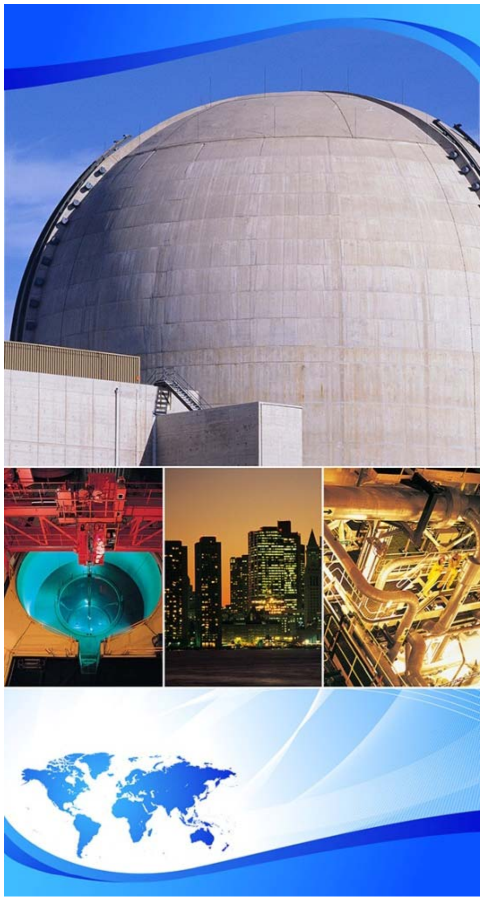

EPRI/NRC-RES FIRE PRA METHODOLOGY

Introduction and Overview: the Scope and Structure of PRA/Systems Analysis Module

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Fire PRA Workshop 2011

San Diego CA and Jacksonville FL

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

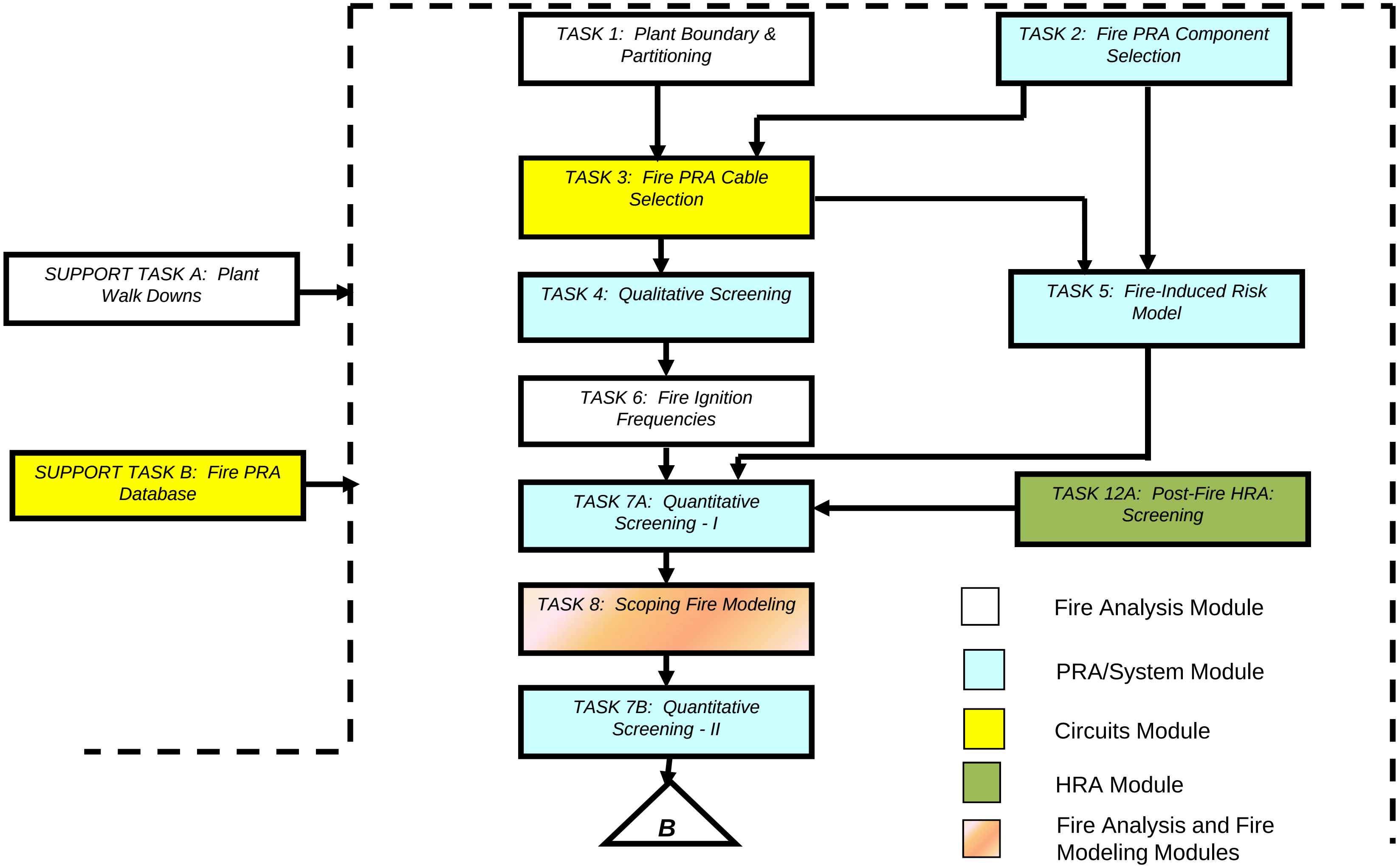
What we'll cover in the next four days
An overview…

- The purpose of this presentation is to provide an Overview of the Module 2 – PRA/Systems Analysis
  - Scope of this module relative to the overall methodology
    - Which tasks fall under the scope of this module
  - General structure of the each technical task in the documentation
  - Quick introduction to each task covered by this module:
    - Objectives of each task
    - Task input/output
    - Task interfaces

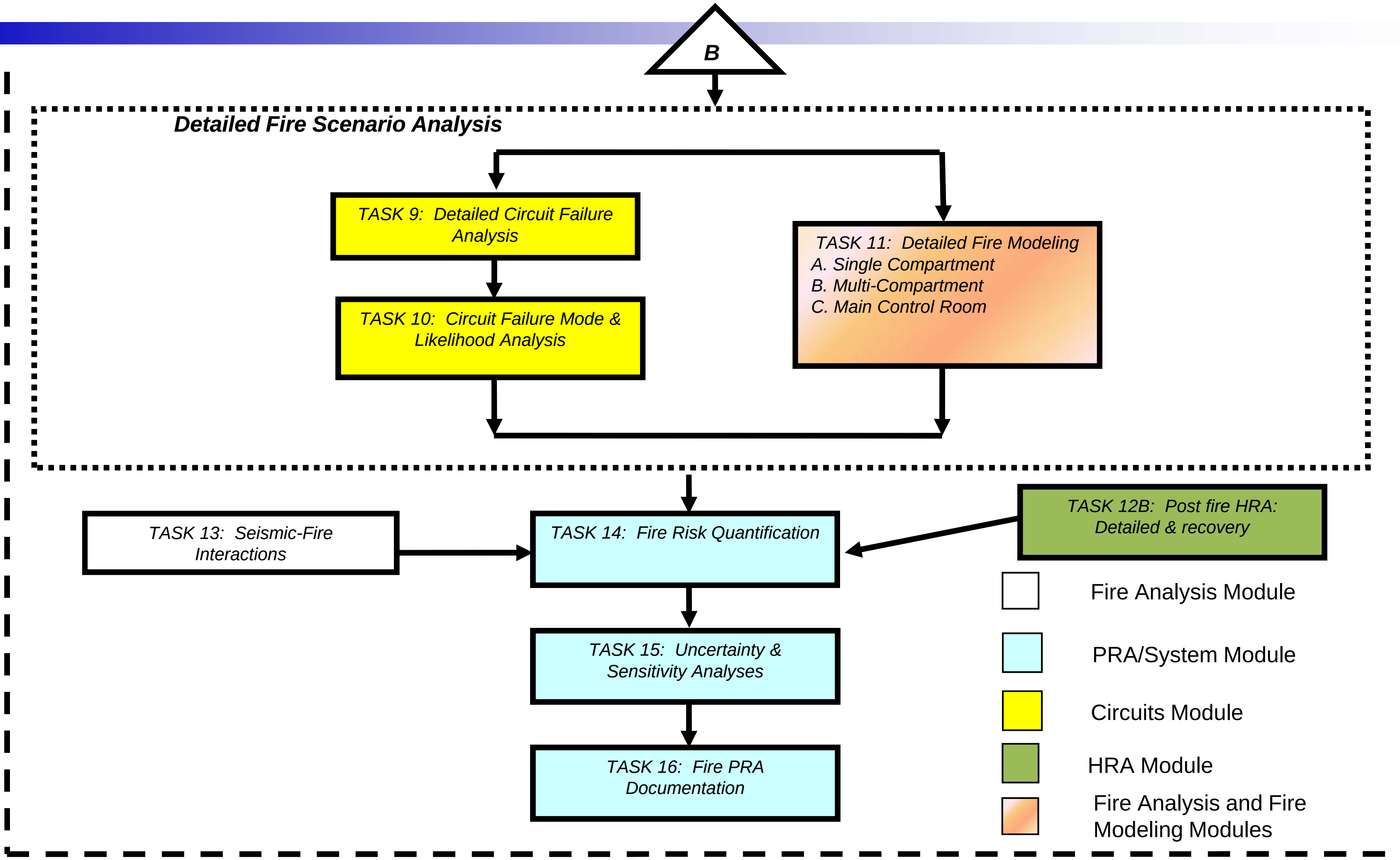
Training Objectives

- Our intent:
  - To deliver practical implementation training
  - To illustrate and demonstrate key aspects of the procedures
- We expect and want significant participant interaction
  - Class size should allow for *questions and discussion*
  - We will take questions about the *methodology*
  - We *cannot* answer questions about a *specific application*
  - *We* will moderate discussions, and *we* will judge when the course must move on

Recall the overall fire PRA structure
Module 2 covers the “blue” tasks



Recall the overall fire PRA structure (2)
Module 2 covers the “blue” tasks



Each technical task has a common structure as presented in the guidance document

1. Purpose
2. Scope
3. Background information: General approach and assumptions
4. Interfaces: Input/output to other tasks, plant and other information needed, walk-downs
5. Procedure: Step-by-step instructions for conduct of the technical task
6. References

Appendices: Technical bases, data, examples, special models or instructions, tools or databases

Scope of Module 1: PRA/Systems Analysis

- This module will cover all aspects of the plant systems accident response modeling, integration of human actions into the plant model, and quantification tasks
- Specific tasks covered are:
  - Task 2: Equipment Selection
  - Task 4: Qualitative Screening
  - Task 5: Fire-Induced Risk Model
  - Task 7: Quantitative Screening
  - Task 15: Risk Quantification
  - Task 16: Uncertainty Analysis

Task 2: Equipment Selection (1 of 2)

- Objective: To decide what subset of the plant equipment will be modeled in the FPRA

- FPRA equipment will be drawn from:
  - Equipment from the internal events PRA
    - We do assume that an internal events PRA is available!
  - Equipment from the Post-Fire Safe Shutdown analysis
    - e.g., the Appendix R analysis or the Nuclear Safety Analysis under NFPA-805
  - Other “new” equipment not in either of these analyses

Task 2: Equipment Selection (2 of 2)

- Many choices to be made in this task, many factors will influence these decisions
  - Fire-induced failures that might cause an initiating event
  - Mitigating equipment and operator actions
  - Fire-induced failures that adversely impact credited equipment
  - Fire-induced failures that could lead to inappropriate or unsafe operator actions
- Choices are important in part because “selecting” equipment implies a burden to *Identify and Trace* cables
  - Cable selection is Task 3 (Module 2)…

Task 4: Qualitative Screening (1 of 2)

- Objective: To identify fire compartments that can be screened out as insignificant risk contributors without quantitative analysis

- This is an *Optional* task
  - You may choose to bypass this task which means that all fire compartments will be treated quantitatively to some level of analysis (level may vary)

Task 4: Qualitative Screening (2 of 2)

- Qualitative screening criteria consider:
  - Trip initiators
  - Presence of selected equipment
  - Presence of selected cables
- Note that any compartment that is “screened out” in this step is reconsidered in the multi-compartment fire analysis as a potential source of multi-compartment fires
  - See Module 3, Task 11c

Task 5: Fire-Induced Risk Model

- Objective: Construct the FPRA plant response model reflecting:
  - Functional relationships among selected equipment and operator actions
- Covers both CDF and LERF
- Begins with internal events model but more than just a "tweak"
  - Adds fire unique equipment – various reasons/sources
  - May delete equipment not to be credited for fire
  - Adds fire-specific equipment failure modes
    - e.g., spurious actuations (Task 9)
  - Adds fire-specific human failure events (Task 12)

Task 7: Quantitative Screening (1 of 2)

- Objective: To identify compartments that can be shown to be insignificant contributors to fire risk based on limited quantitative considerations
- This task is *Optional*
  - Analyst may choose to retain all compartments for more detailed analysis

Task 7: Quantitative Screening (2 of 2)

- Screening may be performed in stages of increasing complexity
- Consideration is given to:
  - Fire ignition frequency
  - Screening of specific fire sources as non-threatening (no spread, no damage)
  - Impact of fire-induced equipment and cable failures
    - conditional core damage probability (CCDP)
- A word of caution: quantitative screening criteria should consider the PRA standard and Reg. Guide 1.200
  - 6850/1011989 criteria are obsolete, but approach is unchanged

Task 14: Fire Risk Quantification

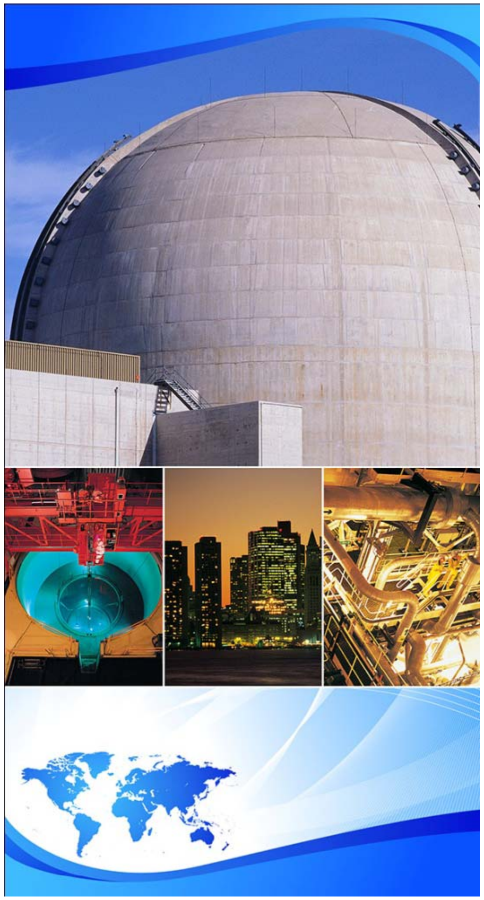
- Objective: To quantify fire-induced CDF and LERF
- Covered in limited detail
- Relatively straight-forward roll-up for fire scenarios considering
  - Ignition frequency
  - Scenario-specific equipment and cable damage
  - Equipment failure modes and likelihoods
  - Credit for fire mitigation (detection and suppression)
  - Fire-specific HEPs
  - Quantification of the FPRA plant response model

Task 15: Uncertainty and Sensitivity

Module 1

- Objective: Provide a process for identifying and quantifying uncertainties in the FPRA and for identifying sensitivity analysis cases
- Covered in limited detail
- Guidance is based on potential strategies that might be taken, but choices are largely left to the analyst
  - e.g., what uncertainties will be characterized as distributions and propagated through the model?

Any questions before we move on?



EPRI/NRC-RES FIRE PRA METHODOLOGY

Sample Plant Description

Joint RES/EPRI Fire PRA Workshop

August 2011, San Diego, CA
November 2011, Jacksonville FL

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Sample Problems / Sample Plant

- Fire PRA module will involve hands-on exercises
  - Intent: To illustrate *key aspects* of the methodology through a cohesive set of sample problems
- All exercises are built around a common sample plant – the Simple Nuclear Power Plant (SNPP)
- The exercises are designed such that taking all modules together presents a fairly complete picture of the FPRA methodology
  - Not every task is covered by the SNPP sample problems
  - Not every aspect of covered tasks are illustrated

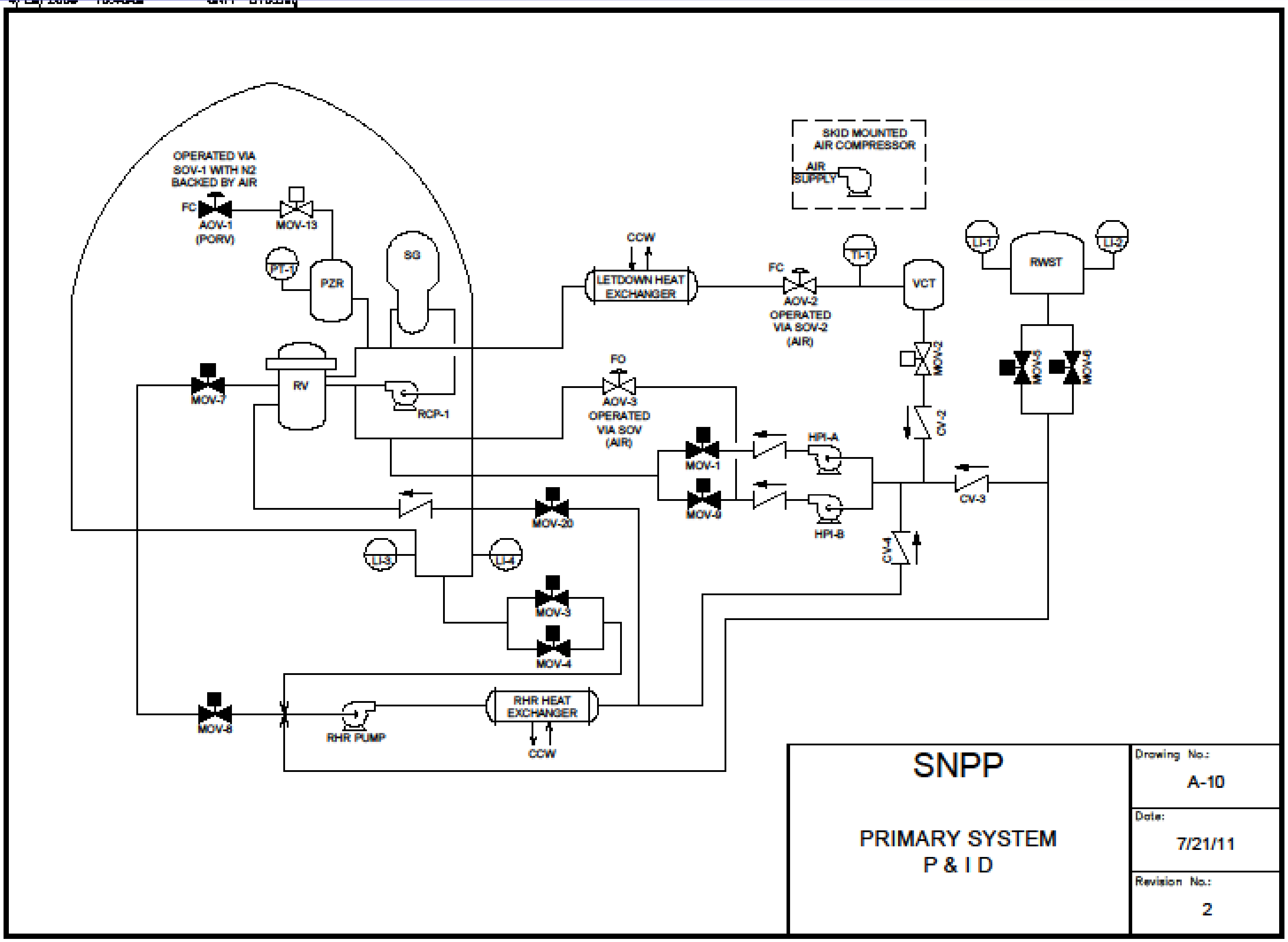
The SNPP: Intent and Approach

- The SNPP is not intended to reflect either regulatory compliance or good engineering practice
  - It is purely an imaginary construct intended to highlight key aspects of the methodology – nothing more!
- The SNPP has been kept as simple as possible while still serving the needs of the training modules
- Aspects of the plant are assumed for purposes of the training exercises, e.g.:
  - BOP equipment not covered in detail
  - Some systems are assumed to remain available

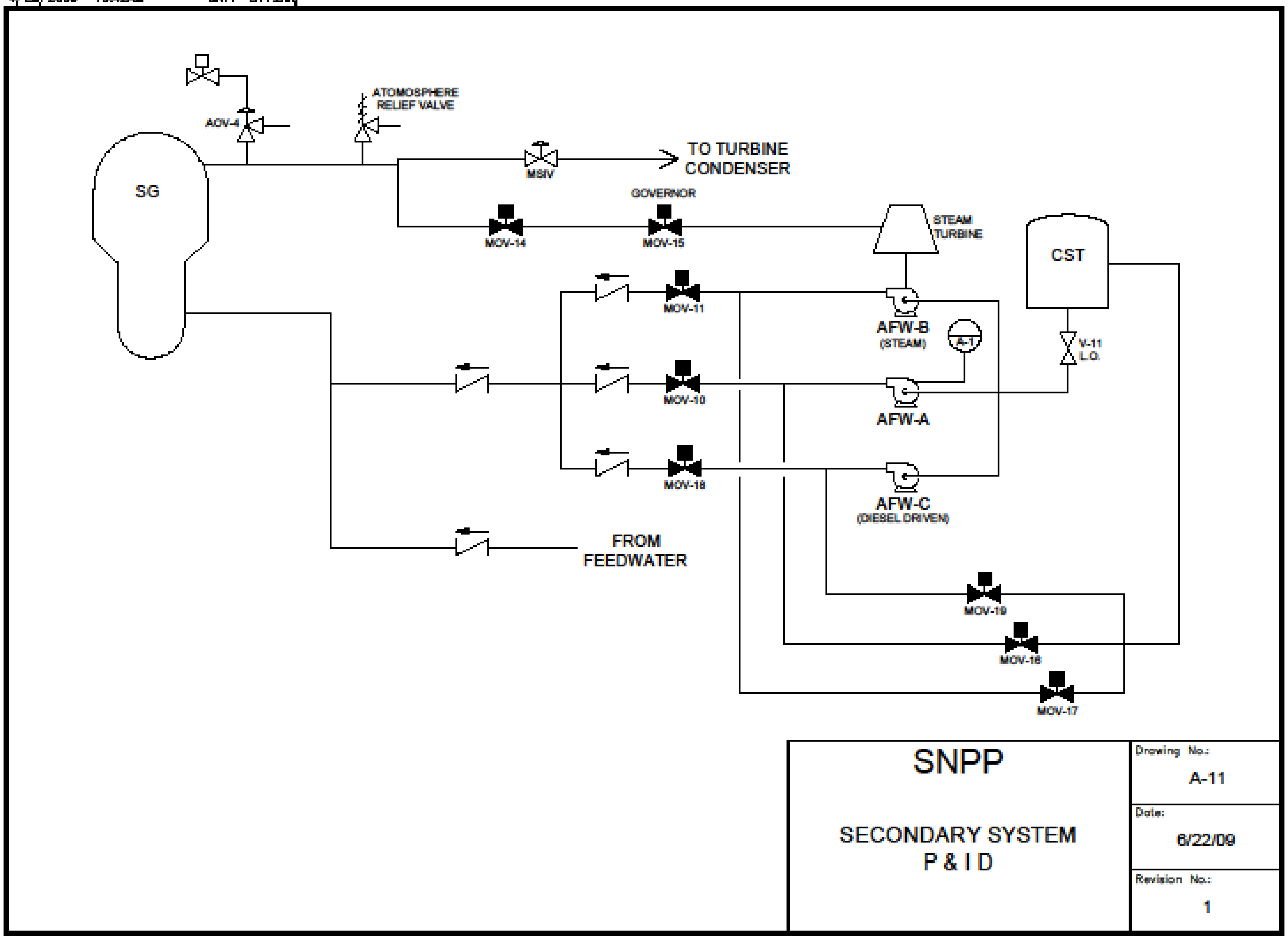
The SNPP: Plant Characteristics

- PWR with one primary coolant loop
  - One steam generator, one RCP, one pressurizer
  - Chemical volume control/high-pressure injection system
  - Residual heat removal system
- Secondary side includes:
  - Main steam and feedwater loop for the single steam generator (not modeled)
  - Multiple train auxiliary feedwater system to provide decay heat removal
- Support systems includes:
  - CCW (not modeled)
  - Instrument air
  - AC and DC power
  - Instrumentation
- See Chapter 2 for complete plant description

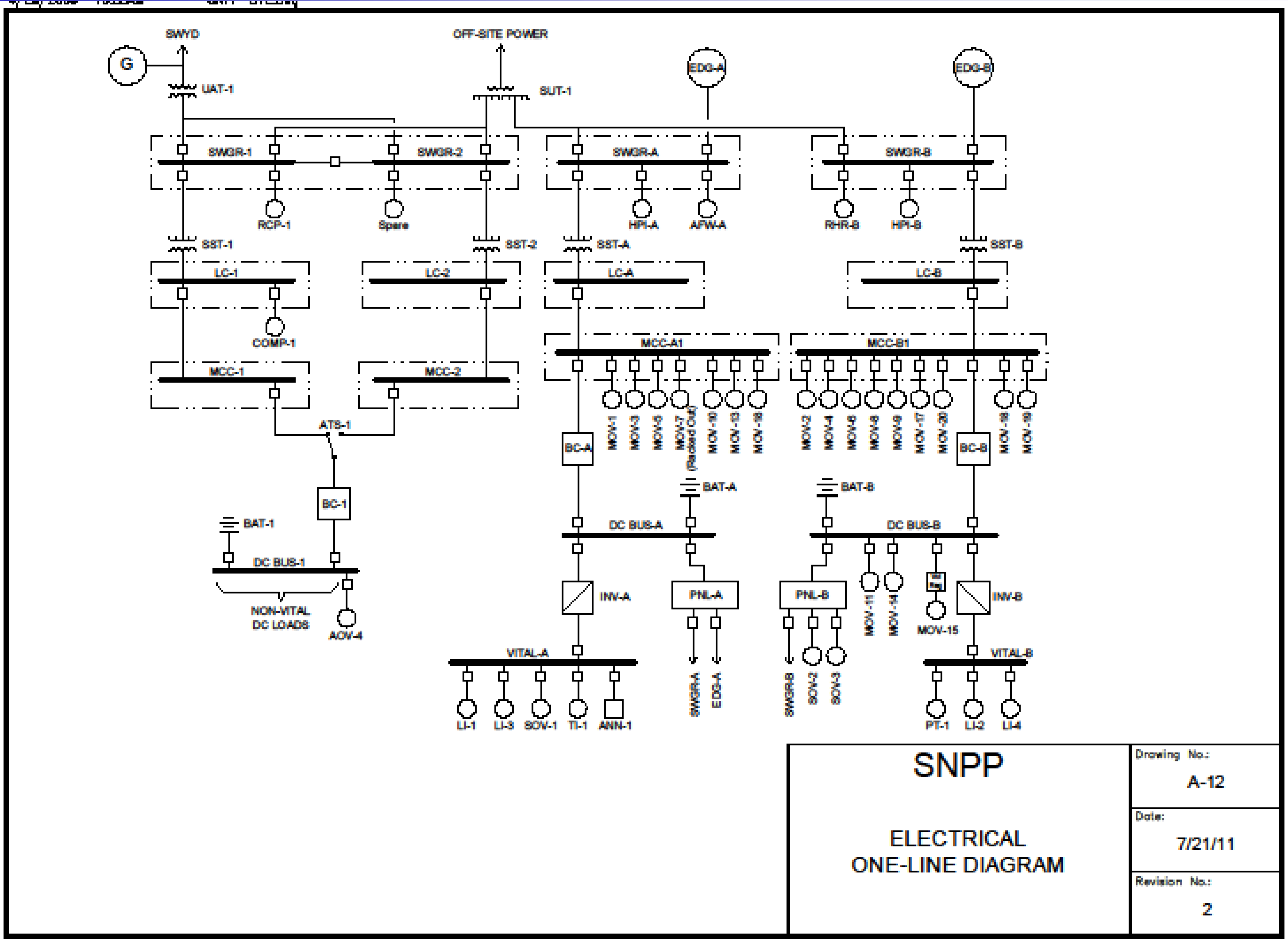
The SNPP: Primary Systems P&ID



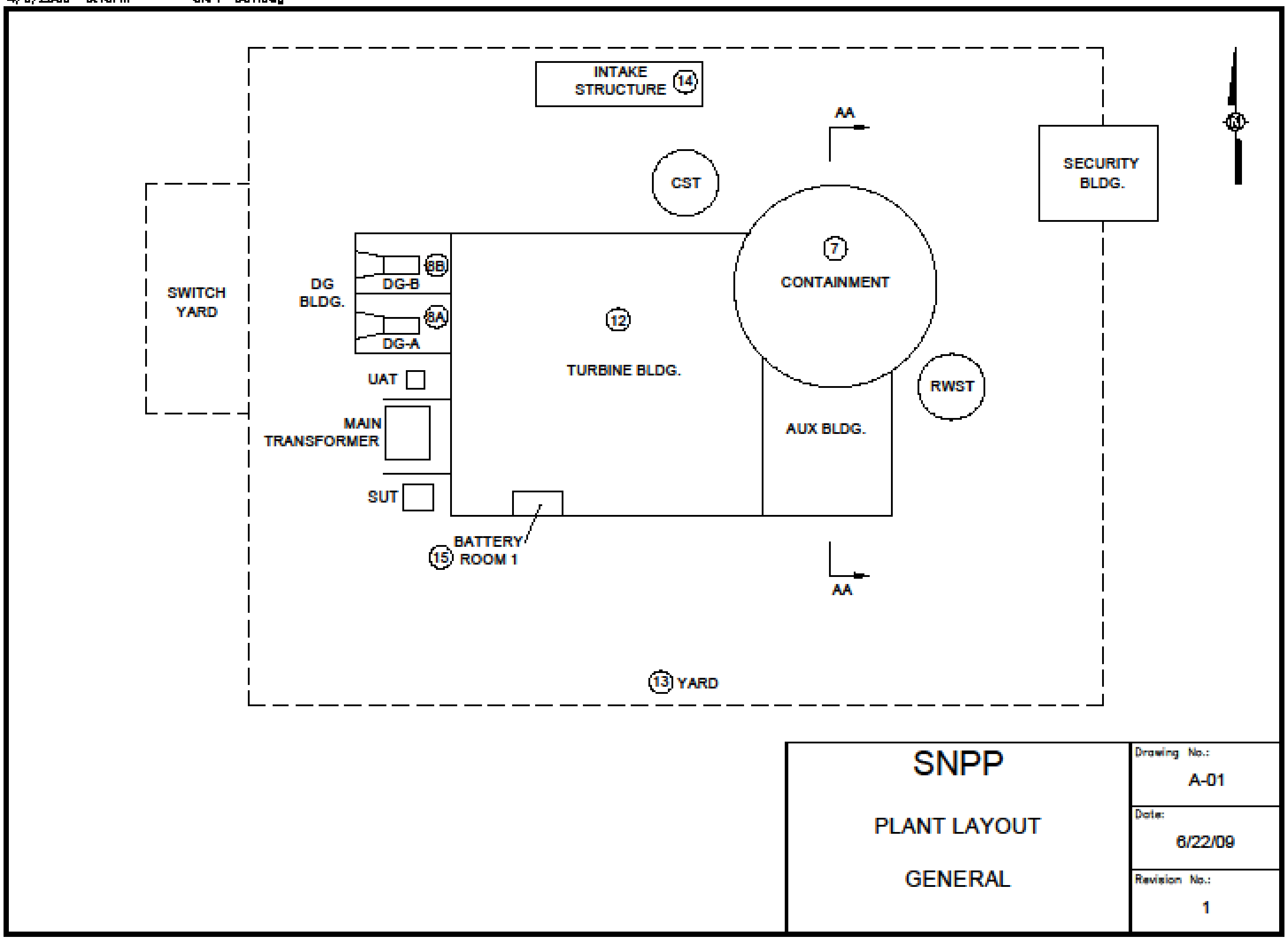
The SNPP: Secondary Systems P&ID



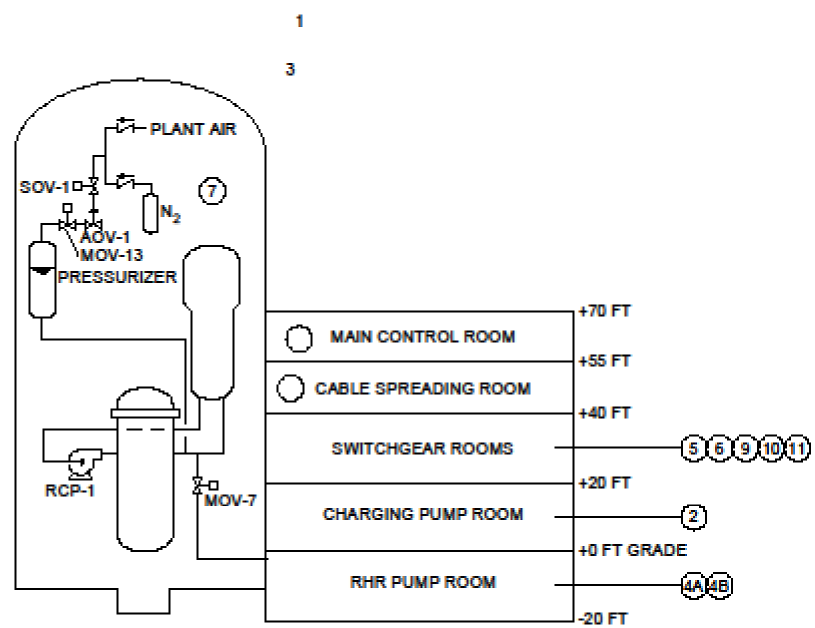
The SNPP: Electrical One-Line Diagram



The SNPP: General Plant Layout - Plan

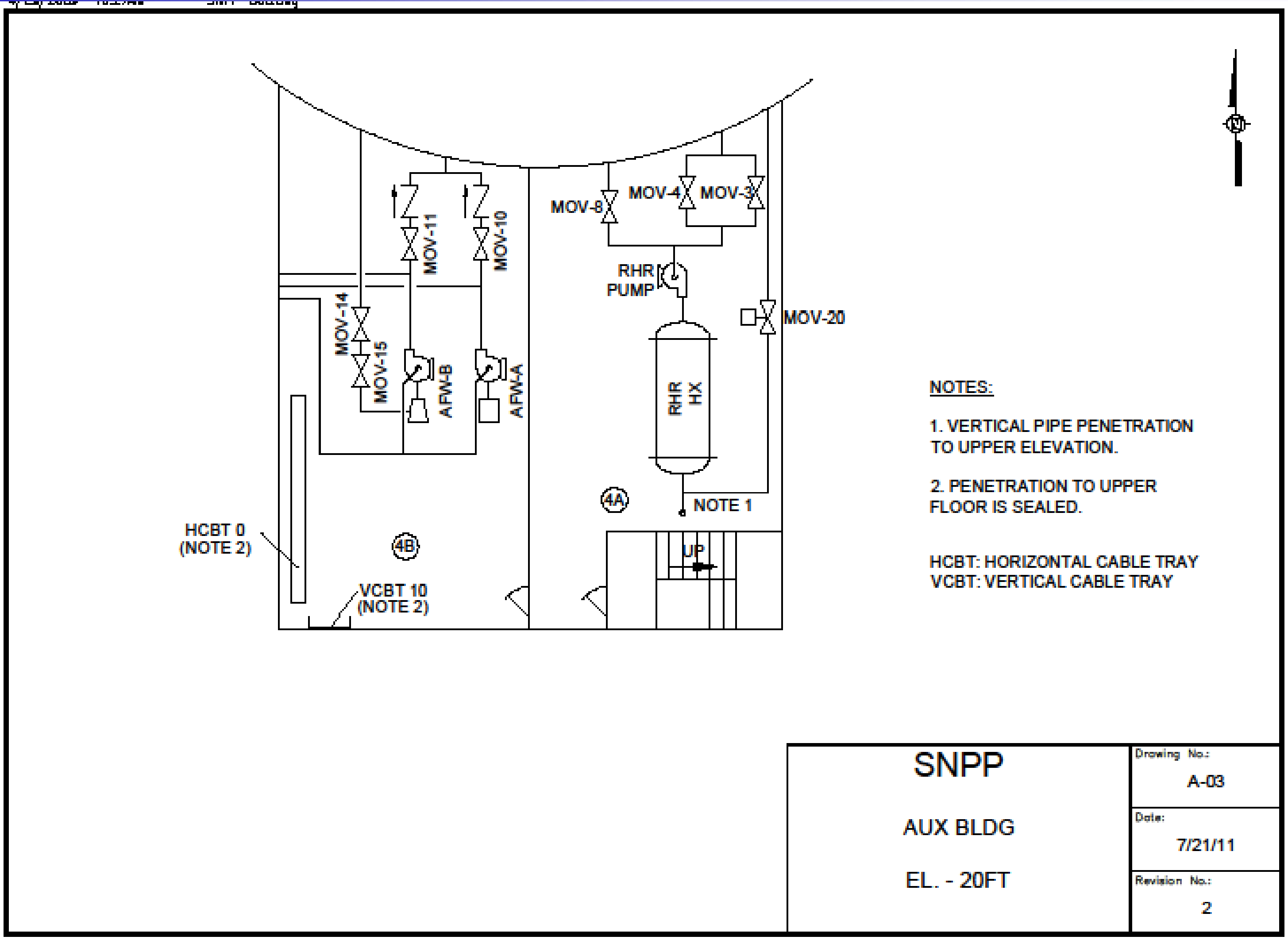


The SNPP: Plant Layout – Elevation Containment and Auxiliary Building

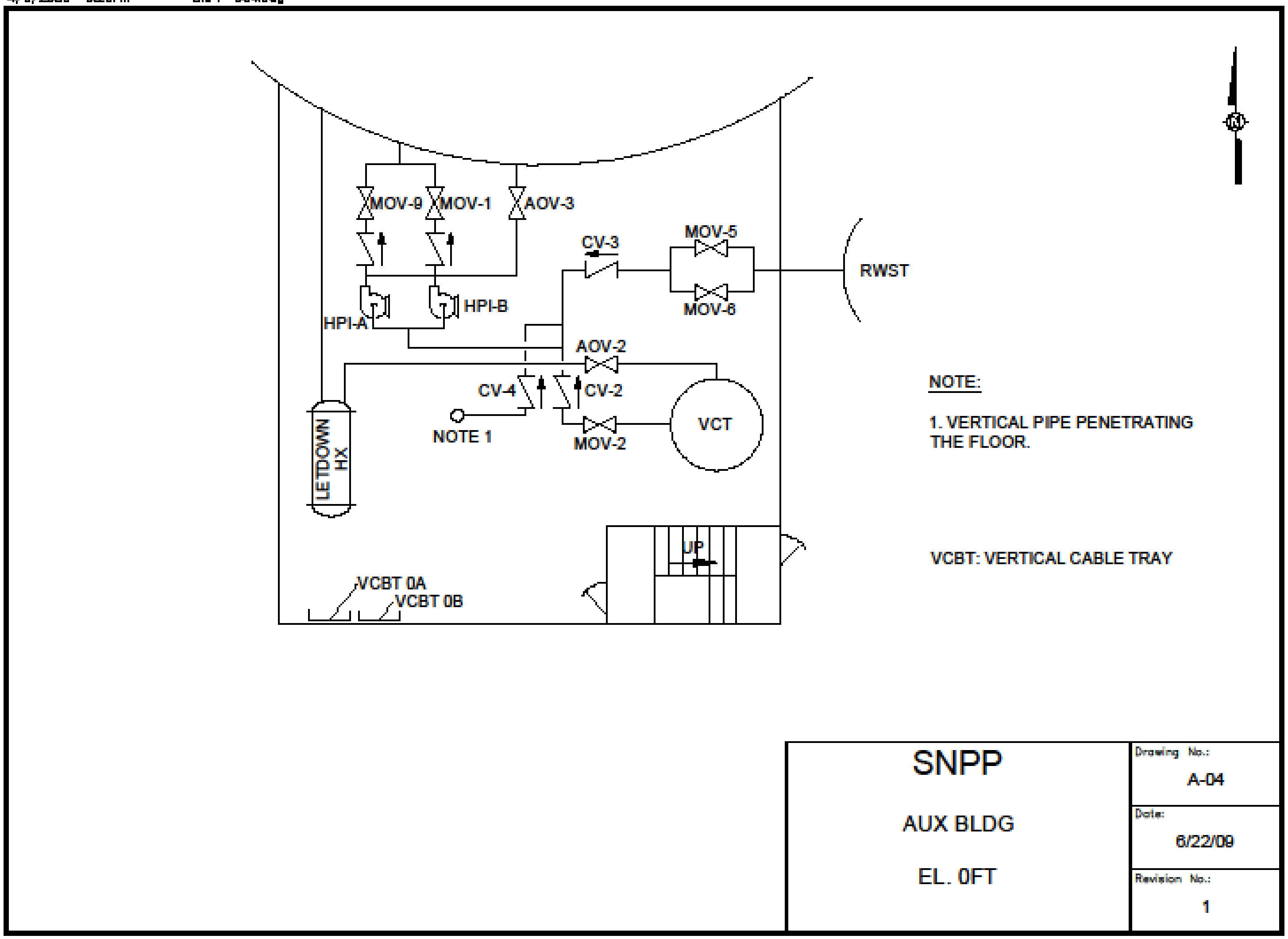


SNPP PLANT LAYOUT SECTION AA	Drawing No.: A-02
	Date: 7/21/11
	Revision No.: 2

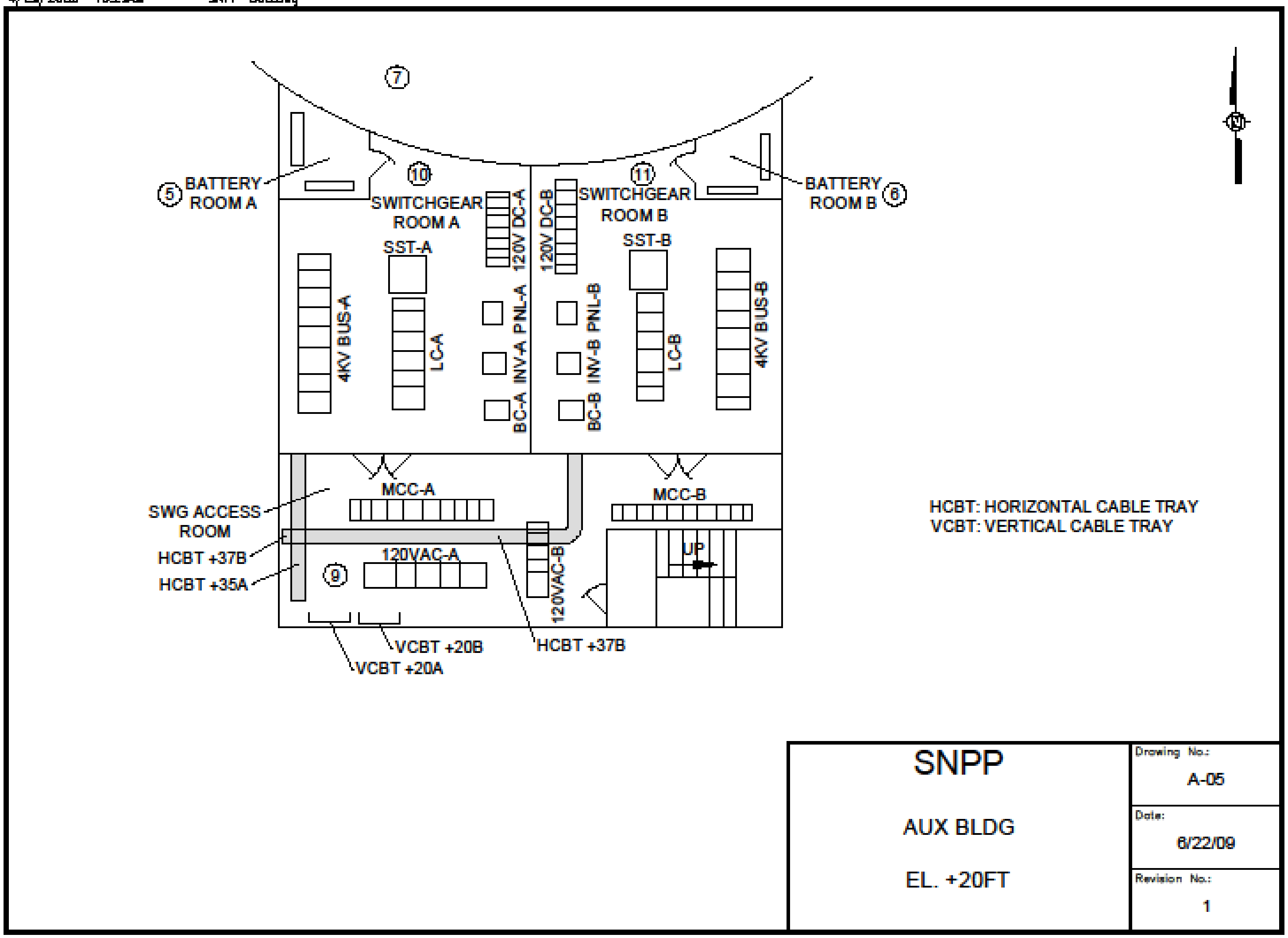
The SNPP: Aux. Bld. – RHR Pump Room



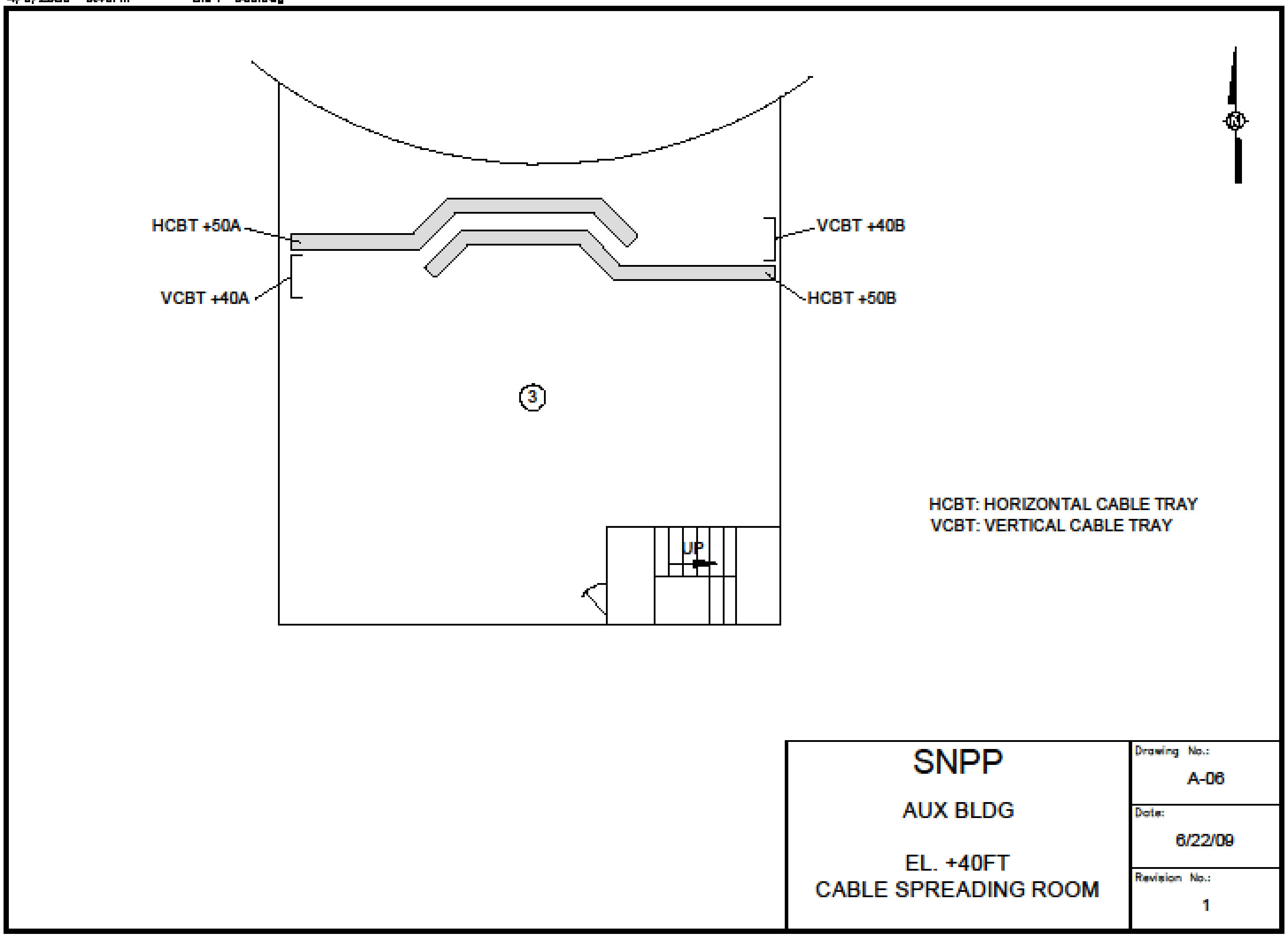
The SNPP: Aux. Bld. – Charging Pump Rm.



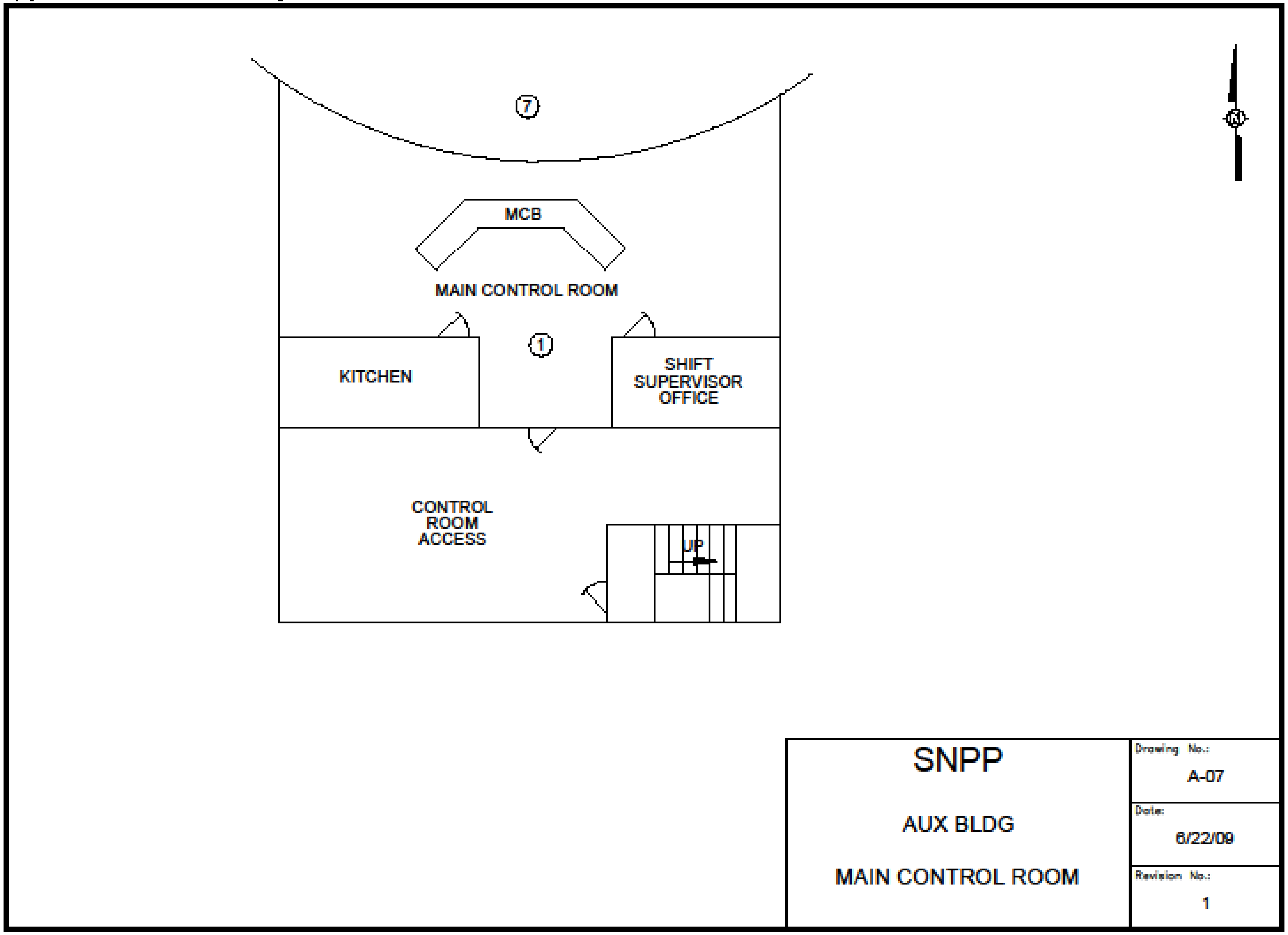
The SNPP: Aux. Bld. – Switchgear Rooms



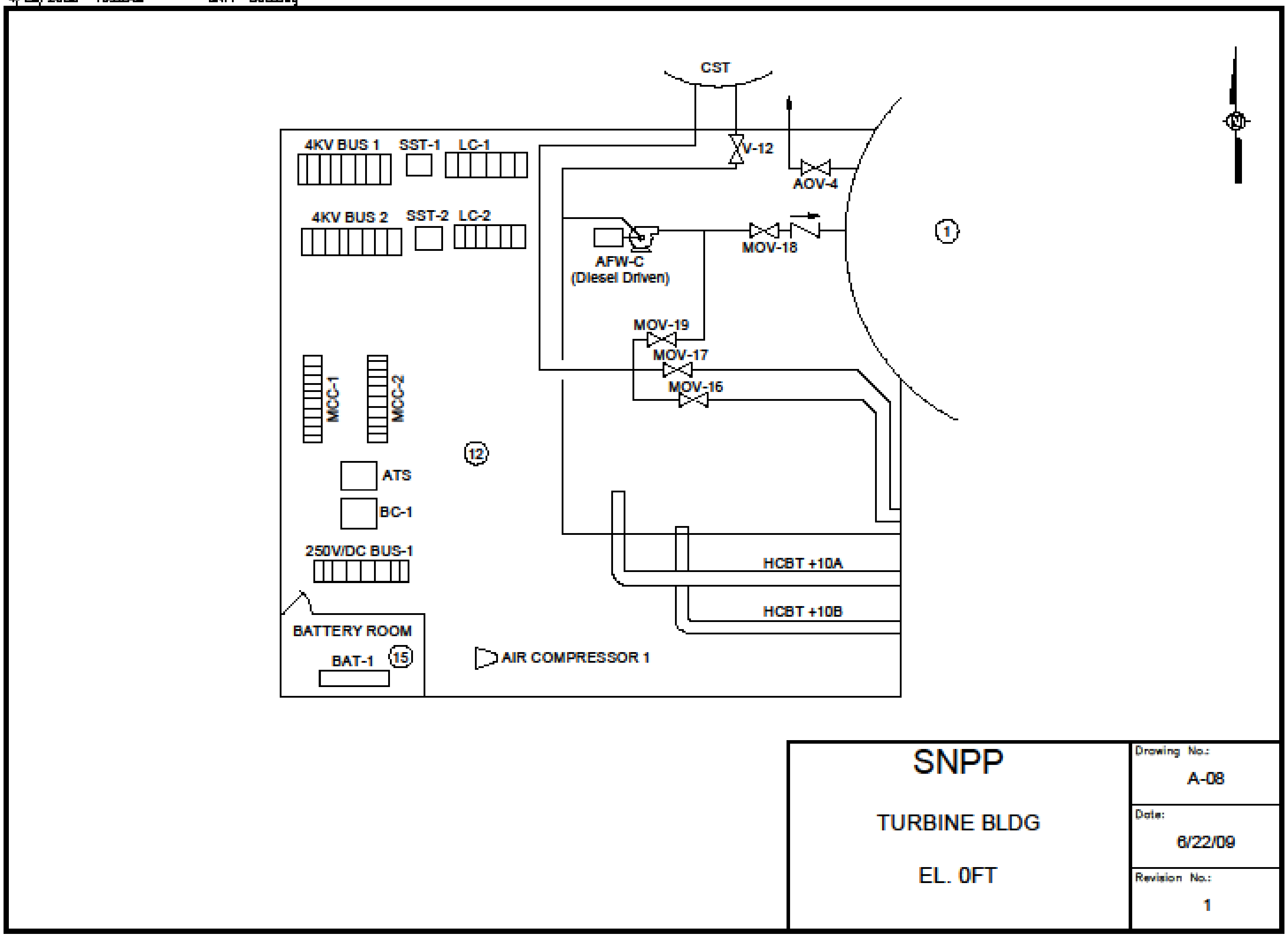
The SNPP: Aux. Bld. – Cable Spreading Rm.



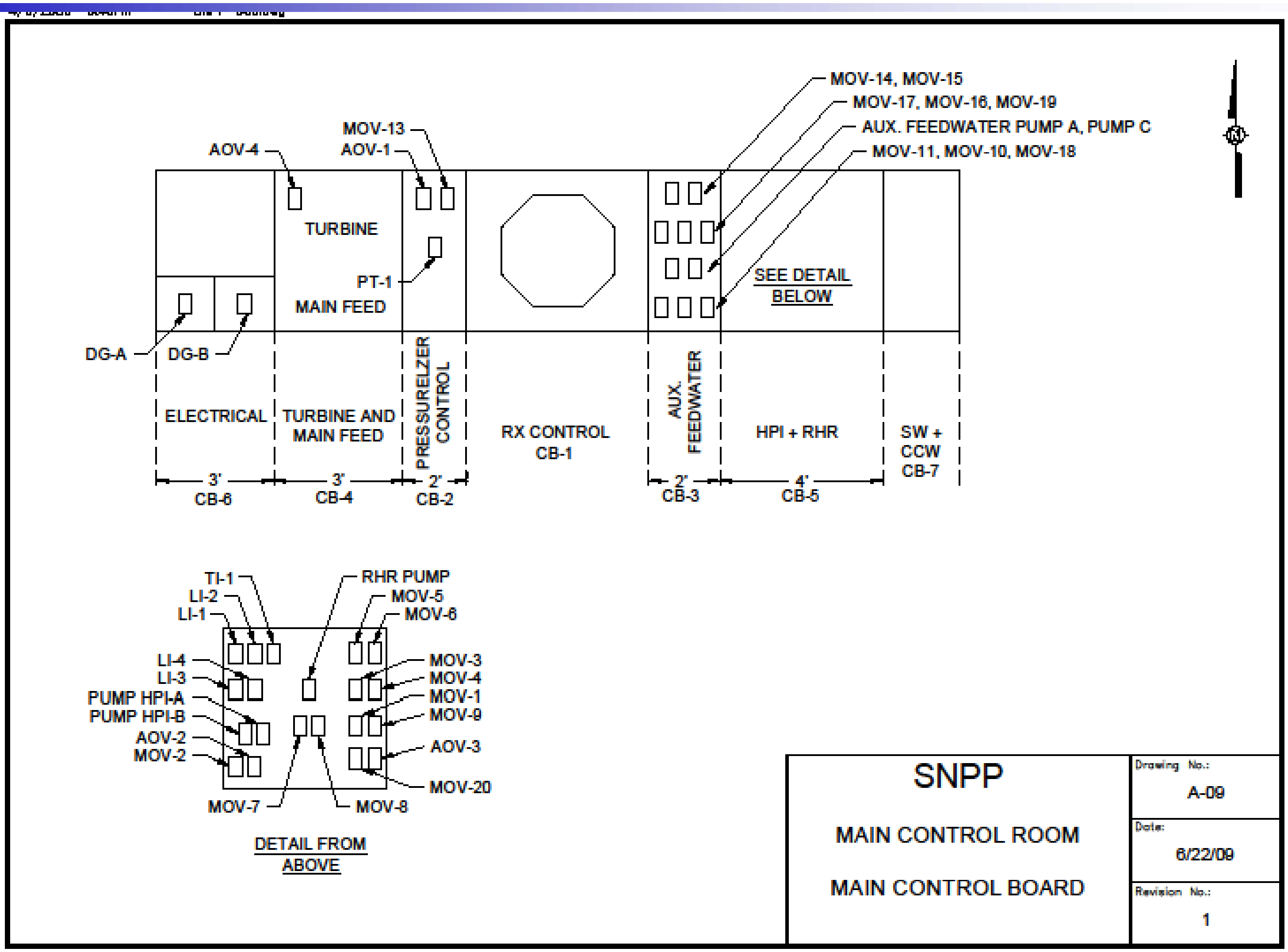
The SNPP: Aux. Bld. – Main Control Room

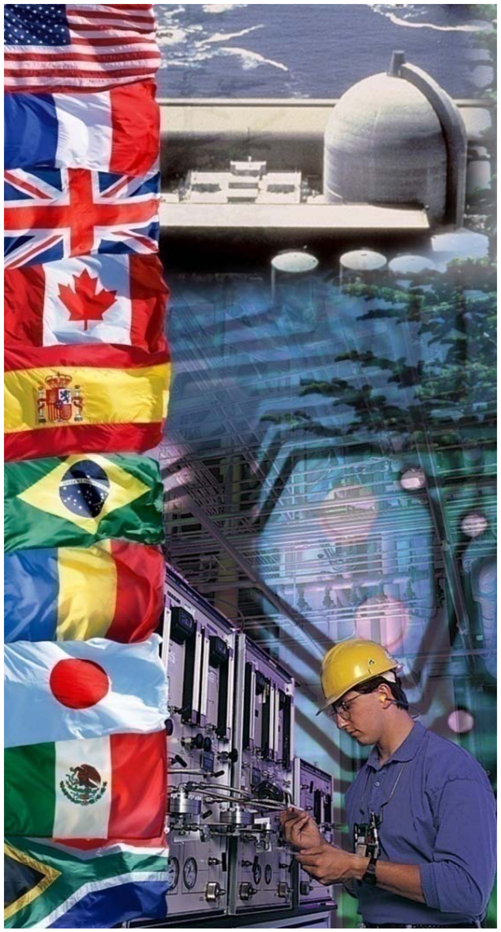


The SNPP: Turbine Building



The SNPP: Main Control Board Layout





EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 2 - Fire PRA Component Selection

Jeff LaChance – Sandia National Laboratories
Rick Anoba – Anoba Consulting Services, LLC

Fire PRA Workshop 2011
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Component Selection
Purpose (per 6850/1011989)

- Purpose: describe the procedure for selecting plant components to be modeled in a Fire PRA
- Fire PRA Component List
  - Key source of information for developing Fire PRA Model (Task 5)
    - Used to identify cables that must be located (Task 3)
- Process is iterative to ensure appropriate agreement among fire PRA Component List, Fire PRA Model, and cable identification

Corresponding PRA Standard Element

- Primary match is to element ES - Equipment Selection
  - ES Objective (as stated in the PRA standard):

    "Select plant equipment that will be included/credited in the fire PRA plant response model."

HLRs (per the PRA Standard)

- HLR-ES-A: The Fire PRA shall identify equipment whose failure caused by an initiating fire including spurious operation will contribute to or otherwise cause an initiating event (6 SRs)
- HLR-ES-B: The Fire PRA shall identify equipment whose failure including spurious operation would adversely affect the operability/functionality of that portion of the plant design to be credited in the Fire PRA (5 SRs)
- HLR-ES-C: The Fire PRA shall identify instrumentation whose failure including spurious operation would impact the reliability of operator actions associated with that portion of the plant design to be credited in the Fire PRA (2 SRs)
- HLR-ES-D: The Fire PRA shall document the fire PRA equipment selection, including that information about the equipment necessary to support the other fire PRA tasks (e.g. equipment identification, equipment type, normal, desired, failed states of equipment) in a manner that facilitates fire PRA applications, upgrades, and peer review (1 SR)

Task 2: Fire PRA Component Selection
Scope (per 6850/1011989)

Fire PRA Component List should include the following major categories of equipment:

- Equipment whose fire-induced failure (including spurious actuation) causes an initiating event
- Equipment needed to perform mitigating safety functions and to support operator actions
- Equipment whose fire-induced failure or spurious actuation may adversely impact credited mitigating safety functions
- Equipment whose fire-induced failure or spurious actuation may cause inappropriate or unsafe operator actions

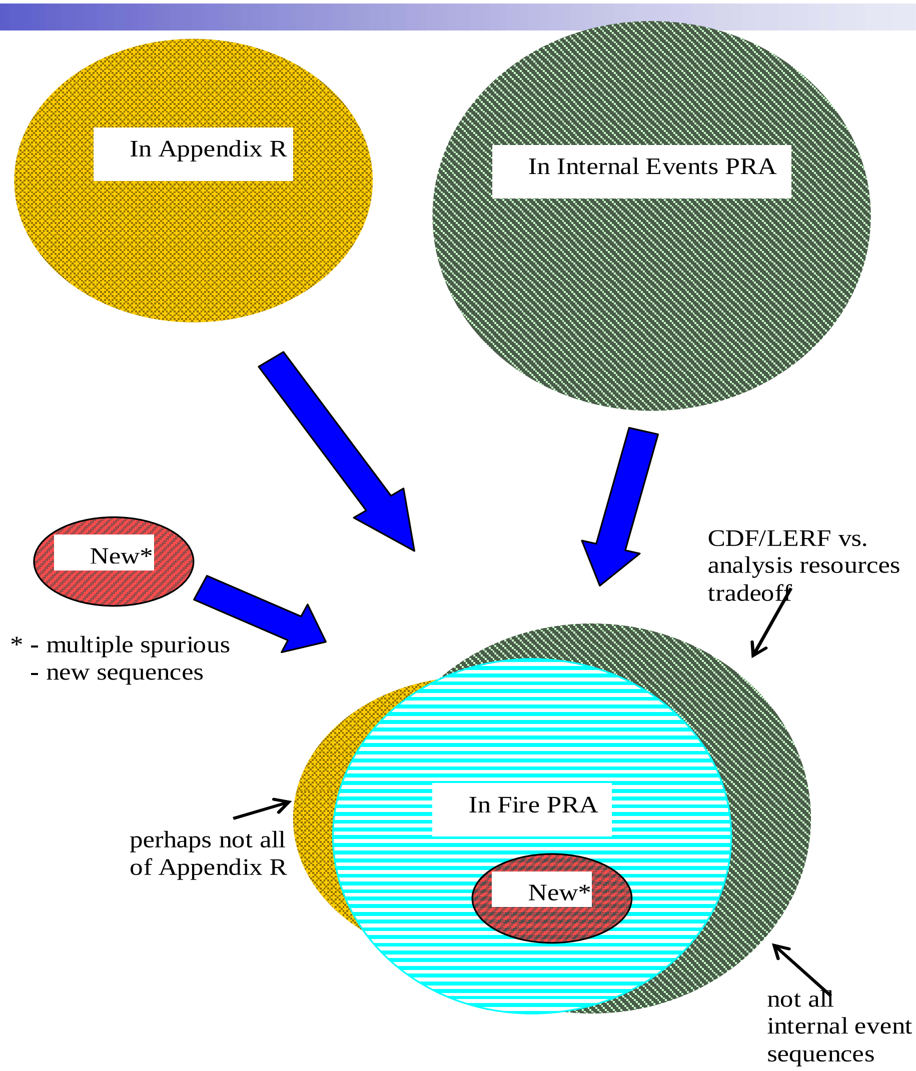
Component Selection
Approach (per 6850/1011989)

- Step 1: Identify Internal Events PRA sequences to include in fire PRA Model (necessary for identifying important equipment)
- Step 2: Review Internal Events PRA model against the Fire Safe Shutdown (SSD) Analysis and reconcile differences in the two analyses (including circuit analysis approaches)
- Step 3: Identify fire-induced initiating events based on equipment affected
- Step 4: Identify equipment subject to fire-induced spurious operation that may challenge the safe shutdown capability
- Step 5: Identify additional mitigating, instrumentation, and diagnostic equipment important to human response
- Step 6: Include "potentially high consequence" related equipment
- Step 7: Assemble the Fire PRA Component List

Component Selection
General Observations

- Two major sources of existing information are used to generate the Fire PRA Component List:
  - Internal Events PRA model
  - Fire Safe Shutdown Analysis (Appendix R assessment)
- Just “tweaking” your Internal Events PRA is probably NOT sufficient – requires additional effort
  - Consideration of fire-induced spurious operation of equipment
  - Potential for undesirable operator actions due to spurious alarms/indications
  - Additional operator actions for responding to fire (e.g., opening breakers to prevent spurious operation)
- Just crediting Appendix R components may NOT be conservative
  - True that all other components in Internal Events PRA will be assumed to fail, but:
    - May be missing components with adverse risk implications (e.g., event initiators or complicatd SSD response)
    - May miss effects of non-modeled components on credited (modeled) systems/components and on operator performance
    - Still need to consider non-credited components as sources of fires

Task 2: Fire PRA Component Selection
Overview of Scope



Task 2: Fire PRA Component Selection
Assumptions

The following assumptions underlie this procedure:

- A good quality Internal Events PRA and Appendix R Safe Shutdown (SSD) analysis are available
- Analysts have considerable collective knowledge and understanding of plant systems, operator performance, the Internal Events PRA, and Appendix R SSD analysis
- Steps 4 thru 6 are applied to determine an appropriate number of spurious actuations to consider
  - Configurations, timing, length of sustained spurious actuation, cable material, etc., among reasons to limit what will be modeled
  - Note that HS duration is a current FAQ topic…

From: Lessons Learned and Insights *In-process FAQs …*

- FAQ 08-0051
  - Issue:
    - The guidance does not provide a method for estimating the duration of a hot short once formed
    - This could be a significant factor for certain types of plant equipment that will return to a “fail safe” position if the hot short is removed or if MSO concurrence could trigger adverse impacts
  - General approach to resolution:
    - Analyze the cable fire test data to determine if an adequate basis exists to establish hot short duration distributions
  - Status:
    - Approved, but limited to AC hot shorts only
    - Will be revisited with lessons learned from DESIREE-FIRE test results for DC hot shorts

Task 2: Fire PRA Component Selection
Inputs/Outputs

Task inputs and outputs:

- Inputs from other tasks: equipment considerations for operator actions from Task 12 (Post-Fire HRA)
- Inputs from the MSO Expert Panel Reviews
- Could use inputs from other tasks to show equipment does not have to be modeled (e.g., Task 9 – Detailed Circuit Analysis or Task 11 - Fire Modeling to show an equipment item cannot spuriously fail or be affected by possible fires)
- Outputs to Task 3 (Cable Selection) and Task 5 (Risk Model)
- Choices made in this task set the overall analysis scope

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 1: Identify sequences to include and exclude from Fire PRA

- Some sequences can generally be excluded
  - Sequences requiring passive/mechanical failures that can not be initiated by fires (e.g., pipe-break LOCAs, SGTR, vessel rupture)
  - Sequences that can be caused by a fire but are low frequency (e.g., ATWS)
  - It may be decided to not model certain systems (i.e., assume failed for Fire PRA) thereby excluding some sequences (e.g., main feedwater as a mitigating system not important)
- Possible additional sequences (recommend use of expert panel to address plant specific considerations)
  - Sequences associated with spurious operation (e.g., vessel/SG overfills, PORV opening, letdown or other pressure/level control anomalies)
  - MCR abandonment scenarios and other sequences arising from Fire Emergency Procedures (FEPs) and/or use of local manual actions

- Corresponding PRA Standard SRs: PRM-B5,B6

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 2: Review the internal events PRA model against the fire safe shutdown analysis

- Identify and reconcile:
  - differences in functions, success criteria, and sequences (e.g., Appendix R - no feed/bleed; PRA - feed/bleed)
  - front-line and support system differences (e.g., App. R - need HVAC; PRA - do not need HVAC)
  - system and equipment differences due to end state and mission considerations (e.g., App. R - cold shutdown; PRA - hot shutdown)
  - other miscellaneous equipment differences.
- Include review of manual actions (e.g., actions needed for safe shutdown) in conjunction with Task 12 (HRA)
- Corresponding PRA Standard SRs: ES-A3(a), ES-B1,B3

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

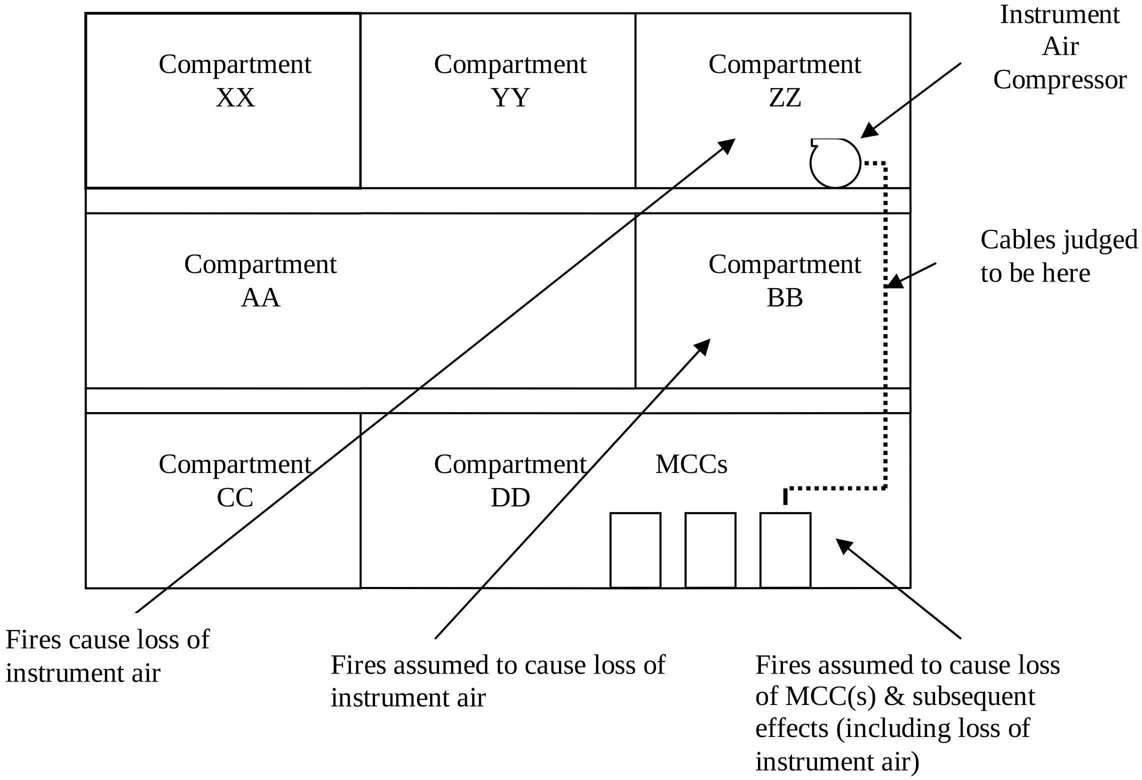
Step 3: Identify fire-induced initiating events based on equipment affected

- Consider equipment whose failure (including spurious actuation) will cause automatic plant trip
- Consider equipment whose failure (including spurious actuation) will likely result in manual plant trip, per procedures
- Consider equipment whose failure (including spurious actuation) will invoke Technical Specification Limiting Condition of Operation (LCO) necessitating a forced shutdown while fire may still be present (prior EPRI guidance recommended consideration of <8 hr LCO)
- Compartments with none of the above need not have initiator though can conservatively assume simple plant trip
- Corresponding PRA Standard SRs: ES-A1,A3 & PRM-B3,B4,B5,B6

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

- Since not all equipment/cable locations in the plant (e.g., all Balance of Plant systems) may be identified, judgment involved in identifying 'likely' cable paths
  - Need a basis for any case where routing is not verified
  - Routing by exclusion (e.g., from a fire area, compartment, raceway…) is a common and acceptable approach
- Should consider spurious event(s) contributing to initiators
- Related PRA standard SR: CS-A11

Task 2: Fire PRA Component Selection
Steps In Procedure/Details



Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 4: Identify equipment whose spurious actuation may challenge the safe shutdown capability

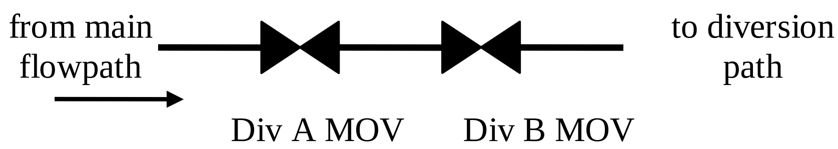
- Examine multiple spurious events within each system considering success criteria
  - PRA standard has specific requirements for multiple spurious
- Review system P&IDs, electrical single lines, and other drawings
- Review/Incorporate PRA related scenarios identified by the MSO Expert Panel to identify new components/failure modes
- Review Internal Events System Notebooks to identify components/failure modes screened based on low probability combinations

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 4: Identify equipment whose spurious actuation may challenge the safe shutdown capability (Continued)

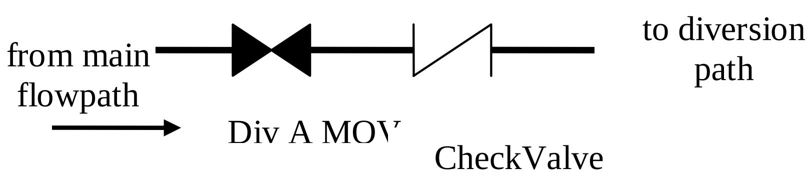
- Be aware of any failure combinations that could cause or contribute to an initiating event.
- Any new failure combinations that could cause or contribute to an initiating event should be addressed in Step 3.
- Any new equipment/failure modes should be added to component list for subsequent cable-tracing and circuit analysis
- Corresponding PRA Standard SRs: ES-B2,B3

Task 2: Fire PRA Component Selection
Flow Diversion Path Examples



takes 2 spurious hot shorts to open diversion path

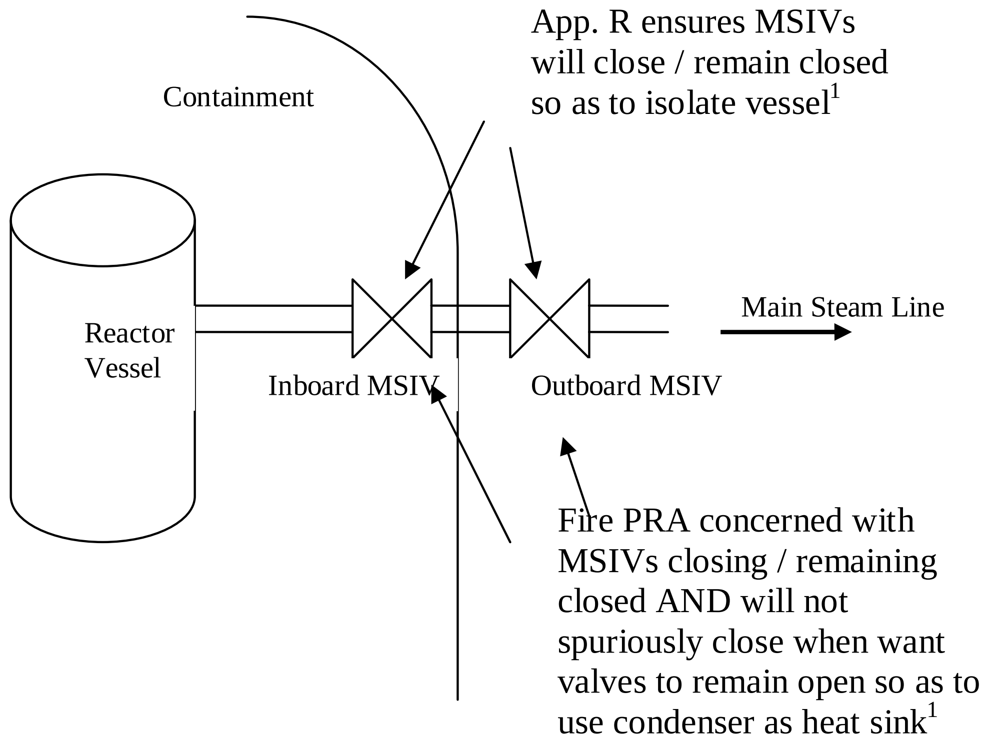
Included in model



takes 1 spurious hot short & failure of check valve to open diversion path

Screened from model if not potential high consequence event

Task 2: Fire PRA Component Selection
Example of a *New Failure Mode of a Component*



[1] different cables and corresponding circuits and analyses may need to be accounted for

Task 2: Fire PRA Component Selection MSO Expert Panel

- This approach *complements* but is *not* part of the published consensus methodology (6850/1011989)

Reference Documents

- NEI 00-01, Revision 2, "Guidance for Post-Fire Safe Shutdown Circuit Analysis", May 2009
  - ❑ Focused on use of the generic list of MSOs provided in Appendix G, and the guidance provided in Section 4.4, "Expert Panel Review of MSOs"
- NEI 04-02 Frequently Asked Question (FAQ) 07-0038, Lessons Learned on Multiple Spurious Operations
- WCAP-16933-NP, Revision 0, "PWR Generic List of Fire-Induced Multiple Spurious Operation Scenarios"**,** April 2009
- NRC Regulatory Guide 1.205, Risk-Informed, Performance-Based Fire Protection for Existing Light-Water Nuclear Power Plants, Revision 1, December 2009

Task 2: Fire PRA Component Selection MSO Expert Panel

Purpose

- Perform a systematic and complete review of credible spurious and MSO scenarios, and determine whether or not each individual scenario is to be included or excluded from the plant specific list of MSOs to be considered in the plant specific post-fire Fire PRA and Safe Shutdown Analysis (SSA).
- Involves group “what-if” discussions of both general and specific scenarios that may occur.

Task 2: Fire PRA Component Selection MSO Expert Panel

Expert Panel Membership:

- Fire Protection
- Fire Safe Shutdown Analysis: This expert should be familiar with the SSA input to the expert panel and with the SSA documentation for existing spurious operations.
- PRA: This expert should be familiar with the PRA input to the expert panel.
- Operations
- System Engineering
- Electrical Circuits

Task 2: Fire PRA Component Selection MSO Expert Panel

Process Overview

- Process is based on a diverse review of the Safe Shutdown Functions. Panel focuses on system and component interactions that could impact nuclear safety
- Review and discuss the potential failure modes for each safe shutdown function
- Identify MSO combinations that could defeat safe shutdown through those failure mechanisms
- Outputs are used in later tasks to identify cables and potential locations where vulnerabilities could exist
- MSOs determined to be potentially significant may be added to the PRA model and SSA

Task 2: Fire PRA Component Selection MSO Expert Panel

Supporting Plant Information for Reviews

- Flow Diagrams
- Control Wiring Diagrams
- Single and/or Three Line Diagrams
- Safe Shutdown Logic Diagrams
- PRA Event Sequence Diagrams
- Post-Fire Safe Shutdown Analysis
- Fire PRA models, analyses and cut-sets
- Plant operating experience

Task 2: Fire PRA Component Selection MSO Expert Panel

MSO Selection

- Review existing Safe Shutdown Analysis (SSA) list
- Expand existing MSO's to include all possible component failures
- Verify SSA assumptions are maintained
- Review generic list of MSO's (NEI 00-01 Revision 2, Appendix G)
- Screen MSO's that do not apply to your plant (i.e., components or system do not exist)

Task 2: Fire PRA Component Selection MSO Expert Panel

MSO Selection (Continued)

- Place all non-screened MSO’s on plant specific list of MSO’s
- Evaluate each MSO to determine if it can be screened due to design or operational features that would prevent it from occurring (i.e., breaker racked out during normal operation)
- Review the generic MSO list for similar or additional MSO’s
- Develop and evaluate list of new MSO’s

Task 2: Fire PRA Component Selection
MSO Expert Panel

MSO Development

- Identify MSO combinations that could defeat safe shutdown through the previously identified failure mechanisms
  - ❑ The panel will build these MSO combinations into fire scenarios to be investigated
  - ❑ The scenario descriptions that result should include the identification of specific components whose failure or spurious operation would result in a loss of a safe shutdown function or lead to core damage

Task 2: Fire PRA Component Selection MSO Expert Panel

MSO Development (Continued)

- The expert panel systematically reviews each system (P&IDs, etc) affecting safe shutdown and the core, for the following Safe Shutdown Functions:
  - ❑Reactivity Control
  - ❑Decay Heat Removal
  - ❑Reactor Coolant
  - ❑Inventory Control
  - ❑Pressure Control
  - ❑Process Monitoring
  - ❑Support Functions

Task 2: Fire PRA Component Selection MSO Expert Panel

Typical Generic PWR MSOs

Scenario	Description
Loss of all RCP Seal Cooling	Spurious isolation of seal injection header flow, ***AND*** *Spurious isolation of CCW flow to Thermal Barrier Heat Exchanger (TBHX)*
RWST Drain Down via Containment Sump	Spurious opening of multiple series containment sump valves

Task 2: Fire PRA Component Selection MSO Expert Panel

Typical Generic BWR MSOs

RPV coolant drain through the Scram Discharge Volume (SDV) vent and drain	MSO opening of the solenoid valves which supply control air to the air operated isolation valves
Spurious Operations that creates RHR Pump Flow Diversion from RHR/LPCI, including diversion to the Torus or Suppression Pool.	RHR flow can be diverted to the containment through the RHR Torus or Suppression Pool return line isolation valves (E11-F024A, B and E11-F028A, B).

Task 2: Fire PRA Component Selection MSO Expert Panel

Outputs and Documentation

- Plant specific list of MSO's
- MSO Expert Panel Review Report
- The MSO Expert Panel is a living entity and the Plant Specific list of MSO's is a living document
- MSO components that could have PRA impact are addressed in Task 2
- MSO scenarios that have PRA impact are addressed in Task 5.

Task 2: Fire PRA Component Selection
Steps In Procedure/Details (per 6850/1011989)

Step 5: Identify additional instrumentation/diagnostic equipment important to operator response (level of redundancy matters!)

- Identify human actions of interest in conjunction with Task 12 (HRA)
- Identify instrumentation and diagnostic equipment associated with credited and potentially harmful human actions considering spurious indications related to each action
  - Is there insufficient redundancy to credit desired actions in EOPs/FEPs/ARPs in spite of failed/spurious indications?
  - Can a spurious indication(s) cause an undesired action because action is dependent on an indication that could be 'false'?
  - If yes – put indication on component list for cable/circuit review
- Watch for new/expanded guidance to be developed by the RES/EPRI fire HRA collaboration…

- Corresponding PRA Standard SRs: ES-C1,C2

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Guidance on identification of harmful spurious operating instrumentation and diagnostic equipment:

- Assume instrumentation is in its normal configuration
- Focus on instrumentation with little redundancy
  - Note that fire PRA standard has language on this subject (i.e., verification of instrument redundancy in fire context)
- When verification of a spurious indication is required (and reliably performed), it may be eliminated from consideration
- When multiple and diverse indications must spuriously occur, those failures can be eliminated if the HRA shows that such failures would not likely cause a harmful operator action
- Include spurious operation of electrical equipment that would cause a faulty indication and harmful action
- Include inter-system effects

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 6: Include "potentially high consequence" related equipment

- High consequence events are one or more related failures at least partially caused by fire that:
  - by themselves cause core damage and large early release, or
  - single component failures that cause loss of entire safety function and lead directly to core damage
- Example of first case: spurious opening of two valves in high-pressure/low pressure RCS interface, leading to ISLOCA
- Example of second case: spurious opening of single valve that drains safety injection water source

- Corresponding PRA Standard SR: ES-A6

Task 2: Fire PRA Component Selection
Steps In Procedure/Details

Step 7: Assemble Fire PRA component list. Should include following information:

- Equipment ID and description (may be indicator or alarm)
- System designation
- Equipment type and location (at least compartment ID)
- PRA event ID and description
- Normal and desired position/status
- Failed electrical/air position
- References, comments, and notes

- Note: development of an actual/physical fire PRA component list is not a requirement of the PRA Standard

Sample Problem Exercise for Task 2, Step 1

- Distribute blank handout for Task 2, Step 1

- Distribute completed handout for Task 2, Step 1

- Question and Answer Session

Sample Problem Exercise for Task 2, Steps 2 and 3

- Distribute blank handout for Task 2, Step 2
- Distribute completed handout for Task 2, Step 2 Question and Answer Session
- Discuss Step 3
- Question and Answer Session

Sample Problem Exercise for Task 2, Steps 4 through 6

- Distribute blank handout for Task 2, Steps 4 through 6

- Distribute completed handout for Task 2, Steps 4 through 6

- Question and Answer Session

Sample Problem Exercise for Task 2, Step 7

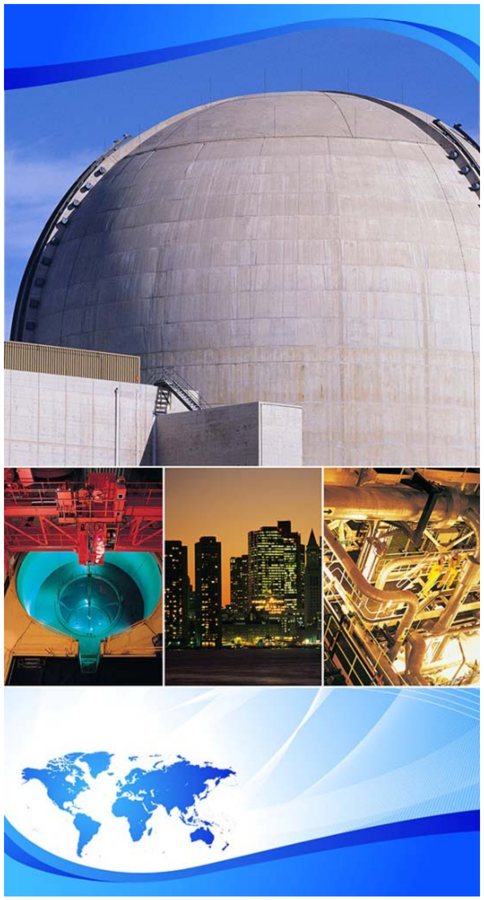
- Distribute blank handout for Task 2, Step 7

- Distribute completed handout for Task 2, Step 7

- Question and Answer Session

Mapping HLRs & SRs for the ES technical element to NUREG/CR-6850, EPRI TR 1011989

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
ES	A	The Fire PRA shall identify equipment whose failure caused by an initiating fire including spurious operation will contribute to or otherwise cause an initiating event.		
		1	2.5.3	
		2	3.5.3	Covered in "Cable Selection" chapter
		3	2.5.3	
		4	2.5.1, 2.5.4	
		5	2.5.4	
		6	2.5.6	
	B	The Fire PRA shall identify equipment whose failure including spurious operation would adversely affect the operability/functionality of that portion of the plant design to be credited in the Fire PRA.		
		1	2.5.2	
		2	2.5.4	
		3	5.5.1	Covered in "Fire-Induced Risk Model" chapter
		4	3.5.3	Covered in "Cable Selection" chapter
		5	n/a	Exclusion based on probability is not covered in 6850/1011989
	C	The Fire PRA shall identify instrumentation whose failure including spurious operation would impact the reliability of operator actions associated with that portion of the plant design to be credited in the Fire PRA.		
		1	2.5.5	
		2	2.5.5	
	D	The Fire PRA shall document the Fire PRA equipment selection, including that information about the equipment necessary to support the other Fire PRA tasks (e.g., equipment identification; equipment type; normal, desired, failed states of equipment; etc.) in a manner that facilitates Fire PRA applications, upgrades, and peer review.		
		1	n/a	Documentation not covered in 6850/1011989



EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 5 - Fire-Induced Risk Model Development

Fire PRA Workshop 2011

San Diego CA and Jacksonville FL

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Fire PRA Risk Model
Purpose (per 6850/1011989)

- Purpose: describe the procedure for developing the Fire PRA model to calculate CDF, CCDP, LERF, and CLERP for fire ignition events.
- Fire Risk Model
  - Key input for Quantitative Screening (Task 7)
    - Used to quantify CDF/CCDP and LERF/CLERP
- Process is iterative to ensure appropriate agreement among fire PRA Component List, Fire PRA Model, cable identification, and quantitative screening

Fire PRA Risk Model
Corresponding PRA Standard Element

- Primary match is to element PRM - Equipment Selection
  - PRM Objectives (as stated in the PRA standard):

    "(a) to identify the initiating events that can be caused by a fire event and develop a related accident sequence model. (b) to depict the logical relationships among equipment failures (both random and fire induced) and human failure events (HFEs) for CDF and LERF assessment when combined with the initiating event frequencies."

Fire PRA Risk Model HLRs (per the PRA Standard)

- HLR-PRM-A: The Fire PRA shall include the Fire PRA plant response model capable of supporting the HLR requirements of FQ.
- HLR-PRM-B: The Fire PRA plant response model shall include fire-induced initiating events, both fire induced and random failures of equipment, fire-specific as well as non–fire-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs provided under this HLR that parallel, as appropriate, Part 2 of this Standard, for Internal Events PRA.
- HLR-PRM-C: The Fire PRA shall document the Fire PRA plant response model in a manner that facilitates Fire PRA applications, upgrades, and peer review.

Fire PRA Risk Model
Scope (per 6850/1011989)

- Task 5: Fire-Induced Risk Model Development
  - Constructing the PRA model
  - Step 1–Develop the Fire PRA CDF/CCDP Model.
  - Step 2–Develop the Fire PRA LERF/CLERP Model

Fire PRA Risk Model
General Comment/Observation

- Task 5 does not represent any changes from past practice, but what is modeled is largely based on Task 2 with HRA input from Task 12

- Bottom line – just “tweaking” your Internal Events PRA is probably NOT sufficient

Task 5: Fire Risk Model Development
General Objectives

Purpose: Configure the Internal Events PRA to provide fire risk metrics of interest (primarily CDF and LERF).

- Based on standard state-of-the-art PRA practices
- Intended to be applicable for any PRA methodology or software
- Allows user to quantify CDF and LERF, or conditional metrics CCDP and CLERP
- *Conceptually, nothing "new" here – need to "build the PRA model" reflecting fire induced initiators, equipment and failure modes, and human actions of interest*

Task 5: Fire Risk Model Development
Inputs/Outputs

Task inputs and outputs:

- Inputs from other tasks: [Note: inclusion of spatial information requires cable locations from Task 3]
  - Sequence considerations, initiating event considerations, and components from Task 2 (Fire PRA Component Selection),
  - Unscreened fire compartments from Task 4 (Qualitative Screening),
  - HRA events from Task 12 (Post-Fire HRA)
- Output to Task 7 (Quantitative Screening) which will further modify the model development
- Can always iterate back to refine aspects of the model

Task 5: Fire Risk Model Development
Steps in Procedure

Two major steps:

- Step 1: Develop CDF/CCDP model
- Step 2: Develop LERF/CLERP model

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1 (2): Develop CDF/CCDP (LERF/CLERP) models

Step 1.1 (2.1): Select fire-induced initiators and sequences and incorporate into the model.

- Corresponding SRs: PRM-A1, A2, A3, B1-B15

- Fire initiators are generally defined in terms of compartment fires or fire scenarios
- Each fire initiator is mapped to one or more internal event initiators to mimic the fire-induced impact to the plant.

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.1 (2.1) – continued

- Initiating events previously screened in the internal events analysis may have to be reconsidered for the Fire PRA
- Final mapping of fire initiator to internal events initiators is based on cable routing information (task 3)
- The structure of Internal Events PRA should be reviewed to determine proper mapping of fire initiators

Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.1 (2.1) – continued

- The Internal Events PRA should have the capability to quantify CDF and LERF sequences
- Internal events sequences form bulk of sequences for Fire PRA, but a search for new sequences should be made (see Task 2). Some new sequences may require new logic to be added to the PRA model

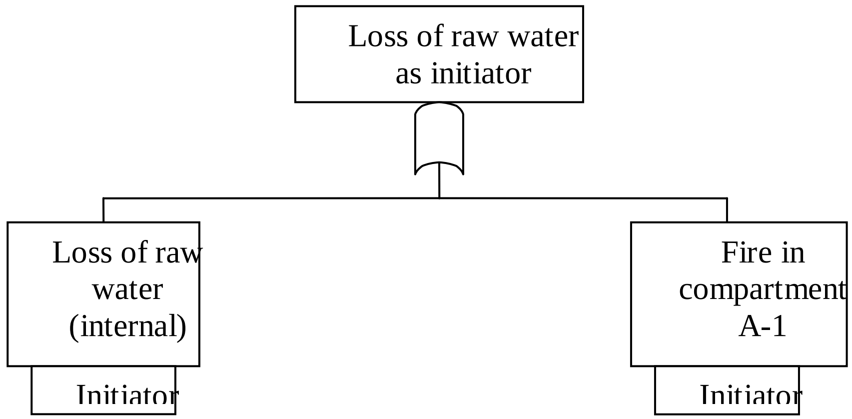
Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.1 (2.1) - continued

- Plants that use fire emergency procedures (FEPs) may need special models to address unique fire-related actions (e.g., pre-defined fire response actions and MCR abandonment).

- Some human actions may induce new sequences not covered in Internal Events PRA and can “fail” components
  - Example: SISBO, or partial SISBO

Task 5: Fire Risk Model Development
Steps in Procedure/Details



Example of new logic with a fire-induced loss of raw water initiating event

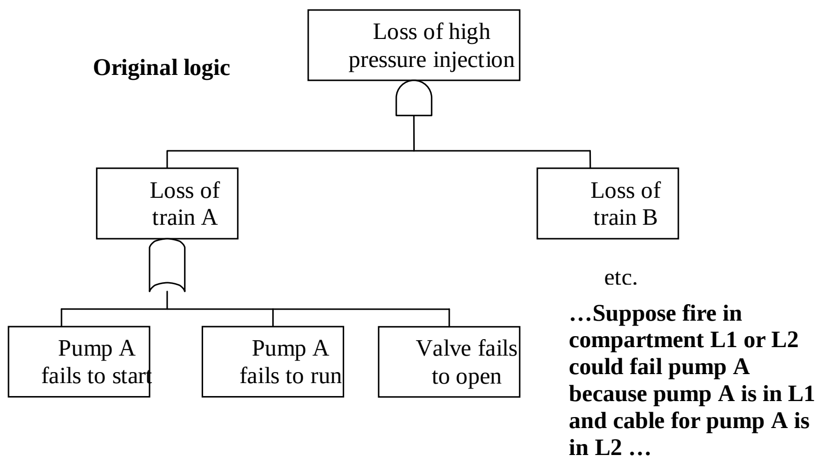
Task 5: Fire Risk Model Development
Steps in Procedure/Details

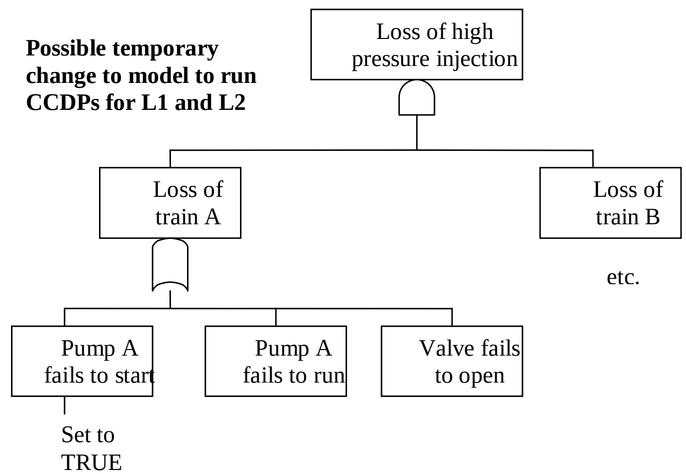
Step 1.2 (2.2): Incorporate fire-induced equipment failures

- Corresponding SRs: PRM-A4, B3, B6, B9

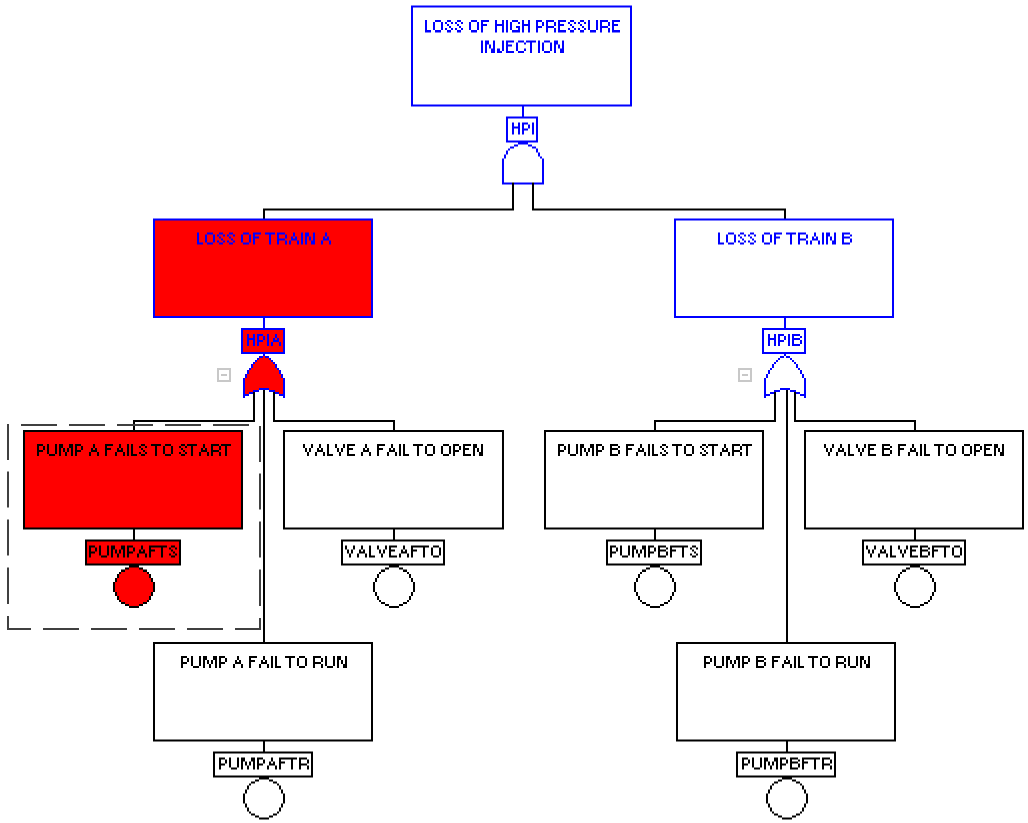
- Fire PRA database documents list of potentially failed equipment for each fire compartment
- Basic events for fire-induced spurious operations are defined and added to the PRA model (FAQ 08-0047)
- Inclusion of spatial information requires equipment and cable locations
  - May be an integral part of model logic, or handled with manipulation of a cable location database, etc.

Task 5: Fire Risk Model Development
Steps in Procedure/Details

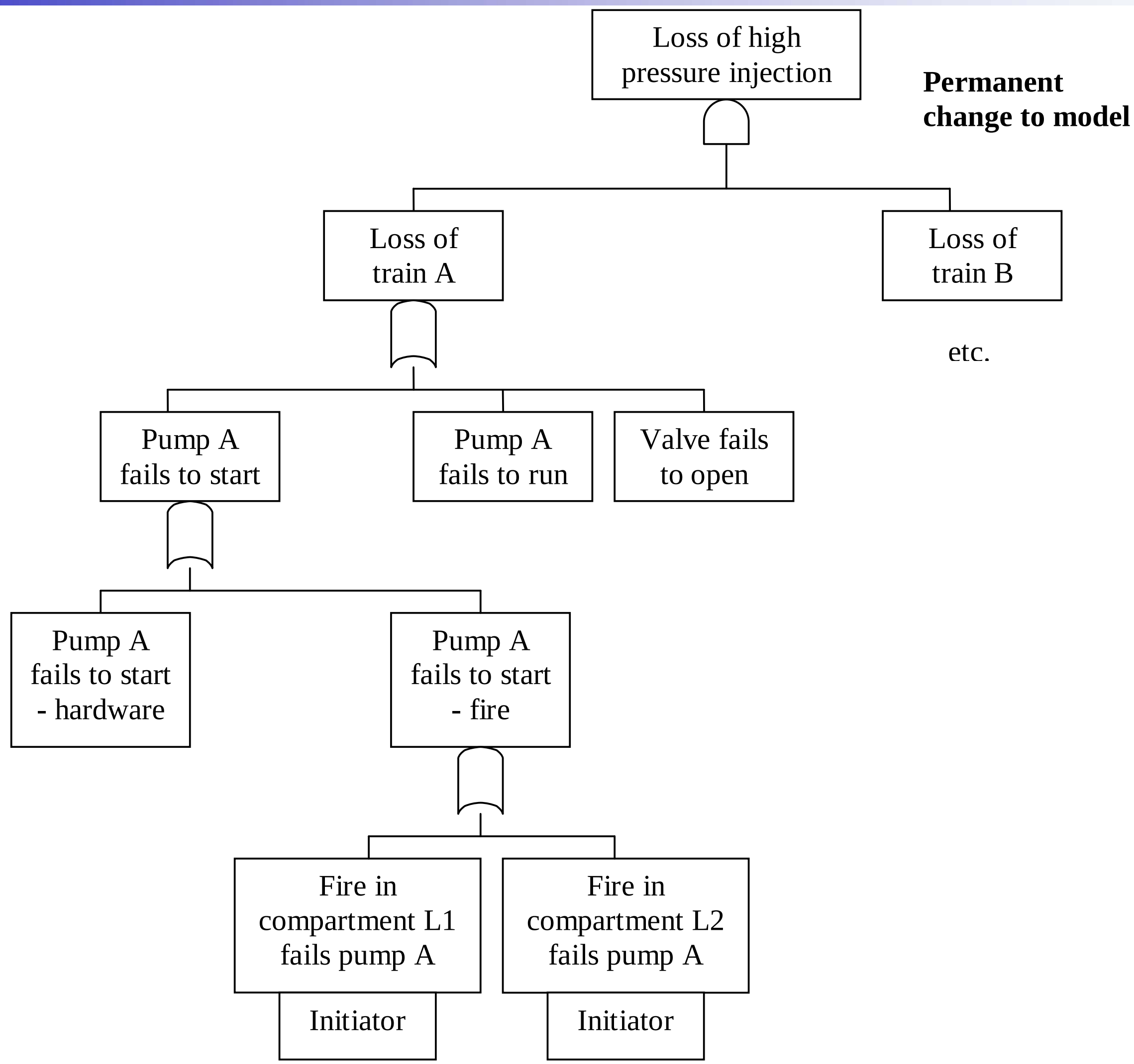




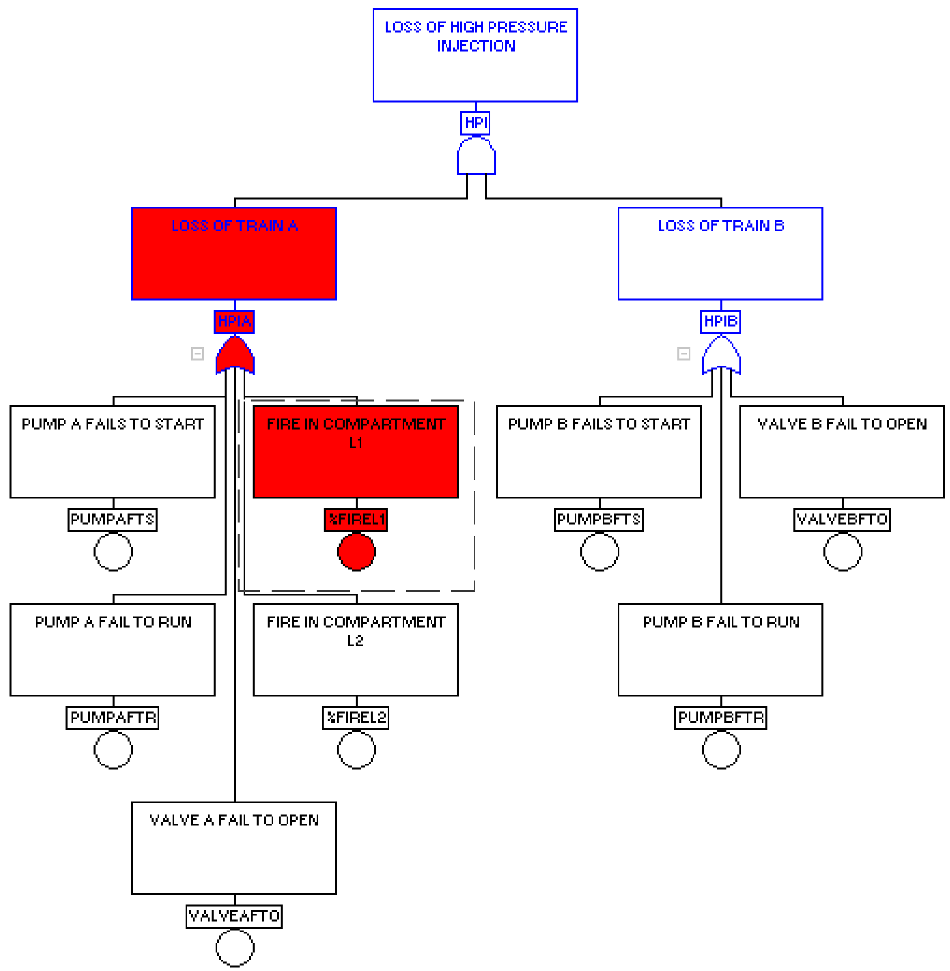
Task 5: Fire Risk Model Development
Steps in Procedure/Details



Task 5: Fire Risk Model Development
Steps in Procedure/Details



Task 5: Fire Risk Model Development
Steps in Procedure/Details



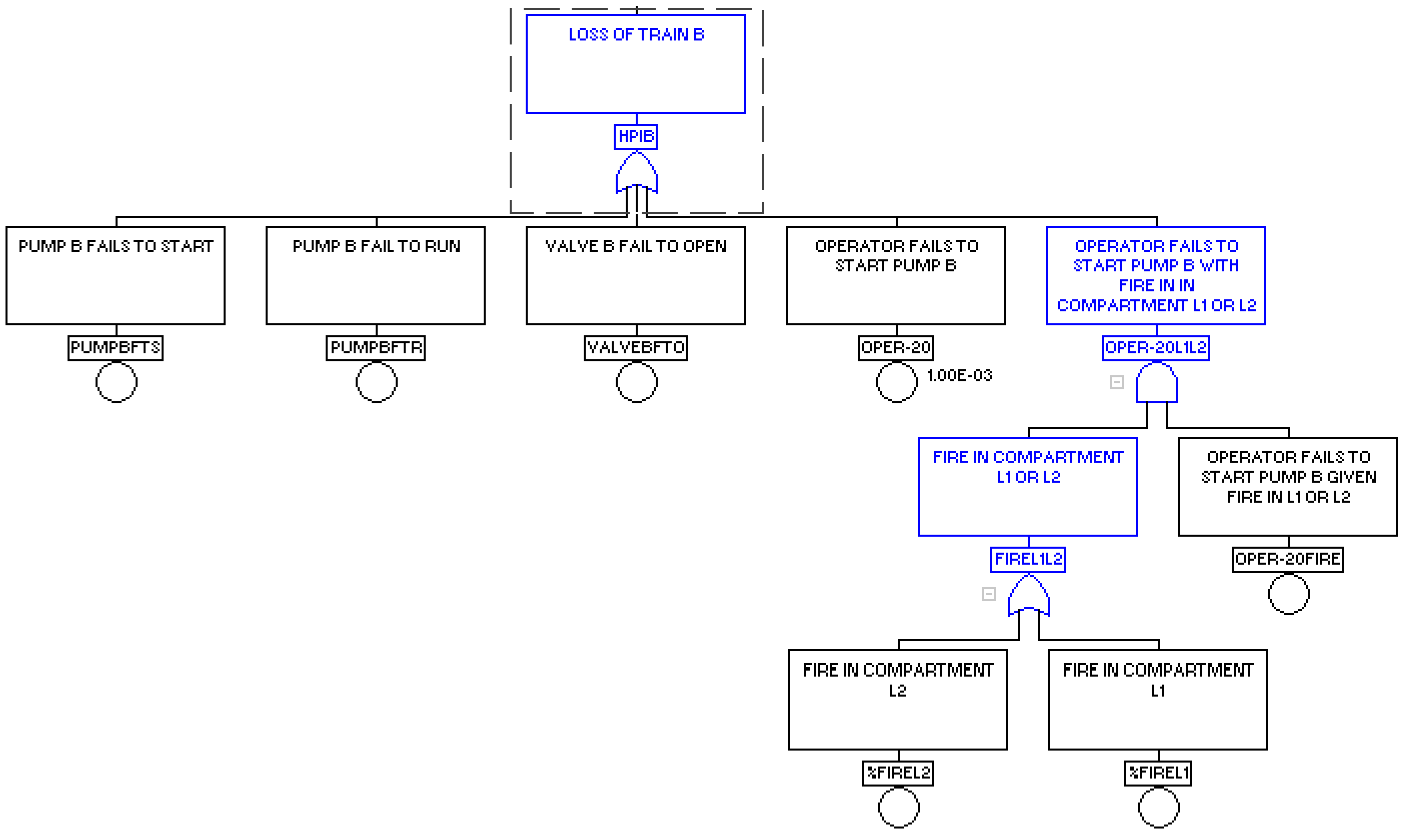
Task 5: Fire Risk Model Development
Steps in Procedure/Details

Step 1.3 (2.3): Incorporate fire-induced human failures

- Corresponding SRs: PRM-B9, B11

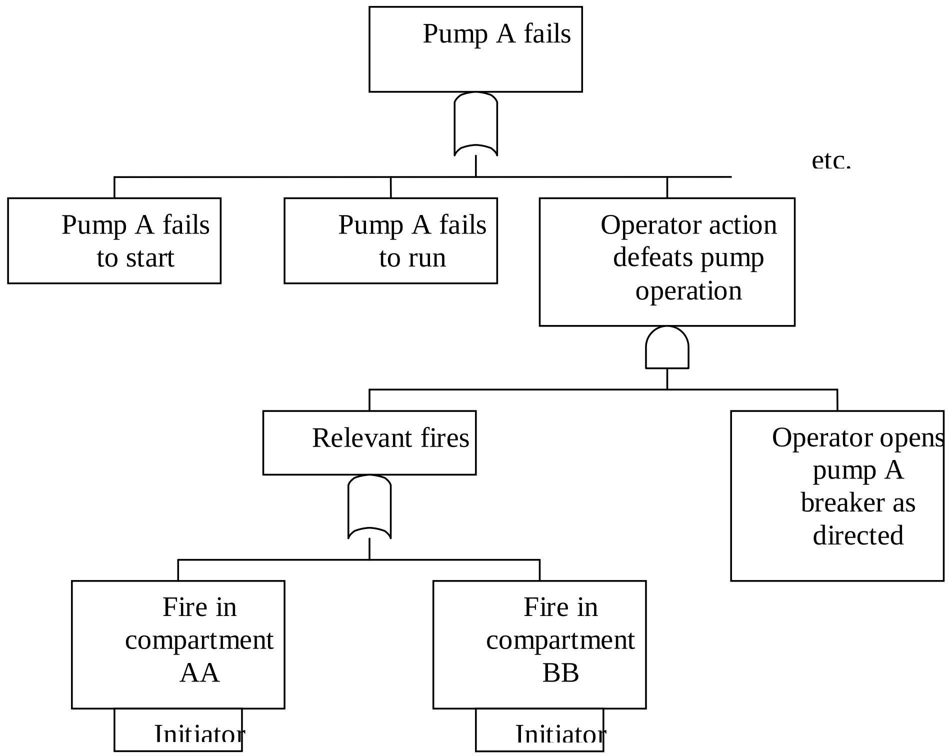
- New fire-specific HFEs may have to be added to the model to address actions specified in FEPs [Note: all HFEs will be set at screening values at first, using Task 12 guidance]
- Successful operator actions may temporarily disable (“fail”) components

Task 5: Fire Risk Model Development
Steps in Procedure/Details



Task 5: Fire Risk Model Development
Steps in Procedure/Details

Suppose a proceduralized manual action carried out for fires in compartments AA & BB defeats Pump A operation by de-energizing the pump (opening its breaker drawer)…



Sample Problem Exercise for Task 5

- Distribute blank handout for Task 5, Steps 1 and 2

- Distribute completed handout for Task 5, Steps 1 and 2

- Question and Answer Session

Mapping HLRs & SRs for the PRM technical element to NUREG/CR-6850, EPRI TR 1011989

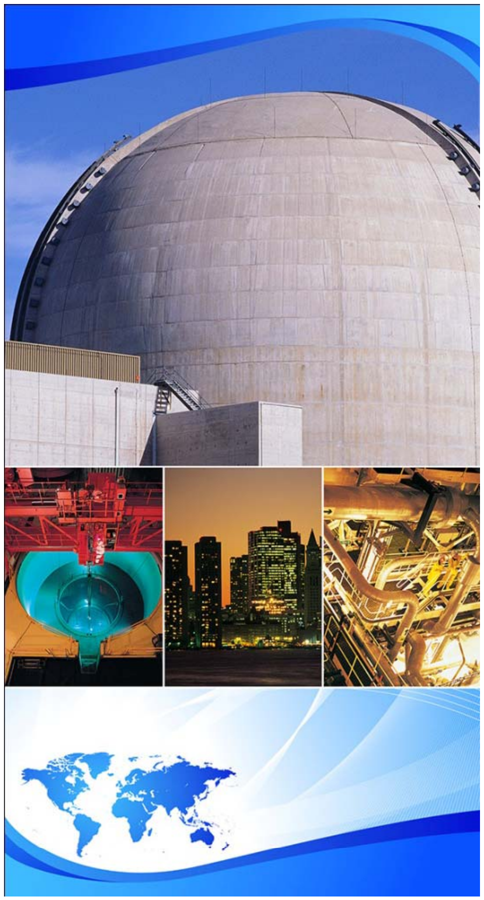
Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
PRM	A	The Fire PRA shall include the Fire PRA plant response model capable of supporting the HLR requirements of FQ.		
		1	5.5.1.1, 5.5.2.1	
		2	5.5.1.1, 5.5.2.1	
		3	5.5.1.1, 5.5.2.1	
		4	5.5.1.1, 5.5.1.2, 5.5.2.1, 5.5.2.2	

Mapping HLRs & SRs for the PRM technical element to NUREG/CR-6850, EPRI TR 1011989

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
PRM	B	The Fire PRA plant response model shall include fire-induced initiating events, both fire induced and random failures of equipment, fire-specific as well as non–fire-related human failures associated with safe shutdown, accident progression events (e.g., containment failure modes), and the supporting probability data (including uncertainty) based on the SRs provided under this HLR that parallel, as appropriate, Part 2 of this Standard, for Internal Events PRA.		
		1	5.5.1.1, 5.5.2.1	
		2	5.5.1.1, 5.5.2.1	
		3	5.5.1.1, 5.5.1.2, 5.5.2.1, 5.5.2.2	
		4	5.5.1.1, 5.5.2.1	
		5	5.5.1.1, 5.5.2.1	
		6	5.5.1.1, 5.5.1.2, 5.5.2.1, 5.5.2.2	
		7	5.5.1.1, 5.5.2.1	
		8	5.5.1.1, 5.5.2.1	
		9	5.5.1.1, 5.5.1.2, 5.5.1.3, 5.5.2.1, 5.5.2.2, 5.5.2.3	
		10	5.5.1.1, 5.5.2.1	
		11	5.5.1.1, 5.5.1.3, 5.5.2.1, 5.5.2.3	
		12	5.5.1.1, 5.5.2.1	
		13	5.5.1.1, 5.5.2.1	
		14	5.5.1.1, 5.5.2.1	
		15	5.5.1.1, 5.5.2.1	
		12	5.5.1.1, 5.5.2.1	
		13	5.5.1.1, 5.5.2.1	
		14	5.5.1.1, 5.5.2.1	
		15	5.5.1.1, 5.5.2.1	

Mapping HLRs & SRs for the PRM technical element to NUREG/CR-6850, EPRI TR 1011989

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
	C	The Fire PRA shall document the Fire PRA plant response model in a manner that facilitates Fire PRA applications, upgrades, and peer review.		
		1	n/a	Documentation not covered in 6850/1011989



EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 4 - Qualitative Screening
Task 7 - Quantitative Screening

Fire PRA Workshop 2011

San Diego CA and Jacksonville FL

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Qualitative / Quantitative Screening
Scope (per 6850/1011989)

- Task 4: Qualitative Screening
  - First chance to identify very low risk compartments
- Task 7: Quantitative Screening
  - Running the Fire PRA model to iteratively screen / maintain modeled sequences at different levels of detail

Qualitative Screening - Corresponding PRA Standard Element

- Primary match is to element QLS – Qualitative Screening
  - QLS Objectives (as stated in the PRA standard):

"*(a) The objective of the qualitative screening (QLS) element is to identify physical analysis units whose potential* fire risk contribution can be judged negligible without quantitative analysis.

(b) In this element, physical analysis units are examined only in the context of their individual contribution to fire risk. The potential risk contribution of all physical analysis units is reexamined in the multicompartment fire scenario analysis regardless of the physical analysis unit's disposition during qualitative screening."

Qualitative Screening – HLRs (per the PRA Standard)

- **HLR-QLS-A: The Fire PRA shall identify those physical analysis units that screen out as individual risk contributors without quantitative analysis (4 SRs).**
- **HLR-QLS-B: The Fire PRA shall document the results of the qualitative screening analysis in a manner that facilitates Fire PRA applications, upgrades, and peer review (3 SRs).**

Task 4: Qualitative Screening
Objectives and Scope

- The objective of Task 4 is to identify those fire compartments that can be shown to have a negligible risk contribution without quantitative analysis
  - This is where you exclude the office building inside the protected area
- Task 4 *only* considers fire compartments as individual contributors
  - Multi-compartment scenarios are covered in Task 11(b)
  - Compartments that screen out qualitatively need to be re-considered as potential Exposing Compartments in the multi-compartment analysis (but not as the Exposed Compartment)

Task 4: Qualitative Screening
Required Input and Task Output

- To complete Task 4 you need the following input:
  - List of fire compartments from Task 1
  - List of Fire PRA equipment from Task 2 including location mapping results
  - List of Fire PRA cables from Task 3 including location mapping results

- Task Output: A list of fire compartments that will be screened out (no further analysis) based on qualitative criteria
  - Unscreened fire compartments are used in Task 6 and further screened in Task 7

Task 4: Qualitative Screening
A Note….

- Qualitative Screening is OPTIONAL!
  - You may choose to retain any number of potentially low-risk fire compartments (from one to all) without formally conducting the Qualitative Screening Assessment for the compartment
    - However, to eliminate a compartment, you must exercise the screening process for the compartment
  - *Example 1*: Many areas will never pass qualitative screening, so simply keep them
  - *Example 2*: If you are dealing with an application with limited scope (e.g. NFPA 805 Change Evaluation) a formalized Qualitative Screening may be pointless

Task 4: Qualitative Screening
Screening Criteria (per 6850/1011989)

- A Fire Compartment may be screened out** if:
  - No Fire PRA equipment or cables are located in the compartment, and
  - No fire that remains confined to the compartment could lead to:
    - An automatic plant trip, or
    - A manual trip *as specified by plant procedures*, or
    - A *near-term* manual shutdown due to violation of plant Technical Specifications*

    *In the case of tech spec shutdown, consideration of the time window <u>is</u> appropriate

      - No firm time window is specified in the procedure – rule of thumb: consistent with the time window of the fire itself
      - Analyst must choose and justify the maximum time window considered

(**Note: screened compartments are re-considered as fire source compartments in the multi-compartment analysis - Task 11c)

Corresponding PRA Standard SRs: QLS-A1, A2

Mapping HLRs & SRs for the QLS technical element to NUREG/CR-6850, EPRI TR 1011989

Technical Element	HLR	SR	6850/1011989 section that covers SR	Comments
QLS	A	**The Fire PRA shall identify those physical analysis units that screen out as individual risk contributors without quantitative analysis**		
		1	4.5	
		2	4.5	
		3	4.5	
		4	n/a	Additional screening not covered in 6850/1011989
	B	**The Fire PRA shall document the results of the qualitative screening analysis in a manner that facilitates Fire PRA applications, upgrades, and peer review**		
		1	n/a	Documentation is discussed in Section 16.5 of 6850/101198
		2	n/a	Documentation is discussed in Section 16.5 of 6850/101198
		3	n/a	Documentation is discussed in Section 16.5 of 6850/101198

Task 7: Quantitative Screening
General Objectives (per 6850/1011989)

Purpose: allow (i.e., optional) screening of fire compartments and scenarios based on contribution to fire risk. Screening is primarily compartment-based (Tasks 7A/B). Scenario-based screening (Tasks 7C/D) is a further refinement (optional).

- Screening criteria not the same as acceptance criteria for regulatory applications (e.g., R.G. 1.174)
- Screening does not mean "throw away" – screened compartments/scenarios will be quantified (recognized to be conservative) and carried through to Task 14 as a measure of the residual fire risk

Quantitative Screening - Corresponding PRA Standard Element

- Primary match is to element QNS – Quantitative Screening
  - QNS Objective (as stated in the PRA standard):

"The objective of the quantitative screening (QNS) element is to screen physical analysis units from further (e.g., more detailed quantitative) consideration based on preliminary estimates of fire risk contribution and using established quantitative screening criteria."

Quantitative Screening – HLRs (per the PRA Standard)

- **HLR-QNS-A: If quantitative screening is performed, the Fire PRA shall establish quantitative screening criteria to ensure that the estimated cumulative impact of screened physical analysis units on CDF and LERF is small (1 SR).**
- **HLR-QNS-B: If quantitative screening is performed, the Fire PRA shall identify those physical analysis units that screen out as individual risk contributors (2 SRs).**
- **HLR-QNS-C: VERIFY that the cumulative impact of screened physical analysis units on CDF and LERF is small (1 SR).**
- **HLR-QNS-D: The Fire PRA shall document the results of quantitative screening in a manner that facilitates Fire PRA applications, upgrades, and peer review (2 SRs).**

Task 7: Quantitative Screening
Inputs/Outputs

- Inputs from other tasks for compartment-based screening (7A/B):
  - Fire ignition frequencies from Task 6,
  - Task 5 (Fire-Induced Risk Model),
  - Task 12 (Post-Fire HRA Screening), and
  - Task 8 (Scoping Fire Modeling) (7B only)

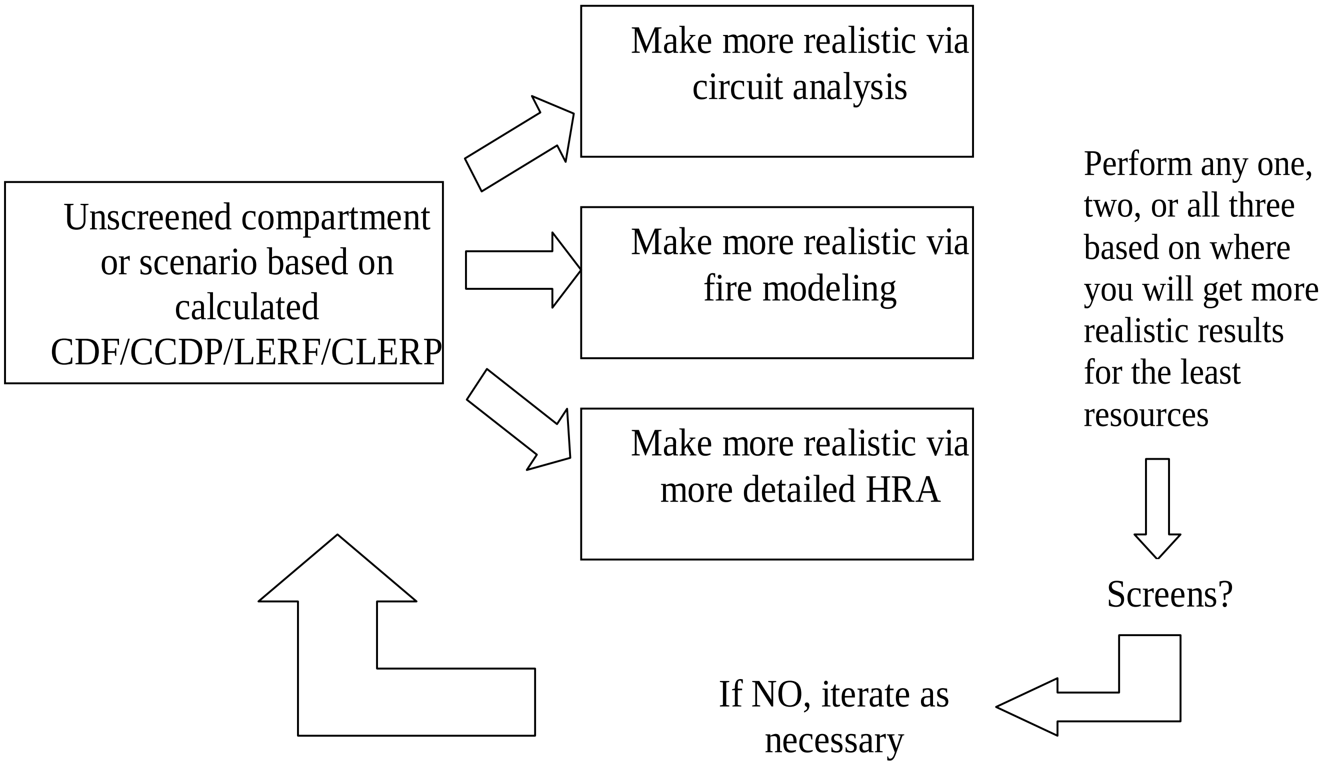
Task 7: Quantitative Screening
Inputs/Outputs (cont'd)

- Inputs from other tasks for scenario-based screening (7C/D) include inputs listed above plus:
  - Task 9 (Detailed Circuit Failure Analysis) and/or
  - Task 11 (Detailed Fire Modeling) and/or
  - Task 12 (Detailed Post-Fire HRA), and
  - Task 10 (Circuit Failure Mode Likelihood Analysis) (7D only)

Task 7: Quantitative Screening
Inputs/Outputs (cont'd)

- Outputs to other tasks:
  - Unscreened fire compartments from Task 7A go to Task 8 (Scoping Fire Modeling),
  - Unscreened fire compartments from Task 7B go to Task 9 (Detailed Circuit Failure Analysis) and/or Task 11 (Detailed Fire Modeling) and/or Task 12 (Detailed Post-Fire HRA),
  - Unscreened fire scenarios from Task 7C/D go to Task 14 (Fire Risk Quantification) for best-estimate risk calculation

Task 7: Quantitative Screening
Overview of the Process



Task 7: Quantitative Screening
Steps in Procedure

Three major steps in the procedure:

- Step 1: Quantify CDF/CCDP model
- Step 2: Quantify LERF/CLERP model
- Step 3: Quantitative screening

Task 7: Quantitative Screening
Steps in Procedure/Details

Step 1: Quantify CDF/CCDP models.

- Step 1.1: Quantify CCDP model
  - Fire-induced initiators are set to TRUE (1.0) for each fire compartment, CCDP calculated for each compartment
  - This step can be bypassed, if desired, by using fire frequencies in the model directly and calculating CDF

Task 7: Quantitative Screening
Steps in Procedure/Details

Step 1: Quantify CDF/CCDP models.

- Step 1.2: Quantify CDF
  - Compartment fire-induced initiator frequencies combined with compartment CCDPs from Step 1.1 to obtain compartment CDFs
- Step 1.3: Quantify ICDP (optional)
  - ICDP includes unavailability of equipment removed from service routinely
  - Recommend this be done if will use PRA for configuration management

Task 7: Quantitative Screening
Steps in Procedure/Details

Step 2: Develop LERF/CLERP models.

- Exactly analogous to Step 1 but now for LERF, CLERP

- Like ICDP, ILERP is optional

Task 7: Quantitative Screening
Establishing Quantitative Screening Criteria

- This is an area that has evolved beyond 6850/1011989
- 6850/1011989 *cumulative* screening criteria are based in part on screening against a fraction of the internal events risk results
  – Published PRA standard echoes 6850/1011989 (SR QNS-C1)
- Regulatory Guide 1.200 took exception to SR QNS-C1
  – NRC staff position: “screening criteria … should relate to the total CDF and LERF for the fire risk, not the internal events risk.”
  – That is, screening should be within the hazard group (e.g., fire)
- An update to the PRA standard is pending and will *likely* revise QNS-C1 to reflect NRC staff position
- Bottom line: If you plan to use your fire PRA in regulatory applications, pay attention to RG 1.200 and watch for the PRA standard update

Task 7: Quantitative Screening
Screening Criteria for Single Fire Compartment

Step 3: Quantitative screening, Table 7.2 from NUREG/CR-6850

Quantification Type	CDF and LERF Compartment Screening Criteria	ICDP and ILERP Compartment Screening Criteria (Optional)
Fire Compartment CDF	CDF < 1.0E-7/yr	
Fire Compartment CDF With Intact Trains/Systems Unavailable		ICDP < 1.0E-7
Fire Compartment LERF	LERF < 1.0E-8/yr	
Fire Compartment LERF With Intact Trains/Systems Unavailable		ILERP < 1.0E-8

Note: The standard and RG 1.200 do not establish screening criteria for individual fire compartments – only cumulative criteria (see next slide…)

Task 7: Quantitative Screening
Screening Criteria For All Screened Compartments

Quantification Type	6850/1011989 Screening Criteria	NRC Staff Position per RG 1.200 for Cat II	NRC Staff Position per RG 1.200 for Cat III
Sum of CDF for all screened-out fire compartments	< 10% of internal event average CDF	the sum of the CDF contribution for all screened fire compartments is **<10%** of the estimated total CDF for **fire** events	the sum of the CDF contribution for all screened fire compartments is **<1%** of the estimated total CDF for **fire** events
Sum of LERF for all screened-out fire compartments	< 10% of internal event average LERF	the sum of the LERF contributions for all screened fire compartments is **<10%** of the estimated total LERF for **fire** events	the sum of the LERF contributions for all screened fire compartments is **<1%** of the estimated total LERF for **fire** events
Sum of ICDP for all screened-out fire compartments	< 1.0E-6	n/a	n/a
Sum of ILERP for all screened-out fire compartments	< 1.0E-7	n/a	n/a

Sample Problem Demonstration for Task 7

- On-line demonstration of Task 7

- Question and Answer Session

Mapping HLRs & SRs for the QNS technical element to NUREG/CR-6850, EPRI TR 1011989

Technical Element	HLR	SR	6850/1011989 section that covers SR	Comments
QNS	A	**If quantitative screening is performed, the Fire PRA shall establish quantitative screening criteria to ensure that the estimated cumulative impact of screened physical analysis units on CDF and LERF is small**		
		1	7.5.3	Specific screening criteria are identified in 6850/1011989
	B	**If quantitative screening is performed, the Fire PRA shall identify those physical analysis units that screen out as individual risk contributors**		
		1	7.5.1, 7.5.2	
		2	7.5.1, 7.5.2	
	C	**Verify that the cumulative impact of screened physical analysis units on CDF and LERF is small**		
		1	7.5.3	Specific screening criteria are identified in 6850/1011989
	D	**The Fire PRA shall document the results of quantitative screening in a manner that facilitates Fire PRA applications, upgrades, and peer review**		
		1	n/a	Documentation is discussed in Section 16.5 of 6850/101198
		2	n/a	Documentation is discussed in Section 16.5 of 6850/101198

TASK 7 – DEMONSTRATION

METHOD 1 – BASIC EVENTS SET TO "TRUE" OR "ONE"

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Run	Scenario	Description	Fire Zone	Ignition Frequency	Severity Factor	Non-Suppr. Probability	Ones Run Result	CCDP	CDF	Screened
	FA-1	Fire Area 1	FA-1	2.68E-03	0.0E+00		1.0E+00	1.0E+00	2.68E-03	No
	FA-10	Fire Area 10	FA-10	4.96E-03	0.0E+00		1.23E-01	1.4E-02	6.95E-05	No
	FA-11	Fire Area 11	FA-11	6.03E-03	0.0E+00		1.0E+00	1.0E+00	6.03E-03	No
	FA-12	Fire Area 12	FA-12	8.12E-04	0.0E+00		1.0E+00	1.0E+00	8.12E-04	No
	FA-13	Fire Area 13	FA-13	6.98E-04	0.0E+00		4.96E-02	1.99E-02	1.39E-05	No
	FA-15	Fire Area 15	FA-15	6.66E-04	0.0E+00		4.85E-04	4.85E-04	3.23E-07	No
	FA-2	Fire Area 2	FA-2	8.07E-04	0.0E+00		1.17E-01	1.3E-02	1.05E-05	No
	FA-3	Fire Area 3	FA-3	8.07E-04	0.0E+00		1.0E+00	1.0E+00	8.07E-04	No
	FA-4A	Fire Area 4A	FA-4A	4.73E-04	0.0E+00		1.05E-02	1.01E-02	4.76E-06	No
	FA-4B	Fire Area 4B	FA-4B	7.3E-04	0.0E+00		1.05E-01	4.22E-02	3.09E-05	No
	FA-5	Fire Area 5	FA-5	5.0E-04	0.0E+00		1.45E-02	1.4E-02	7.01E-06	No
	FA-6	Fire Area 6	FA-6	5.0E-04	0.0E+00		2.04E-02	2.0E-02	1.0E-05	No

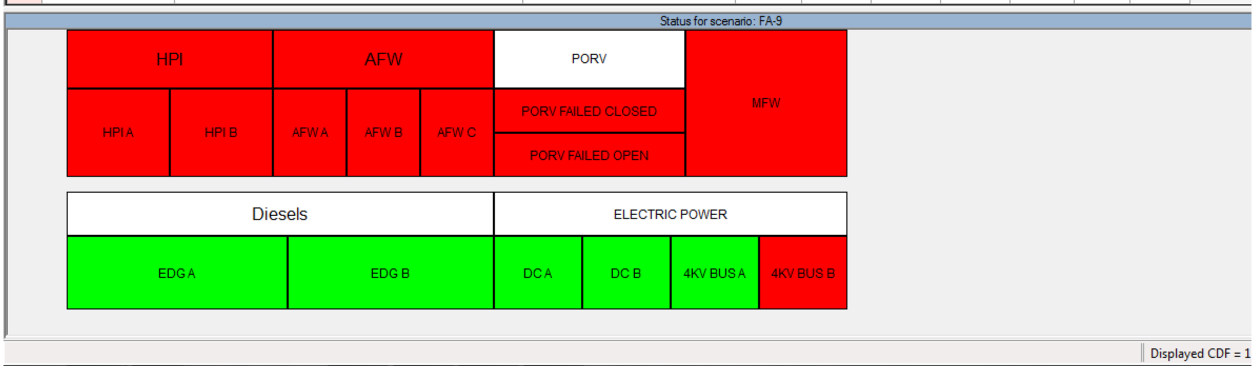

Figure 1: FIRE SCENARIO RESULTS SUMMARY AND SYSTEM STATUS (METHOD 1)

Zone_to_Raceway

Zone	ToEvent	ToType	Unknown	Click to Add
FA-1	AFWA-FTS	0		
FA-1	AFWB-FTS	0		
FA-1	AFWC-FTR	0		
FA-1	AFWC-FTS	0		
FA-1	ANN-1_FH	0		
FA-1	AOV-1_FTO	0		
FA-1	AOV-1_TO	0		
FA-1	AOV-2-FTC	0		
FA-1	AOV-2-TC	0		
FA-1	AOV-3-FTC	0		
FA-1	AOV-3-TO	0		
FA-1	AOV-4_TO	0		
FA-1	EPS-480VLC1F	0		
FA-1	EPS-480VLC2F	0		
FA-1	EPS-480VLCAF	0		
FA-1	EPS-480VLCBF	0		
FA-1	EPS-4VBUS1F	0		
FA-1	EPS-4VBUS2F	0		
FA-1	EPS-4VBUSAF	0		
FA-1	EPS-4VBUSBF	0		
FA-1	EPS-DGAF	0		
FA-1	EPS-DGBF	0		

Figure 2: SCENARIO TO BASIC EVENT MAPPING TABLE (METHOD 1)

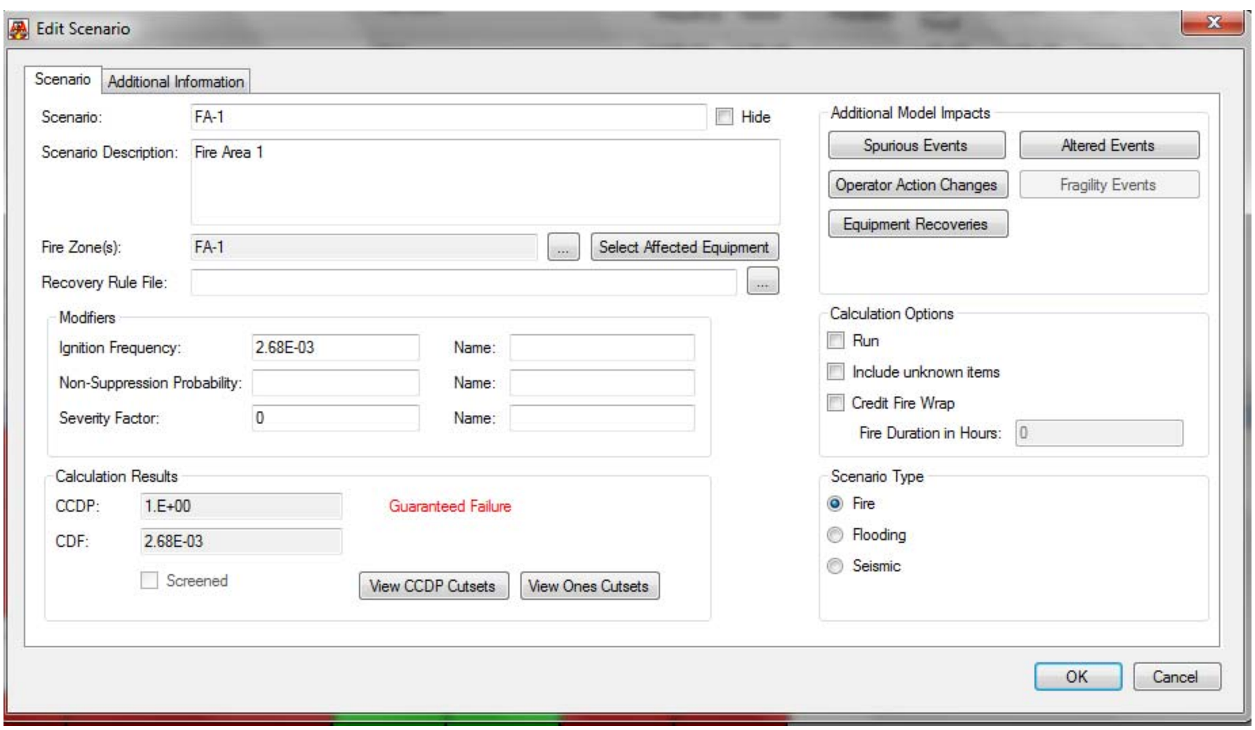

Figure 3: SCENARIO DEFINITION (METHOD 1)

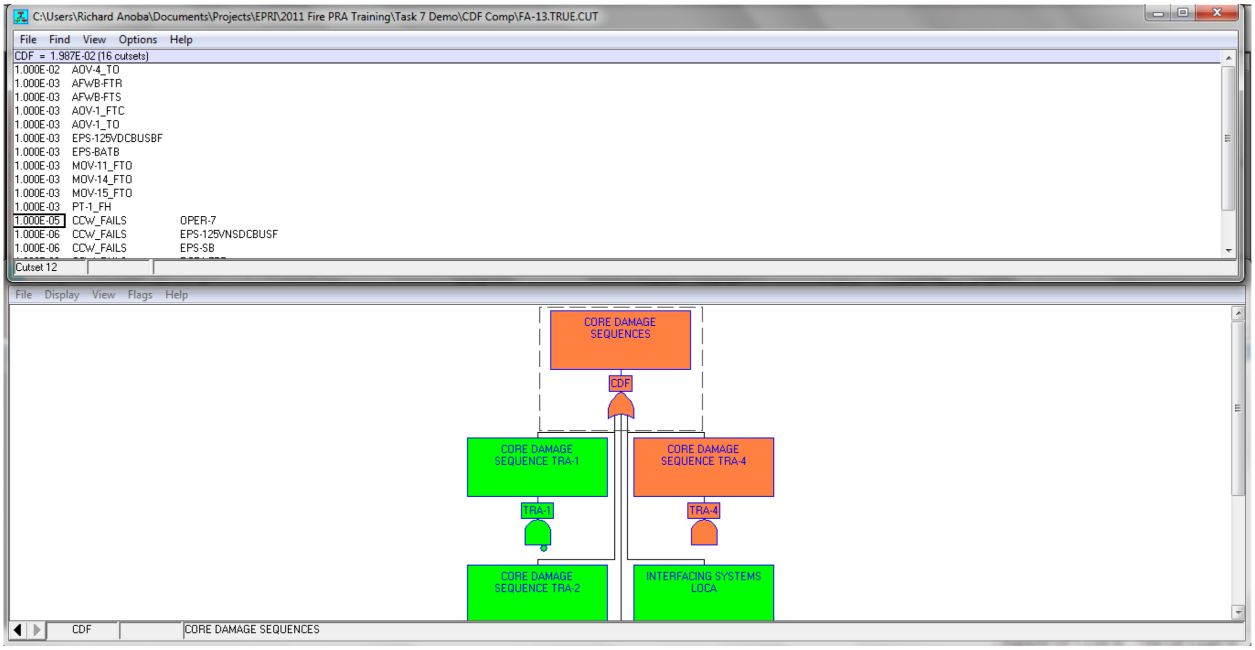

Figure 4: RESULTS PRESENTATION (METHOD 1)

METHOD 2 – FIRE INITIATING EVENTS INSERTED IN FAULT TREE LOGIC – SINGLE-TOP CDF/LERF

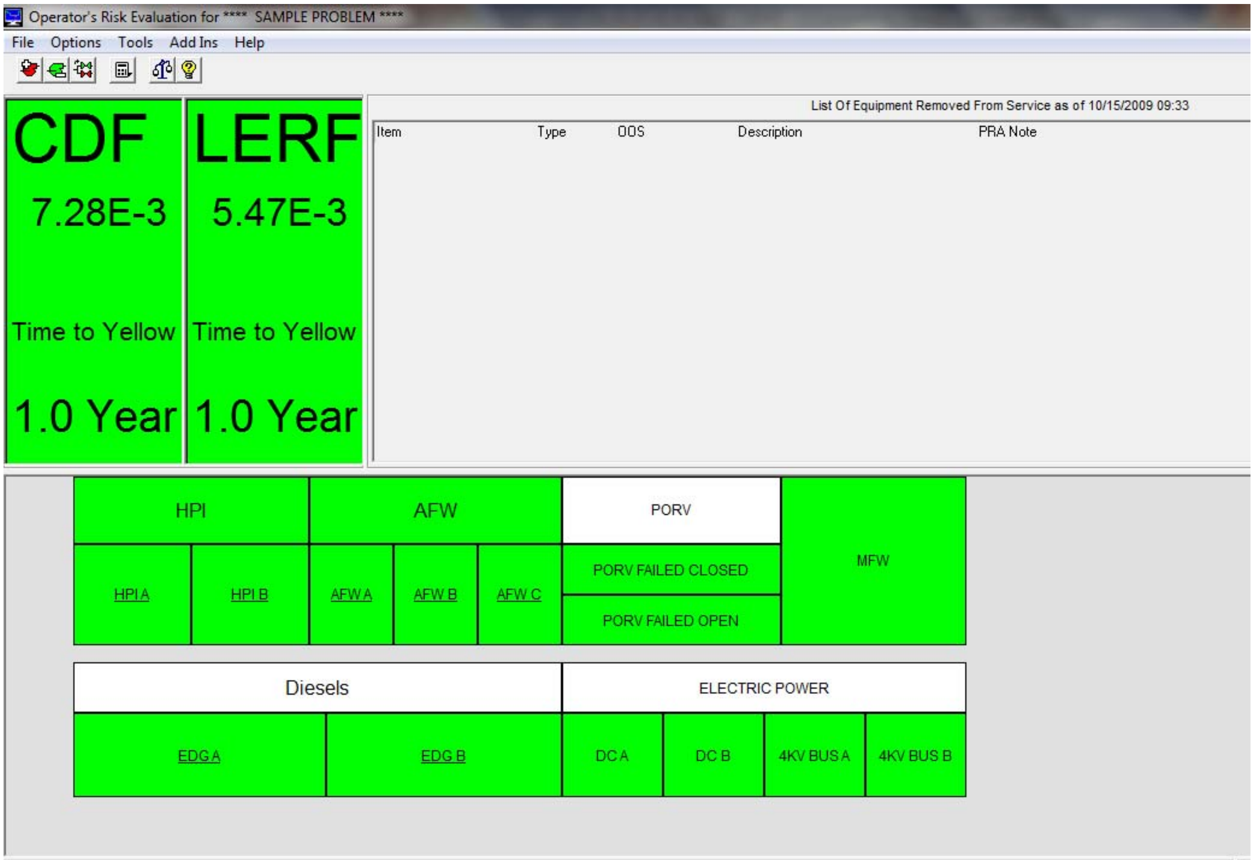

Figure 5: RISK MONITOR PANEL (METHOD 2)

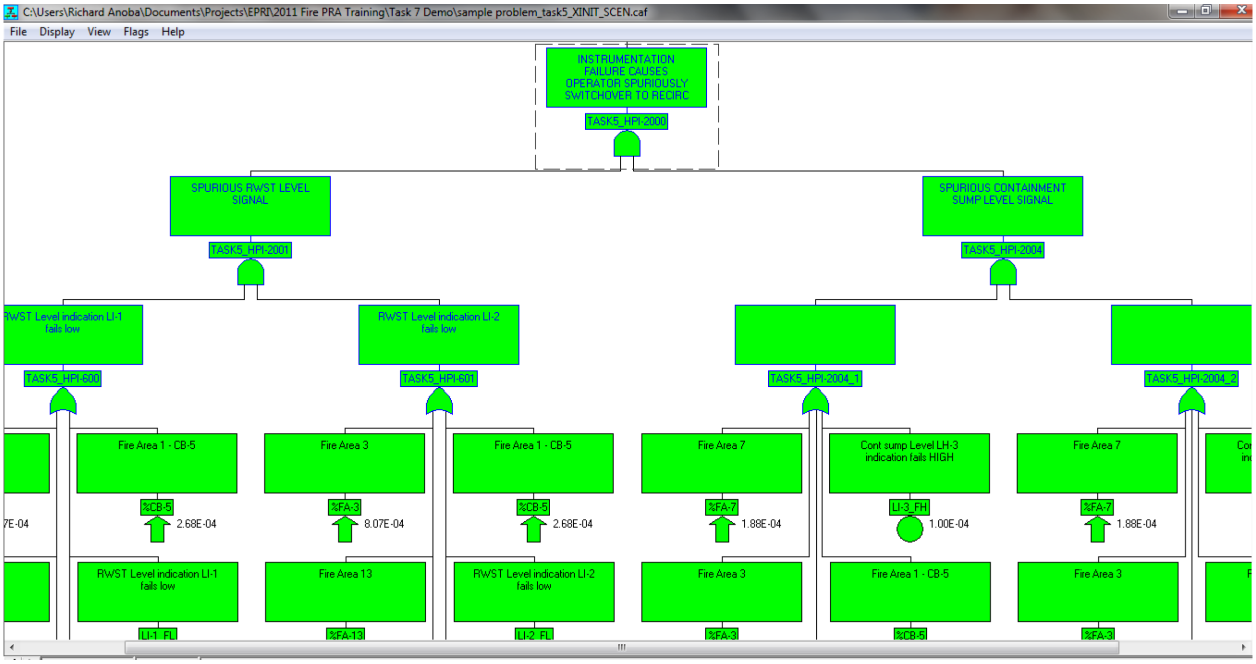

Figure 6: FAULT TREE EXAMPLE (METHOD 2)

C:\Users\Richard Anoba\Documents\Projects\EPRI\2011 Fire PRA Training\Task 7 Demo\E

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CDF = 7.282E-03 (1362 cutsets)

4.189E-03	%FA-9		
8.120E-04	%FA-12		
8.072E-04	%FA-3		
4.729E-04	%FA-4A		
2.678E-04	%CB-6		
7.047E-05	%FA-8B	AOV-4_TO	
6.025E-05	%FA-11	AOV-4_TO	
5.880E-05	%T6	OPER-4	
4.959E-05	%FA-10	AOV-4_TO	
1.000E-05	%T15	AOV-4_TO	
1.000E-05	%T15	OPER-7	
8.072E-06	%FA-2	AOV-4_TO	
8.000E-06	%T1	AOV-4_TO	OPER-4
7.350E-06	%T6	AOV-1_FTO	
7.350E-06	%T6	AOV-3_FTC	
7.350E-06	%T6	CCW_FAILS	
7.350E-06	%T6	COMP1_FTR	
7.350E-06	%T6	EPS-120VBUSAF	
7.350E-06	%T6	EPS-120VBUSAINVF	
7.350E-06	%T6	EPS-120VBUSBF	
7.350E-06	%T6	EPS-120VBUSBINVF	
7.350E-06	%T6	EPS-125VDCBUSAF	
7.350E-06	%T6	EPS-125VDCBUSBF	
7.350E-06	%T6	EPS-125VDCPNLAF	
7.350E-06	%T6	EPS-125VDCPNLBF	
7.350E-06	%T6	EPS-480VLC1F	
7.350E-06	%T6	EPS-480VLC1XTF	
7.350E-06	%T6	EPS-480VLCAF	
7.350E-06	%T6	EPS-480VLCAXTF	
7.350E-06	%T6	EPS-480VLCBF	
7.350E-06	%T6	EPS-480VLCBXTF	
7.350E-06	%T6	EPS-480VMCCA1F	
7.350E-06	%T6	EPS-480VMCCB1F	
7.350E-06	%T6	EPS-4VBUS1F	
7.350E-06	%T6	EPS-4VBUSAF	
7.350E-06	%T6	EPS-4VBUSBF	
7.350E-06	%T6	EPS-BATA	
7.350E-06	%T6	EPS-BATB	
7.350E-06	%T6	MOV-13_TC	
7.350E-06	%T6	MOV-2_FTC	
7.350E-06	%T6	MOV-3_TO	
7.350E-06	%T6	MOV-4_TO	
7.350E-06	%T6	MOV-5_FTC	

Figure 7: EXAMPLE RESULTS (METHOD 2)

METHOD 3 – EVENT TREE WITH FIRE COMPARTMENT HOUSE EVENTS INSERTED IN FAULT TREE

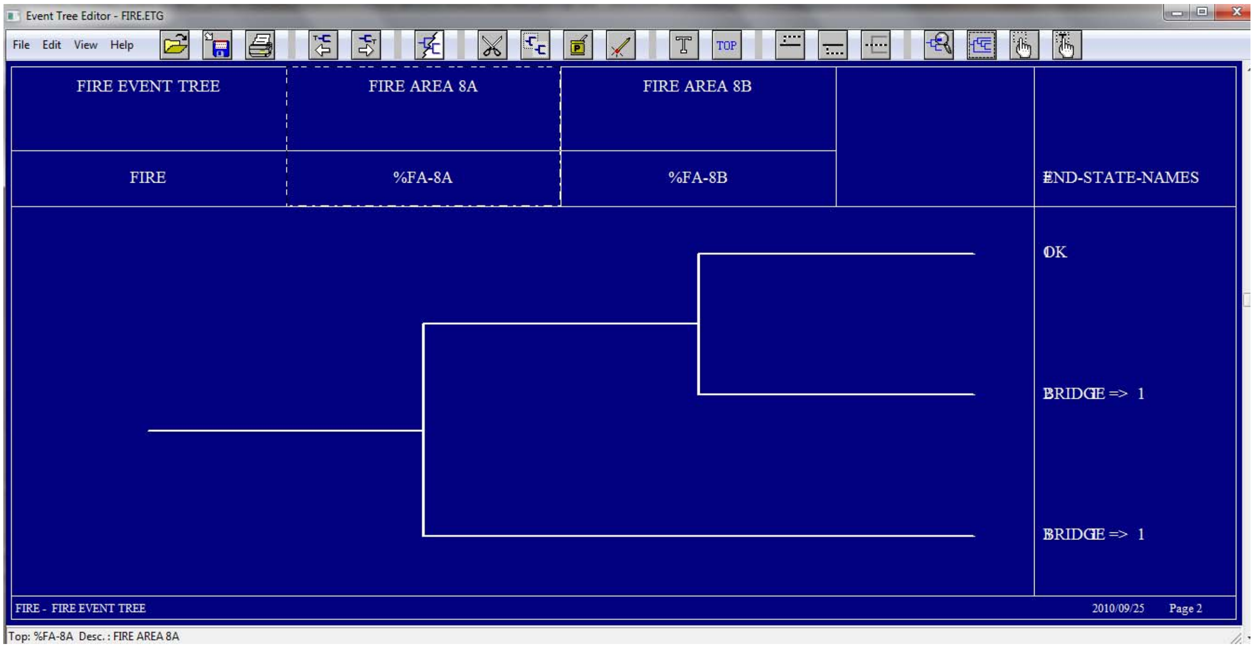


Figure 8: EXAMPLE FIRE EVENT TREE (METHOD 3)

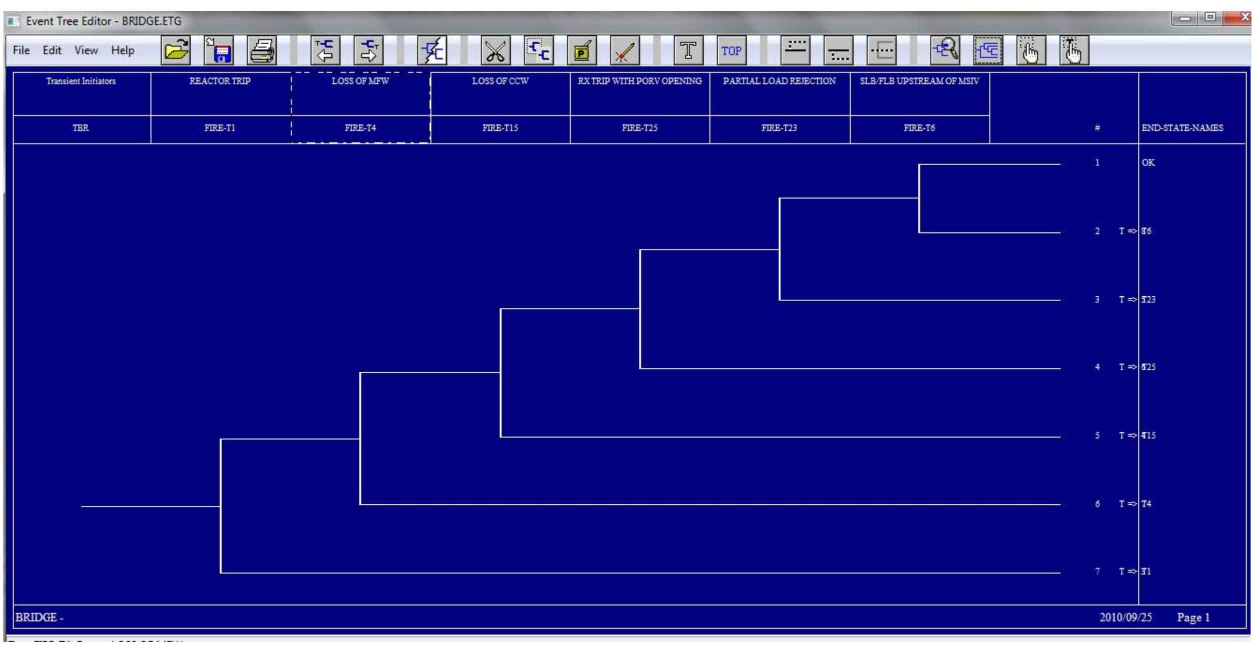


Figure 9: EXAMPLE BRIDGE TREE (METHOD 3)

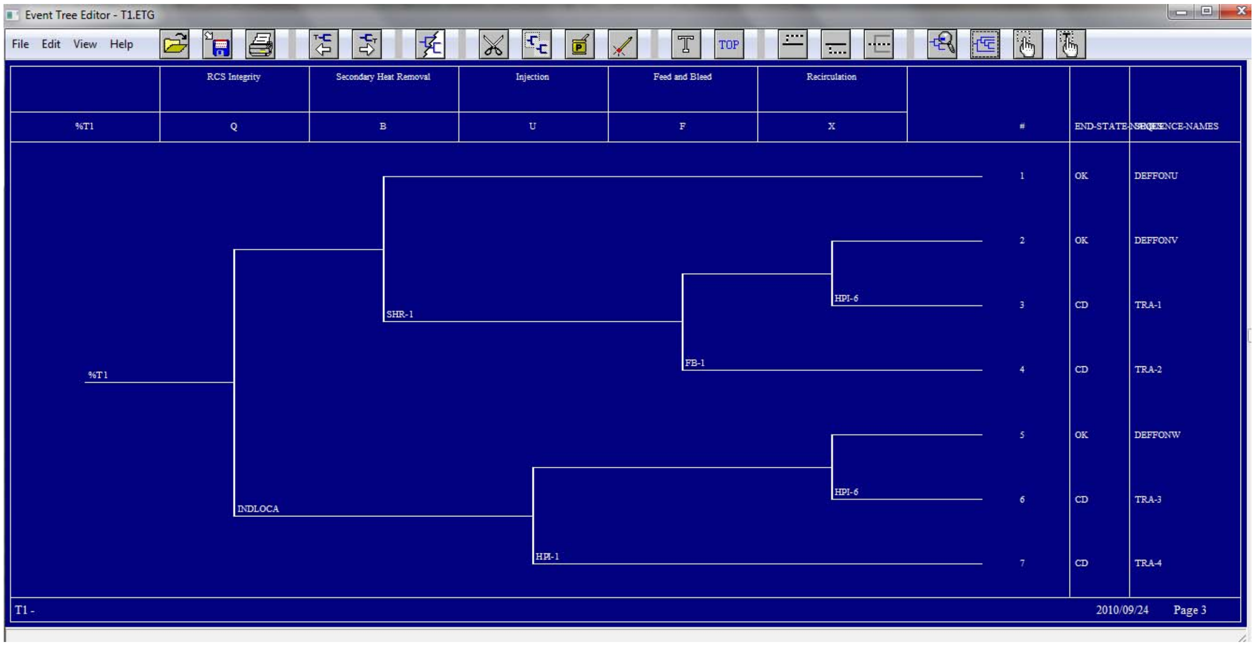


Figure 10: INTERNAL EVENT TREE (METHOD 3)

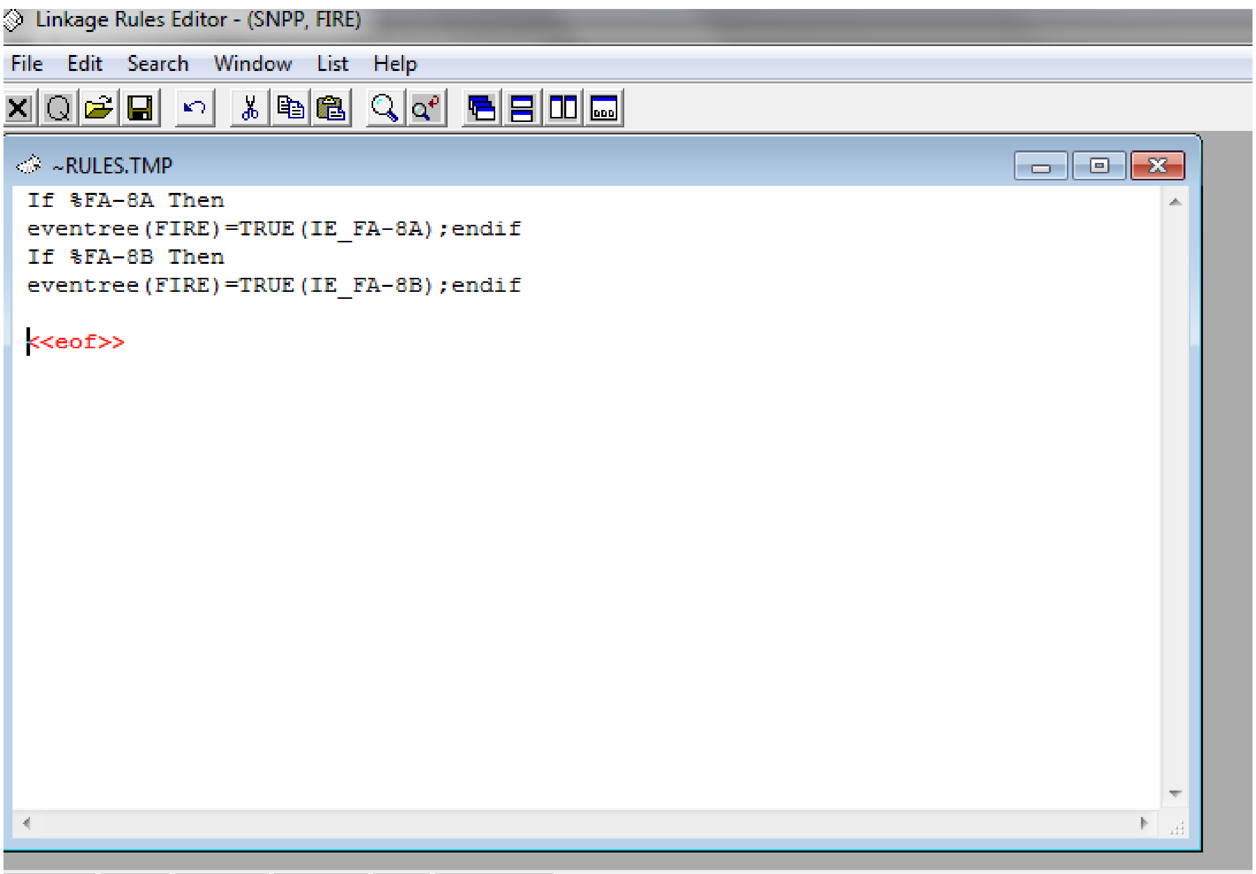


Figure 11: FIRE EVENT TREE LINKAGE RULES

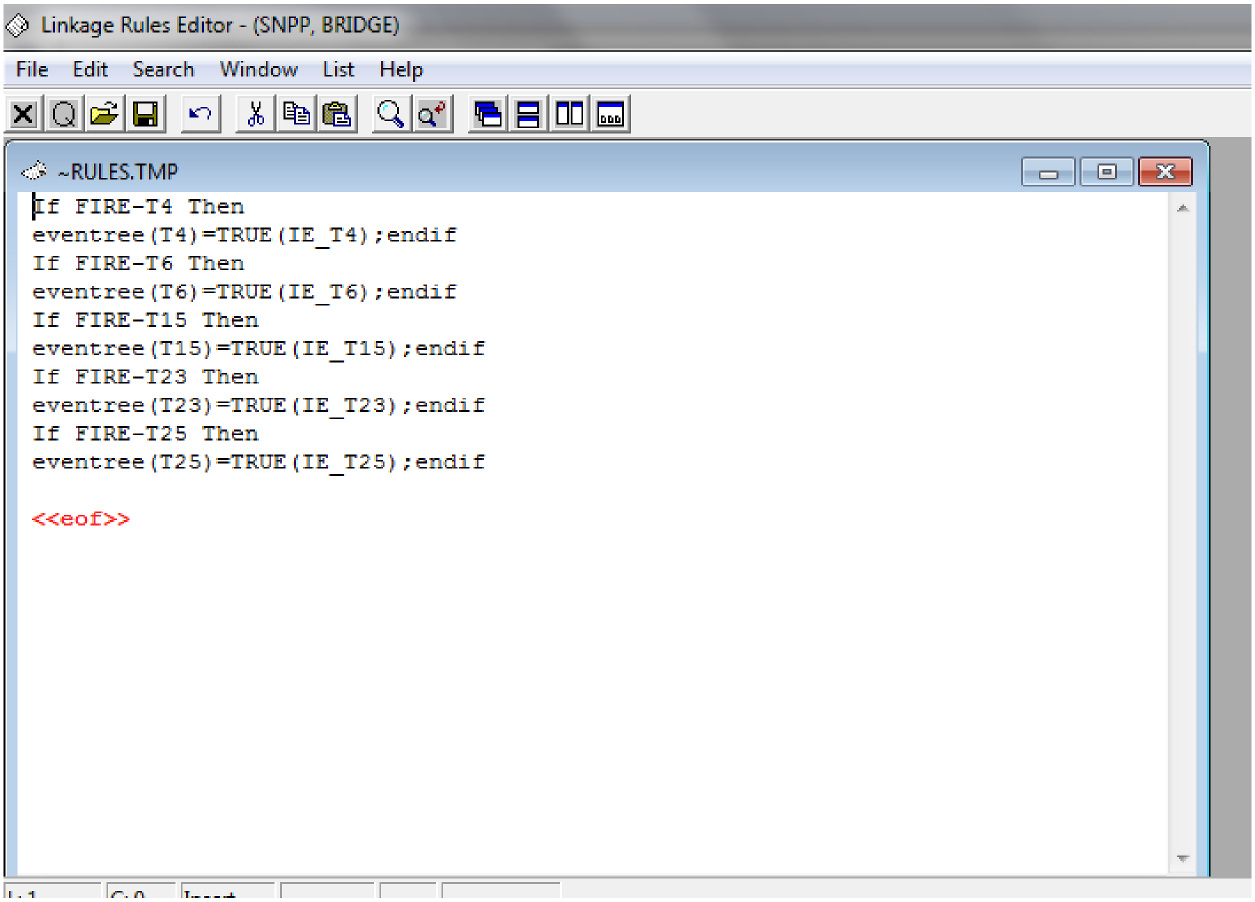


Figure 12: BRIDGE TREE LINKAGE RULES

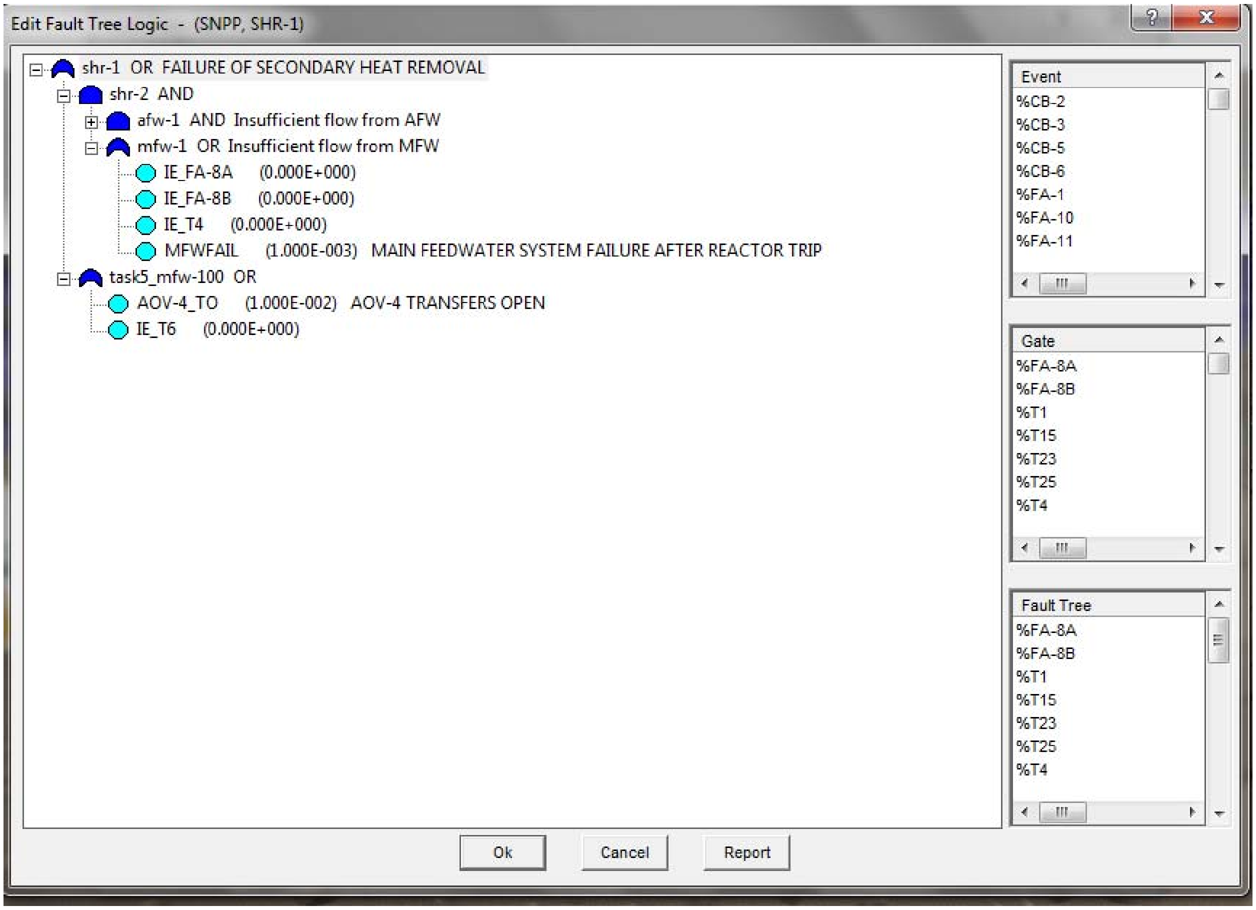
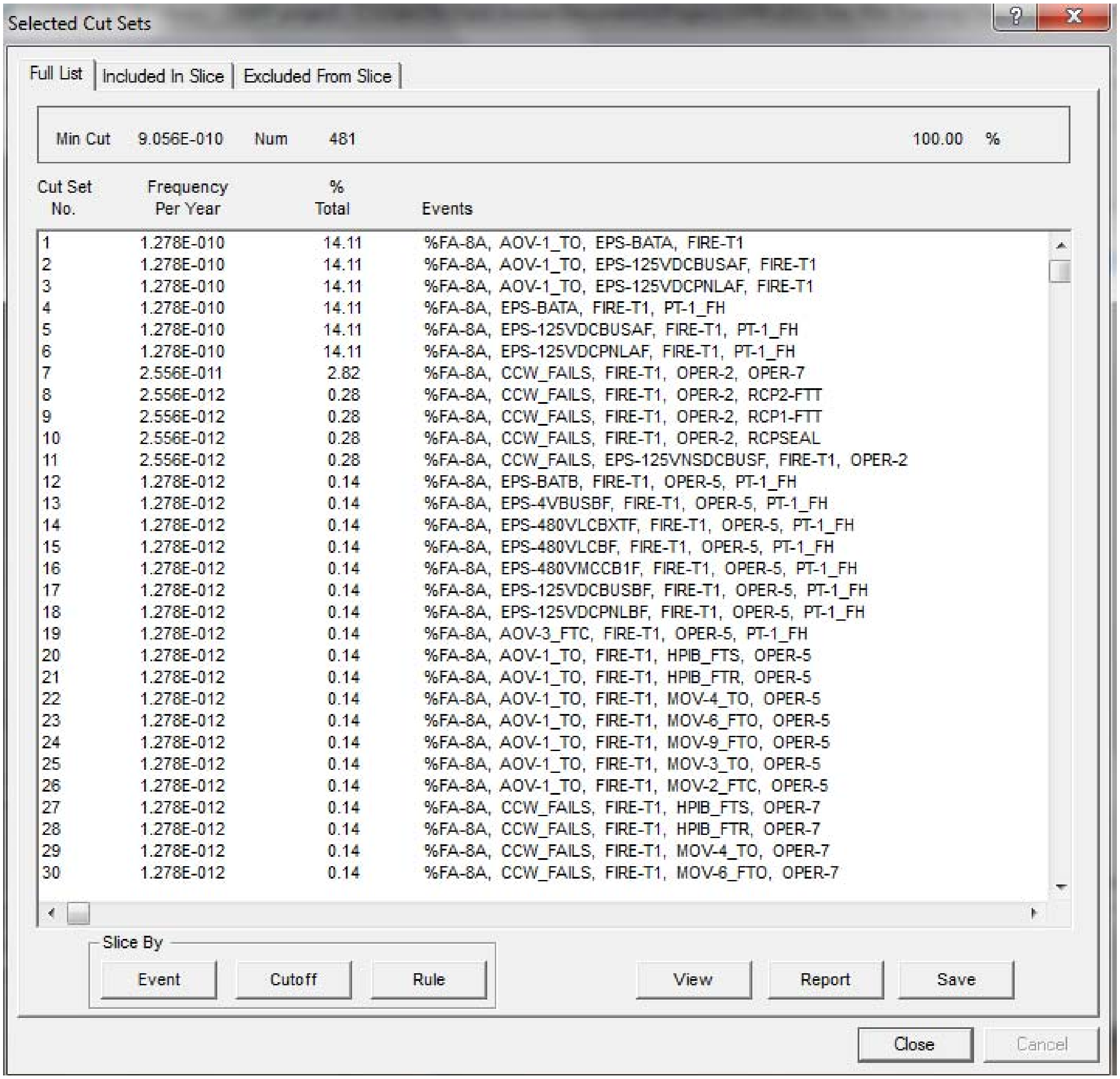
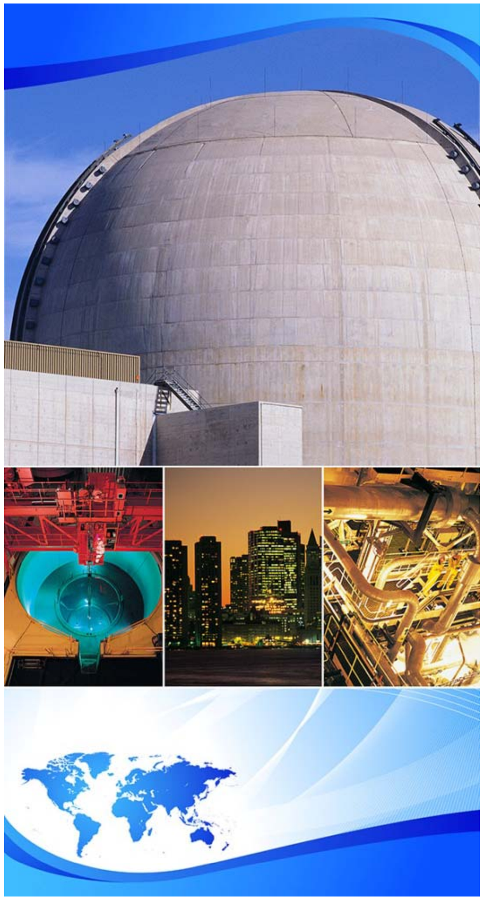


Figure 13: FAULT TREE MODEL WITH INSERTED FIRE COMPARTMENT HOUSE EVENTS (METHOD 3)



Cut Set No.	Frequency Per Year	% Total	Events
1	1.278E-010	14.11	%FA-8A, AOV-1_TO, EPS-BATA, FIRE-T1
2	1.278E-010	14.11	%FA-8A, AOV-1_TO, EPS-125VDCBUSAF, FIRE-T1
3	1.278E-010	14.11	%FA-8A, AOV-1_TO, EPS-125VDCPNLAF, FIRE-T1
4	1.278E-010	14.11	%FA-8A, EPS-BATA, FIRE-T1, PT-1_FH
5	1.278E-010	14.11	%FA-8A, EPS-125VDCBUSAF, FIRE-T1, PT-1_FH
6	1.278E-010	14.11	%FA-8A, EPS-125VDCPNLAF, FIRE-T1, PT-1_FH
7	2.556E-011	2.82	%FA-8A, CCW_FAILS, FIRE-T1, OPER-2, OPER-7
8	2.556E-012	0.28	%FA-8A, CCW_FAILS, FIRE-T1, OPER-2, RCP2-FTT
9	2.556E-012	0.28	%FA-8A, CCW_FAILS, FIRE-T1, OPER-2, RCP1-FTT
10	2.556E-012	0.28	%FA-8A, CCW_FAILS, FIRE-T1, OPER-2, RCPSEAL
11	2.556E-012	0.28	%FA-8A, CCW_FAILS, EPS-125VNSDCBUSF, FIRE-T1, OPER-2
12	1.278E-012	0.14	%FA-8A, EPS-BATB, FIRE-T1, OPER-5, PT-1_FH
13	1.278E-012	0.14	%FA-8A, EPS-4VBUSBF, FIRE-T1, OPER-5, PT-1_FH
14	1.278E-012	0.14	%FA-8A, EPS-480VLCBXTF, FIRE-T1, OPER-5, PT-1_FH
15	1.278E-012	0.14	%FA-8A, EPS-480VLCBF, FIRE-T1, OPER-5, PT-1_FH
16	1.278E-012	0.14	%FA-8A, EPS-480VMCCB1F, FIRE-T1, OPER-5, PT-1_FH
17	1.278E-012	0.14	%FA-8A, EPS-125VDCBUSBF, FIRE-T1, OPER-5, PT-1_FH
18	1.278E-012	0.14	%FA-8A, EPS-125VDCPNLBF, FIRE-T1, OPER-5, PT-1_FH
19	1.278E-012	0.14	%FA-8A, AOV-3_FTC, FIRE-T1, OPER-5, PT-1_FH
20	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, HPIB_FTS, OPER-5
21	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, HPIB_FTR, OPER-5
22	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, MOV-4_TO, OPER-5
23	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, MOV-6_FTO, OPER-5
24	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, MOV-9_FTO, OPER-5
25	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, MOV-3_TO, OPER-5
26	1.278E-012	0.14	%FA-8A, AOV-1_TO, FIRE-T1, MOV-2_FTC, OPER-5
27	1.278E-012	0.14	%FA-8A, CCW_FAILS, FIRE-T1, HPIB_FTS, OPER-7
28	1.278E-012	0.14	%FA-8A, CCW_FAILS, FIRE-T1, HPIB_FTR, OPER-7
29	1.278E-012	0.14	%FA-8A, CCW_FAILS, FIRE-T1, MOV-4_TO, OPER-7
30	1.278E-012	0.14	%FA-8A, CCW_FAILS, FIRE-T1, MOV-6_FTO, OPER-7

Figure 14: EXAMPLE RESULTS (METHOD 3)



EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 14 – Fire Risk Quantification

Fire PRA Workshop 2011
San Diego CA and Jacksonville FL

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Fire Risk Quantification
Purpose (per 6850/1011989)

- Purpose: describe the procedure for performing fire risk quantification.
- Provides a general method for quantifying the final Fire PRA Model to generate the final fire risk results

Fire Risk Quantification
Corresponding PRA Standard Element

- Primary match is to element FQ – Fire Risk Quantification
  - FQ Objectives (as stated in the PRA standard):

    (a) quantify the fire-induced CDF and LERF contributions to plant risk.(b) understand what are the significant contributors to the fire-induced CDF and LERF.”

Fire Risk Quantification HLRs (per the PRA Standard)

- HLR-FQ-A: Quantification of the Fire PRA shall quantify the fire-induced CDF
- HLR-FQ-B: The fire-induced CDF quantification shall use appropriate models and codes and shall account for method-specific limitations and features.
- HLR-FQ-C: Model quantification shall determine that all identified dependencies are addressed appropriately.
- HLR-FQ-D: The frequency of different containment failure modes leading to a fire-induced large early release shall be quantified and aggregated, thus determining the fire-induced LERF.

Fire Risk Quantification HLRs (per the PRA Standard)

- HLR-FQ-E: The fire-induced CDF and LERF quantification results shall be reviewed, and significant contributors to CDF and LERF, such as fires and their corresponding plant initiating events, fire locations, accident sequences, basic events (equipment unavailabilities and human failure events), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the Fire PRA.
- HLR-FQ-F: The documentation of CDF and LERF analyses shall be consistent with the applicable SRs.

Fire Risk Quantification
Scope (per 6850/1011989)

- Task 14: Fire Risk Quantification
  - Obtaining best-estimate quantification of fire risk
  - Step 1–Quantify Final Fire CDF Model
  - Step 2–Quantify Final Fire LERF Model
  - Step 3–Conduct Uncertainty Analysis

Task 14: Fire Risk Quantification
General Objectives

Purpose: perform final (best-estimate) quantification of fire risk

- Calculate CDF/LERF as the primary risk metrics
- Include uncertainty analysis / sensitivity results (see Task 15)
- Identify significant contributors to fire risk
- Carry along insights from Task 13 to documentation but this is not an explicit part of "quantifying" the Fire PRA model
- Carry along residual risk from screened compartments and scenarios (Task 7); both (final fire risk and residual risk) are documented in Task 16 to provide total risk perspective

Task 14: Fire Risk Quantification
Inputs/Outputs

Task inputs:

- Inputs from other tasks:
  - Task 5 (Fire-Induced Risk Model) as modified/run thru Task 7 (Quantitative Screening),
  - Task 10 (Circuit Failure Mode Likelihood Analysis),
  - Task 11 (Detailed Fire Modeling), and
  - Task 12 (Post-Fire HRA Detailed Analysis)

Task 14: Fire Risk Quantification
Inputs/Outputs

- Output is the quantified fire risk results including the uncertainty and sensitivity analyses directed by Task 15 (Uncertainty and Sensitivity Analysis), all of which is documented per Task 16 (Fire PRA Documentation)

Task 14: Fire Risk Quantification
Steps in Procedure

Four major steps in the procedure*:

- Step 1: Quantify CDF
- Step 2: Quantify LERF
- Step 3: Perform uncertainty analyses including propagation of uncertainty bounds as directed under step 4 of Task 15
- Step 4: Perform sensitivity analyses as directed under step 4 of Task 15

* In each case, significant contributors are also identified

Task 14: Fire Risk Quantification
Quantification Process

Characteristics of the quantification process:

- Procedure is "general"; i.e., not tied to a specific method (event tree with boundary conditions, fault tree linking…)
- Can calculate CDF/LERF directly by explicitly including fire scenario frequencies or first calculate CCDP/CLERP and then combine with fire scenario frequencies
- Quantify consistent with relevant ASME-ANS PRA Standard (RA-Sa-2009) supporting requirements
  - Many cross-references from FQ to internal events section (Part 2) for most aspects of risk quantification

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 1 (2): Quantify Final Fire CDF/LERF Model

Step 1.1 (2.1): Quantify Final Fire CCDP/CLERP Model

- Corresponding SRs: FQ-A1, A2, A3, A4, B1, C1, D1, E1

- Final HRA probabilities including dependencies
- Final cable failure probabilities
- Final cable impacts

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 1.2 (2.2): Quantify Final Fire CDF/LERF Frequencies

– Corresponding SRs: FQ-A1-A4, B1, C1, D1, E1

- Final compartment frequencies
- Final scenario frequencies
- Final fire modeling parameters (i.e., severity factors, non-suppression probabilities, etc)

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 1.3 (2.3): Identify Main Contributors to Fire CDF/LERF

- Corresponding SRs: FQ-A1-A3, E1

- Contributions by fire scenarios, compartments where fire ignition occurs, plant damage states, post-fire operator actions, etc.

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 3: Propagate Uncertainty Distributions

- Probability distributions of epistemic uncertainties propagated through the CDF and LERF calculations
- Monte Carlo or Latin hypercube protocols

Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 4.1: Identification of Final Set of Sensitivity Analysis Cases

- Review sensitivity cases identified in Task 15
- Finalize sensitivity cases for Step 4.2

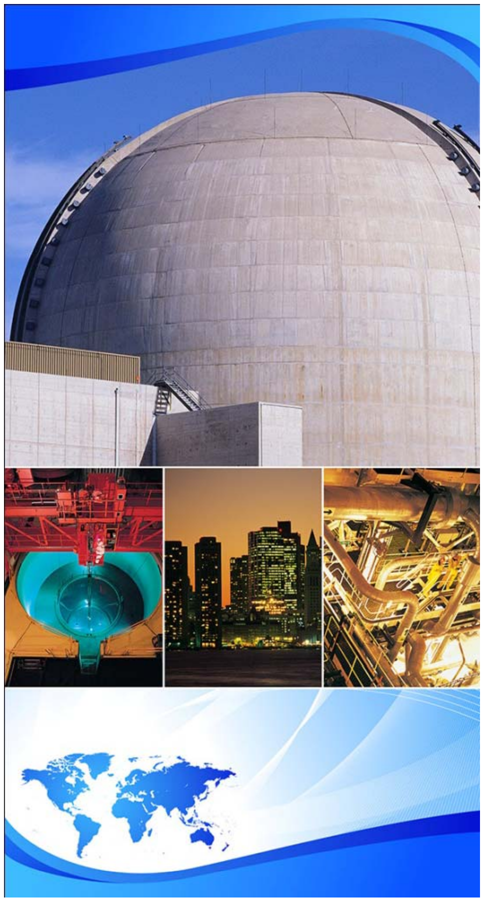
Task 14: Fire Risk Quantification
Steps in Procedure/Details

Step 4.2: CDF and/or LERF Computations and Comparison

- Mean CDF/LERF values computed for each sensitivity analysis case considered in Step 4.1
- The results should be compared with the base-case considered in Steps1 and 2

Mapping HLRs & SRs for the FQ technical element to NUREG/CR-6850, EPRI TR 1011989

Technical element	HLR	SR	6850/1011989 sections that cover SR	Comments
FQ	A	Quantification of the Fire PRA shall quantify the fire-induced CDF.		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
		2	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
		3	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
		4	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	B	The fire-induced CDF quantification shall use appropriate models and codes and shall account for method-specific limitations and features.		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	C	Model quantification shall determine that all identified dependencies are addressed appropriately.		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	D	The frequency of different containment failure modes leading to a fire-induced large early release shall be quantified and aggregated, thus determining the fire-induced LERF		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2	
	E	The fire-induced CDF and LERF quantification results shall be reviewed, and significant contributors to CDF and LERF, such as fires and their corresponding plant initiating events, fire locations, accident sequences, basic events (equipment unavailabilities and human failure events), plant damage states, containment challenges, and failure modes, shall be identified. The results shall be traceable to the inputs and assumptions made in the Fire PRA		
		1	14.5.1.1, 14.5.1.2, 14.5.2.1, 14.5.2.2, 14.5.2.3	
	F	The documentation of CDF and LERF analyses shall be consistent with the applicable SRs.		
		1	n/a	Documentation not covered in 6850/1011989
		2	n/a	Documentation not covered in 6850/1011989



EPRI/NRC-RES FIRE PRA METHODOLOGY

Task 15 – Uncertainty and Sensitivity Analysis

Fire PRA Workshop 2011

San Diego CA and Jacksonville FL

A Collaboration of U.S. NRC Office of Nuclear Regulatory Research (RES) & Electric Power Research Institute (EPRI)

Task 15:Uncertainty and Sensitivity Analysis
Purpose (per 6850/1011989)

Purpose: Provide a process for identifying and treating uncertainties in the Fire PRA, and identifying sensitivity analysis cases

- Many of the inputs to the Fire PRA are uncertain
- Important to identify sources of uncertainty and assumptions that have the strongest influence on the final results
- Fire risk can be quantified without explicit quantification of uncertainties, but the risk results cannot be considered as complete without it
- Sensitivity analysis is an important complement to uncertainty assessment

Task 15:Uncertainty and Sensitivity Analysis
Scope

Scope of Task 15 includes:

- Background information on uncertainty
- Classification of the types of uncertainty
- A general approach on treating uncertainties in Fire PRA

Uncertainty and Sensitivity Analysis - Corresponding PRA Standard Element

- Primary match is to element UNC – Uncertainty and Sensitivity Analysis
- UNC Objectives (as stated in the PRA standard):

"(a) identify sources of analysis uncertainty

(b) characterize these uncertainties

(c) assess their potential impact on the CDF and LERF estimates"

Uncertainty and Sensitivity Analysis – HLRs (per the PRA Standard)

- **HLR-UNC-A: The Fire PRA shall identify sources of CDF and LERF uncertainties and related assumptions and modeling approximations. These uncertainties shall be characterized such that their potential impacts on the results are understood.**

Task 15:Uncertainty and Sensitivity Analysis
Types of Uncertainty

- Distinction between aleatory and epistemic uncertainty:
  - “Aleatory” - from the Latin alea (dice), of or relating to random or stochastic phenomena. Also called “random uncertainty or variability.”
    - Reflected in the Fire PRA models as a set of interacting random processes involving a fire-induced transient, response of mitigating systems, and corresponding human actions
  - “Epistemic” - of, relating to, or involving knowledge; cognitive. [From Greek episteme, knowledge]. Also called “state-of-knowledge uncertainty.”
    - Reflects uncertainty in the parameter values and models (including completeness) used in the Fire PRA – addressed in this Task

Task 15:Uncertainty and Sensitivity Analysis
Inputs and Outputs

- Inputs from other Tasks:
  - Identification of sources of epistemic uncertainties from Tasks 1 through 13 worthy of uncertainty/sensitivity analysis (i.e., key uncertainties)
  - Quantification results from Task 14 including risk drivers used to help determine key uncertainties
  - Proposed approach for addressing each of the identified uncertainties including sensitivity analyses
- Outputs to other Tasks:
  - Sensitivity analyses performed in Task 14
  - Results of uncertainty and sensitivity analysis are reflected in documentation of Fire PRA (Task 16)

Task 15:Uncertainty and Sensitivity Analysis
General Procedure (per 6850/1011989)

Addresses a process to be followed rather than a pre-defined list of epistemic uncertainties and sensitivity analyses, since these could be plant specific

- Step 1: Identify uncertainties associated with each task
- Step 2: Develop strategies for addressing uncertainties
- Step 3: Review uncertainties to decide which uncertainties to address and how
- Step 4: Perform uncertainty and sensitivity analyses
- Step 5: Include results of uncertainty and sensitivity analyses in Fire PRA documentation

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

See Appendix U to NUREG/CR-6850 for background on uncertainty analysis. See Appendix V for details for each task.

Step 1: Identify epistemic uncertainties for each task

- Initial assessment of uncertainties to be treated is provided in Appendix V to NUREG/CR-6850 (but consider plant specific analysis for other uncertainties such as specific assumptions)
- From a practical standpoint, characterize uncertainties as modeling and data uncertainties
- Outcome is a list of issues, by task, leading to potentially important uncertainties (both modeling and data uncertainty)

Related SRs:

- PRM-A4, FQ-F1, IGN-A10, IGN-B5, FSS-E3, FSS-E4, FSS-H5, FSS-H9, and CF-A2 for sources of uncertainty

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

Step 2: Develop strategies for addressing uncertainties

- Strategy can range from no action to explicit quantitative modeling
- Each task analyst is expected to provide suggested strategies
- Possible strategies include propagation of data uncertainties, developing multiple models, addressing uncertainties qualitatively, quality review process, and basis for excluding some uncertainties
- Basis for strategy should be noted and may include importance of uncertainty on overall results, effects on future applications, resource and schedule constraints

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

Step 3: Review uncertainties to decide which uncertainties to address and how

- Review carried out by team of analysts familiar with issues, perhaps meeting more than once
- Review has multiple objectives:
  - Identify uncertainties that will not be addressed, and reasons why
  - Identify uncertainties to be addressed, and strategies to be used
  - Identify uncertainties to be grouped into single assessment
  - Identify issues to be treated via sensitivity analysis
  - Instruct task analysts who perform the analyses

Task 15:Uncertainty and Sensitivity Analysis
Sensitivity Analysis

- Sensitivity analysis can provide a perspective that cannot be obtained from a review of significant risk contributors.
  - Each task analyst can provide a list of parameters that had the strongest influence in their part of the analysis
  - Experiment with modified parameters to demonstrate impact on the final risk results
  - Modeling uncertainties can be demonstrated through sensitivity analysis
  - Sensitivities should be performed for individual uncertainties as well as for appropriate logical groups of uncertainties

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

Step 4: Perform uncertainty and sensitivity analyses

- Uncertainty analyses may involve:
  - Quantitative sampling of parameter distributions
  - Manipulation of models to perform sensitivity analyses
  - Qualitative evaluation of uncertainty
- Following items should be made explicit:
  - Uncertainties being addressed
  - Strategy being followed
  - Specific methods, references, computer programs, etc. being used (to allow traceability)
  - Results of analyses, including conclusions relative to overall results of Fire PRA
  - Potential impacts on anticipated applications of results

Task 15:Uncertainty and Sensitivity Analysis
Steps in Procedure/Details

Step 5: Include results in PRA documentation

- Adequate documentation of uncertainties and sensitivities is as important as documentation of baseline results
- Adequate documentation leads to improved decision-making
- Documentation covered more fully under Task 16

Task 15: Uncertainty and Sensitivity Analysis *Expectations*

- Minimum set of uncertainties expected to have a formal treatment:
  - Fire PRA model structure itself, representing the uncertainty with regard to how fires could result in core damage and/or large early release outcomes (Tasks 5/7)
  - Uncertainty in each significant fire ignition frequency (Task 6)
  - Uncertainty in each significant circuit failure mode probability (Task 10)
  - Uncertainty in each significant target failure probability (Task 11)
    - Heat release rate
    - Suppression failure model and failure rate
    - Position of the target set vs. ignition sources
  - Uncertainty in each significant human error probability (Task 12)
  - Uncertainty in each core damage and large early release sequence frequency based on the above inputs as well as uncertainties for other significant equipment failures/modes (Task 14)

Task 15:Uncertainty and Sensitivity Analysis *Expectations*

- Other uncertainties may be relevant to address
  - Other activities related to uncertainty are underway
  - You might need to consult other resources for information (e.g., NUREG-1855, EPRI TR 1016737)
- Sensitivity analyses should be performed where important to show robustness in results (i.e., demonstrate where results are / are not sensitive to reasonable changes in the inputs)
- While not really a source of uncertainty, per se, technical quality issues and recommended reviews are also addressed

Mapping HLRs & SRs for the UNC technical element to NUREG/CR-6850, EPRI TR 1011989

Technical Element	HLR	SR	6850/1011989 section that covers SR	Comments
	A	**The Fire PRA shall identify sources of CDF and LERF uncertainties and related assumptions and modeling approximations. These uncertainties shall be characterized such that their potential impacts on the results are understood**		
		1	15.5.1	
		2	15.5.5	Documentation is discussed in Section 16.5 of 6850/1011989