

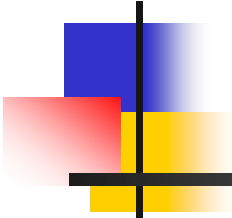


Treating Common Cause Failures in Multi-unit PRA

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- Background
 - Problems revealed
 - Conclusion



Background

- Previous study for the methodology of multi-unit event sequence development
 - S. ZHANG, J. TONG and J. ZHAO, “An integrated modeling approach for event sequence development in multi-unit probabilistic risk assessment,” Reliability Engineering & System Safety, 155, 147- 159 (2016)
 - Small Event tree/Large Fault tree
 - Illustrated by IE “Loss of Offsite Power”



Background

- What is Common Cause Failure given the multiple units situation?
 - a failure of two or more components arising from a single shared cause during a short period of time

NUREG/CR-5485

- It seems applicable to extend the above definition to the so-called inter-unit CCF.



Background

- CCFs are the results from two co-existing factors: root cause and coupling mechanism



- The root cause of the failure represents a condition or a series of conditions creating susceptibility for components to fail.
 - Identical components



- The existence of coupling mechanism depends
 - Traditional: same procedure or same personnel
 - New : Multi-unit IE

Inter-unit CCFs are theoretically possible



Background

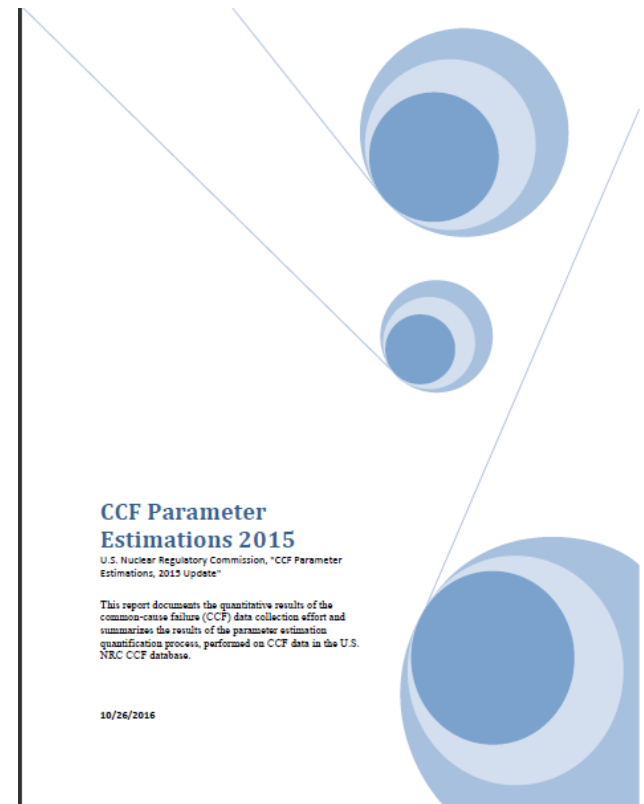
- What we had done in the study
 - Directly enlarge the single unit CCGs (Common Cause Component Group) to include all the identical components of the affected units
 - 3 pumps per unit → 6 pumps per site
 - Same CCF parameter model, i.e. MGL

Problems revealed

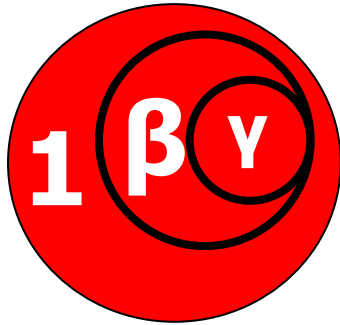
Problem #1

Current CCF databases cannot support large size CCCGs

- ◆ Typically less than 6(4)
- ◆ Is there any potential relationship exist among the CCF parameters which are of same kind but from different size of CCCGs, i.e. beta of CCCG=2 versus beta of CCCG=3?



Physical meaning of CCF parameters



MGL	CCCG=2	CCCG=3	CCCG=4	CCCG=5	CCCG=6
1-Beta	9.84E-01	9.84E-01	9.83E-01	9.86E-01	9.87E-01
Beta	1.61E-02	1.63E-02	1.66E-02	1.44E-02	1.29E-02
Gamma		3.11E-01	3.75E-01	5.47E-01	6.42E-01
Delta			3.05E-01	4.09E-01	5.25E-01
Epsilon				2.36E-01	3.81E-01
Mu					1.91E-01

From the component point of view, should the CCF portion of its failure change due to different CCCG size?

CCCGs are in fact made by the analyst!

Problems revealed

Can be solved by special modeling skill

Problem #2: PRA software limitation

- RiskSpectrum PSA example (only beta, gamma and delta are allowed)

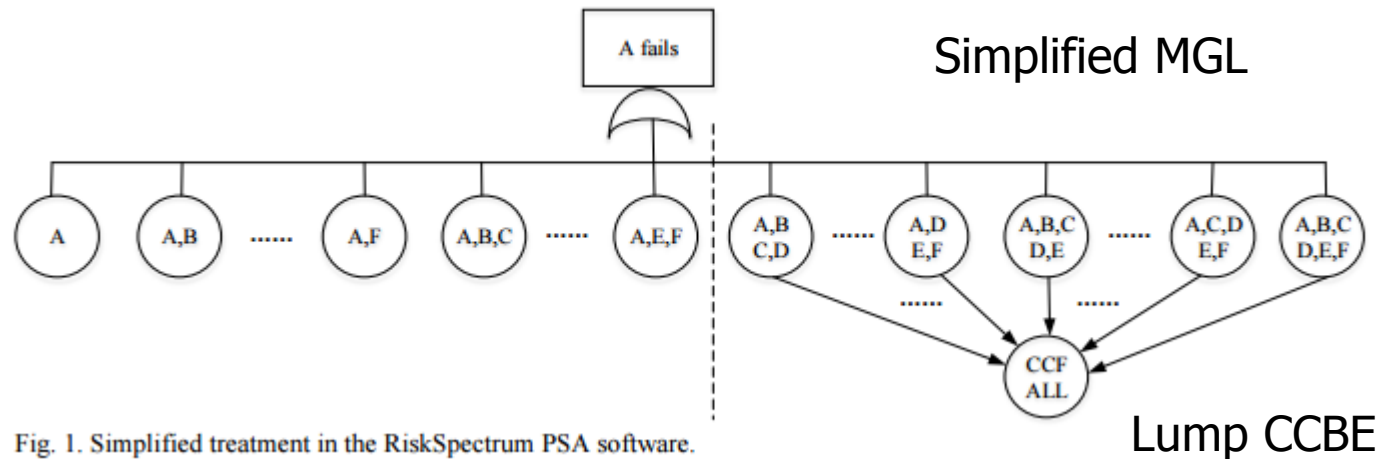


Fig. 1. Simplified treatment in the RiskSpectrum PSA software.



Problems revealed

Problem #3:

It seems that with the enlargement of CCOG size, the single unit risk will almost surely decrease if the unit has redundant design

- some of the new CCF combinations will not contribute to either unit
- Mathematically correct, but physically hard to be understood
- Extreme case: put all the valves of the plant into one CCOG

Problems revealed

Unit 1: redundant component 1 and 2. Both 1 and 2 fail will fail Unit 1.

Unit 2: identical design with component 3 and 4

MCS of Unit 1

CCF_{12}

β_2

MCS of Unit 1 given both units are affected by the MRIE simultaneously

CCF12	CCF13	CCF14	CCF23	CCF24	CCF34
CCF123	CCF124	CCF134	CCF234		
CCF1234					

$\beta_4 \approx \beta_2$

$< \beta_2$



Conclusion

- There's no difference between intra-unit CCF and inter-unit CCF
- The fact that CCCG size can change the single unit risk need further explanation
- We might need to revisit the CCF modeling methodology as well as CCF data collecting/analyzing process



Thanks for your attention!