

# Sensitivity Analysis for Seismic PSA about the Correlation of the Component Damages

Nuclear Engineering, Ltd.  
Kensuke TOYOSHIMA

1/12

## Background

- Assumption of correlation for the component damages by seismic in the conventional Seismic PSA (SPSA)
  - Full dependence among redundant components
    - Two or three HHSI pumps
  - Zero dependence among components of different systems
    - HHSI pumps and LHSI pumps



Inconsistent about the correlation

Assumption for simple modeling



- It is important to **confirm the sensitivity of the correlation** of the component damages with the consistent assumption.

2/12

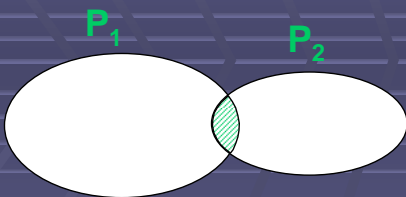
# Approach

- Expand the Existing SPSA Model
    - Zero and full dependence Including different systems
    - Based on existing Event Tree Linking (ETL) SPSA model.
- ↓
- Confirm the Sensitivity
    - Core Damage Frequency → Not sensitive
    - Component Importance → Sensitive

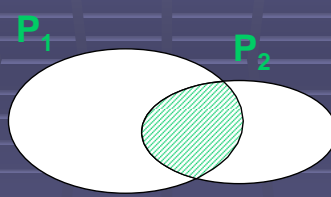
3/12

## Correlation and CDF (Unreliability)

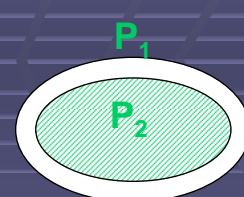
Zero dependence



Partial dependence

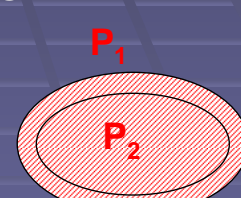
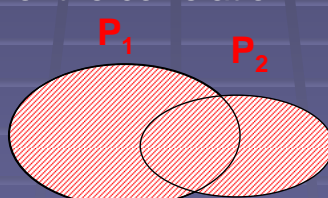
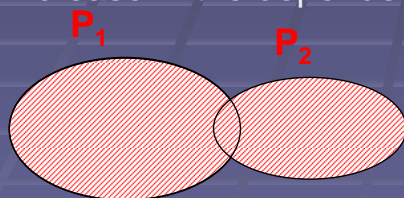


Full dependence



AND Combination :  $P(P_1 \cap P_2)$

Increase in the dependency of the correlation increases CDF



OR Combination :  $P(P_1 \cup P_2)$

Increase in the dependency of correlation decreases CDF



**Dependency**

4/12

# Selection of the component

## ■ AND effect

- Between the same components (e.g. HHSI pumps )
  - All selected. They seem sensitive for CDF
- Between the different components (e.g. HHSIP and LHSIP)
  - Selected based on the existing sequences and the success criteria.
  - No components are selected.

## ■ OR effect

- Between the same components (e.g. Steam Generators)
  - All selected. They seem sensitive for CDF
- Between the different components (e.g. SWP and CCWP)
  - Selected based on the existing Top 10 Fussell-Vesely importance and the location
  - 9 components are selected

5/12

# Selected components

## ■ Between the same components

### ■ OR effect

- RCP (3), RCS Piping (3), SG(3), RHR Isolation Valve (2), RHR Injection Piping (3), Charging Piping (2), Pressurizer Safety Valve (3), HHSI Hot-Leg Piping (3), PORV (2), Main Steam Line Piping (3), MSR (3), MSSV (21), HHSIP [Structural] (3), RHRP [Structural] (2), CV Spray Pump [Structural] (4)

### ■ AND effect

- Same components in the same system (Top Event)

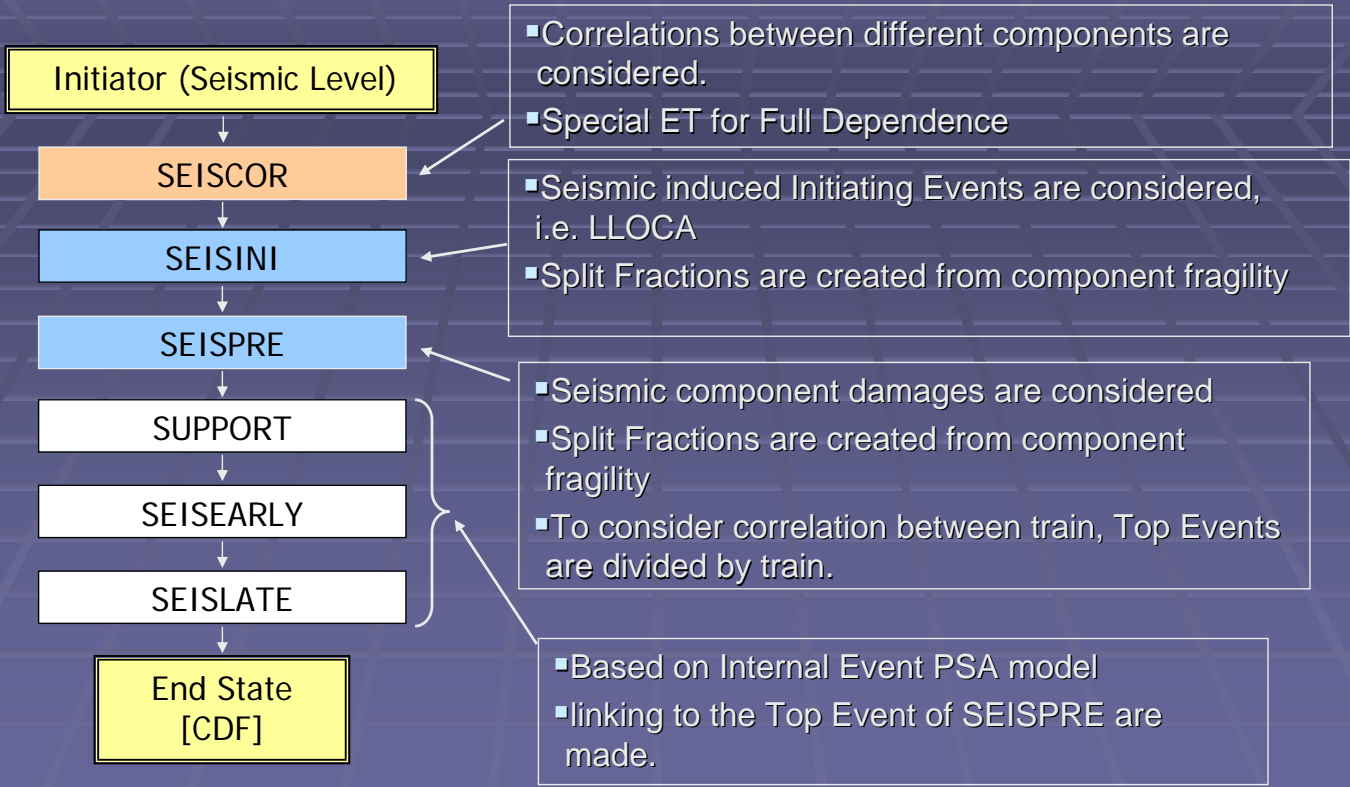
## ■ Between the different components

### ■ OR effect

- RTB, CV Spray Hx, Check Valve, CCWP, SG, RV, Control Building, Reactor Building, DG, Control Rod Cluster

6/12

# PSA Modeling (ET)



# Construction of the Model

CDF  $\nearrow$  Inc    Dependency  $\nearrow$  Inc

combinations		AND	
		Zero	Full
OR	Dependence	-	(B) Full Dependence
	Full	(E) Quasi-conventional	(D) Conventional
	Full in a system	(A) Zero dependence	(C) Max. CDF
	Zero		

5 types calculations

# Results [Total CDF (Relative)]

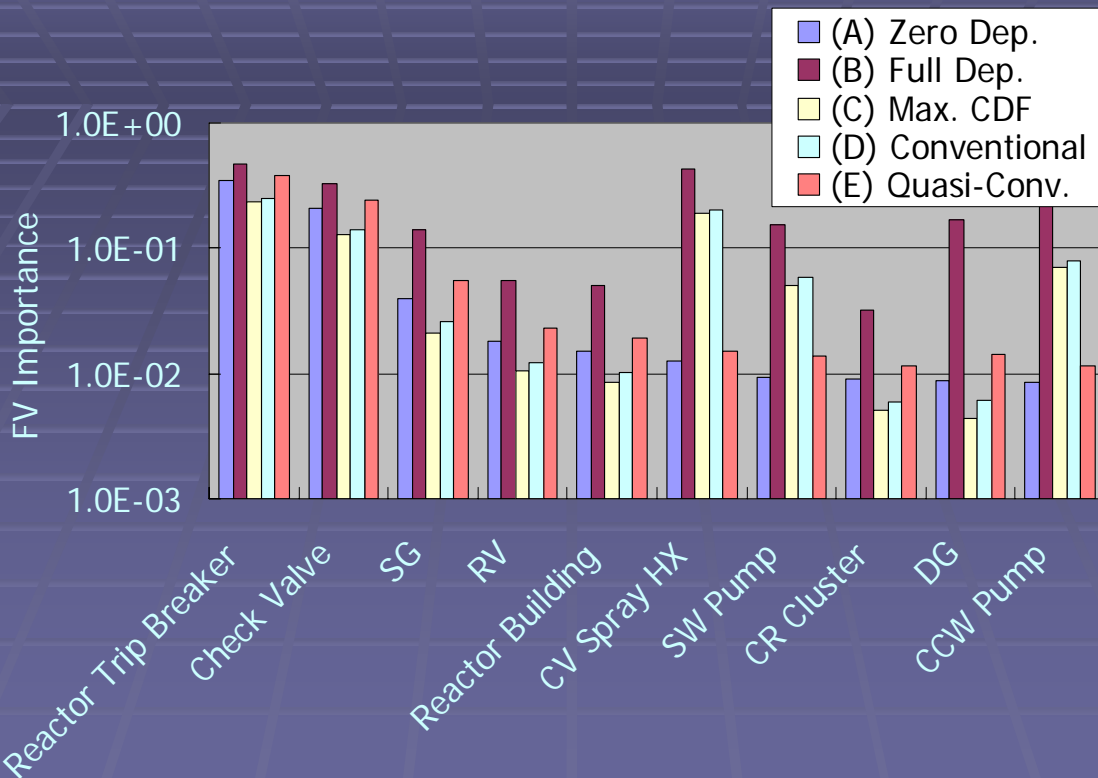
CDF  $\nearrow$  Inc Dependency  $\nearrow$  Inc

CDF  $\nearrow$  Inc  
Dependency  $\nearrow$  Inc  
Dec  $\searrow$

combinations		AND	
	Dependence	Zero	Full
OR	Full	-	(B) 0.59
	Full in a system	(E) 0.67	(D) 1.00
	Zero	(A) 0.74	(C) 1.06

Normalized by (D) Conventional CDF

# Results [Comp. FV importance]



## Conclusion (1)

- CDF
  - Sensitivity for the correlation is not so high
    - CDF changes is not more than twice.  $[(C)/(B)]$
    - SPSA have very large uncertainty.



Not a big problem

11/12

## Conclusion (2)

- Component FV Importance
  - Sensitivity for the correlation is depend on the component
    - FV changes for redundant components.  
e.g. SW Pump, DG, CCW Pump



It is impotent to take into account the correlation when the precise importance is required.

12/12