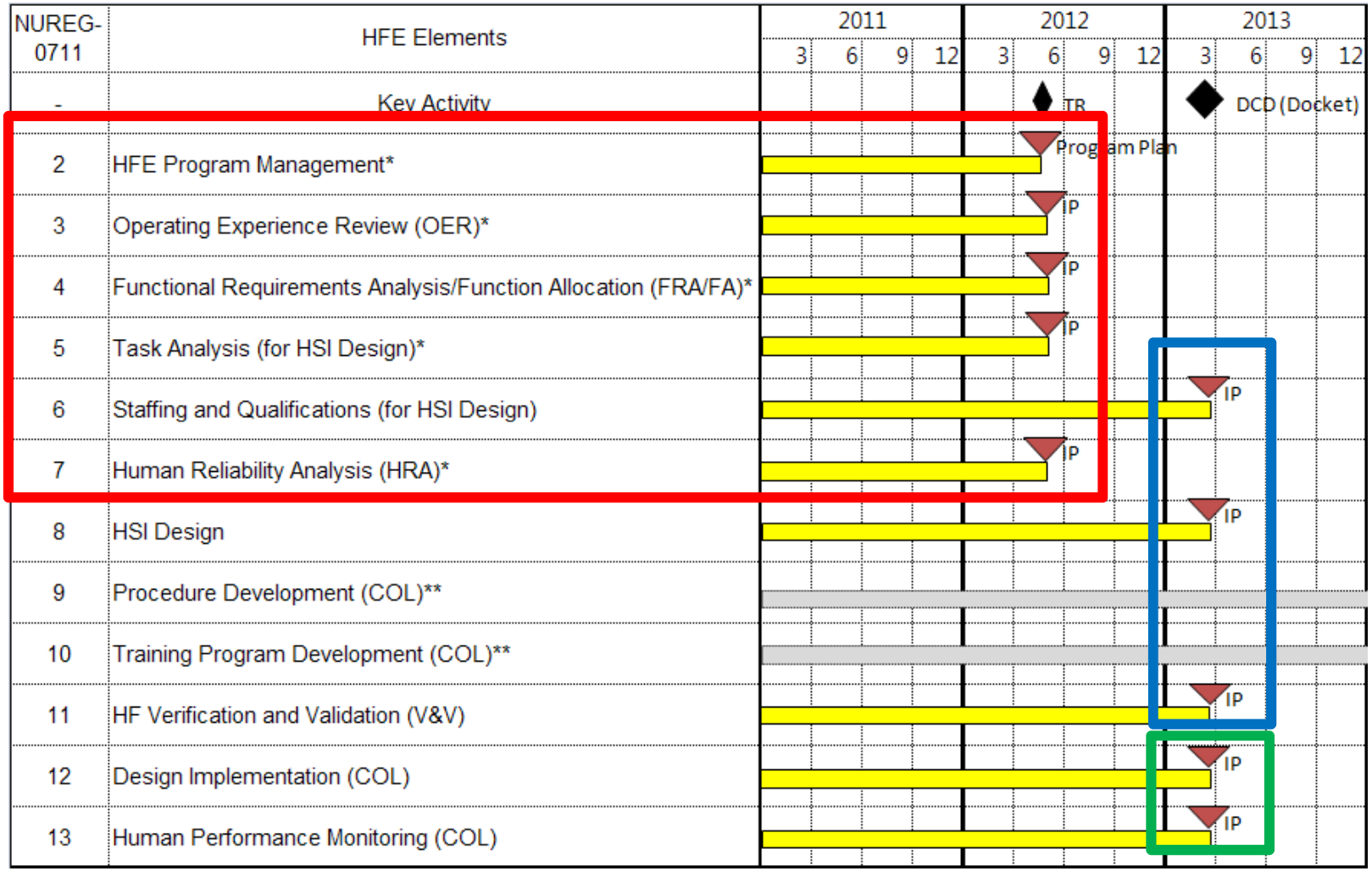
1. Applicable Codes and Regulations

- HF Verification and Validation
  - DI&C-ISG-04, Highly-Integrated Control Rooms-Communications Issues, 2009
  - DI&C-ISG-05, Highly-Integrated Control Rooms-Human Factors Issues, 2008
  - NUREG/CR-6393, Advanced Information Systems: Technical Basis and Human Factors Review Guidance, 2000

- Design Implementation
  - NUREG-0711, Human Factors Engineering Program Review Model, 2004

- Human Performance Monitoring
  - NUREG-1649, Reactor Oversight Process, 2000
  - NUREG/CR-6751, The Human Performance Evaluation Process: A Resource for Reviewing the Identification and Resolution of Human Performance Problems, 2001

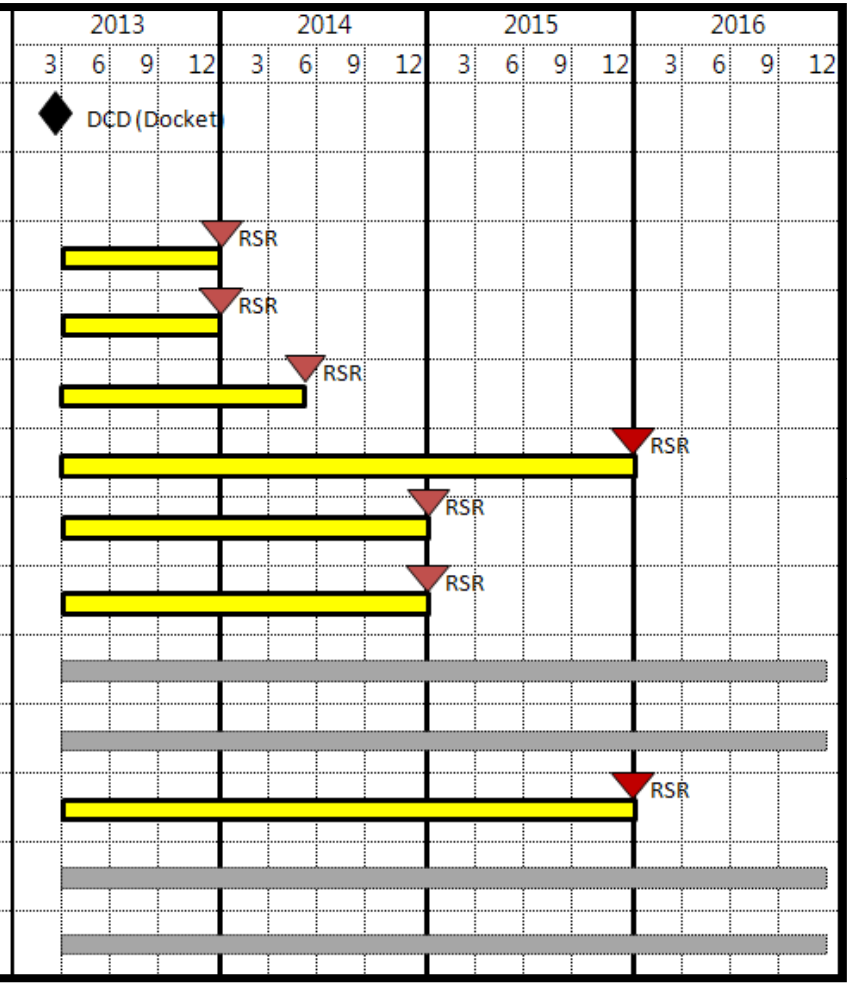
2. Schedule for HFE Program (DC)



*** IP will be included in TR ; ** IP schedule will be decided after COLA**

2. Schedule for HFE Program (COL)

NUREG-0711	HFE Elements
-	Key Activity
2	HFE Program Management
3	Operating Experience Review (OER)
4	Functional Requirements Analysis/Function Allocation (FRA/FA)
5	Task Analysis (for HSI Design)
6	Staffing and Qualifications (for HSI Design)
7	Human Reliability Analysis (HRA)
8	HSI Design
9	Procedure Development (COL)
10	Training Program Development (COL)
11	HF Verification and Validation (V&V)
12	Design Implementation (COL)
13	Human Performance Monitoring (COL)



※RSR is a tentative schedule for planning purpose only

3. Topical Report

Purpose and Scope

- Purpose
  - The purpose of this topical report is to receive early feedback from the NRC staff on the contents of the topical report
  - This topical report is applicable to APR1400 design only

- Scope
  - This topical report describes the HFE design process in accordance with NUREG-0711 (Rev. 2) for the following five HFE elements:
    - HFE Program Management
    - Operating Experience Review
    - Functional Requirements Analysis & Function Allocation
    - Task Analysis
    - Human Reliability Analysis

3. Topical Report

Table of Contents (1/3)

3. Topical Report

Table of Contents (2/3)

3. Topical Report

Table of Contents (3/3)

4. HFE Design Process for APR1400

- HFE Program Management
- Operating Experience Review
- Functional Requirements Analysis and Function Allocation
- Task Analysis
- Human Reliability Analysis
- Human System Interface Design
- HF Verification & Validation
- Staffing and Qualification
- Procedure Development
- Training Program Development
- Design Implementation
- Human Performance Monitoring

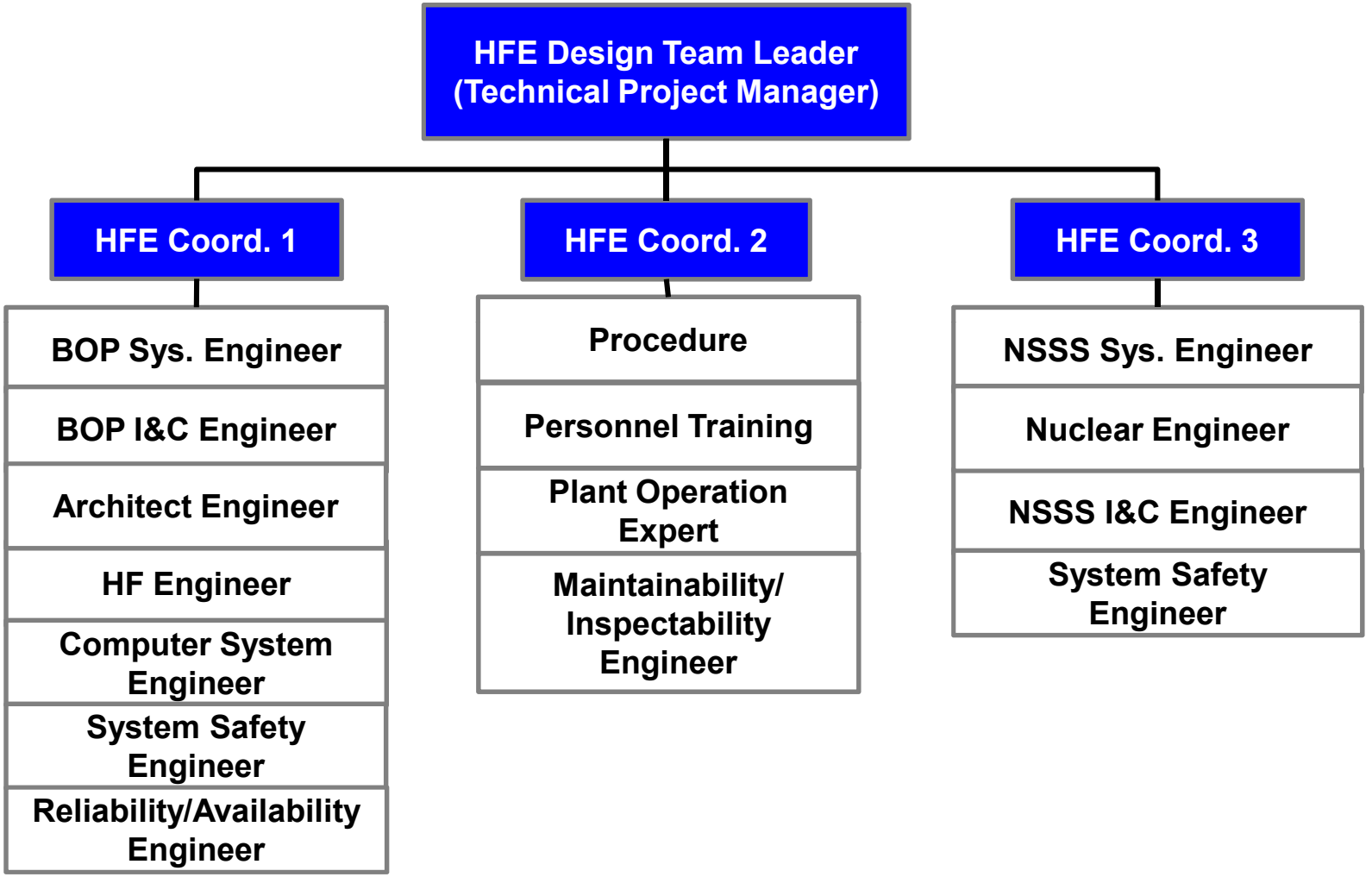
4.1 HFE Program Management

Human Factors Engineering Program Plan

- HFE Program Plan is important to integrate the HFE into plant development, design, and evaluation
- The HFE Program Plan is developing in compliance with HFE Program Review Model of NUREG-0711 (Rev. 2)
- The scope of APR1400 HFE Program includes the following facilities:
  - Main control room
  - Remote shutdown room
  - Local control stations
  - Technical support center
  - Emergency operating facility

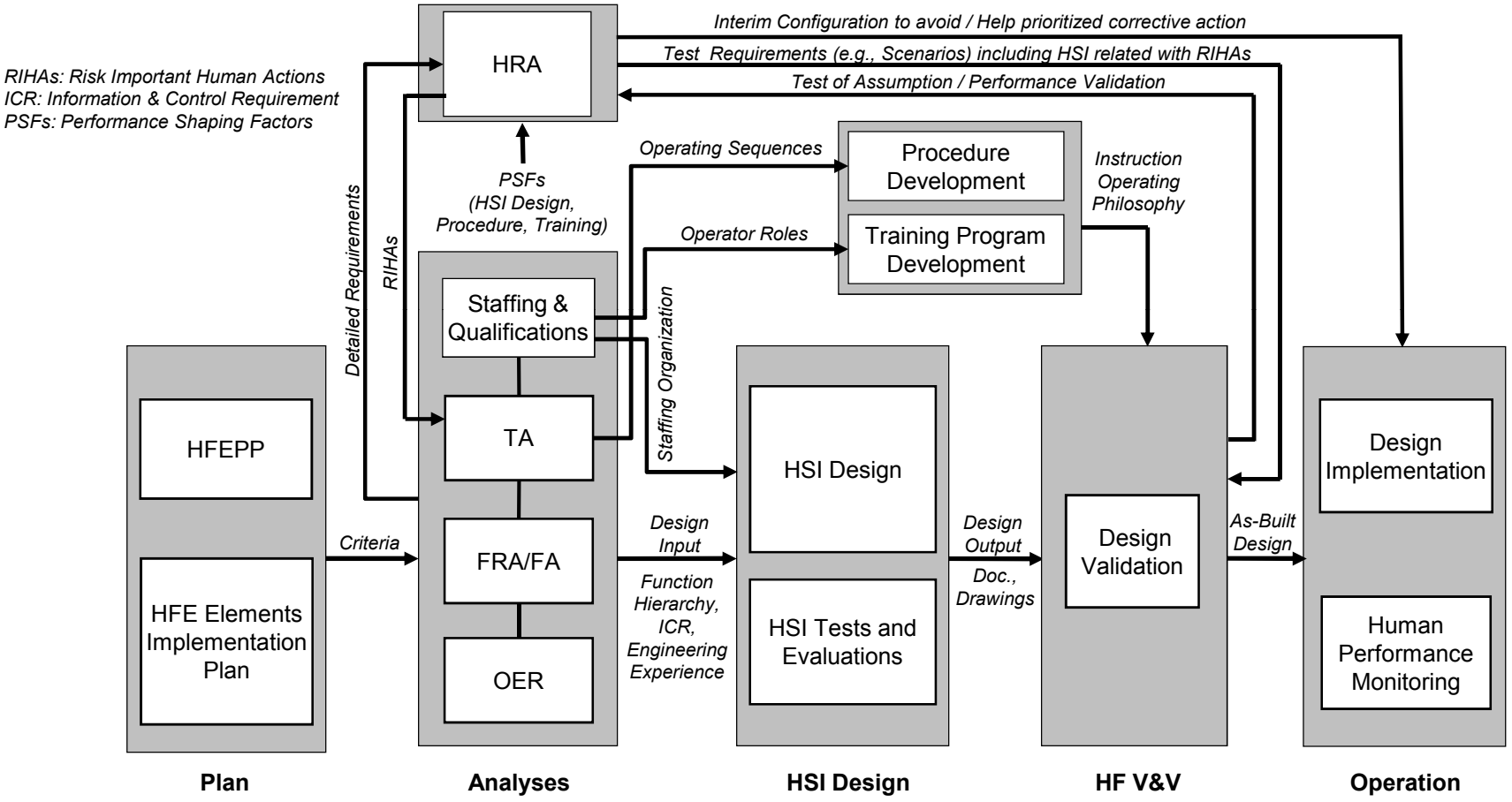
4.1 HFE Program Management

HFE Team Composition



4.1 HFE Program Management

HFE Design Process (1/2)



4.1 HFE Program Management

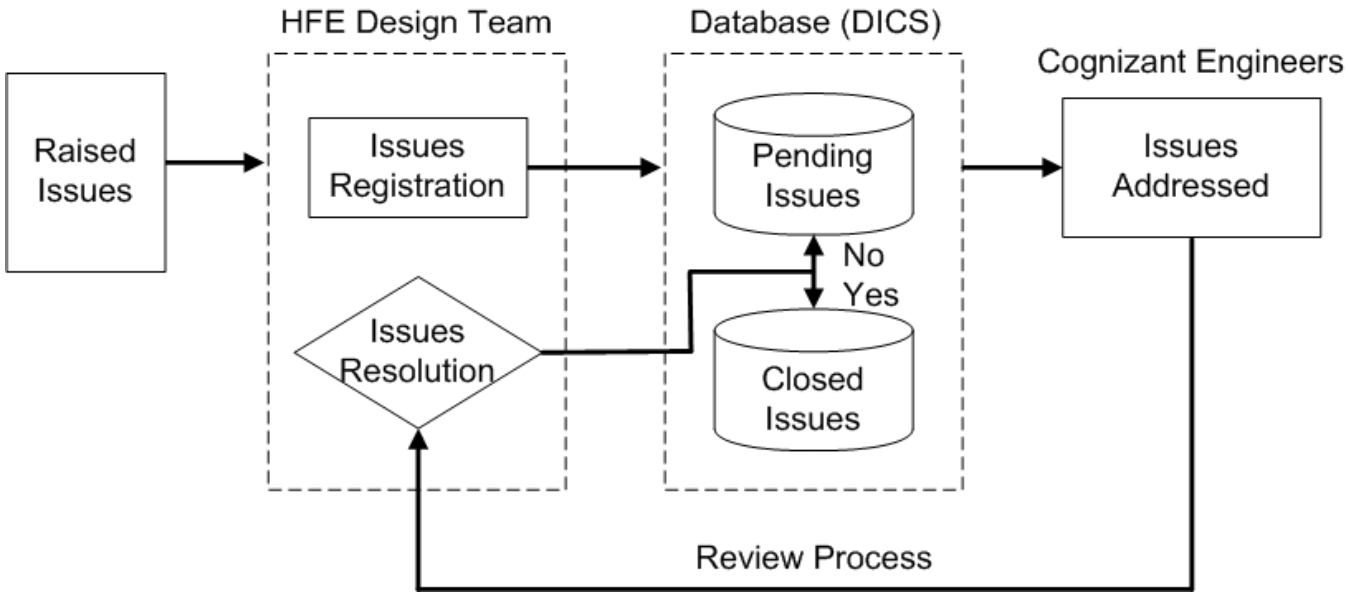
HFE Design Process (2/2)

- The design process is iterative
- HFE analyses such as OER, FRA/FA, TA, and HRA are provided to the designers for incorporation of results including insights into their design
- Design tests and evaluations using dynamic mockup or simulator are used extensively throughout HSI design process
- HFE design products will be validated on full scope simulator

4.1 HFE Program Management

Process Management Tool

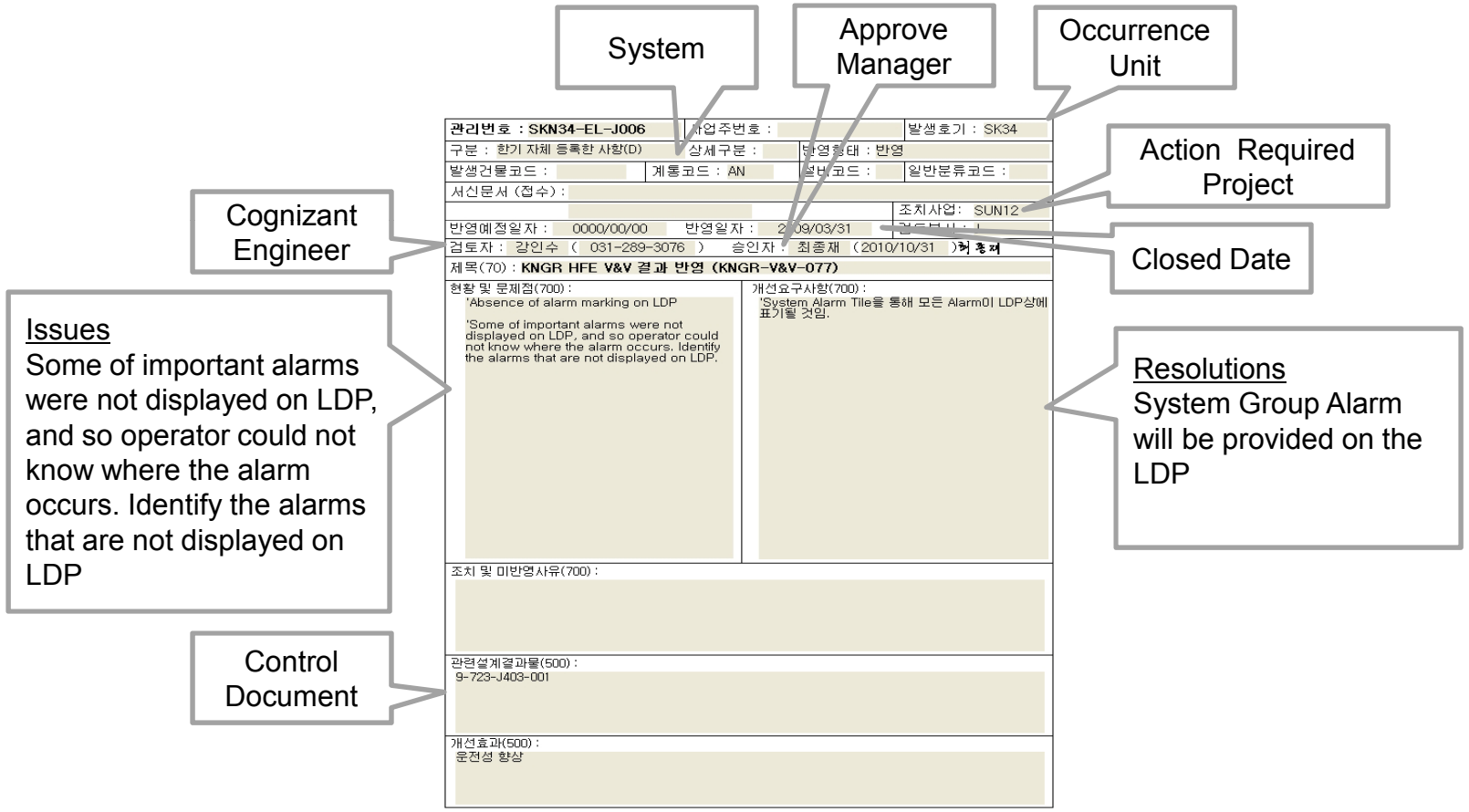
- Issue Tracking System (ITS) is used for the development of HSI
  - The ITS provides means to track design issues identified during the process as well as HF V&V
  - Process flow diagram for ITS is as follows:



4.1 HFE Program Management

Design Improvement Control System (DICS)

- As part of ITS, DICS (database) will be used to track design issues



4.2 Operating Experience Review

Operating Experience Data Acquisition (1/2)

- Operating experience review is conducted under an Implementation Plan contained in the TR, and the results will be reported in a Results Summary Report
- Operating experience for commercial nuclear power plants
  - US NRC USI and GSI
  - US NRC NUREGs, including NUREG/CR-6400, that address lessons learned for US
  - US NRC generic letters and information notices
  - Korean experience
  - Event analyses and information exchange from the US Institute of Nuclear Power Operations (INPO)
  - Significant operating experience and significant event reports from the World Association of Nuclear Operators (WANO)
- Investigation of the experience of other industries, such as aircraft, telecommunications, etc. will be made with respect to digital I&Cs and computer based HSIs

4.2 Operating Experience Review

Operating Experience Data Acquisition (2/2)

- Operating experience data acquisition will cover the following facilities and HSI resources:
  - Control room (including MCR, RSR, and LCS)
  - Information display
  - Control
  - Alarm
  - Computer based procedure
  - Communication, etc.

- In addition to the documented operating experience, operating personnel interviews are conducted to learn from their experiences in conducting plant operations

4.2 Operating Experience Review

OER Database

- APR1400 HFE team maintains a database of operating experience that includes, but are not limited to, data fields containing:
  - A description of issues
  - The name of the organization
  - A description of the root cause
  - The lesson learned (i.e., best correction to address the root cause)
- OER database for SKN 3&4 will be used as a starting point
  - Root cause analysis results of the data will be evaluated and updated by HFE design team
- Up-to-date operating experience data will be added and reviewed by multi-disciplinary HFE design team

4.2 Operating Experience Review

OER Database for SKN 3&4

Cat./ No	Issue	MMI	Resolution	Completion Status
1*/ 70	AEOD/S92-12:54 August 26, 1992 Draft 2-A: Loss of annunciator and computer availability,	Alarm	The KNGR Information Processing System (IPS) and Qualified Indication and Alarm System (QIAS) provide redundant and diverse annunciator functions. Plant operation can continue for a period of up to 24 hours without the IPS. Validation of the alarm systems will ensure that the operator can use them effectively under all operating conditions including complete loss of the IPS and the loss of a QIAS segment.	Resolved Item

* Issues Identified in Nuclear Regulatory Authority Documents Analysis and Evaluation of Operational Data (AEOD)

4.2 Operating Experience Review

OER Sources for SKN 3&4

- System 80+ OER Analysis Report

- Operating Experience Review added
  - The operating experience of the OPR1000 plants
  - Related HFE technology
  - Issues identified by plant personnel
  - Operator interview
  - Operating plant event reports
  - Halden Reactor Project reports

4.2 Operating Experience Review

Operating Experience (OE) Analysis

- From the collected set of operating experiences and events, the HFE design team examines the root cause and lesson learned from the experience
- The lesson learned from OE analysis will be sufficiently applied during the remainder of the design and implementation process
- The HSI lesson learned from operating experiences are applied to the HSI design

4.2 Operating Experience Review

Design Test with respect to OE Lesson Learned

- As part of the HFE design process, the generalized root cause descriptions, usually in the form of design functional requirements or design guidelines, are included to be assessed during the HSI design process

4.3 FRA/FA

FRA/FA Implementation (1/2)

- The FRA/FA is conducted under an Implementation Plan and its results will be reported in a Results Summary Report
- As a starting point for the APR1400, the FRA/FA is based on historical applications in existing PWRs as applied to the reference plant (SKN 3&4) designs
- The APR1400 FRA/FA are conducted by first assessing the design differences to that of its predecessor PWRs and the reference plant (SKN 3&4) designs
- When differences are identified, a full FRA/FA is performed based on the differences in design

4.3 FRA/FA

FRA/FA Implementation (2/2)

- Confirmation of the APR1400 critical safety functions (CSFs) will be performed by comparing the associated status trees with the FMEA of the PRA analysis
- Confirmation of success paths of the APR1400 will be performed by comparing the success path for CSFs with those of SKN 3&4 plant design
- The result will be used for safety equipment operation allocation between human operators and automation

4.3 FRA/FA

SKN 3&4 FRA/FA Scope

- The FRA/FA includes the systems and components which are
  - Important to safety
  - Required for safe shutdown
  - Provided for severe accident mitigation

- The allocation criteria resulting from IEEE Std 603 and NUREG/CR-3331 are applied to verify compatibility of the allocated functions

4.3 FRA/FA

SKN 3&4 FRA/FA Methodology

- The evolutionary approach includes the followings:
  - Review the requirements applying to functional requirements and function allocation
  - Describe the CSFs and success paths
  - Identify the relevant changes from predecessor designs
  - State the operator's role in executing safety functions
  - Identify all legally mandated allocations
  - Document the rationale for the assigned allocations and function allocation criteria

4.3 FRA/FA

SKN 3&4 CSFs and Success Paths

	Critical Safety Functions	Success Paths	
		Safety Grade	Non-Safety Grade
1	**Reactivity Control**	**- Reactor Trip - Safety Injection**	**- Rod Control - CVCS Boration**
2	Maintenance of Vital Auxiliaries	- Emergency Diesels - Station Batteries	- Unit Transformer Backfeed - Alt. AC Generator - Station Batteries - Standby Aux. Transformer
3	RCS Inventory Control	- Safety Injection	- CVCS Charging & Letdown
4	RCS Pressure Control	- Safety Injection - Reactor Coolant Gas Vent - Primary Reliefs	- PZR Heaters & Sprays - CVCS Charging & Letdown - CVCS Aux. Spray - SG Steaming - Safety Depressurization & Vent Sys
5	Core Heat Removal	- Natural Circulation - Safety Injection	- Forced Circulation
6	RCS Heat Removal	- Auxiliary Feed - Shutdown Cooling	- Main Feed - Startup Feed - Safety Depressurization & Vent System
7	Containment Isolation	- Penetration Flowpath Isolation	- Penetration Flowpath Control
8	Containment Environment	- Containment Spray - PAR	- Fan Coolers - Reactor Cnmt H_2 Purge - H_2 Ignitors - PAR
9	Radiation Emission	- Release Path Isolation	- Release Path Monitoring & Control

4.3 FRA/FA

Applying the Results of FRA/FA

- SKN 3&4 CSFs and Success Paths will be reviewed as a starting point
- The FRA results, i.e., the selection of the CSFs are input to the design of the APR1400 HSI that meets the criteria for the Safety Parameter Display System
- The CSFs are also the basis for the development of the APR1400 EOPs

4.4 Task Analysis

TA Scope

- The following event sequences will comprise a representative cross-section of operations for the APR1400 TA:
  - All Emergency Operating Procedures
  - A set of General Operating Procedures
  - A set of Abnormal Operating Procedures
  - A set of System Operating Procedures
  - A set of Maintenance Procedures
  - A set of Test Procedures

4.4 Task Analysis

TA Methodology

- Hierarchical task analysis (HTA) and task decomposition methods will be used for APR1400 TA
  - HTA produces a hierarchy of operations, and provides an effective means of stating how work should be organized in order to meet a system's goals
  - Task decomposition is an information collection tool which is used to systematically expand upon the descriptions of activities in each task element
  - The following hierarchical structure is used as the framework to decompose event sequences into components:

    Level 1: Gross functions (Operating Procedure)

    Level 2: Sub-function

    Level 3: Task

    Level 4: Task Element

4.4 Task Analysis

TA Implementation

- The TA is conducted under an Implementation Plan as contained in the TR and its results will be reported in a Results Summary Report
- TA database will be constructed for ease of use
  - All required display and control inventory for tasks will be identified using the database
- A subset of the identified alarms, displays, and controls is specified as the MCR minimum inventory required to execute the EOPs and perform the risk important human actions
  - The MCR minimum inventory will be used to determine fixed HSI (i.e., Spatially Dedicated Continuously Viewable)
- Staffing and HSI design will be reviewed and revised based on TA results

4.4 Task Analysis

Example : TA Database for SKN 3&4

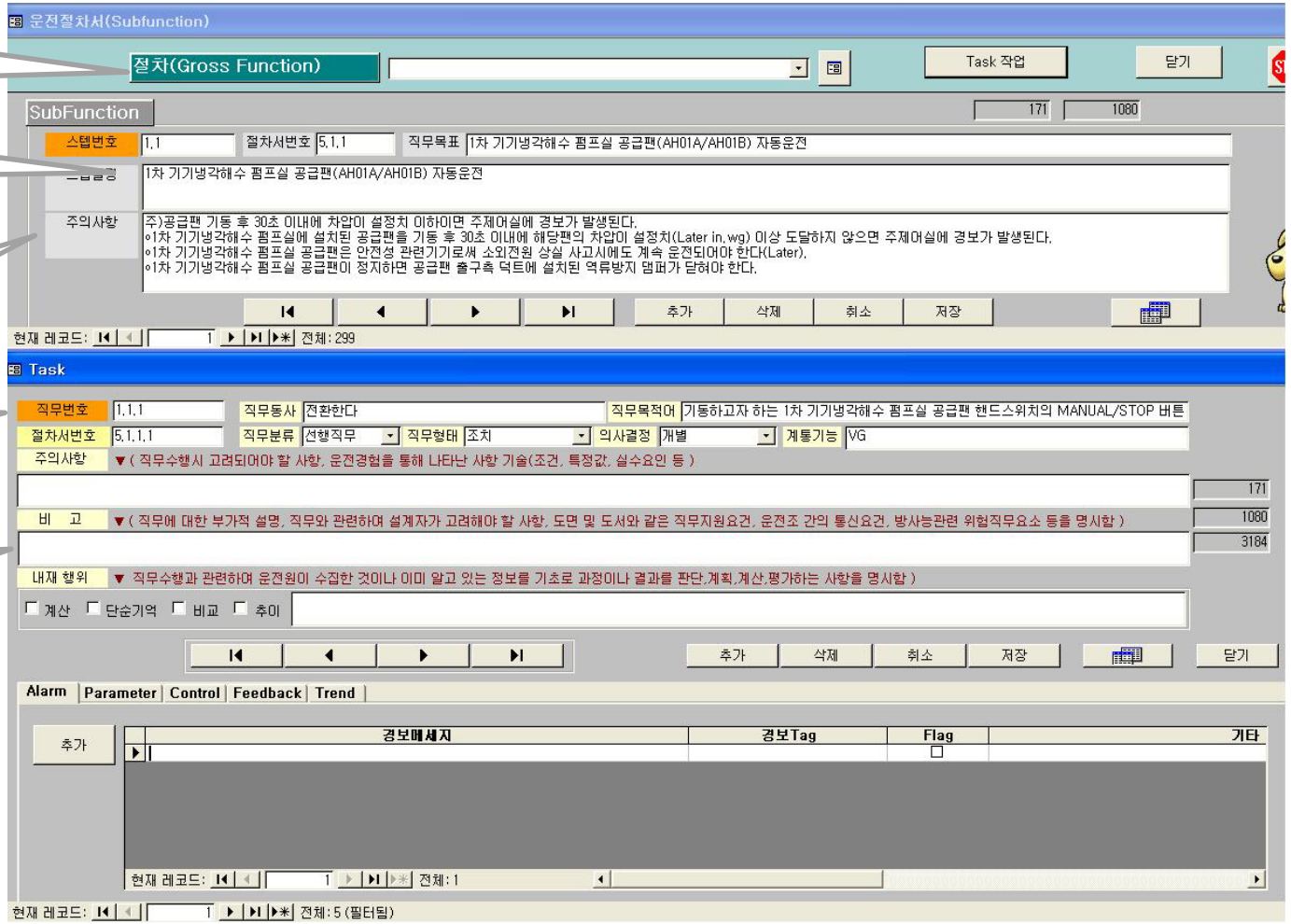
Gross Function

Sub Function

Caution

Task

Operator Aids



4.5 Human Reliability Analysis

HRA Scope

- The scope of the PRA/HRA includes human actions (HAs) developed from Level 1 (core damage) and Level 2 (release from containment) for both internal and external events
- HRA includes HAs within the MCR as well as at applicable LCS
- The HRA model considers the following three types of human interactions:
  - Type A: pre-initiating event human interactions (errors that can occur during test and maintenance)
  - Type B: initiating event related human interaction (if not completed correctly may cause an initiating event)
  - Type C: post-initiating event human interaction (evaluated to determine the likelihood of error)

4.5 Human Reliability Analysis

HRA Methodology (1/3)

- Risk important human actions (RIHAs) are HAs that have been determined to have a significant impact on plant risk by the PRA
- The HRA is used to identify RIHAs that can impact plant safety

4.5 Human Reliability Analysis

HRA Methodology (2/3)

- Following methodologies are used for PRA/HRA,
  - For pre-initiator Human Failure Events;
    - Accident Sequence Evaluation Program (ASEP) HRA
  - For post-initiator Human Failure Events;
    - Cognitive Errors
      - Human Cognitive Reliability/Operator Reliability Experiments (HCR/ORE)
      - Cause-Based Decision Tree Methodology (CBDTM)
    - Execution Errors
      - Technique for Human Error Rate Prediction (THERP)

4.5 Human Reliability Analysis

Methodology (3/3)

- The RIHAs will be identified using the selected important measures and HRA sensitivity analyses;
  - Risk Achievement Worth (RAW) ≥ 2.0, or
  - Fussell-Vesely (F-V) ≥ 0.005

- In the process of PRA/HRA using the employed methodologies, the characteristics related to a fully computerized, highly integrated control room that have a significant impact on human error rates will be implicitly considered

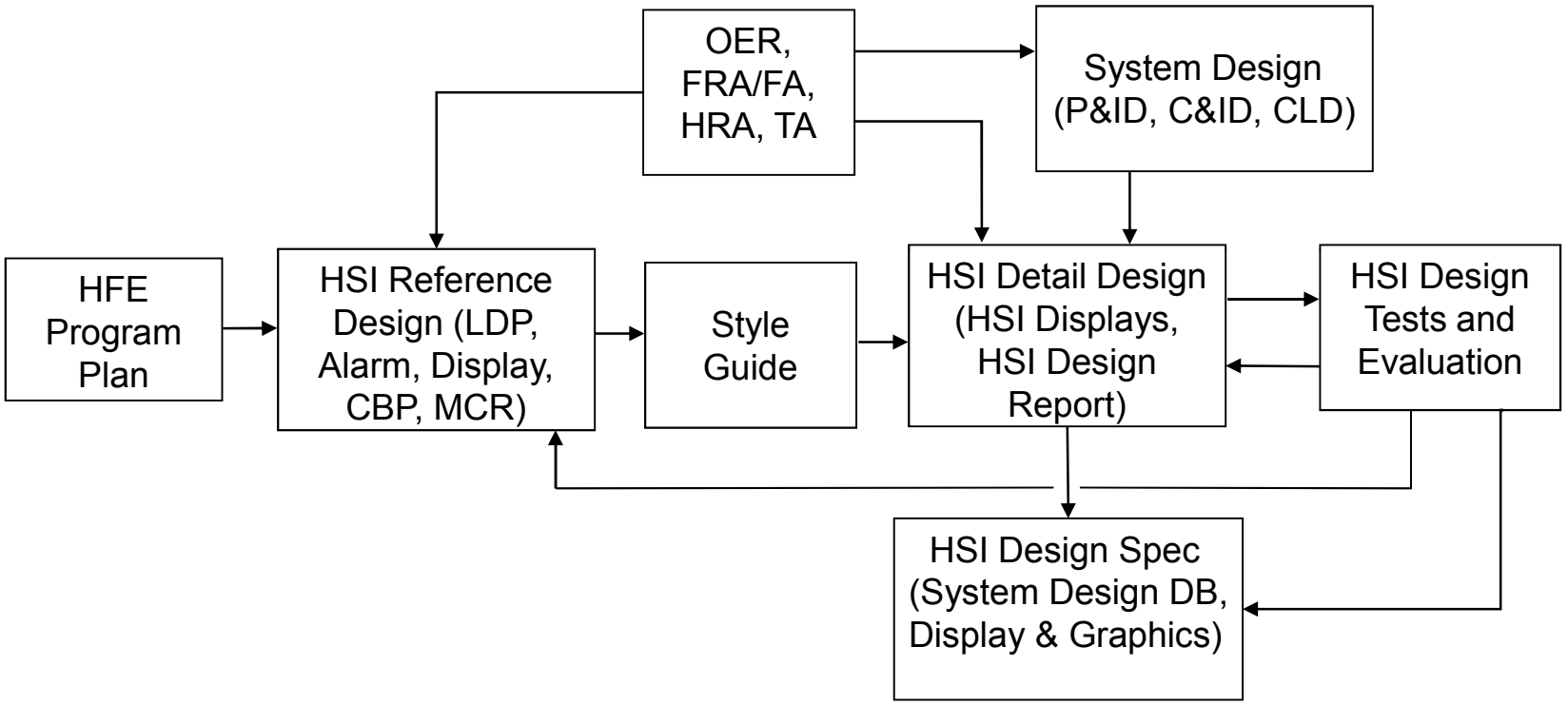
4.6 HSI Design

HSI Design Implementation

- The Scope of HSI design is MCR, RSR, TSC, EOF and LCS
- A style guide that complies with NUREG-0700 (Rev. 2) will be developed and applied to HSI design
- Tests and evaluations will be conducted iteratively throughout the HSI development
- The HSI design will be conducted under an Implementation Plan and its results will be reported in a Results Summary Report once the design is completed

4.6 HSI Design

Example: HSI Design Process for SKN 3&4



4.7 HF V&V

HF V&V Implementation

- The V&V will be conducted under an Implementation Plan that will be submitted in the future. It will be implemented in accordance with a test procedure and its results will be reported in a Results Summary Report
- The V&V will be performed to meet the criteria described in NUREG-0711 (Rev. 2)
- Test scenarios for use in the Integrated System Validation will be available for review prior to the performance of the validation tests

4.8 Staffing and Qualification

Staffing and Qualification Implementation

- The staffing and qualification element will be conducted under an Implementation Plan and its results will be reported in a Results Summary Report
- The staffing and qualification element will be performed based on the utility's preferences and experience with previous plant operation
- The staffing and qualification element will be performed to meet the criteria described in NUREG-0711 (Rev. 2)

4.9 Procedure Development

Procedure Development Implementation

- Procedure development will be performed by the COL applicant
  - The COL applicant is responsible for development of plant procedures including operating, maintenance and administrative procedures

- HFE design team provides required input to the process on procedure development (e.g., analysis results for HSI design, TA, HRA)

4.10 Training Program Development

Training Program Development Implementation

- Training program development will be performed by the COL applicant
  - A training program development process meeting current licensing requirements is a COL applicant action item

- HFE design team provides required input for the development of training program (e.g., analysis results for OER, FRA/FA, TA, HRA, HSI design, Plant Procedures, HF V&V)

4.11 Design Implementation

Design Implementation Plan

- Design Implementation is the responsibility of COL applicant. Top level description will be included in Ch.18 of SAR.
  - The description will include the Final Plant Verification process and top level process for design changes

- HFE design team will provide required input for the design implementation (e.g., as-built design)

4.12 Human Performance Monitoring

Human Performance Monitoring Implementation

- Human performance monitoring (HPM) is performed by the COL applicant. Top level description will be included in Ch.18 of SAR
  - The description will include input from the HFE design activities (e.g., training for RIHAs)

- HFE design team will provide required input for the development of HPM program (e.g., analysis results for HRA, HSI design, Plant Procedures, Training, HF V&V)

5. SKN 3&4 HSI Design

- HSI Design Features
- HSI Design Tests and Evaluations

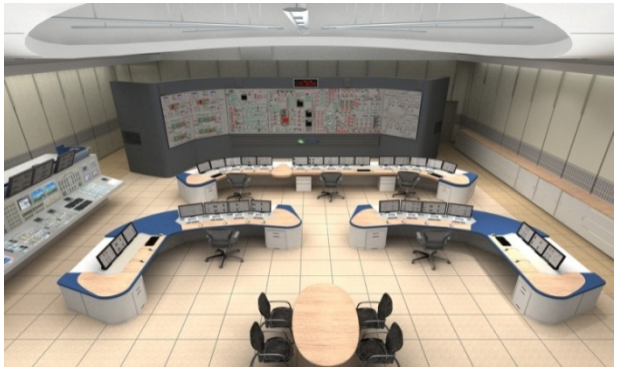
5.1 HSI Design Features

Historical Relation of SKN 3&4

OPR1000 (YGN 5&6)

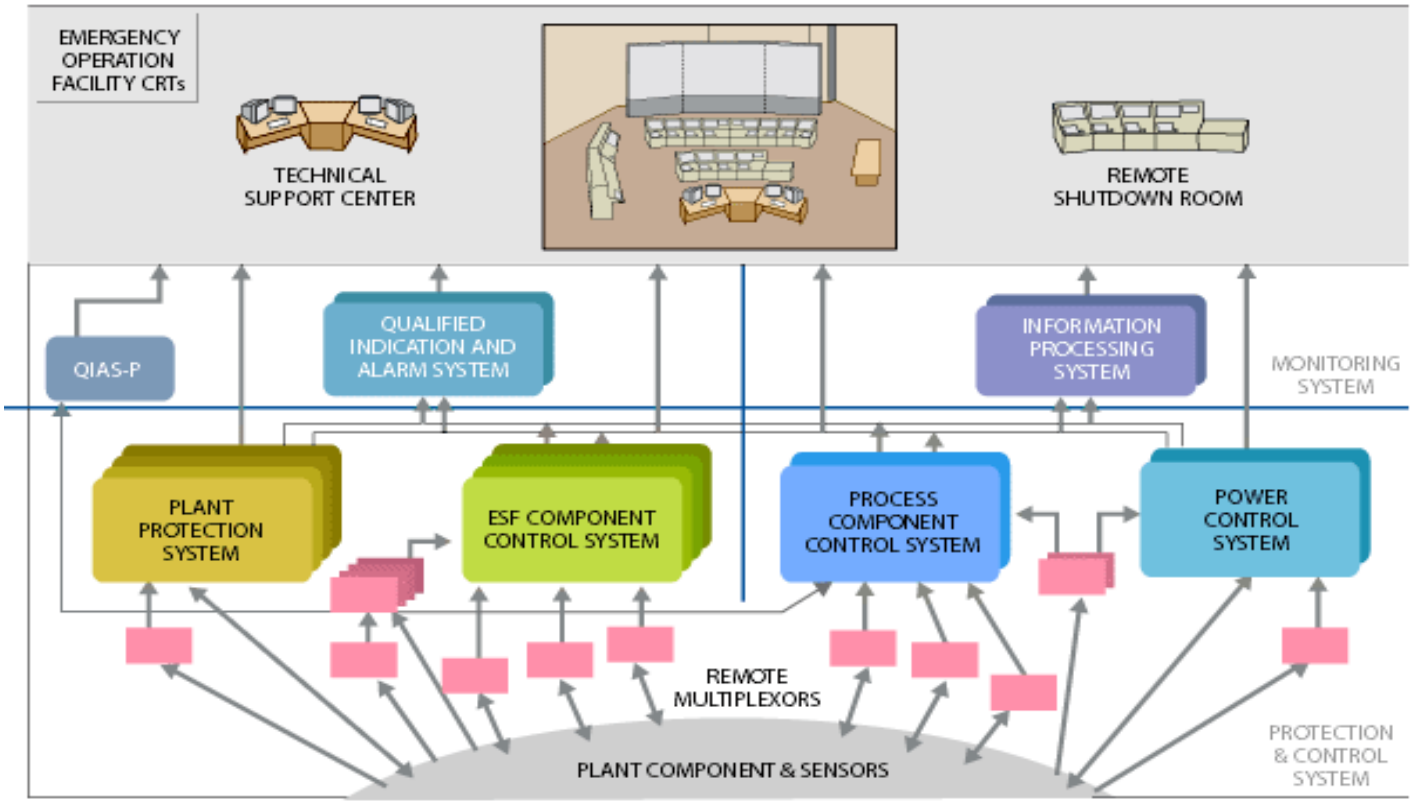
OPR1000+ (SKN 1&2)

SKN 3&4



5.1 HSI Design Features

HSIS Overview



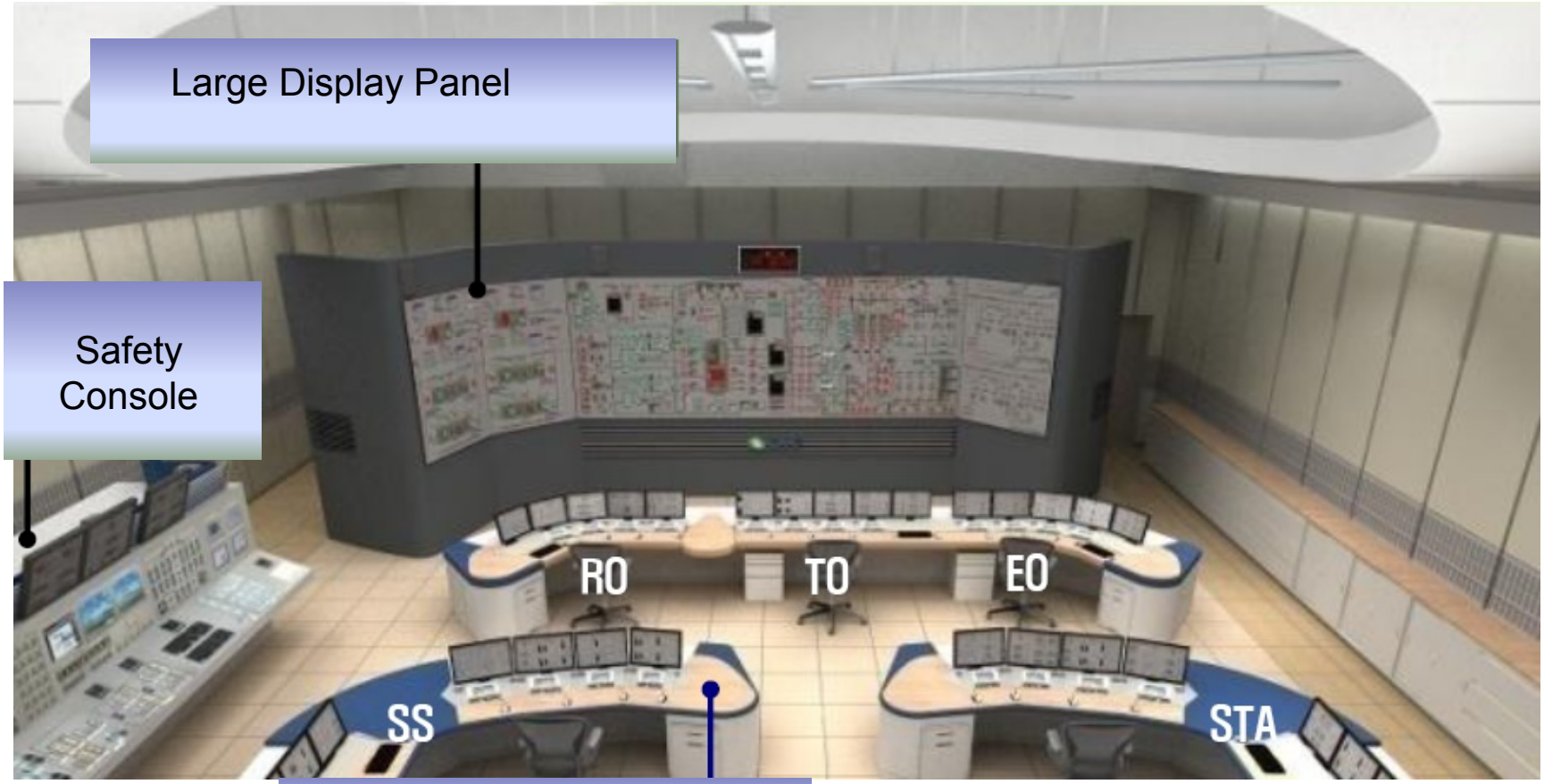
5.1 HSI Design Features

Main Control Room (1/3)

- Computer based advanced MCR
  - Five identical compact and computer-driven operation consoles (for RO, TO, EO, SS, and STA)
  - A large display panel (LDP) to display overview and key plant information to assess the plant safety status
  - A safety console provides the safe shutdown capability
- Diverse architecture of HSI system
  - Two diverse data processing and monitoring systems (information processing system (IPS) and qualified indication and alarm system (QIAS-N))

5.1 HSI Design Features

Main Control Room (2/3)



EO : Electrical Operator, SS: Shift Supervisor, STA: Shift Technical Advisor, RO : Reactor Operator, TO: Turbine Operator

5.1 HSI Design Features

Main Control Room (3/3)

- Console design

5.1 HSI Design Features

Safety Console (1/3)

- Function
  - Provides qualified HSI to cope with abnormal situation in plant when redundant operator consoles are unavailable
  - Provides system level controls and display to cope with CCF of safety I&C system

- Configuration
  - Minimum inventory components
  - Qualified Display
    (e.g., Mini-LDP, QIAS-P, and operator module for plant protection system)
  - Qualified touch screen
  - Diverse indication system/diverse manual actuation switches

5.1 HSI Design Features

Safety Console (2/3)

- Minimum inventory for alarms, controls, and indication on the safety console are listed by the following criteria:
  - Preferred/credited success path information in a major safety system flow path from FRA/FA
  - Information required to perform safe shutdown from FRA/FA
  - Information required to perform the PRA/HRA critical tasks

5.1 HSI Design Features

Safety Console (3/3)

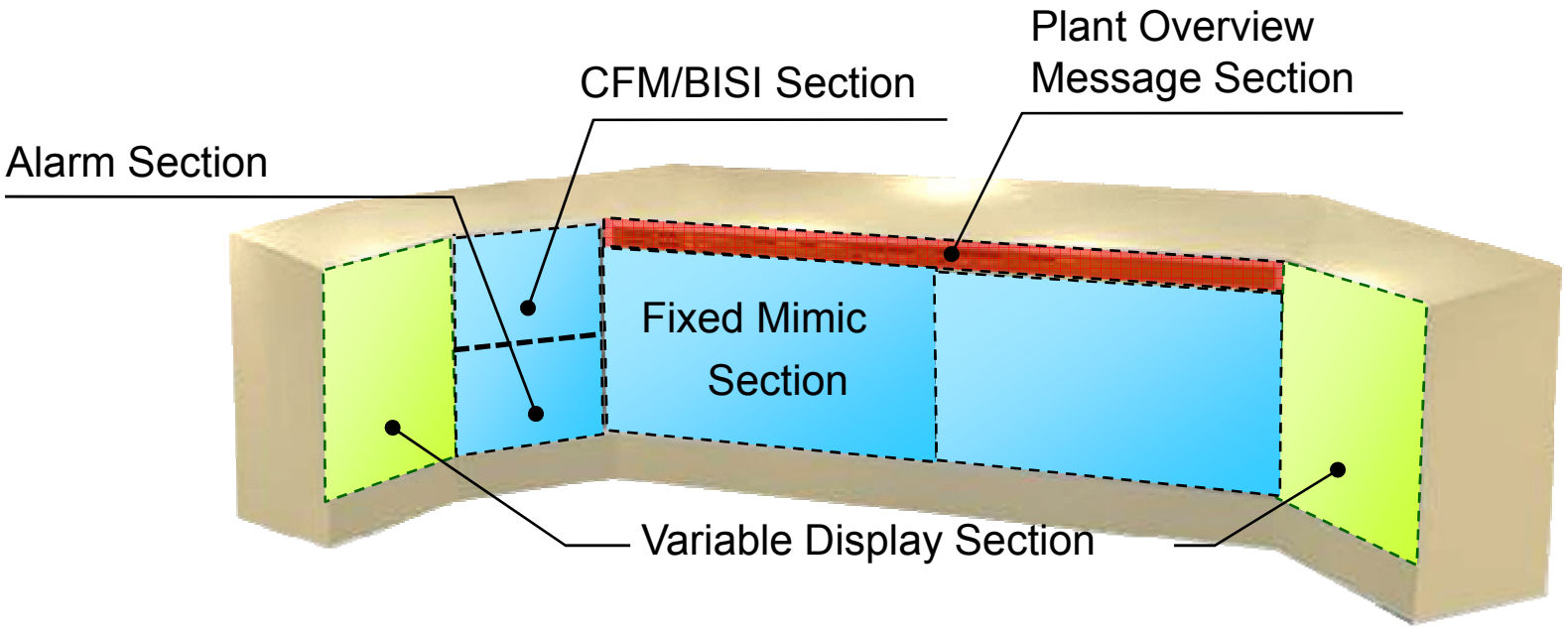
MCR Safety Console

5.1 HSI Design Features

Large Display Panel

- Function
  - Provides the operator with the information to assess overall plant process performance and safety status of the plant

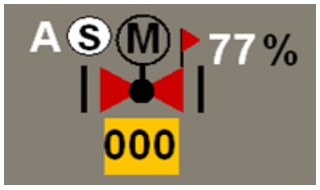
- Layout



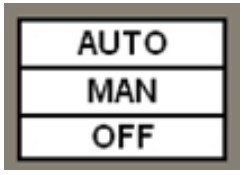
5.1 HSI Design Features

Display

- Function
  - Provides the operator with integrated information to improve operability
- Types of display
  - System mimic display: graphical layout of plant and process
  - Safety parameter display and evaluation system display: present status of critical safety function
  - Global aid display: aid display for specific functions to support operator
  - Alarm display
  - Computer based procedure display
- Display elements

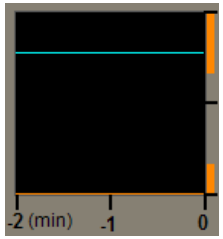


Control Valve



Control Target

Page Link

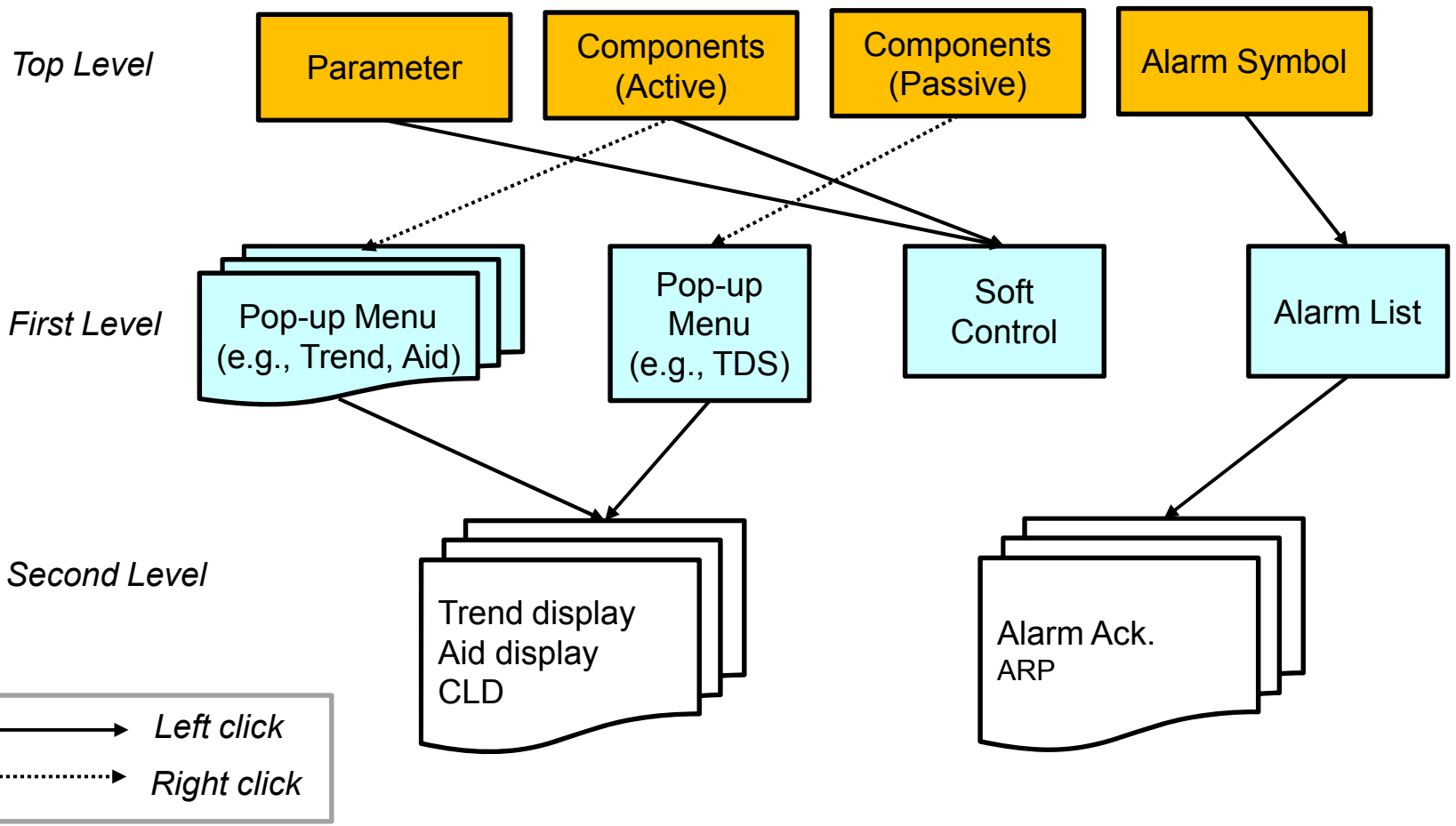


Mini Trend

Tab Menu

5.1 HSI Design Features

Example of Display Navigation



5.1 HSI Design Features

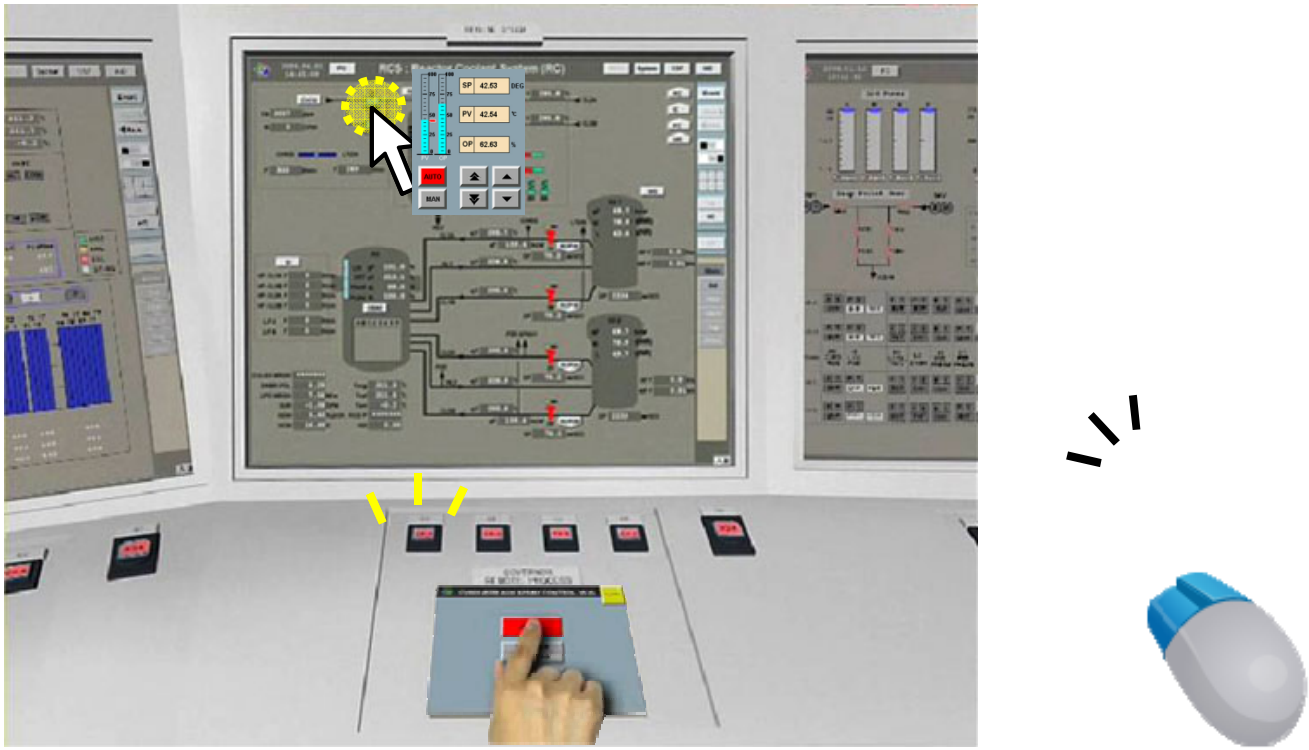
Soft Control (1/2)

- Function
  - Provides the operator with manual control for component-level
  - Allows both continuous control of plant process and discrete control of components

- Configuration
  - The soft control is comprised of safety and non-safety control
    - Safety soft control is displayed on qualified touch screen
    - Non-safety soft control is displayed on information display.

5.1 HSI Design Features

Soft Control (2/2)



5.1 HSI Design Features

Alarm (1/2)

- Alarm and flag
  - Alarm is an alerting, warning, informing and directing information, which requires operator's acknowledgement and action
  - Flag is information, which does not require operator's acknowledgement nor action(e.g., Turn Gear Engaged)

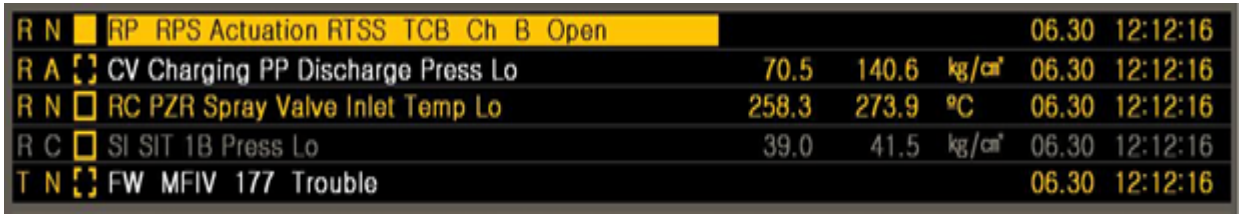
- Alarm priority
  - Alarms are classified into three priorities based on their importance or urgency
  - First priority alarm: plant shutdown and radiation release
  - Second priority alarm: plant conditions defined in Tech. Spec.
  - Third priority alarm: plant conditions representing problem (e.g., system degradation)

5.1 HSI Design Features

Alarm (2/2)

- Design characteristics
  - Shape and flash coding for alarm presentation

  - Sound coding for RO, TO, EO and ESFAS
  - Various kinds of alarm lists
    (e.g., chronology based alarm)



  - Link to alarm response procedure

5.1 HSI Design Features

Computer Based Procedure System (1/2)

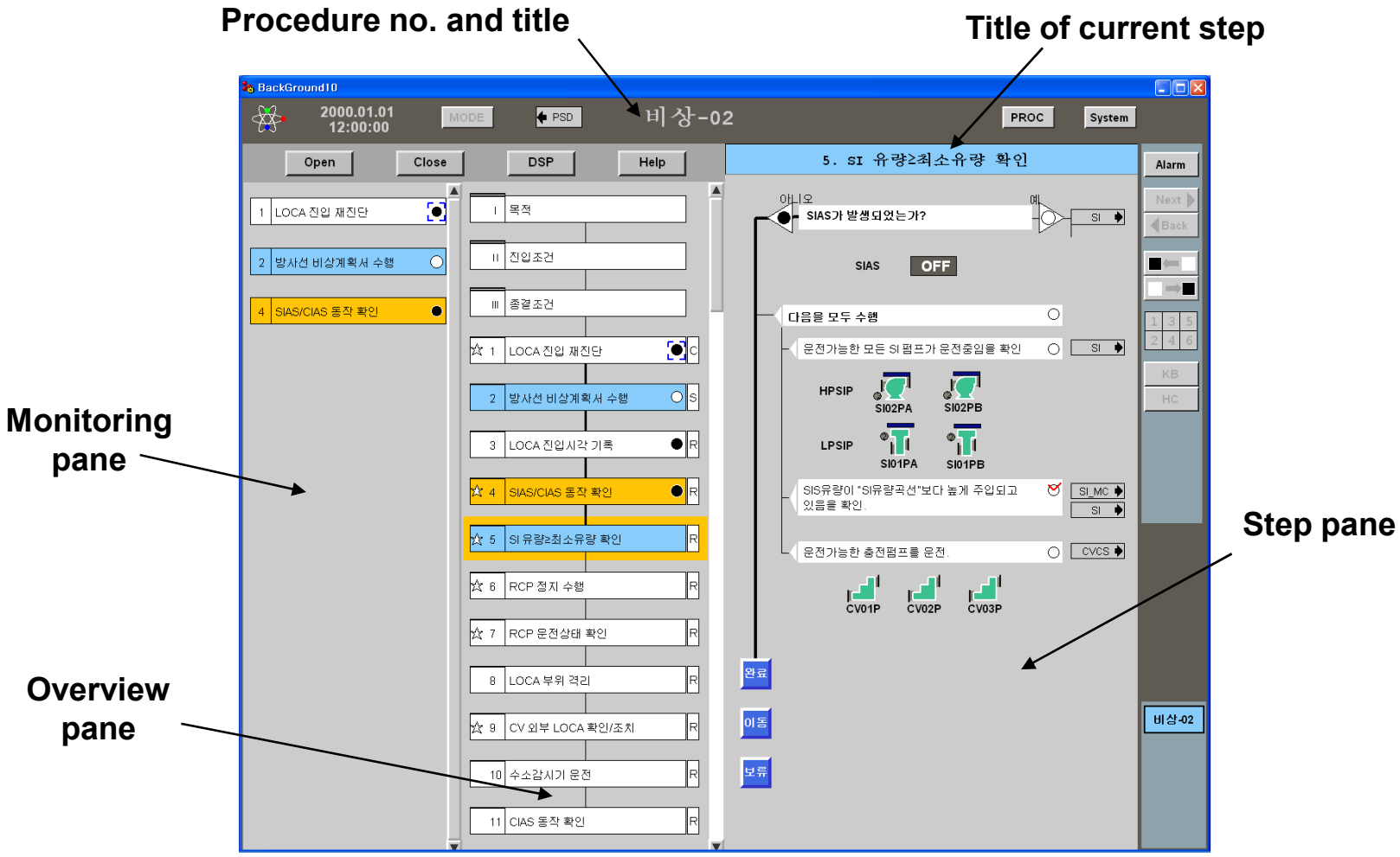
- Function
  - Integrates operation procedure with process information and links to associated display pages
  - Provides logic based checking for operators judgments to detect operator error and recovery

- Location
  - One of Information displays on an operator console is assigned for computer based procedure system

- Page link
  - The procedure can access the information display using page link button

5.1 HSI Design Features

Computer Based Procedure System (2/2)



5.2 HSI Design Tests and Evaluations

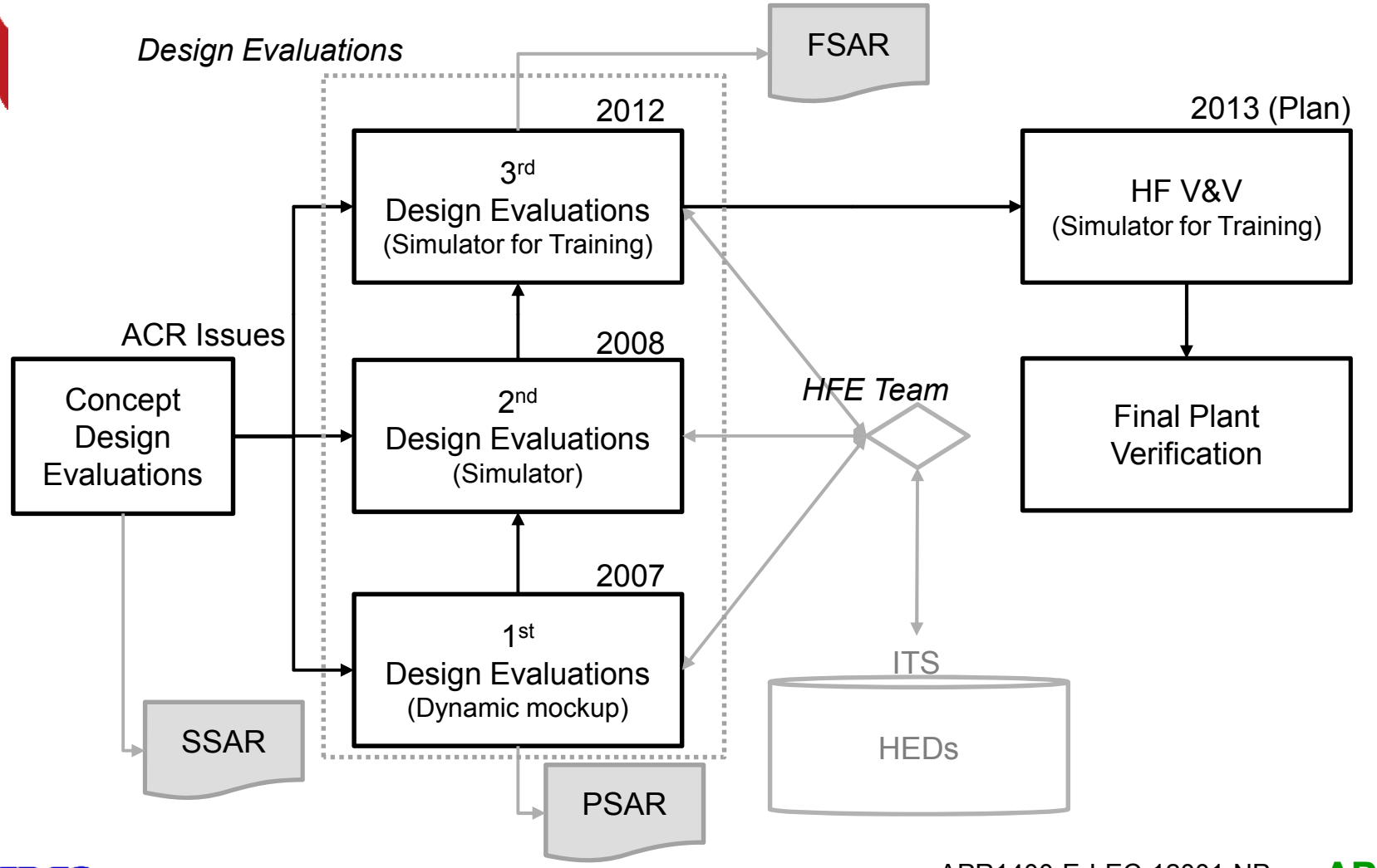
Scope and Methodology

- Three distinct types of design evaluation for selected scenarios:
  1. Task support evaluations
  2. HFE design evaluations
     - Top-down suitability evaluation
     - Bottom-up suitability evaluation
  3. Integrated System Validation

- HF V&V and Final Plant Verification will be performed before fuel loading

5.2 HSI Design Tests and Evaluations

Schedule for SKN 3&4 HSI Design



5.2 HSI Design Tests and Evaluations

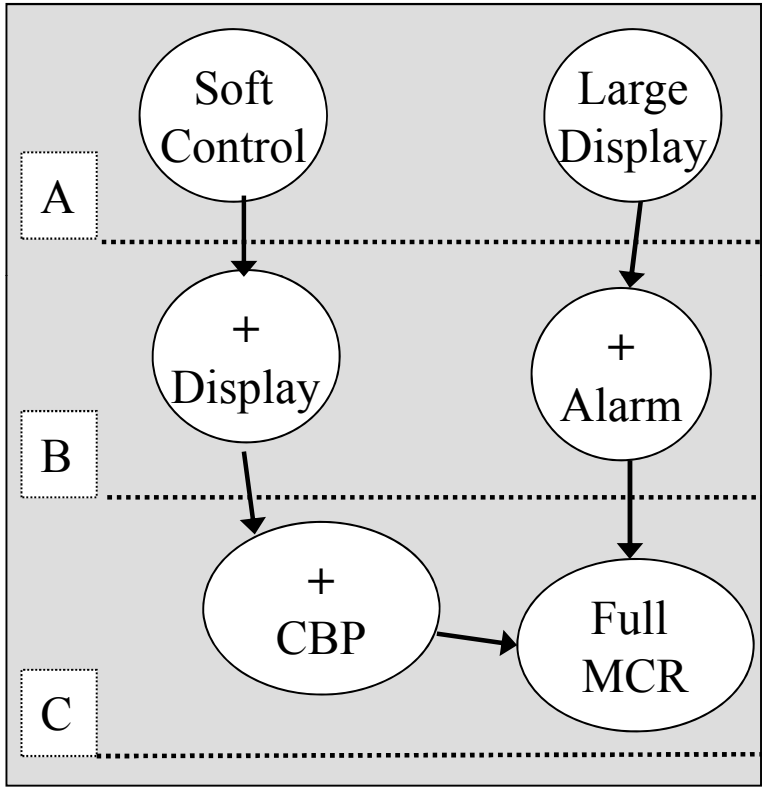
Concept Design Evaluation

- A compact workstation control room per EPRI-URD
  - Nuplex 80+ was used as a reference design
- The design features representing the greatest difference from the reference design were selected for individual evaluation
  - Evaluated by a team for technical feasibility, licensing, schedule and cost, and I&C systems
- Special attention was given to establish design bases for each design feature
- The results were considered by the entire team of engineers /managers from Korea and ABB-CE engineers in design review meetings

5.2 HSI Design Tests and Evaluations

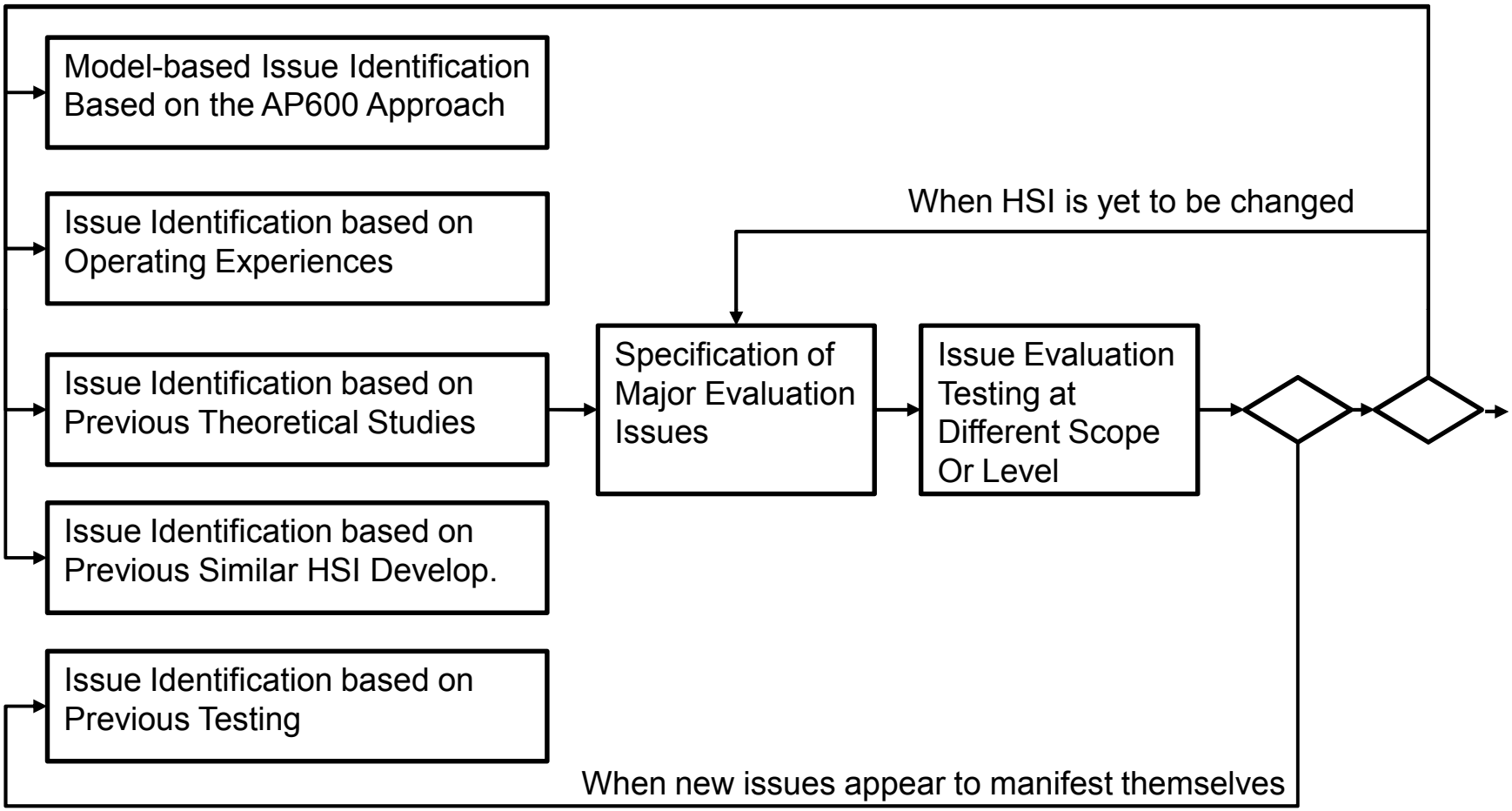
Concept Tests

- The HSI resources were examined by a series of concept tests
- The resources are combined in successively larger groups (A-B-C), culminating in tests of the whole HSI system ensemble
  - To provides proof-of-concept for both individual resources and for their successive integration.
  - To improves the efficiency of iterative design and testing, and is consistent with the bottom-up nature of systems implementation



5.2 HSI Design Tests and Evaluations

Advanced Control Room Issue Testing



5.2 HSI Design Tests and Evaluations

Task Support Evaluations

- Methods to examine are as follows:
  - I&C system inventory meet;
    - Information and control requirements as specified in the task analysis
    - Mandated indication and control requirements in regulatory documents
    - Fixed position HSI identified in the EOPs
  - Verifying and documenting that all I&C system inventory are available in the HSI design

5.2 HSI Design Tests and Evaluations

HFE Design Evaluations

- Method to examine suitability that HSI design follows HFE guideline
  - Part 1 (top-down suitability evaluations)
    - HF specialists* and operation experts*
    - Experience and knowledge based evaluations (e.g., consistency, simplicity, compatibility, usability, etc.)
  - Part 2 (bottom-up suitability evaluations)
    - HF engineers
    - Conformance to the SKN 3&4 HFE guideline (e.g., character size, colors, labels, etc.)

* Independent specialists from outside of design team

5.2 HSI Design Tests and Evaluations

Integrated System Validation (1/3)

- A variety of tools and methods are used to test the HSI design
  - Interviews
  - Questionnaires
  - Checklists
  - Dynamic mockups and/or simulators

- The design test team is debriefed after the completion of each scenario to identify HEDs

5.2 HSI Design Tests and Evaluations

Integrated System Validation (2/3)

- The major questions examined are as follows:
  - What are the effects of the SKN 3&4 HSI design on situation awareness and workload?
  - What are the effects of the SKN 3&4 HSI design on team interaction?
  - What are the present status of the SKN 3&4 HSI on the identified HFE issues from ACR issues, HEDs, and questions or comments by regulatory body?

5.2 HSI Design Tests and Evaluations

Integrated System Validation (3/3)

- Summary of measures

Measures	Technique	Type	Rater
System Performance	Objective Performance Data	Log Data	Simulator
Situation Awareness	KSAX	Questionnaire	SMEs
Workload	NASA-TLX	Questionnaire	SMEs
Team interaction	BARS	Questionnaire	SMEs
Subjective rating & Opinions	Subjective Questionnaire	-	HF Eng.

KSAX: Korean Situation Assessment Index
NASA-TLX: National Aeronautics and Space Administration Task Load Index
BARS: Behaviorally Anchored Rating Scale
SMEs: Subject Matter Experts (i.e., HFE Specialists and Operation Experts)

5.2 HSI Design Tests and Evaluations

Example of Workload Evaluations

- Data Collection
  - NASA-TLX with six questionnaires is provided to the operators when the scenario is completed
  - Operation expert and HF specialist observed the activity of operators during the performance of scenario

- Evaluation
  - Operation expert and HF specialist investigated the reason for the high workload point during the debriefing time
  - Seven points rating scale is used for the NASA-TLX evaluation
  - The statistical software is used for the data analysis (e.g., T-test)

Summary

- APR1400 HFE TR will provide IPs for five elements (HFE Program Plan, OER, FRA/FA, TA, and HRA)
- IPs for three elements (Staffing and Qualification, HSI Design, and HF V&V) will be submitted as separate technical report for the DCD review
- SKN 3&4 is designed to meet requirements from Korean regulatory body. APR1400 will be designed to meet the latest HFE design requirements from NRC
- The APR1400 design team has a long and successful history of NPP design and operations