Common Cause Modeling

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Agenda

- Objective
- Key Definitions
- Calculating Common Cause
- Examples
- Defense against Common Cause
- Impact of varied CCF and abortability
- Response Surface for various CCF Beta
- Takeaways
Objective

- Common Cause Failures (CCFs) are known and documented phenomenon that limit the benefit of system redundancy as a design approach to achieve high reliability.

- Because Launch vehicle data is sparse, generic data from the nuclear industry is used to estimate CCF for launch vehicles.

- This presentation addresses the impact of CCF risk on system reliability and safety.
A common cause failure (CCF) is a failure where:
- Two or more items fail within the mission time from a common failure mechanism.

Beta Factor is defined as the fraction of the component failures that result in a common cause failure.
CCFs may also be viewed as being caused by the presence of two factors:

1. Root or proximate Cause, i.e., the reason (or reasons) for failure of each component that failed in the CCF event, and a 
2. Coupling Factor (or factors) that was responsible for the involvement of multiple components.

\[
\beta = \frac{\lambda_C}{\lambda_T} \Rightarrow \lambda_C = \beta \lambda_T;
\]

\[
\lambda_I = (1 - \beta)\lambda_T
\]
The following are examples of actual CCF events:

- Hydrazine leaks leading to two APU explosions on Space Shuttle mission STS-9
- Multiple engine failures on aircraft (Fokker F27 –1997, 1988; Boeing 747, 1992)
- Three hydraulic system failures following Engine # 2 failure on a DC-10, 1989
- Failure of all three redundant auxiliary feed-water pumps at Three Mile Island NPP
- Failure of two Space Shuttle Main Engine (SSME) controllers on two separate engines when a wire short occurred
- Failure of two O-rings, causing hot gas blow-by in a solid rocket booster of Space Shuttle flight 51L
- Failure of two redundant circuit boards due to electro-static shock by a technician during replacement of an adjacent unit
- A worker accidentally tripping two redundant pumps by placing a ladder near pump motors to paint the ceiling at a nuclear power plant
- A maintenance contractor unfamiliar with component configuration putting lubricant in the motor winding of several redundant valves, making them inoperable
- Undersized motors purchased from a new vendor causing failure of four redundant cooling fans
- Check valves installed backwards, blocking flow in two redundant lines
- CCFs may also be viewed as being caused by the presence of two factors:
Reducing it

Checklist for reducing common cause categorized into 8 groups

1. Degree of physical separation/segregation
2. Diversity/redundancy (e.g., different technology, design, different maintenance personnel)
3. Complexity/maturity of design/experience
4. Use of assessments/analysis and feedback data
5. Procedures/human interface (e.g., maintenance/testing)
6. Competence/training/safety culture
7. Environmental control (e.g., temperature, humidity, personnel access)
8. Environmental testing
Impact of Varied CCF and Abortability

- CCF estimate becomes important when trading between a 1 out of 2 system and 1 component fails
  - Abort immediately or continue mission
  - STS used fail opt/fail safe redundancy
- Cost/weight concerns limit some systems to one level of redundancy
- What is the benefit of adding an additional level of redundancy
Response Surface for Various CCF Beta

Odds Against Continuing with the Mission after 1st Failure
(Contour Plot)

Example: "2:1 Against" means the crew is twice as likely to be lost by continuing the mission versus aborting the mission.
Takeaways

- Common cause failure is a known impact to redundant system

- Common modeling assumptions may underestimate the real risks

- When data is unavailable, it is important to judge the impact of system reliability, safety, and common cause factors over a range of values
