EPRI/NRC-RES FIRE PRA METHODOLOGY

Module II-15: Task 12b – Post-Fire HRA Detailed Analysis

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Joint RES/EPRI Fire PRA Workshop

May 24-26, 2006

Rockville, MD

Post-Fire HRA Detailed Analysis
Scope of this Module

Module II-15 covers one task:

- Task 12b: Post-Fire Human Reliability Analysis (Detailed Analysis)
  - Obtaining more realistic human error probabilities (i.e., not screening values)

Task 12b: Post-Fire HRA Detailed Analysis
General Objectives

Purpose: assign best-estimate HEPs to allow more realistic estimate of fire risk.

- Does not specify an HRA method to use
  - There are too many methods analysts might use (THERP, ASEP, CBDT…) and each is unique in what it treats and how to determine HEPs
  - Hence, procedure outlines what should be addressed but not how to specifically incorporate into existing HRA methods because there are too many of them
- Incorporates fire-scenario-induced changes in assumptions, model structure, and performance shaping factors
- Addresses need to use procedures (e.g., FEPs) beyond those modeled in the Internal Events PRA

Task 12b: Post-Fire HRA Detailed Analysis
Inputs/Outputs

Task inputs and outputs:

- Inputs from other tasks: feedback from Task 7 (Quantitative Screening) identifying HFEs needing detailed analysis
- Outputs to other tasks: best-estimate HEPs for Task 14 (Fire Risk Quantification)

Task 12b: Post-Fire HRA Detailed Analysis
Team Makeup and ASME PRA Standard

Procedure addresses HRA team makeup and interface with ASME PRA Standard

- Should follow basic HRA approach addressed in ASME PRA Standard
- Recommends individual with experience in human behavior during fires (firefighter trainers, etc.) be involved in quantification
  - But need to recognize the difference between operator safe shutdown actions generally in the MCR vs. fire-fighting actions in the vicinity of the fire

Task 12b: Post-Fire HRA Detailed Analysis
PSFs and Fire Effects to Consider

Guidance focuses on identification of fire-relevant performance shaping factors (PSFs) and potential interactions among the PSFs (fire conditions could make PSFs different than those for internal events):

- Available staffing resources
- Applicability and suitability of training/experience
- Suitability of relevant procedures and administrative controls
- Availability and clarity of instrumentation

more…

Task 12b: Post-Fire HRA Detailed Analysis
PSFs and Fire Effects to Consider

- Time available and needed to complete action, including impact of concurrent and competing activities
- Environment in which action is to be performed
- Accessibility and operability of equipment
- Need for special tools and clothing
- Communications
- Team/crew dynamics and crew characteristics
- Special fitness needs

Task 12b: Post-Fire HRA Detailed Analysis
MCR Abandonment

It is important to consider as part of the PSF evaluations:

- Procedural/training approach and explicitness/clarity of criteria for abandoning MCR
- Potential confusion about need to evacuate MCR
- Potential impact of crew reluctance to abandon MCR
- Timeliness of decision and problems associated with delays in abandoning MCR

Task 12b: Post-Fire HRA Detailed Analysis
MCR Abandonment (continued)

It is important to consider as part of the PSF evaluations:

- Inappropriate abandonment of MCR (e.g., premature or less viable option)
- Effects of crew no longer having access to complete MCR indications and the information they provide
- Number and complexity of actions to shift control and carry out subsequent activities
- Number of different locations to be visited

Task 12b: Post-Fire HRA Detailed Analysis
MCR Abandonment (continued)

It is important to consider as part of the PSF evaluations:

- Extent to which multiple actions need to be coordinated or sequentially performed
- Ability to communicate between different locations
- Need to wear breathing apparatus or special clothing
- Adequacy of human-machine interface at remote shutdown and local panels

Task 12b: Post-Fire HRA Detailed Analysis
Cases Where Little or No Credit Should be Allowed

- Tasks needing significant interaction/communication between individuals wearing SCBAs unless can be justified as not a problem
- Fire causes numerous spurious actuations (or stops) and affects reliability of multiple instruments
- Actions performed in fire areas or requiring travel through fire areas
- Actions requiring use of damaged equipment
- Actions without procedural direction or training, lacking necessary tools, or with inadequate time available

Task 12b: Post-Fire HRA Detailed Analysis
Documentation

Product of this task is a calculation package, which should contain (per ASME PRA Std.):

- All human actions and HFEs considered, including descriptions in context of fire scenarios
- Quantification approach (screening or best estimate) and method/tools used
- HEP results and bases for HEP calculations, including dependencies, PSFs, and uncertainty
- Important sensitivities

EPRI/NRC-RES FIRE PRA METHODOLOGY

Module II-16: Task 10 - Circuit Failure Mode Likelihood Analysis

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Joint RES/EPRI Fire PRA Workshop

May 24-26, 2006

Rockville, MD

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Purpose & Scope

The Circuit Failure Mode Likelihood Analysis Task is Intended to:

- Establish First-Order Probability Estimates for the Circuit Failure Modes of Interest

AND

- Correlate Those Failure Mode Probabilities to Specific Components

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Introduction (1)

- Probabilistic Based Analysis
- Two Methods Presented
  - Expert Panel Results (Look-Up Tables)
  - Computation-Based Analysis (Formulas)
- Requires Knowledge About Circuit Design, Cable Type and Construction, Installed Configuration, and Component Attributes
- Generally Reserved for Only Those Cases that Cannot be Resolved Through Other Means

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Introduction (2)

- Caveats:
  - Our Knowledge is Greatly Improved but Uncertainties are Still High
    - Very limited data for many issues
  - For This Reason, Implementing Guidance is Conservative
  - Practical Implementation is Challenging
  - Further Analysis of Existing Test Data and Follow-On Tests Would be Beneficial:
    - Reduce Uncertainties, including conservatisms as appropriate
    - Solidify Key Influence Factors
    - Incorporate Time as a Factor
    - Incorporate “End-Device” Functional Attributes and States (e.g., latching circuits vs. drop-out design)
- Probabilities of sufficient quality to move ahead

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Introduction (3)

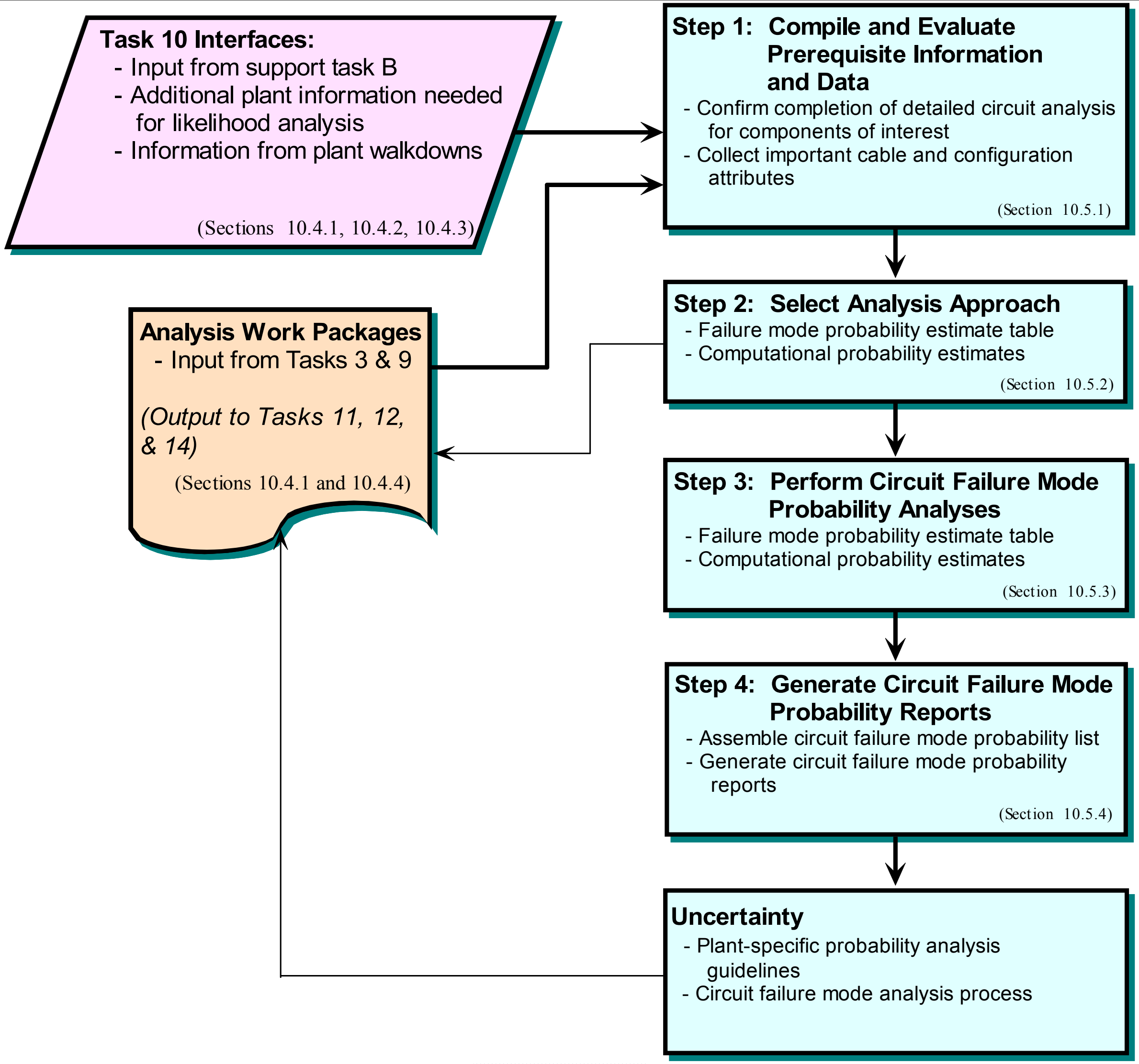
- Public and Peer Review Comments
  - Several Questions Involving Interpretation of the EPRI Test Data Lead to Extensive Discussions Regarding the Most Appropriate Way to Tally Spurious Actuation Probabilities (Many Subtleties for Implementation)
  - Team's Consensus is that Expert Panel Values are, in General, somewhat Conservative
  - Additional Independent Review of the Computational Method was Solicited as a Result of Peer and Public Comments
    - Review was Favorable, However the Team Acknowledges the Inevitable Limitations With a "Version 1.0" Release
  - Task 10 Examples Include Only Spurious Operation Failure Modes

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Assumptions

The Following Assumptions Form the Basis for Task 10:

- Specific Cable/Circuit Configuration Attributes are Available or Can Be Determined
- The Equipment is in Its Normal Position or Operating Condition at the Onset of the Fire
- Users of This Procedure are Knowledgeable and Have Experience with Circuit Design and Analysis Methods and Probability Estimating Techniques
- This Analysis Method is Applied to Cables with No More than 15 Conductors

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Flowchart



CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Task Interfaces - Inputs

- Fire PRA Cable List (Task 3)
- Fire PRA Database (Support Task B)
- Results of Detailed Circuit Failure Analysis (Task 9)
- Specific Scenarios Identifying Affected Cables (Tasks 11 & 14)
- Cable & Circuit Configuration Attributes
- Plant Drawings

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Task Interfaces - Outputs

- Quantification of Fire Risk (Task 14)
- Post-Fire HRA (Task 12)
- Detailed Fire Scenario Quantification (Task 11)
- Circuit Failure Mode Probability Reports
- Component Work Packages (Finalized)
- Fire PRA Database & Model

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Step 1 - Compile Prerequisite Information

Ensure that Prerequisite Information and Data is Available and Usable before Beginning the Analyses.

- Confirm Completion of Detailed Circuit Analysis for Components of Interest
- Collect Important Cable and Configuration Attributes
  - Insulation
  - Number of Conductors
  - Raceway Types
  - Power Source(s)
  - Number of Source & Target Conductors (for Option #2 Only)

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Step 2 - Select Analysis Approach

Decide Which Analysis Option is Best Suited for Conducting the Evaluation.

1. Failure Mode Probability Estimate Tables
   - Grounded Circuit Design
   - Non-Complex Control Circuit
   - Single Component Service
   - Cable Configuration Matches Table Categories
   - Principal Failure Mode of Concern is Spurious Actuation
2. Computational Probability Estimate Formulas
   - Ungrounded or Resistance-Grounded Circuit Design
   - Complex Circuit or Component
   - Failure Potentially Affects Multiple Components
   - Cable Configuration Not Easily Categorized in Tables

Step 3 - Estimate Circuit Failure Mode Probabilities

Estimate Circuit Failure Mode Probabilities Employing the Selected Method

Option #1: Failure Mode Probability Estimate Tables

- Table 10-1, Thermoset Cables with CPTs
- Table 10-2, Thermoset Cables without CPTs
- Table 10-3, Thermoplastic Cables with CPTs
- Table 10-4, Thermoplastic Cables without CPTs
- Table 10-5, Armored or Shielded Cables

Option #2: Computational Probability Estimate Formulas

$$P_{CC} = (C_{Tot} - C_G) / [(C_{Tot} - C_G) + (2 \times C_G) + n]$$

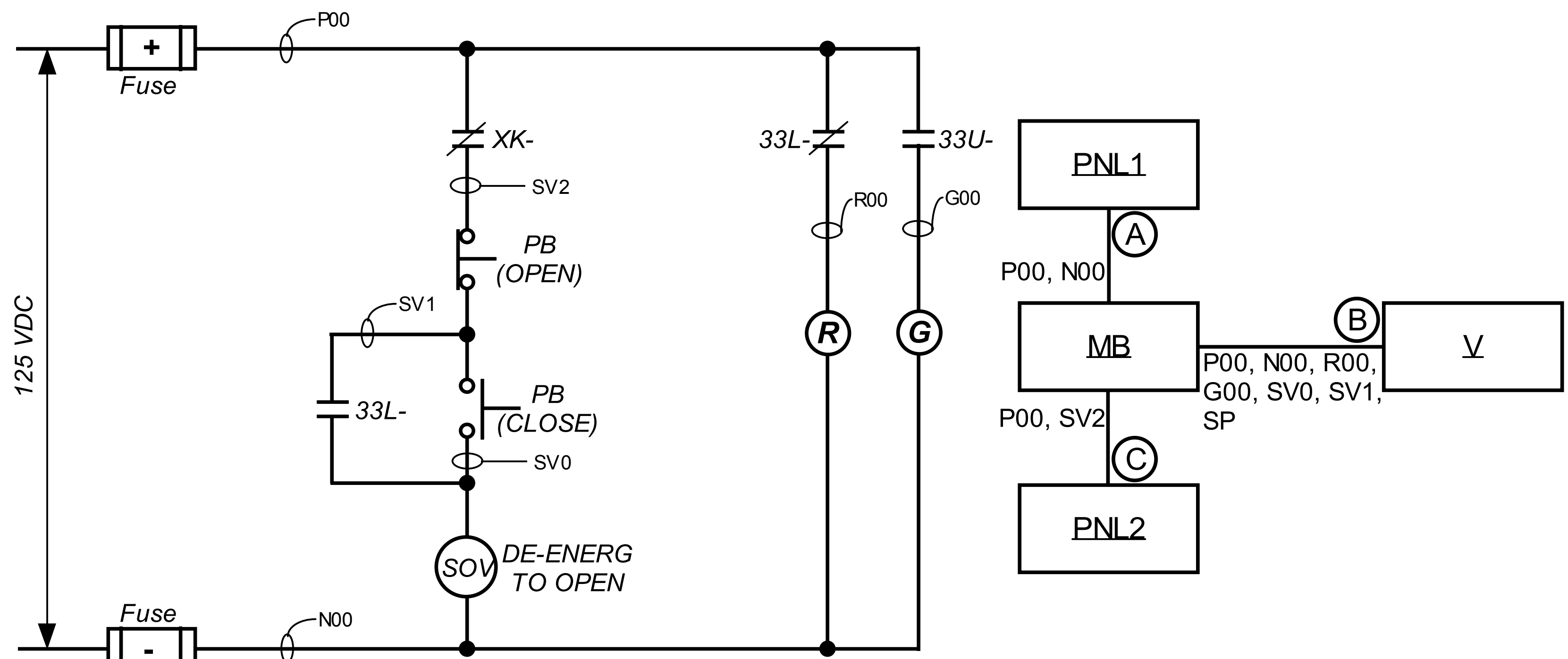
$$CF = \{C_T \times [C_S + (0.5 / C_{Tot})]\} / C_{Tot}$$

$$P_{FM} = CF \times P_{CC}$$

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Step 4 - Generate Failure Mode Probability Reports

- Enter Results into Fire PRA Database
- Generate Circuit Failure Mode Probability Reports
  - Listing the Probability Estimates for the Circuit Failure Modes of Concern for Each Component of Interest by Plant Area (Compartment, Fire Area, Fire Zone, etc.)

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Example - Typical SOV Control Circuit



Valve Shown in Open Position

NEXT QUESTION: What is the *probability* that damage to Cable B will result in spurious closure of the SOV?

See next slide →

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Example – Step 1: Prerequisite Information

- Detailed circuit analysis completed & documented? ***Yes***

Answers to Previous Example:

Cable	+125 VDC Hot Probe	-125 VDC Hot Probe
A	LOC	LOC
B	LOC, EI, SO - Close	LOC
C	NC	LOC

- Collect important cable and configuration data:
  - Cable insulation? ***Thermoset***
  - Number of conductors? ***Seven***
  - Raceway type? ***Tray***
  - Power source? ***Ungrounded DC bus (no CPT)***
  - Number of source & target conductors? ***3 sources, 1 target***

See next slide→

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Example – Step 2: Select Analysis Approach

- Option #1: Failure Mode Probability Tables
  - Grounded circuit design? ***No***
  - Control circuit cable? ***Yes***
  - Single component circuit? ***Yes***
  - Known cable configuration? ***Yes***
  - Spurious operation concern? ***Yes***
- Option #2: Computational Probability Estimate
  - Ungrounded circuit? ***Yes***
  - Complex circuit/component? ***No***
  - Multiple component circuit? ***No***
  - Cable configuration not categorized? ***No***

For this example, we'll show both methods

See next slide →

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Example – Step 3: Perform Analysis (1)

- Option #1:
  - Which Table to Use? ***Table 10-2, Thermoset Cable without CPT***

Raceway Type	Description of Hot Short	Best Estimate	High Confidence Range
Tray	M/C Intra-cable 1/C Inter-cable M/C → 1/C Inter-cable M/C → M/C Inter-cable	0.60 0.40 0.20 0.02 – 0.1	0.20 – 1.0 0.1 – 0.60 0.1 – 0.40
Conduit	M/C Intra-cable 1/C Inter-cable M/C → 1/C Inter-cable M/C → M/C Inter-cable	0.15 0.1 0.05 0.01 – 0.02	0.05 – 0.25 0.025 – 0.15 0.025 – 0.1

  - Probability Estimate, **P** = 0.66 (0.60 + 0.06)

See next slide →

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS

Example – Step 3: Perform Analysis (2)

- Option #2:
  - Calculate probability of a conductor-to-conductor short:

$$P_{CC} = (C_{Tot} – C_G) / [(C_{Tot} – C_G) + (2 * C_G)]$$

$$P_{CC} = (7 – 1) / [(7 – 1) + (2 * 1)]$$

$$P_{CC} = 6 / [6 + 2]$$

$$P_{CC} = 0.75$$

  - Determine cable configuration factor:

$$CF_{SO} = \{C_T * [C_S + (0.5 / C_{Tot})]\} / C_{Tot}$$

$$CF_{SO} = \{1 * [3 + (0.5 / 7)]\} / 7$$

$$CF_{SO} = 3.071 / 7$$

$$CF_{SO} = 0.44$$

  - Probability of spurious operation, $\mathbf{P}_{SO}$ = 0.75 * 0.44 = <u>0.33</u>

CIRCUIT FAILURE MODE LIKELIHOOD ANALYSIS
Example – Step 4: Failure Mode Probability Report

Failure Code	Estimated Probability (Calculated)	Estimated Probability (From Table 10-2)
SO (Closed)	0.33	0.66

EPRI/NRC-RES FIRE PRA METHODOLOGY

Module II-17: Task 13, Seismic Fire Interactions

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Joint RES/EPRI Fire PRA Workshop

May 24-26, 2006

Rockville, MD

Module 17: Seismic Fire Interactions
Scope of this Module

- Module 17 covers the Seismic Fire Interactions review
  - You will find that little has changed compared to the guidance available in the IPEEE days
  - The review remains a qualitative, walk-down based approach to identify and address potential vulnerabilities or weaknesses
  - The procedure does not recommend any quantitative work in this area

<u>The main goal of the outlined methodology is to verify that the the risk associated with seismically induced fires is low.</u>

Module 17: Seismic Fire Interactions
Seismically Induced Fires

A severe seismic event may cause fires inside or outside an NPP by damaging . . .

- Pipes and storage tanks containing flammable liquids or gases
- Electrical equipment

An EPRI study and NPPs experiencing earthquakes have demonstrated that these events are rare.

Module 17: Seismic Fire Interactions
Background

- Seismic Fire Interactions originated with the Fire Risk Scoping Study (NUREG/CR-5088, 1989)
- The conclusion of that study was:

  "It would appear that this is an issue which is more easily corrected than quantified. A series of simple steps was outlined which if implemented on a plant specific basis would significantly reduce the potential impact of such considerations."

  This conclusion remains valid today.

Module 17: Seismic Fire Interactions
Key Compartments

- The review should focus on those compartments that house equipment and cables needed to support post-seismic safe shutdown
  - Review your seismic-related procedures and identify key equipment (components and cables) and any required manual actions
  - To the extent possible, map equipment to compartments
  - Identify the associated compartments and focus efforts on these compartments
    - Areas/compartments housing the key equipment (components and cables)
    - Areas were a manual action takes place
    - Access paths for manual actions

Module 17: Seismic Fire Interactions
Seismically-Induced Fires

- Potential sources:
  - Unanchored electrical equipment such as where motion during seismic event might cause a fire
  - Unanchored gas cylinders
  - Flammable gas piping
  - Flammable liquid piping or storage tanks
- If any *significant* sources are identified, consider potential plant modifications to minimize potential hazard

Module 17: Seismic Fire Interactions
Degradation of FP Systems and Features

- Review:
  - General plant practice related to seismic restraints for fire protection systems and features
  - Installed systems and features and assess potential for seismic-induced failure
- Assess potential significance of system or feature failure to post-seismic event operations
- If any potential vulnerabilities are identified, consider fixes to reduce likelihood of failure

Module 17: Seismic Fire Interactions
Spurious Detection Signals

- A seismic event will likely trigger activation of various fire detection systems – especially smoke detectors
- Consider how the operators will respond to multiple fire detection signals
  - You can't ignore them even though many may be false
  - Have you identified the issue in your response procedures?
  - Have you (can you) prioritize your response based on the important compartments?
- Consider potential procedural enhancements to recognize and deal with this issue

Module 17: Seismic Fire Interactions
Spurious Suppression Actuation/Release

- Review the fixed fire protection systems in key areas for the potential that they might spuriously operate
  - Got any of those mercury switches left?
  - How about a non-seismic deluge valve?
  - What happens if a sprinkler head is damaged or a pipe breaks?
  - Are storage tanks for gaseous suppressants seismically robust?
- If any potential vulnerabilities are identified, consider fixes to reduce likelihood of spurious suppressant release

Module 17: Seismic Fire Interactions
Manual Fire Fighting

- Access pathways to key areas – could something block the path and are there alternative paths?
- Required fire fighting assets – will assets remain available after an earthquake
  - Especially fire water system and fire hoses
- Do post-seismic response procedures allow for manual fire fighting needs and responsibilities
- If any potential vulnerabilities are identified, consider fixes

Module 17: Seismic Fire Interactions
Summary

- Seismic fire interaction is considered a low risk phenomena
- NPP and other industry experiences partly verify this premise
- A qualitative approach is suggested for verifying that plant specific conditions confirm low risk notion
- Systemic or procedural upgrades are recommended for identified potential vulnerabilities

Module 17: Special Models Part 2
End of Module

- Questions?
- Comments?
- Discussion?

EPRI/NRC-RES FIRE PRA METHODOLOGY

Module II-18: Task 14 - Fire Risk Quantification

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Joint RES/EPRI Fire PRA Workshop

May 24-26, 2006

Rockville, MD

Fire Risk Quantification
Scope of this Module

Module II-18 covers one task:

- Task 14: Fire Risk Quantification
  - Obtaining best-estimate quantification of fire risk

Task 14: Fire Risk Quantification
General Objectives

Purpose: obtain 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) separately from this best –estimate calculation, but 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

* and identify significant contributors

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
- Quantification is to be done in conformance with relevant ASME PRA Standard requirements and supporting requirements (especially sections 4.5.8 and 4.5.9)

EPRI/NRC-RES FIRE PRA METHODOLOGY

Module II-19: Task 15 - Uncertainty and Sensitivity Analysis

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Joint RES/EPRI Fire PRA Workshop

May 24-26, 2006

Rockville, MD

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

Uncertainty and Sensitivity Analysis
Scope of this Module

Module II-19 covers one task:

- Task 15: Uncertainty and Sensitivity Analysis
  - Without this, the risk results/perspectives are incomplete

Task 15:Uncertainty and Sensitivity Analysis
General Objectives & Inputs and Outputs

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

- Inputs from other tasks: identification of uncertainties from other tasks worthy of uncertainty/sensitivity analysis
- Outputs to other tasks: analysis results to be reflected in documentation of Fire PRA (Task 16)

Task 15:Uncertainty and Sensitivity Analysis

General Procedure

Addresses a process to be followed rather than a pre-defined list of uncertainties and sensitivity analyses, since these could be plant analysis 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 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 (note whether modeling or data uncertainty)

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

Step 2: Develop strategies for addressing uncertainties

- Appendix V to NUREG/CR-6850 provides 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: (see next slide)

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

- 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
  - Instructions to task analysts to perform the analyses

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

Step 4: Perform uncertainty and sensitivity analyses

- 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)
  - Uncertainty in each significant human error probability (Task 12)
  - Uncertainty in each sequence core damage and large early release 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 (see Appendix V)
- Sensitivity analyses (see Appendix V) should be performed where important to show robustness in results (i.e., demonstrate where results are not (or are) 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 in Appendix V

EPRI/NRC-RES FIRE PRA METHODOLOGY

Module II-20, Task 16, Fire PRA Documentation

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Joint RES/EPRI Public Workshop

May 24-26, 2006

Rockville, MD

FIRE PRA DOCUMENTATION
General Objectives

A general practice is provided for documenting the Fire PRA and its results.

- Adequate documentation to allow review
- Written basis for any future uses of Fire PRA
- Suggested organization
  - Main report
  - Supporting documents

FIRE PRA DOCUMENTATION
Table of Contents of Main Report

Executive Summary

I. Introduction

II. Methodology

III. Fire CDF

Data Sources Used,

Plant Partitioning and Compartment Definition,

Fire PRA Model,

Circuit Analysis,

Fire PRA Components and Fire Compartments,

Qualitative Screening,

Fire Ignition Frequency, and

etc.

FIRE PRA DOCUMENTATION
Fire PRA Supporting Documents

The details of each task may be recorded in stand-alone reports of documents.

- A comprehensive list of documents, files and data sources
- All calculations and relevant notes
- Walkdown notes, sketches, marked drawings and photographs
- Provide the minimal cut set for the CDF and LERF in terms of:
  - Compartments
  - Fire scenarios
  - Ignition sources
- Should facilitate future uses and possible changes to the Fire PRA
- Completeness and easy to navigate through

FIRE PRA DOCUMENTATION
Summary

Fire PRA documentation is critical to its usefulness and review.

- Completeness
- Well organized
- Amenable to changes
- Easy to navigate
- Easy to use and interpret

EPRI/NRC-RES FIRE PRA METHODOLOGY
Module III-1: Lessons Learned and Insights

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Joint RES/EPRI Fire PRA Workshop
May 24-26, 2006
Rockville, MD

Lessons Learned and Insights

Scope of this Module

- Intent here is to discuss some of the lessons learned from our own demonstration studies, and to provide the team's insights regarding methodology application
- There is a heavy dose of team judgment here
  - We cannot provide numerical results to back up some of our insights in particular
  - The judgments cited represent a consensus of the EPRI and NRC Technical Teams
- Focus is on the practitioner – what should you expect, where are the potential pitfalls, what's the bottom line

Lessons Learned and Insights
Our Demonstration Studies

- The procedures have been individually tested:
  - By our team at two PWR's
  - By one independent utility team
- A third team demonstration is currently underway at a BWR (2005/2006)
  - Should yield a complete full-scope analysis
- All the procedures worked, and seemed to be of reasonable depth, scope, and clarity to make implementation practical
- The procedures *have not yet been tested* top-to-bottom as a full, consolidated, and complete set
  - There could be some hidden surprises in store for us – and *you may be the one to find them*
  - Please pass your experience back to us – the procedures are intended to be "living documents" to at least some extent

Lessons Learned and Insights
Practical Applications: Component Selection

- Your fire PRA component list will almost certainly be larger than your Appendix R component list
  - You *will* want/need to consider things beyond Appendix R to get a realistic risk result
- Adding components does add to analysis burden and impact cable selection and tracing
  - You can easily end up with double the number of components compared to the Appendix R list
- Exercise judgment
  - Your choices *will* impact on resources required to complete study
  - Consider using the iterative options – go after bang for the buck, don't try to tackle everything in one big plant-sized bite

Lessons Learned and Insights
Practical Applications: Cable Selection

- Cable selection is probably the single biggest factor that will drive your resource requirements
  - The burden comes largely with the need to trace selected cables
  - You also need an *accessible* cable database, and constructing such a database from your existing system may not be so easy
  - This is going to depend a lot on the depth of your cable tracing and the nature of your current tracking system
- Exercise judgment
  - You may initially want to chase *all* your cables, but that may not be the best choice – you are taking on quite a job at most plants
  - Take advantage of the iterative approaches to cable tracing

Lessons Learned and Insights
Practical Applications: Circuit Analysis

- Circuit analysis need not be a huge burden
- Compared to cable tracing, circuit analysis should be far less resource intensive – although it does require participation of key personnel (the electrical guru)
- The procedure provides various approaches that have been drawn from past practice and experience
  - Make use of those options!
  - Go after the “bang for the buck” circuits and “take the hit” when it is not risk important

Lessons Learned and Insights
The Role of Your IPEEE Analysis

- Given the procedural changes, your IPEEE analysis may be of little help, even as a starting point
  - Some changes are substantial, but could be incorporated with some effort (e.g., fire frequency)
  - Other changes are more fundamental - you won't be able to simply change a few numbers and get a new answer, e.g.:
    - Component selection and circuit analysis – implications for Fire PRA model
    - Fire characterization and severity – a new way of looking at fires
- This depends to some extent on the approach used in the IPEEE, but…
- Even a full scope fire PRA of IPEEE vintage will need *substantial* updating
- You *can* likely benefit from the information gathering results
  - Plant features, partitioning, fire ignition sources, whatever cable and component mapping information you have

Lessons Learned and Insights
Pilot Studies – Our Experience Shows…

- Easy to get distracted, e.g.:
  - If you want to re-baseline Appendix R, do that first, then do your fire PRA – the objectives are *NOT* the same although the Fire PRA would benefit
- Be sure you get a team of the right people with the right knowledge to do the job, e.g.:
  - The PRA guru may think they know circuits, but you really need someone with a true electrical expertise

Lessons Learned and Insights

Pilot Studies – Our Experience Shows…

- Set a realistic timetable, but don't stretch the analysis too far out in time
  - Managers change
  - Corporate priorities change
  - Budgets change
- Best to get in, and get it done rather than letting these inevitable changes short circuit your Fire PRA in mid-stream

Lessons Learned and Insights
Looking Forward to the Bottom Line

- We don't expect the methods changes to result in industry-wide changes to the perception of fire risk
  - Fire Risk in the IPEEE Program:

    Fire-induced core damage frequencies range from 4E-8 to 2E-4/RxYr, with vast majority between 1E-6 and 1E-4/RxYr

    Fire contribution to the combined fire and internal events risk range from 1% to 90%
- However, plant-specific perspectives could be impacted by this method

Lessons Learned and Insights
Looking Forward to the Bottom Line (cont)

- Relative importance of fire scenarios, locations or fire protection systems/features
  - IPEEE Program:

    nearly 1 of every 3 studies, reported the risk associated with control room fires as the highest contributor to the fire risk with switchgear rooms a close second

- Plant specific insights and results may change *substantially*
  - Which plant areas are most important
    - You may well see shifts among your dominant areas
  - What types of scenarios are dominant
    - e.g., importance of high energy arcing faults will be plant specific
  - How much impact will the circuit analysis issues have on your risk estimates?

Lessons Learned and Insights
Limitations of the State-of-the-Art

- Our work identified some areas of limitation:
  - Number of combined fire-induced spurious operations
    - Team judgment is that current estimates for probability of spurious actuation remains conservative for most cases
  - Dynamic versus static modeling of fire damage and operator response
  - Limitations in Internal Events analysis that carry over to fire, e.g., model uncertainty
  - Multiple Fires, particularly those in multiple fire areas
  - Multiple Initiating Events from the same root cause
    - e.g., Fire and flood, or fire and earthquake (quantitatively)
  - Smoke Damage
  - Administrative Aspects of the Fire Protection Program
  - Effectiveness of Fire Protection Systems and Passive Fire Barriers
- It is not possible to know the exact impact but *where possible* we adjusted the approach to ensure that the risk is not under-predicted
  - Intent was not, however, to be intentionally conservative

Lessons Learned and Insights
Resource Estimates

- In the absence of a full test of the methodology, based on collective experience of the authors with the past and this method (demonstration studies)
  - Best estimate range: 4000 – 7000 hours
  - The lower end is based on a large number of positive factors in the quality of the plant analyses and the desired sophistication of the Fire PRA
  - The upper bound should be interpreted as an industry average
  - The largest source of uncertainty in the estimate of resources is for cable/circuit selection and routing and to a lesser extent the circuit failure modes analysis

Lessons Learned and Insights
End of Module

- Questions?
- Comments?
- Discussion?

EPRI/NRC-RES FIRE PRA METHODOLOGY
Module III-2: Perspective

Robert P. Kassawara - EPRI
J.S. Hyslop - RES

Joint RES/EPRI Fire PRA Workshop
May 24-26, 2006
Rockville, MD

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

ON THE REQUANTIFICATION PROJECT

- An important milestone in cooperation between RES and EPRI
- A consensus methodology for Fire PRA that can facilitate implementation of risk-informed fire protection
- Best available method to estimate fire risk & obtain insights
- Well received:
  – Industry; number of plants starting to use the method
  – NRR; reviewed the draft and provided comments which were addressed; document is identified (although not endorsed) in Draft RG-1139
  – ACRS; positive reaction from fire protection subcommittee and full committee
  – Internationally; used in part by one plant, currently being considered for use by another

CONTINUED COOPERATION

- We established a potential framework for future research cooperation
  - Quality of work and positive technical reviews pave the way for continued cooperation
  - Positive remarks on collaboration from specific members of the ACRS Subcommittee on Fire Protection
- The cooperation under the MOU is continuing
  - On-going fire model Verification & Validation. This is another critical piece to facilitate implementation of the risk-informed fire protection
  - Others…