Common Cause Failure Data and Alpha Factor Modeling

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Common Cause Failure (CCF) Modeling

- Attempt to model simultaneous failures of multiple components due to a single cause
CCF Model Parameter Estimation

- INL reviews licensee event reports (LERs) and INPO Consolidated Events System (ICES) failure records to identify candidate common cause failure events.
  - Data coder identifies candidate event, creating an event impact vector that characterizes uncertainty about the event.
    - Degraded state
    - Failures close in time but not simultaneous
    - Shared cause cannot be established with certainty
  - Candidate events receive independent review at INL.
  - Periodically candidate events are sent to the Westinghouse Owners Group (WOG) for review

- CCF parameters are computed from database of quality-assured CCF event records.
  - Stand-alone code CCF package
  - Web version on the NROD web site
CCF Model Parameter Estimation (cont.)

• The CCF software (both stand-alone and web versions) provides:
  – Impact vector summaries,
  – Parameter estimates for alpha factors,
  – Parameter estimates for Multiple Greek Letter (MGL) parameters,
  – Parameter estimates scaled to CCF group sizes of up to 16.

• The CCF software implements computational procedures detailed in NUREG/CR-5485.

• Parameter estimates are published on the NRC web site.

• Parameter estimates are used to estimate CCF probabilities in the SPAR models.
Selection of CCF Groups

- Identify components that share one or more coupling mechanisms
  - Same design
  - Same hardware
  - Same function
  - Same installation, maintenance, or operation staff
  - Same procedures
  - Same system
  - Same location
  - Same environment
Selection of CCF Groups (cont.)

• Identical, functionally non-diverse, active components.
• Diverse components that have identical piece parts.
• Passive components omitted, with exception of debris blockage of redundant or diverse strainers.
• Review of operating experience
  – System studies
  – Generally stay within bounds of NRC data collection (CCF database)
    – Generally assume common failure rate
• Generally do not cross system boundaries.
Representation in the SPAR models

- Method follows NUREG/CR-5485, Section 5.3
- $Q^{(m)}_k$ is the probability of $k$ specific components failing in a group of size $m$.
- $Q^{(m)}_k$ is estimated using the alpha factor method.
  - Rigorous estimators for beta factor and MGL models parameters are difficult to obtain.
  - Alpha factors can be estimated from observable data and a known sampling scheme.
  - MGL parameters can be estimated from alpha factors.
  - Details are provided in Appendices to NUREG/CR-5485.
Representation (cont.)

- The cut sets for a two train system are
  \{A_i, B_i\}; \{CCF_{AB}\}

- The failure probability for the system (using a staggered testing formulation) is
  \[ P(S) = P(A_i \cdot B_i) + P(CCF_{AB}) = Q_1 Q_1 + Q_2 = (\alpha_1 Q_T)^2 + \alpha_2 Q_T \]

  where

  \( Q_1 \) = probability of independent component failure

  \( Q_2 \) = probability of two components failing from common cause

  \( Q_T \) = probability of component failure from all causes

  \( \alpha_1 \) = alpha factor for independent failure

  \( \alpha_2 \) = alpha factor for two components failing from common cause
Representation (cont.)

• There are two formulations relating alpha factor estimates to CCF probability based on the testing scheme that produced the data:
  – Staggered Testing – Equation (5.6) of NUREG/CR-5485
  – Non-Staggered Testing – Equation (5.7) of NUREG/CR-5485

• SPAR models assume all data was collected as a result of staggered component testing.

• Templates are provided for all alpha factors used in the SPAR models

• SPAR model templates are periodically updated with data from the website.

• SAPHIRE does all CCF calculations internally using a compound event plug-in module.
SAPHIRE CCF Calculation Types

- **R-type**: The standard CCF calculation type for mitigating system failures. Allows for expansion of CCF terms or roll-up into a single basic event.
- **Q-type**: New CCF calculation type introduced to support SSIE modeling.
- **Compound event**: Historical event type used for CCF modeling in SPAR. All CCF terms are rolled up into a single basic event. This calculation type will eventually be replaced with R-type.
SAPHIRE Workspace Options for CCF Adjustments

- When adjusting individual failure basic events, SAPHIRE Workspace will make implied changes to the associated CCF basic event. The options are:
  - New probability / frequency
    - CCF is recalculated conditioned on the *individual* failure of component and the multiple failure terms default to the lowest\(^1\) failure probability in the group.
  - Single Failure (with potential shared cause)
    - CCF is recalculated conditioned on the *total* failure of component.
  - Single Failure (without potential shared cause)
    - CCF is recalculated conditioned on the *individual* failure of component.

\(^1\)Note that for Compound Events, SAPHIRE now defaults to the highest failure probability in the group. Current SPAR models include a mix of Compound events and R-type events.
The conditional CCF probability for observed failures with potential shared cause is triggered when an input is specified as TRUE.

The conditional CCF probability without potential shared cause is triggered when an input is specified as 1.0.

Calculations based on NUREG/CR-5485, Appendix E.

Review of SAPHIRE calculation results provided by basic event modification dialog.
SAPHIRE CCF Calculation Types, R, Q
SAPHIRE CCF Calculation Types, R, Q (cont.)
SAPHIRE CCF Calculation Types, R, Q (cont.)
SAPHIRE CCF Calculation Types, R, Q (cont.)

![Image of SAPHIRE software interface showing failure model and event data](image-url)