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
  - Data collection & reduction: Marshall, Mosleh, and Rasmuson, Common-Cause Failure Database and Analysis System, NUREG/CR-6268, Volumes 1-4.
  - Modeling methods: Mosleh, Rasmuson, and Marshall, Guidelines on Modeling Common-Cause Failures in Probabilistic Risk Assessment, NUREG/CR-5485

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

  $$P(S) = P(A_I * B_I) + P(CCF_{AB}) = Q_1 Q_1 + Q_2 = (\alpha_1 Q_T)^2 + \alpha_2 Q_T$$

  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

  α_1 = alpha factor for independent failure

  α_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

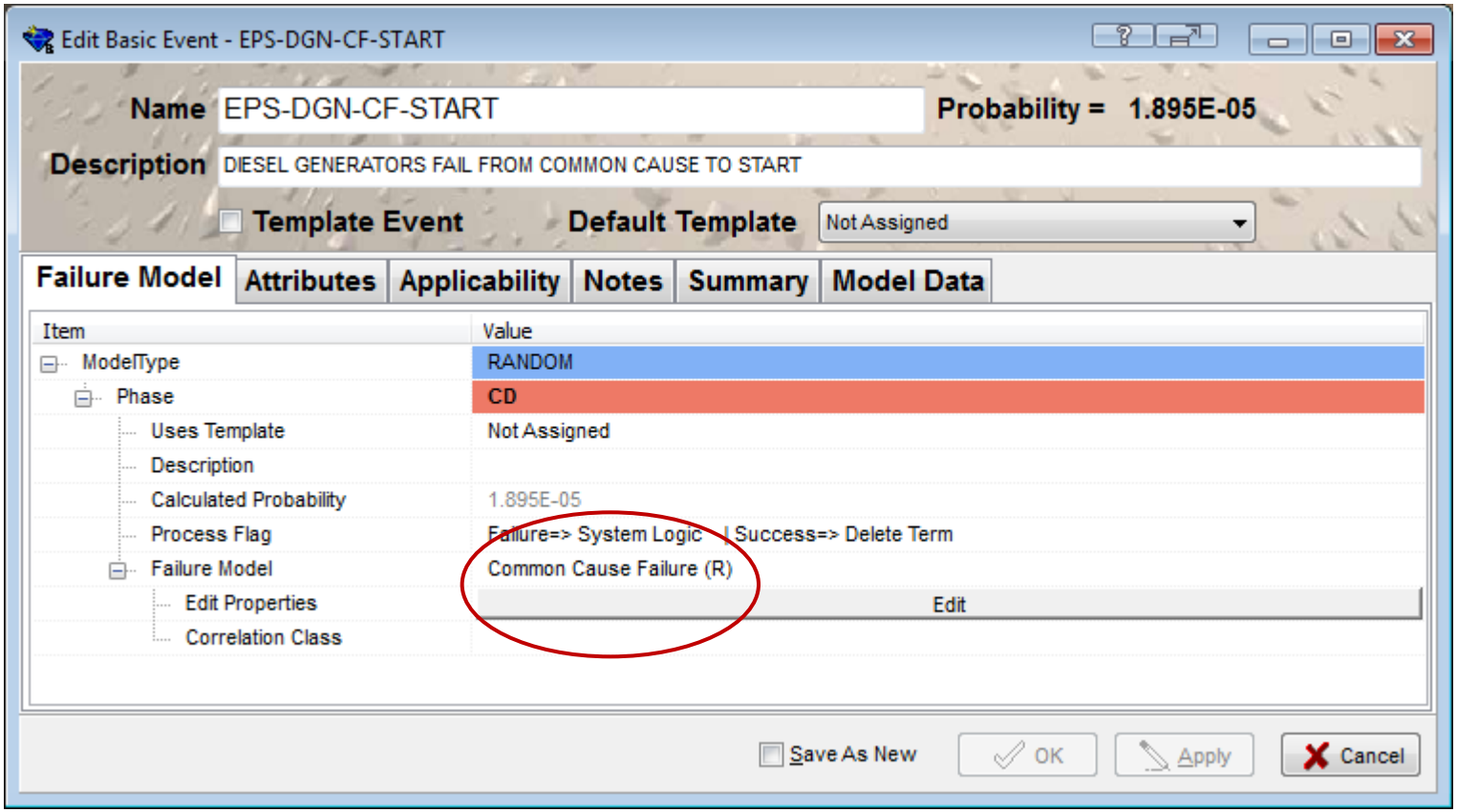
- When adjusting individual failure basic events, SAPHIRE Workspace will make implied changes to the associated CCF basic event. The options are:
  - New probability / frequency
    - CCF is recalculated conditioned on the *individual* failure of component and the multiple failure terms default to the 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.

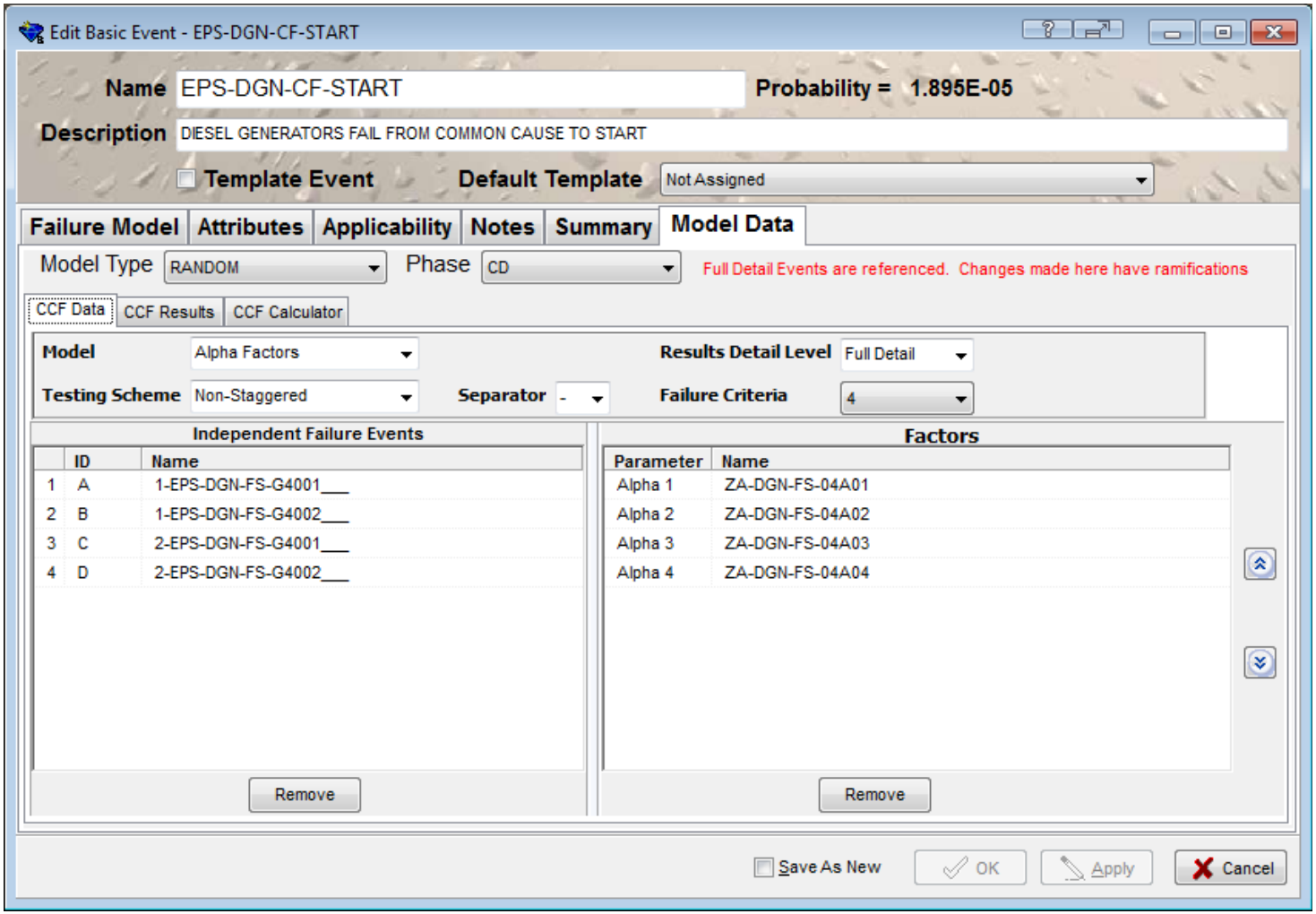
SAPHIRE Workspace Options (cont.)

- 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.

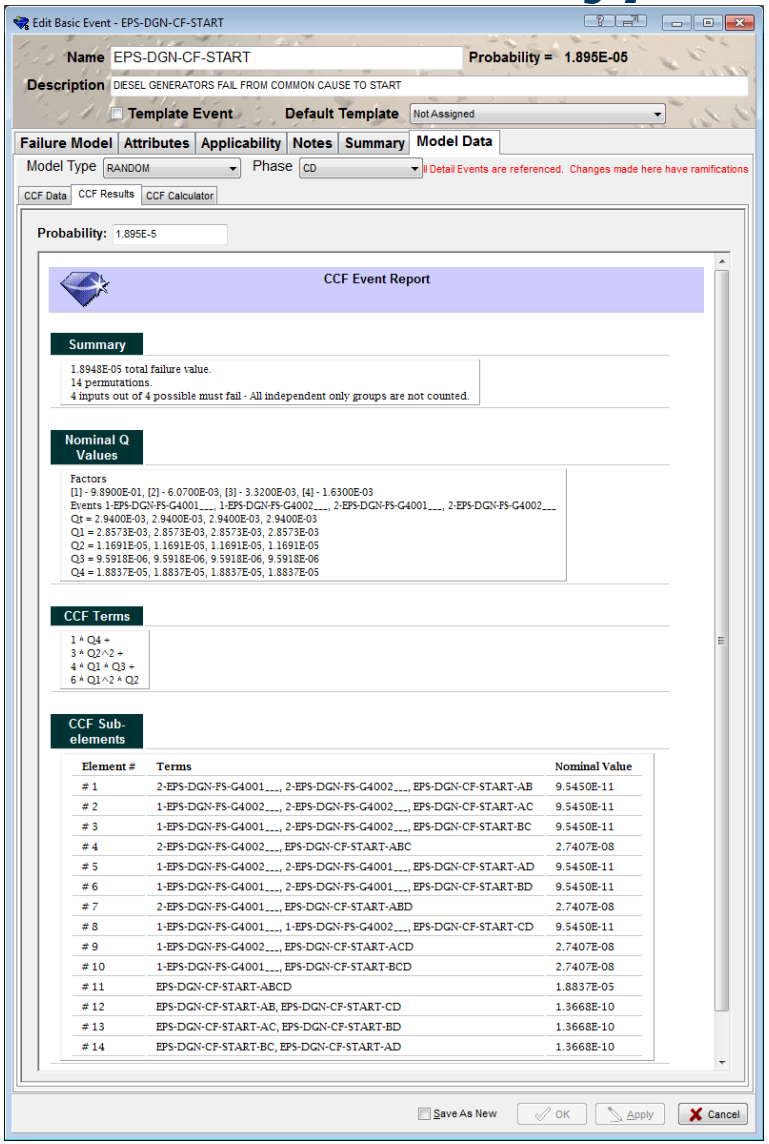
SAPHIRE CCF Calculation Types, R, Q



SAPHIRE CCF Calculation Types, R, Q (cont.)



SAPHIRE CCF Calculation Types, R, Q (cont.)



SAPHIRE CCF Calculation Types, R, Q (cont.)