Identification and Analysis of Multiple Spurious Component Operation In Support of a New License Basis under NFPA-805

Dennis Henneke – Duke Power

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ATTACHMENT 6

Outline

- Background
  - Proposed New License Basis
- General Method for Modeling Spurious Operation in the Fire PRA.
- Present SSA Component and Circuit Selection
- Present PRA Model Review
- Expert Panel Process

Outline

- Analysis Details:
  - Scope of the Fire PRA
  - Inclusion in the LB, without PRA
  - Use of Bounding Analysis
  - Use of Qualitative Screening
  - Use of Quantitative Screening
  - Timing Issues
  - Change Analysis of Multiple Spurious
- Peer Review for Multiple Spurious
- Conclusions

Purpose

- The purpose of this presentation will be to provide a overview of the methodology for the Fire PRA supporting the fire-induced multiple spurious operation analysis. This analysis will be used for a new risk-informed license basis (LB) for fire-induced spurious events.
  - The presentation will provide both overview and concepts, many of which are conceptual at this point.
  - The presentation in no way attempts to provide a complete discussion on all areas, and will not talk about all areas of the analysis.

Background

- ONS PRA (NSAC-60) completed in the early 1980s.
  - Fire PRA based on NUREG/CR-0654 (1979)
  - PRA Revised 3 major times, with the latest completed this year.
- New ONS Fire PRA started this summer:
  - Will use NUREG/CR-6850 (EPRI TR-1011989)
    - No full plant application performed to date
  - Contractor support: ERIN Engineering

Background

- The proposed new License Basis (LB) for multiple spurious is listed:
  - "The Safe Shutdown Analysis shall address all single spurious and all potentially risk-significant multiple spurious failures."
- Will need to review this against latest NRC RIS and Generic Letter:
  - Language above does not use "Any and all, one at a time," so should be OK.

Background

- Potentially risk-significant was initially defined as follows:
  - Risk is above Reg. Guide 1.174 criteria (CDF >1E-06, LERF > 1E-07), prior to operator response.
  - Defense-in-Depth (DID) or Safety Margins are inadequate per NEI Implementation Guide, prior to operator response.
- Some additional discussion on credited operator response will need to be provided.
  - For example, operator actions not associated with the spurious action may be OK to credit in the PRA.

Background

- New Multiple Spurious scenarios identified are considered outside the license basis, until they are determined to be potentially risk significant.
- Gray Area: Multiple Spurious Combinations that do not meet the "Potentially Risk Significant" Criteria, but have an estimated CDF risk > 1E-08/year (LERF > 1E-09/year), are treated as follows:
  - Design change or procedure change put in place, if possible
  - Procedural actions still meet feasibility criteria, but actions are not considered "required."

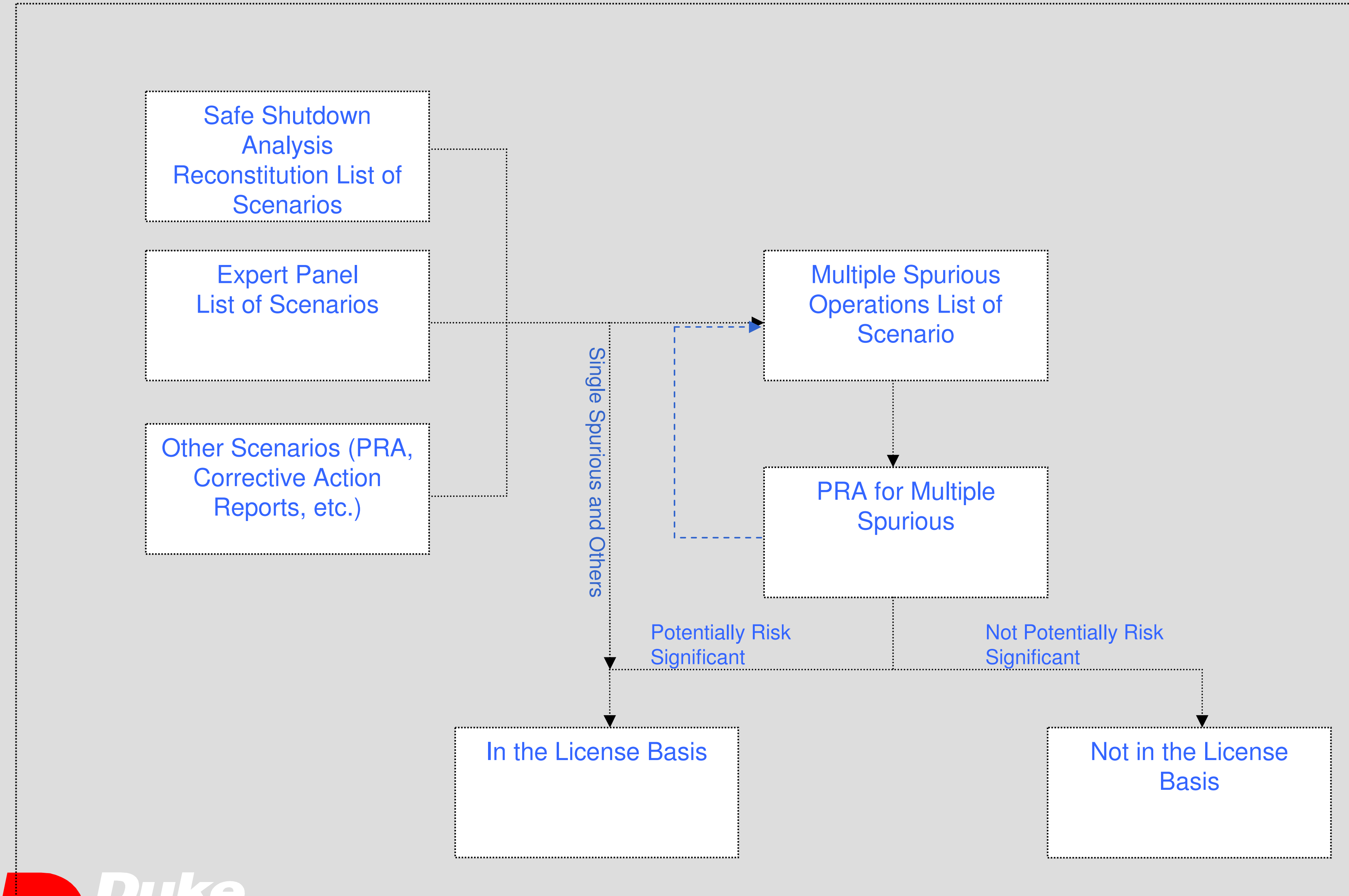
Change Versus Change

- Change Evaluation:
  - *A plant change evaluation shall be performed to ensure that a change to a previously approved fire protection program element is acceptable. The evaluation process shall consist of an integrated assessment of acceptability of risk, defense-in-depth, and safety margins. [NFPA 805, Section 2.4.4]*
- *Change Process: Alternative to 50.59 reviews. The NFPA 805 change process is an acceptable method of evaluating fire protection program changes (NEI 04-02, Section 1.3).*
- *Both are consistent within NEI 04-02. During this presentation we will refer to the Risk-Informed Change Evaluation.*

General Method for Modeling Spurious Operation in the PRA

- Three general inputs (each discussed in detail):
  - Fire Safe Shutdown Reconstitution components and scenarios
  - Present PRA modeling, including scenarios and components
  - Expert Panel Input

Dispositioning of Multiple Spurious



Reconstitution Input

- Harry Barrett to Review Reconstitution Effort.

Reconstitution Input

- Note: Although the Appendix R analysis may identify a single spurious, the PRA will combine all spurious operations into multiples when the PRA logic results in a valid combination causing a core damage sequence.
  - For example, the Appendix R program may include a PORV spurious opening, and resolve this by closing the Block Valve. However, the PRA will look at spurious opening of the PORV and Block (or failure of the block prior to operator action).

Reconstitution Input

- The following issues were identified as a result of the Appendix R reconstitution.
  - Spurious Pump Starts:
    - HPI Pumps
    - LPI Pumps
    - Condensate Booster Pumps
    - Main Feedwater Pumps
    - EFW Pumps
    - BS Pumps
    - RCPs
  - Spurious ES Actuation
  - Spurious Pressurizer Heater Operation
  - Spurious Valve Operations (~25 new per unit)

Reconstitution Input

- Let's look at HPI Pump Start:
  - Starting of the HPI C pump results in direct injection to the vessel.
  - Accident Scenarios associated with spurious injection are numerous:
    - PORV Fails Open, Block Open, results in a LOCA
    - PORV or Block fail closed, eventual water relief through the Pressurizer Safety – LOCA
    - Eventually, BWST inventory fills containment, fails SSF Makeup pump due to flooding.
    - Etc.
- Result: PRA review expands single spurious operation into multiple scenarios.

Current PRA Effort

- The Present PRA models a number of component spurious operations. Fire-induced failure of each will be reviewed:
  - All MOV (>100), AOV (33) and SOV (15) spurious operations will be modeled.
  - Other spurious operations (>400) will be reviewed to see if they are within the above scope or if they result in component failures, also already modeled (e.g., pump fails to operate).

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Currently Modeled Events

- AVT: Air Operated Valves Transfer Position
- C4T: 4kV AC Circuit Breakers Transfer Position
- CDT: DC Circuit Breaker Transfers Position
- CHT: High Voltage PCB 200 to 300 kV Transfers Position
- CLT: Low Voltage Circuit Breaker Transfers Position
- CTT: Circuit Breaker Auxiliary Contact Spurious Operation
- DMT: Damper Spurious Operation
- MVT: Motor Operated Valve Transfers Position
- PDF: Pushbutton Spuriously Closes
- PST: Pressure Switch Spurious Operation
- PTK: Pressure Transmitter Output Fails High
- RGT: Self Regulating Valve Spurious Operation
- RTK: Resistance Temperature Detector Output Fails High
- RYT: Relay Spurious Operation
- SVT: Solenoid Valve Transfers Position
- SWT: Control Switch Spurious Operation
- TVT: Temperature Control Valve Spurious Operation

EPRI TR-1011989 NUREG/CR-6850

- Method involves the identification of:
  - Fire-induced initiating events, including those not modeled in the Level 1 PRA (2.5.3)
  - Equipment with the potential for spurious actuation for failing Safe Shutdown Equipment (2.5.4):
    - Including new accident sequences not previously modeled.
  - Additional Mitigating, Instrumentation and Diagnostic equipment important to Human Response (2.5.5).
- Care will be taken in the application of this new methodology to ensure full implementation.

ONS Initiating Events

- The following Initiating Events will be reviewed for Fire-induced failures causing each:
  - ISLOCA
  - PORV Fails to Reseat after spuriously opening.
  - Reactor Coolant Pump Seal LOCA
  - 1 or More Safety Valves Fail to Reseat (See HPI discussion above).
  - Excessive Feedwater
  - Spurious Engineered Safeguards (ES)
  - Typical Fire PRA Events (LOP, Loss of FW, etc).

ONS Initiating Events

- Screened Initiating events will need to be reviewed to determine if any can become more important as a result of Fire-Induced Spurious Operation. For example:
  - Initiating Event is more likely than Level I PRA estimate.
  - Consequences are worse
  - Accident sequences change

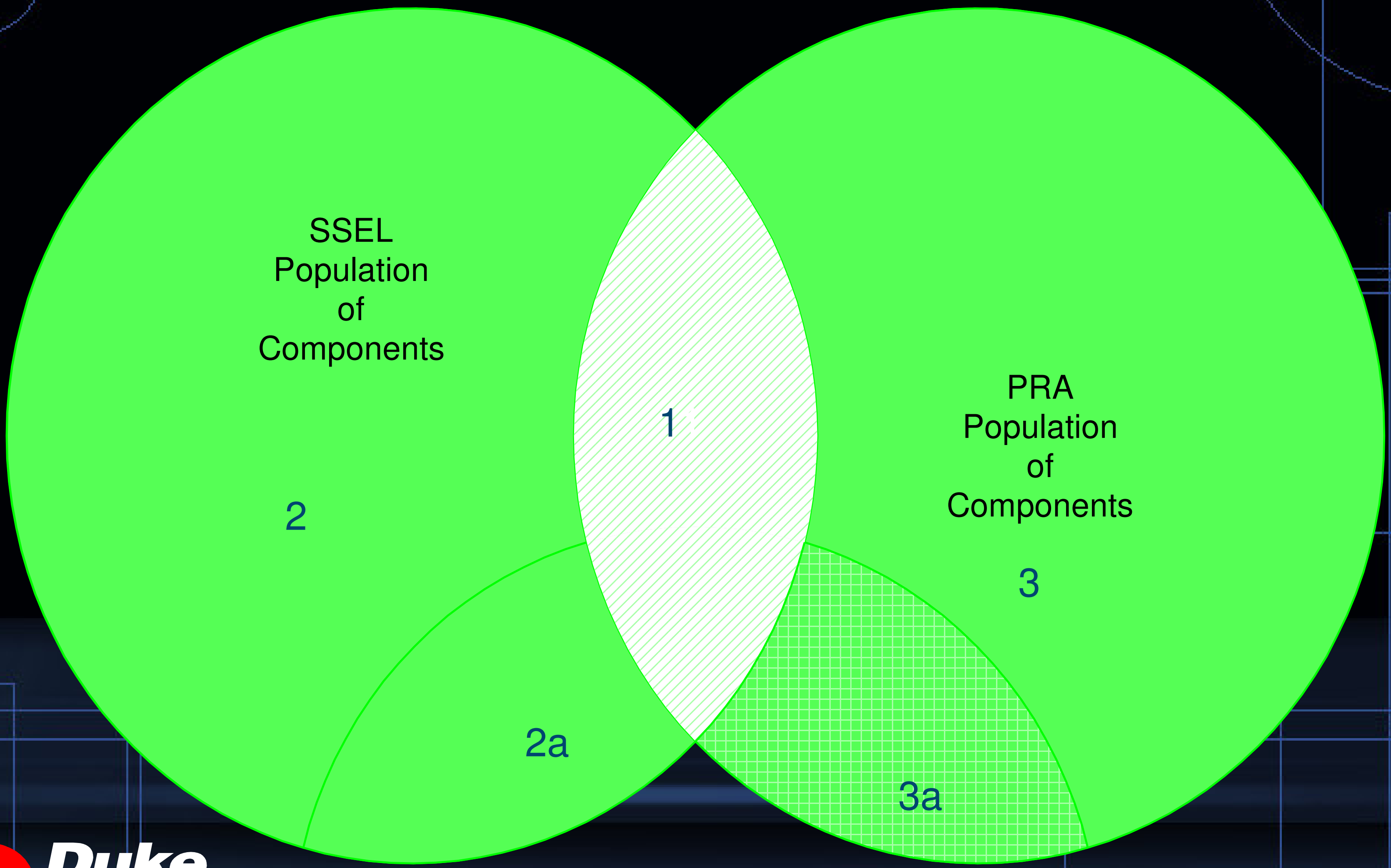
Interfacing Systems LOCA (ISLOCA)

- ISLOCA was reviewed for this presentation:
  - Base analysis includes no spurious operation of MOVs, AOVs or SOVs (dominated by check valve failures and ruptures).
  - Previously screened scenarios will need to be reviewed for the potential for increased importance as a result of fire-induced spurious operation.

ISLOCA

- The following are screened scenarios:
  - *HPI System, injection to loop A*
  - *HPI System, injection to loop B*
  - *HPI System, RCP seal injection*
  - *HPI System, RCP seal return*
  - *HPI System, auxiliary pressurizer spray*
  - *LPI System, auxiliary pressurizer spray*
  - *CA System, pressurizer sample*
  - *CA System, post accident RCS sample*

PRA Versus SSA



PRA versus SSA

- Area 1: A large percentage of SSA Components should be in the PRA. Affect of fire on the PRA is modeled directly through a component to basic event mapping (complete).
  – Spurious Operation is initially assumed in the PRA, unless the SSA says it can not happen.

PRA versus SSA

- Area 2: SSA Components not modeled in the PRA will be reviewed to determine why it is not in the PRA:
  - Cold Shutdown
  - Supports a PRA component
    - May need to add to PRA mapping (Area 2a: Moves components into area 1).
  - Operator Actions: Review of effect on Operator actions is required by NUREG/CR-6850.

PRA versus SSA

- Area 3: PRA Components not in the SSA will need to be treated in one of several ways:
  - PRA component is not in sequences that are fire-induced (SG Tube Rupture). Nothing required.
  - Assumed to Fail for all fires (spurious included).
  - Assumed routing per NUREG/CR-6850 rules.
  - Perform Cable Routing (Area 3a):
    - Likely for important PRA components.
    - May need to iterate, once detailed scenario analysis is performed.
    - May end up moving important 3a components into area 1 by adding them to the SSA SSEL.

Containment Isolation

- Existing LERF Model will be treated as above:
  - It is likely many Isolation valves will not be traced in the SSA.
- Review of screened containment isolation paths will be performed to see if any can become more important as a result of fire-induced failures.

Expert Panel Elicitation

- An Expert Panel review for new spurious actuation combinations will be performed as a part of this project:
  - Uses NEI 00-01 Appendix F methodology.
  - Scope of scenarios includes NEI 04-02, Appendix A issues (see below).
- Expert Panel has met once to test the method:
  - Identified a combination of concern involving failure of injection and cooling to 1 RCP.

Expert Panel Elicitation

- *The expert panel process is based on diverse review of the Safe Shutdown Functions.*
- *Each expert panel meeting will review/discuss one of the Safe Shutdown Functions (note, it may be necessary to limit the discussion to one or more fire zones or areas for one Safe Shutdown function).*
  - *For that Safe Shutdown Function, the panel will identify possible failure mechanism*
  - *Using various tools, identify "Choke Points" that could defeat safe shutdown through the previously identified failure mechanisms*
    - *Flow Diagrams*
    - *Safe Shutdown Logic Diagrams*
    - *PRA Event Sequence Diagrams*
  - *The panel will build these "Choke Points" into fire scenarios to be investigated*

Expert Panel Elicitation

- *Safe Shutdown Functions*
  - *Reactivity Control*
  - *Decay Heat Removal*
  - *Reactor Coolant*
    - *Inventory Control*
    - *Pressure Control*
  - *Process Monitoring*
  - *Support Functions*
- *Safe Shutdown Failure Mechanisms to be considered*
  - *Loss of Reactivity Control*
  - *Loss of Reactor Coolant System (RCS) Inventory*
  - *Excessive RCS Injection*
  - *Loss of RCS Pressure Control*
  - *RCS Overcooling*
  - *Loss of Steam Generator Cooling*

Expert Panel Elicitation

- *Safe Shutdown Failure Scenarios*
  - *Loss of Reactivity Control*
    - *Boron Dilution*
  - *Loss of RCS Inventory*
    - *Reactor Coolant Pump Seal LOCA*
    - *Stuck Open Pressurizer Safety Valve*
    - *Spurious Opening of Head/High Point Vents*
    - *Failure of RCMUP due to RB Flooding (ONS)*
    - *Spurious Opening of Letdown Line*
    - *Loss of Electrical Power*
  - *Excessive RCS Injection*
    - *Spurious HPI/NI injection beyond letdown with failure of Pressurizer Safety Valve open*

Expert Panel Elicitation

- *Safe Shutdown Failure Scenarios (Continued)*
  - *Loss of RCS Pressure Control*
    - *Spurious Auxiliary Pressurizer Spray*
    - *Spurious Pressurizer Heater Actuation*
    - *Spurious Start of RCP with subsequent pump heat*
    - *Spurious Start of RCP with spurious normal pressurizer spray*
  - *RCS Overcooling*
    - *Excessive Feedwater Flow*
      - *Spurious EFW actuation with spurious EFW Control Valve opening*
      - *Failure to trip/isolate Main Feedwater/Hotwell/Booster Pumps*
    - *Excessive Steam Flow*
      - *Spurious Turbine Bypass Valve actuation*
      - *Failure to Isolate SSRH with loss of Instrument Air*
  - *Loss of Steam Generator Cooling*
    - *Spurious isolation of ASW/FDW flow path*
    - *Loss of Electrical Power*

Analysis Methodology

- Let's look at a few areas of concern for the Fire PRA:
  - Scope of the Analysis for Multiple Spurious.
  - Including Scenarios in the LB, without PRA support.
  - Use of Bounding Analysis, Qualitative Screening, and Quantitative Screening.
  - Timing issues in the PRA.
  - Change Analysis for Multiple Spurious.
  - How Duke will be including spurious events in the PRA.

Analysis Methodology

- Scope of the Analysis for Multiple Spurious: It is expected that not all spurious actuation sequences will be analyzed in detail, due to the overwhelming number of possible sequences:
  - Cable Room: 129 cabinet sections, 1E-02/year fire frequency, damaging fire at 3E-04/year (roughly).
  - With a 0.2 spurious operation probability, CDF for a given 2-spurious sequences is 1.2E-05.
  - Let's guess at 150 combinations/sequences in the Cable Room (not including the events already in the PRA)
  - Can not trace cables in detail for all 150 sequences, and perform fire modeling for all 129 cabinets.
  - Need some sort of method to limit the detailed analysis performed. Let's look at some options.

Analysis Methodology

- Inclusion of the Combination in the LB, without inclusion in the PRA:
  - Can do this if:
    - The PRA results for these combinations will likely be low
    - Accuracy of the PRA not affected.
  - Will likely not use this very often, since low risk scenarios can be screened out of the LB
    - If DID fails, but risk is low, may use.

Analysis Methodology

- Use of Bounding Analysis:
  - NEI 00-01 talks about development of bounding scenarios for groups of component failures.
  - NEI 00-01 pilot analysis showed bounding Analysis can not be used when the analyzed scenario is shown to be low risk as a result of scenario specific attributes:
    - 2 Cables in a scenario don’t travel near each other.

Analysis Methodology

- Bounding Analysis should be limited to:
  - Scenarios where the bounded scenario includes all components in the analyzed scenario, or
  - Fire Damage Aspects are applicable to all scenarios. For example:
    - Low Fire Frequency,
    - Automatic Suppression and Detection,
    - All cables are assumed to be in the most conservative location (lowest tray), etc.

Analysis Methodology

- Qualitative Screening of multiple spurious combinations can be performed using methodology described in NEI 04-06. In general, qualitative screening will be limited to:
  - Those scenarios that can be demonstrated with certainty to be low risk, and
  - Those scenarios not easily analyzed in the Fire PRA (e.g., if the PRA already includes the accident scenario, then the first attempt would be to quantitatively analyze the scenario).

Analysis Methodology

- Quantitative Screening may be used for a large number of scenarios, where the following can be demonstrated:
  – The CDF and LERF risk is well below the Reg. Guide 1.174 criteria, and
  – Additional scenario development, modeling and recovery would lower the risk further.
- Quantitative Screening will be consistent with NEI 00-01 guidance.

Analysis Methodology

- Timing is not addressed well in deterministic space, but can be addressed in the PRA in a number of ways:
  - Time to damage (unique for each scenario)
  - Differences between time to damage for multiple targets.
  - Time for operator response.
  - Time to Core Uncovery/damage
  - Time available for AOVs, SOVs to return to its failed Safe Position.

Analysis Methodology

- Let's look at an example:
  – NEI 00-01 pilot at MNS identified a scenario where the RWST valve could be failed as-is, prior to an HPI pump start (injection signal).
  – Cables for the RWST valves were in cable trays above Injection signal cables, and would be damaged last.
  – Hot Gas Layer failure would not occur
  – Therefore, RWST valves would open prior to damage, and the scenario is shown to be low risk.

Analysis Methodology

- Let's look at another example:
  - VCT Outlet valve scenario is included in the SSA, but operator credit for opening the suction to the RWST is taken.
  - PRA shows VCT outlet valve cable will be damaged early in a scenario, and time for the operator response is insufficient to save the pump from damage.
  - If the opposite pump is running, and the fire damage spreads, both trains of injection would be failed.
  - PRA would show SSA action would not be OK, from a DID aspect.

Change Analysis for Multiple Spurious

- Because of the criteria (Reg. Guide 1.174) used to determine the component combinations within the Multiple Spurious LB, the change analysis under NFPA-805 is unique.
- Let's look at 3 areas of concern:
  – Single Spurious
  – Multiples in the LB
  – Multiples non in the LB

Change Analysis for Multiple Spurious

- Single Spurious (all within the LB) can be analyzed using change analysis.
  - The analysis would need to show the risk is acceptable (less than Reg. Guide 1.174 guidelines), and DID is acceptable.
  - For single spurious, DID needs to be carefully reviewed to since the single spurious failure of a safe shutdown function represents less than optimal DID for protection of the core.
    - Single spurious that do not affect core damage can easily be shown to be acceptable.

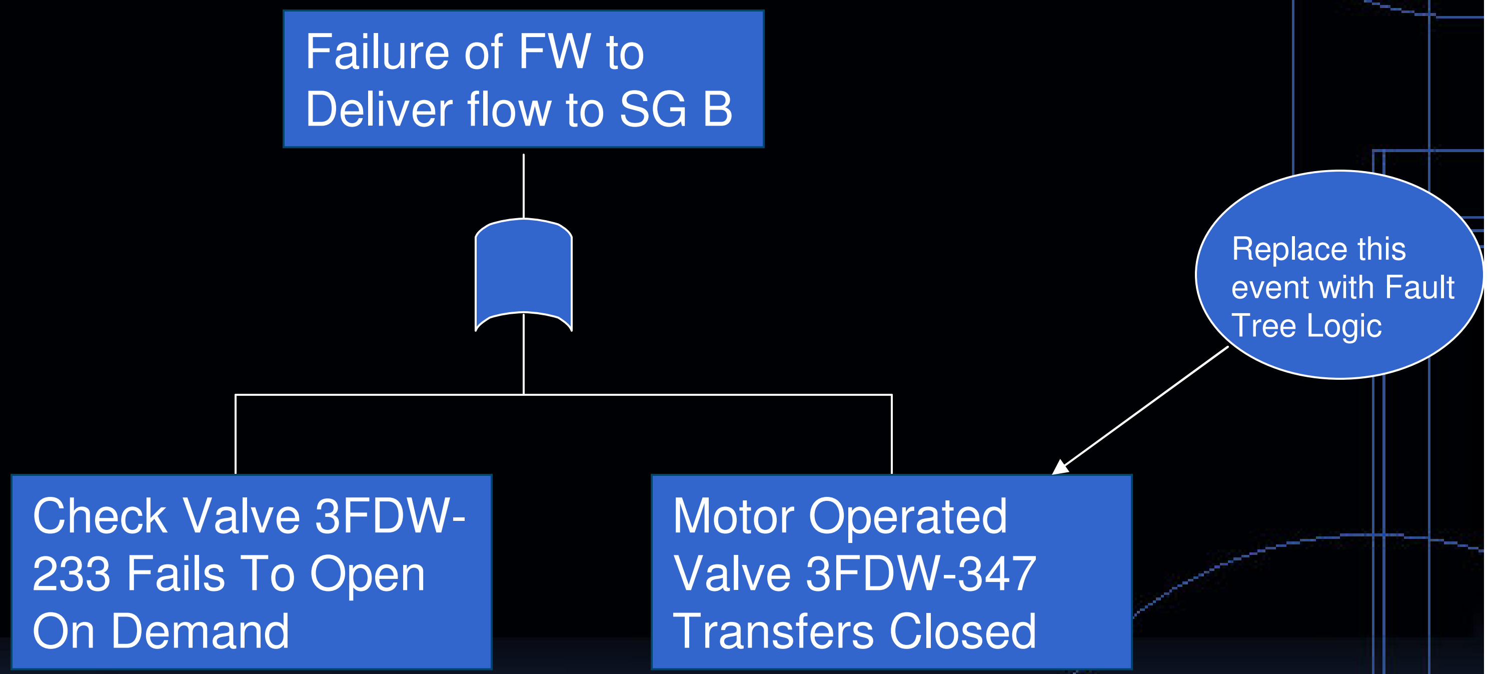
Change Analysis for Multiple Spurious

- Multiple spurious that are within the LB can (probably) not be treated with Change Analysis, since the combination has already been shown to be potentially risk significant (See 2.0 above).
  - This means all LB multiples should be provided a deterministic compliance strategy within the SSA.
  - May be able to use Change Analysis for Manual Actions that do not fully meet Feasibility Criteria, as long a risk reduction is acceptable.
  - The Change Process can be used to review changes to procedures that are used for manual actions

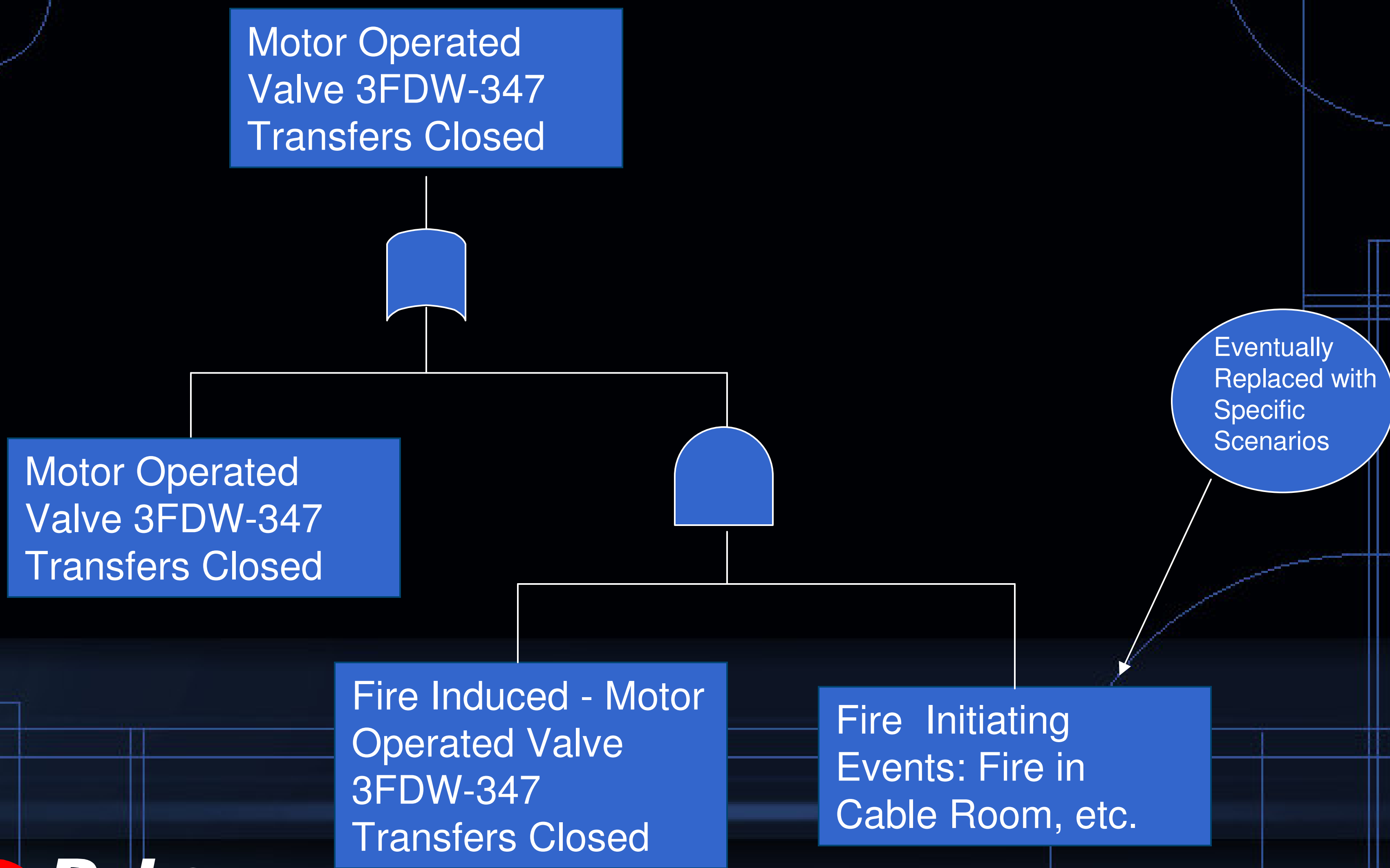
Change Analysis for Multiple Spurious

- Multiple spurious that are outside the LB do not need to be treated with a change analysis, and any deterministic strategy associated with these component combinations can be changed outside of NFPA-805.
  - The process should however carefully review the component combinations within the Gray area.

How to include Multiple Spurious Events in Fire PRA



How to include Multiple Spurious Events in Fire PRA



Peer Review

- Peer Review of the Fire PRA will include a special Peer Review of the Multiple Spurious Analysis and Model Development.
  - Will be consistent with the ANS Fire PRA standard.

Conclusions

- The combined process provided above will provide a comprehensive analysis for fire-induced multiple spurious operations in support of NFPA-805.
  - The use of 3 independent approaches to develop component and scenario lists, followed by an independent Peer Review will provide a complete and state of the art analysis.