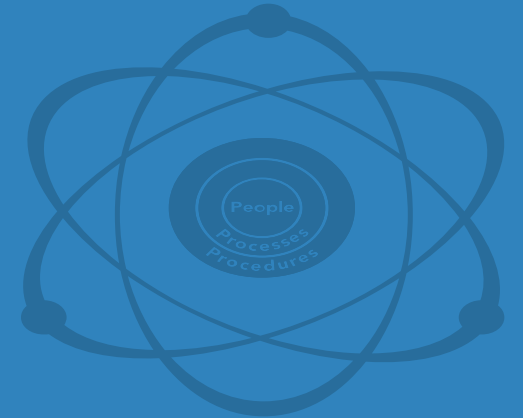


Correlation of Equipment Failures in Seismic PRAs

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Discussion Topics

- **Motivation**
- **Background**
- **What is Correlation of Seismic Failures?**
- **Fragility Calculations- General Information**
- **PRA Modeling of Correlation**
- **SSC Configuration**
 - Parallel
 - Series
- **Conclusions**

Motivation

- **In general, correlation of equipment in SPRA is often thought of as being conservative.**
- **Sensitivity studies show that in some cases breaking correlation could increase plant Risk level.**

Background

- Fukushima Earthquake/Tsunami
- Issuance of 50.54(f) letter
- NTTF Recommendation 2.1
- Seismic PRA
 - Hazards
 - Fragility
 - Plant Response Modeling

This interface is where decisions on correlation are performed.

What is Seismic Correlation

“Correlation between component failures occurs because the components respond similarly in an earthquake, have common materials and fabrication, or their fragilities are calculated assuming the same failure modes and models.”

“Because redundant pieces of equipment are generally identical and located adjacent to each other, it is hard to defend any assumption other than fully correlated.”

EPRI 3002000709, *Seismic Probabilistic Risk Assessment Implementation Guide*, (2013).



Fragility Calculations

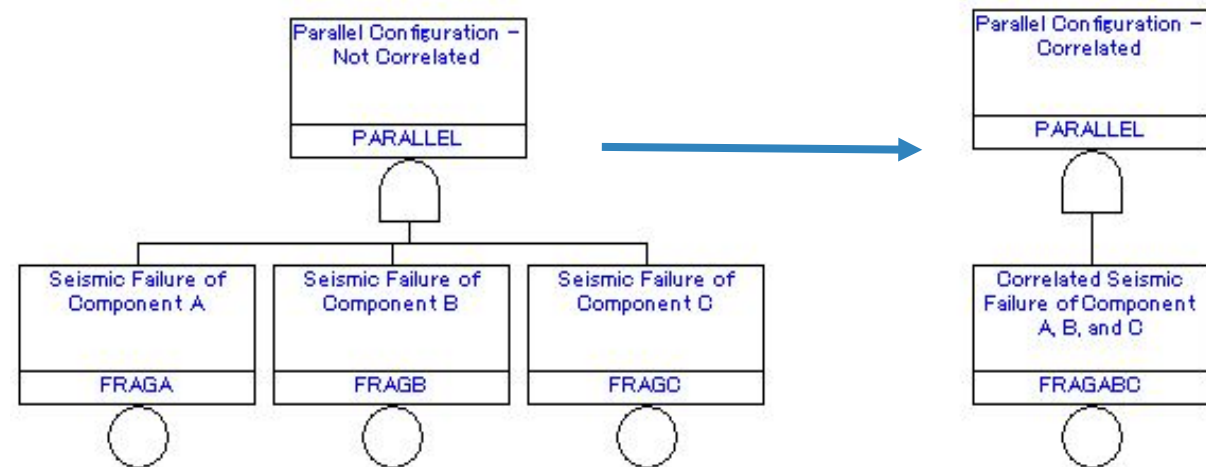
- **PRA Analysis Typically Provided Table of fragility parameters**
- **SSCs are grouped for fragility calculations**
 - Component Type
 - Component Location
- **These Groups are NOT Correlation groups**

How is Correlation Modeled in a SPRA

- **Correlated SSCs are represented by a single Basic Event**
- **Uncorrelated SSCs are represented by a basic event for each SSC**
- **The impact of Correlation on Risk metrics can be determined from the configuration of the SSCs in a potential correlation group.**
- **Two main groups of SSC configuration:**
 - Parallel
 - Series

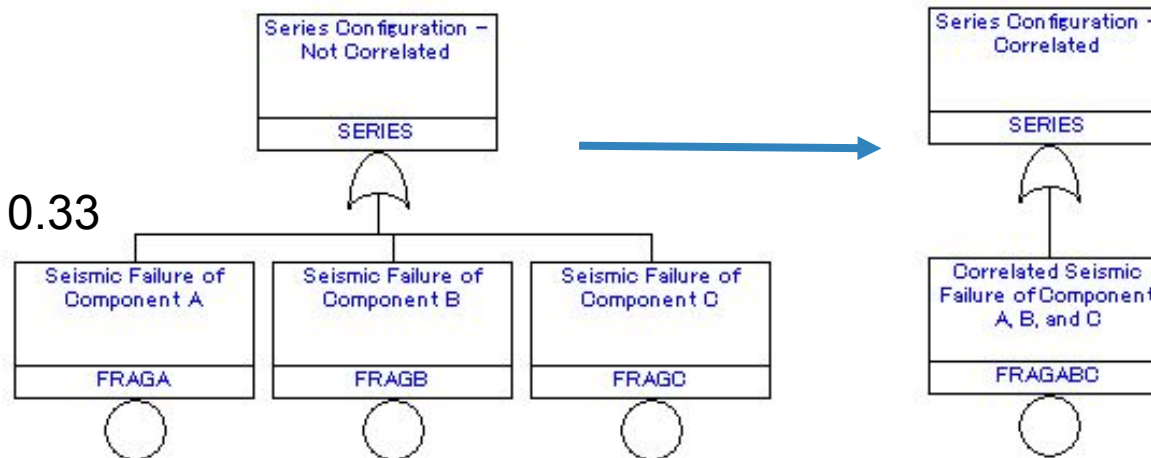
Parallel Configuration

- The components would be modeled under an AND gate.
- Normally represents components in separate trains.
- Lets Consider 3 components with seismic failure rates of 0.33.
 - Uncorrelated Components
 - $P(A)*P(B)*P(C)$
 - 1 CUTSET with a frequency of 0.035
 - Correlated Components
 - $P(A)$
 - 1 CUTSET with a frequency of 0.33



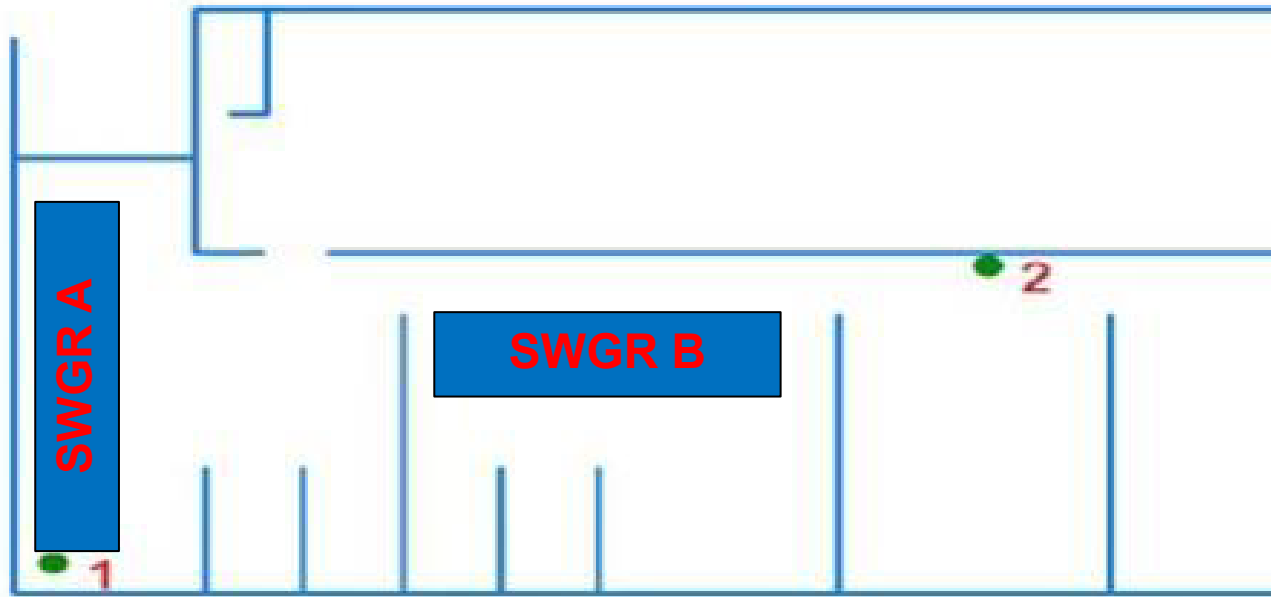
Series Configuration

- The components would be modeled under an OR gate.
- Normally represents components in line.
- Lets Consider 3 components with seismic failure rates of 0.33.
 - Uncorrelated Components
 - 3 CUTSETs each with a frequency of 0.33
 - Using Min Cut Upper Bound equation: $1 - (1 - P(A)) * (1 - P(B)) * (1 - P(C))$ gives you a total frequency of 0.699
 - Correlated Components
 - $P(A)$
 - 1 CUTSET with a frequency of 0.33



Parallel Configuration Plant Example

- Consider two Emergency AC power switchgear.



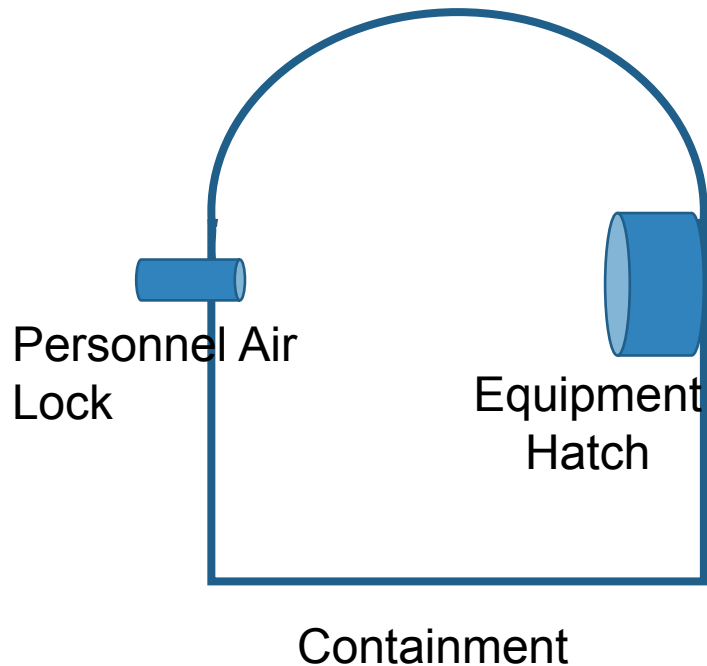
Service Building – Switchgear Room

- Originally Correlated
- Extremely Important Equipment
- Conservative to correlate (parallel configuration), but potential large impact on CDF.
- In this case, orientation and floor location matters.
- Most Benefit in PRA seen by simply breaking correlation (Don't need to calculate individual fragilities.)

Series Configuration Plant Example

■ Consider Large Containment Penetrations

- Equipment Hatch & Personnel Air Lock



- Originally Correlated
- Extremely Important Equipment (LERF)
- NON-Conservative to correlate (series configuration).
- **This is an example of what to look for because correlation here is non-conservative.**

Conclusion

- **Correlation assessment is a multi-discipline effort – interaction among fragility and systems analysts is a must.**
- **Correlation is not always conservative**
 - Breaking correlation for parallel configuration (separate trains) could lead to lower frequency of failure.
 - Breaking correlation for series configuration (components in line) could lead to higher frequency of failure
- **When correlating Components in a series configuration there is an opportunity to reduce cutsets, which will ultimately reduce the Core Damage Frequency.**

THANKS FOR YOUR ATTENTION. QUESTIONS????

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