Seismic Performance Assessment Analysis and its Uses

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Objectives

- What can SPAA do for us? Or rather what do we need?
- Use SPAA to get a limit state annual probability result
- Use it to help motivate the basis of the Framing Equation
- Show its relationship to the needs

The Framing Equation

$$\lambda_{DV}(z) = \int_{y}\int_{x} G_{DV|DM}(z \mid y) \left| dG_{DM|IM}(y \mid x) \right| \left| d\lambda_{IM}(x) \right|$$

$\lambda_{DV}(z)$ = Mean Annual Frequency of DV $\geq z$

DV Decision Variable(s) *(costs, lives lost, collapse limit states, ...)*

DM Damage Measure(s) *(displacements, fractures, ...)*

IM Ground Motion Intensity Measure(s) *(PGA, S_a, ...)*

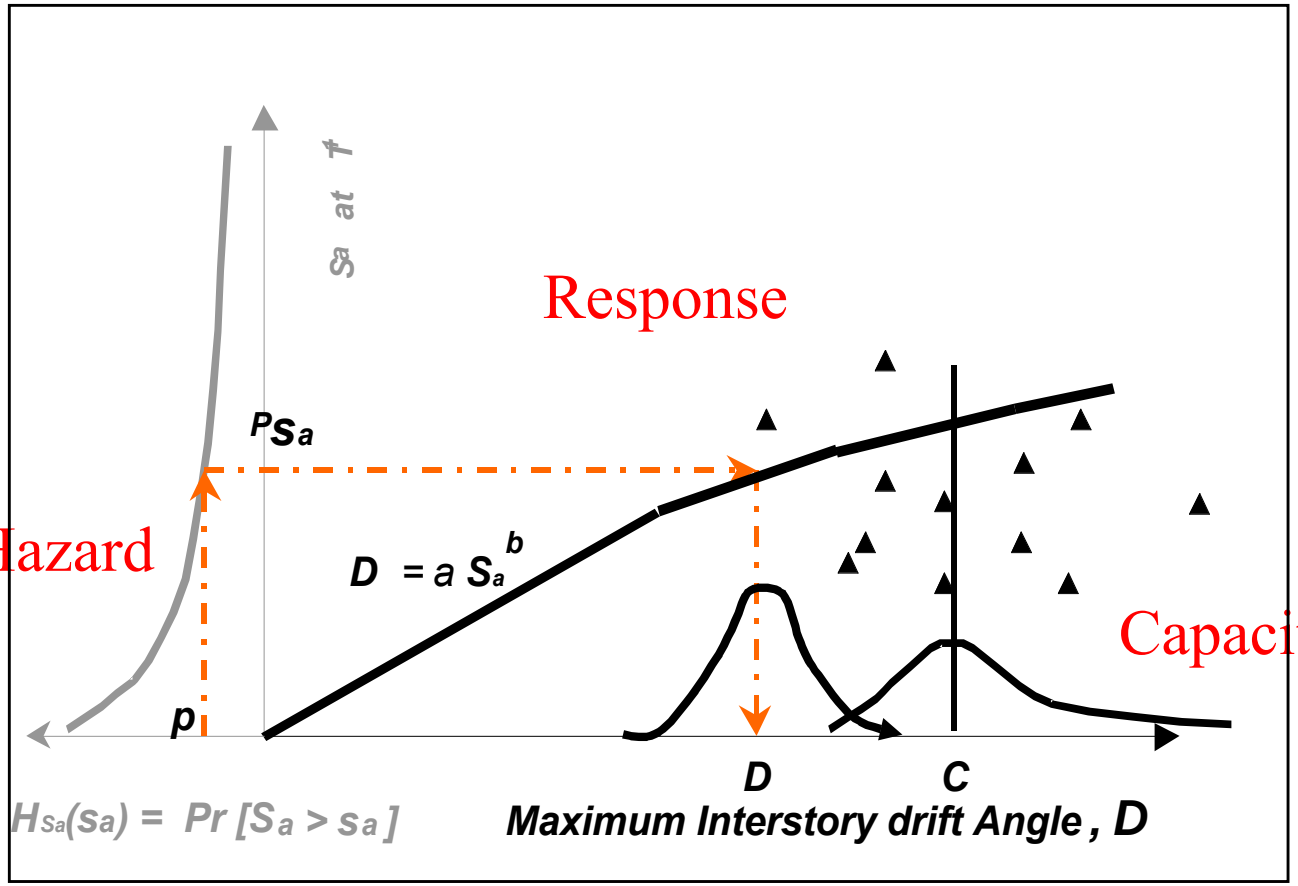
PBEE Assessment Needs: Can SPA-Analysis Help?

- Limit State (e.g., collapse) Probabilities
- Familiar format(s) for checking that limit state probabilities meet objectives.

$$\phi \cdot C = \gamma \cdot D$$

- Economic Loss Assessment

Elements of the Assessment



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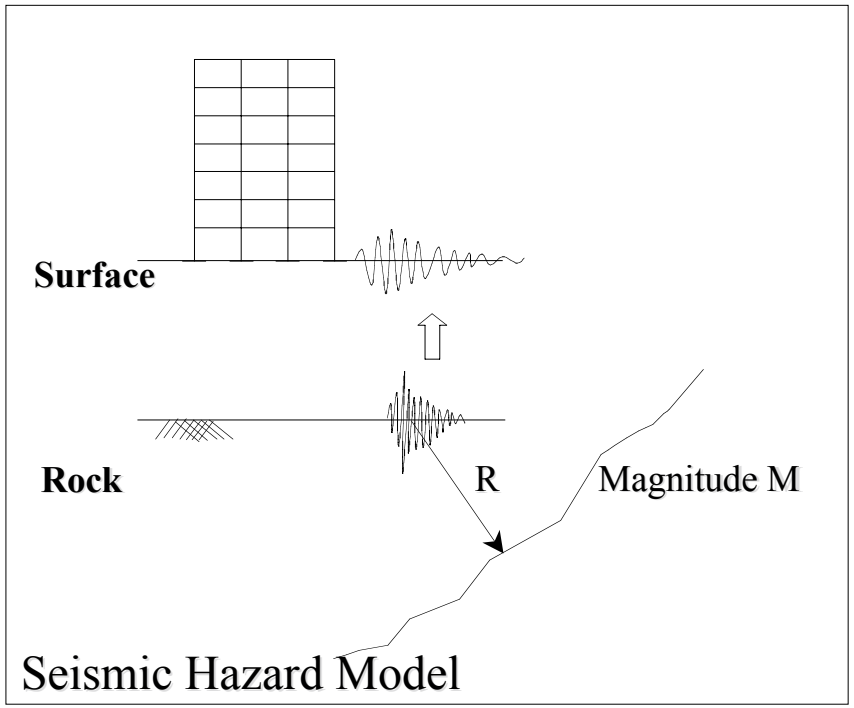
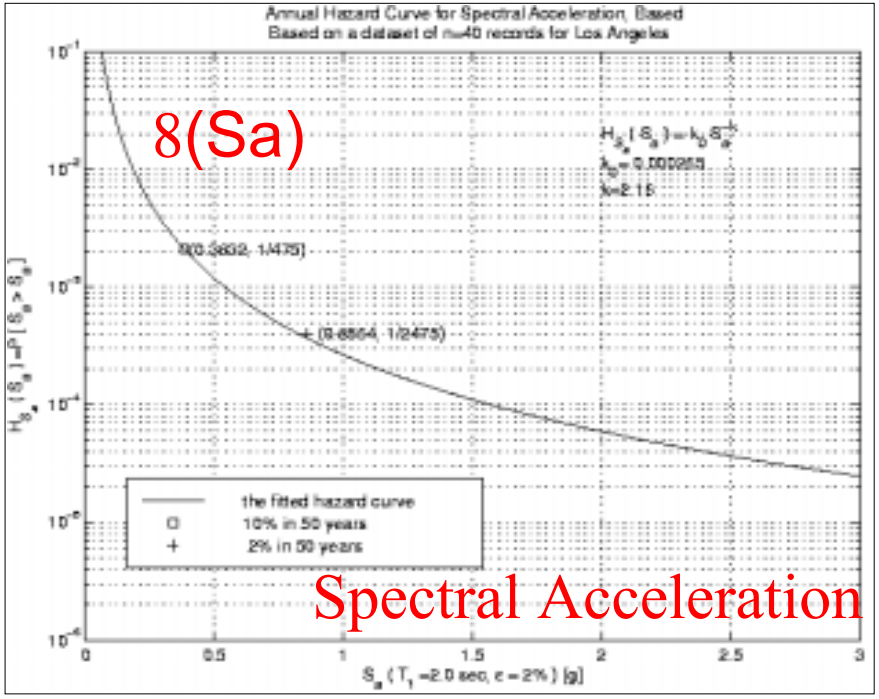
Ground Motion Hazard





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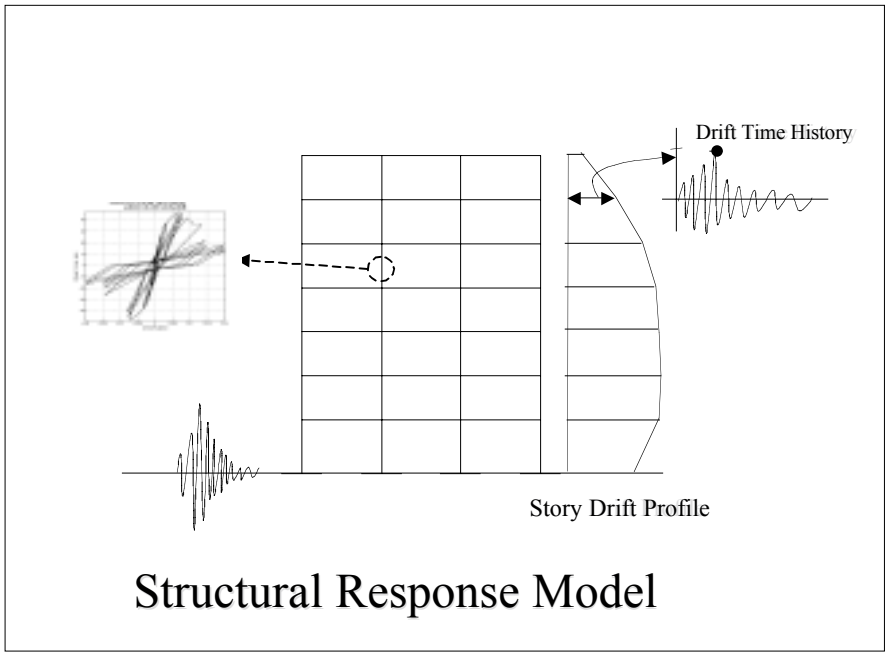
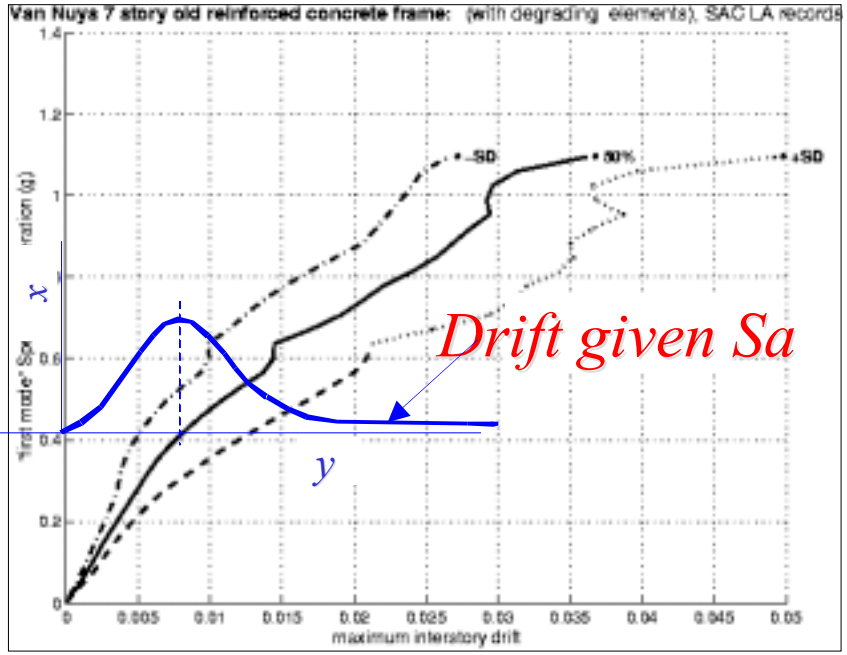
Dynamic Response vs. Ground Motion Intensity



Structural Response Model



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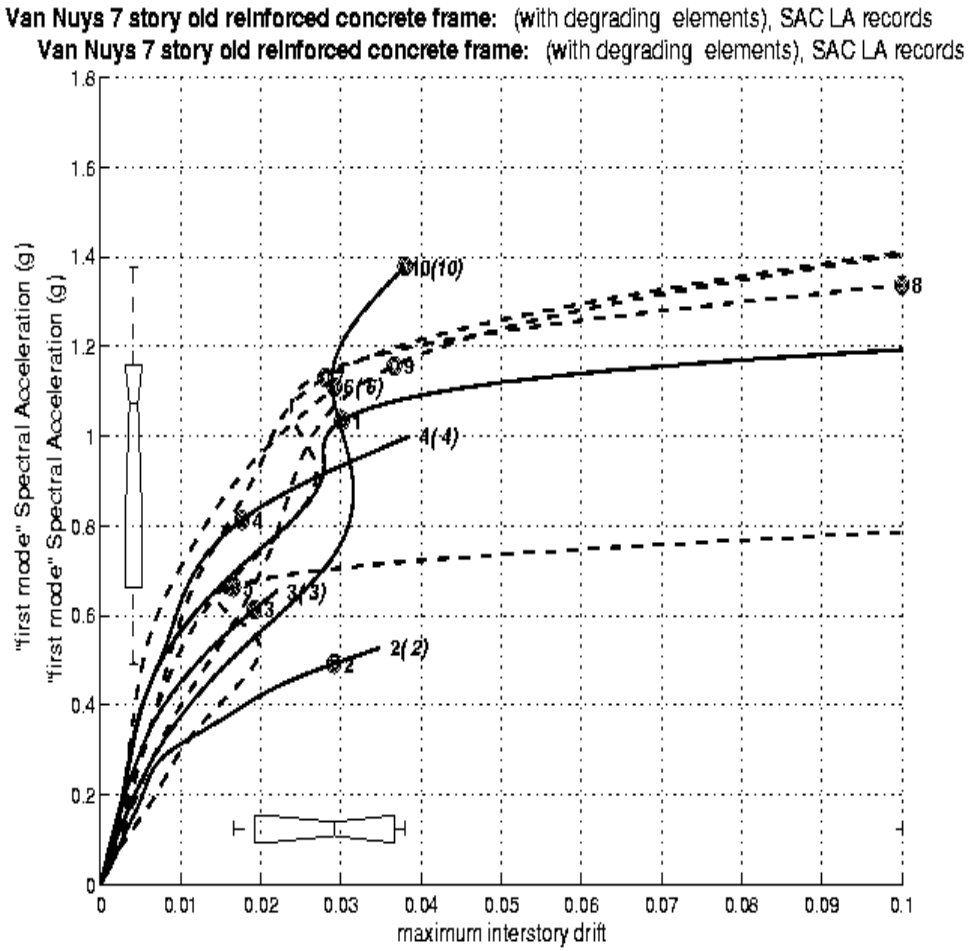
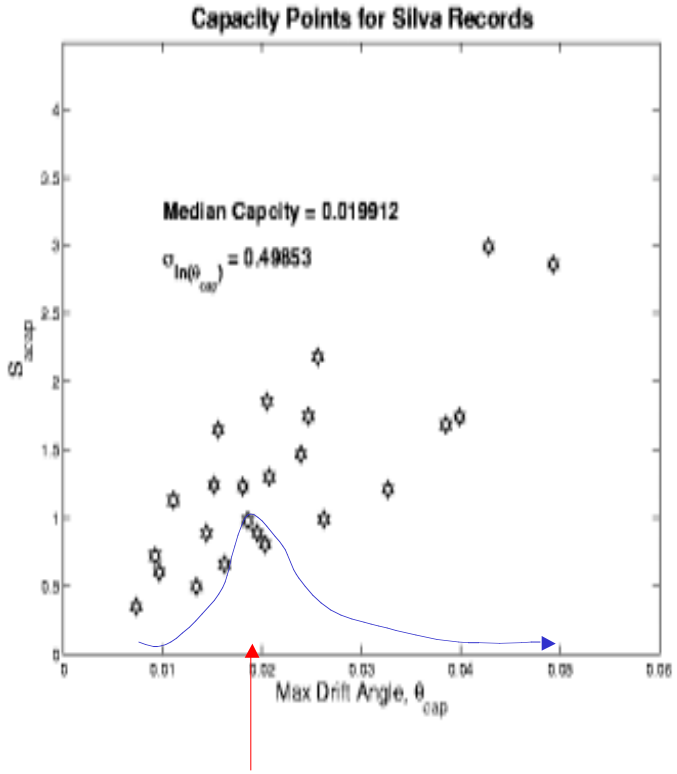
Dynamic Global Instability Capacity





Median Capacity, C

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Limit State Probability

$$\lambda_f = \lambda\, P[D > C]$$

$$\lambda_f = \lambda \int P[D > C \mid s]\, f_{S_a}(s)\, ds$$

$$\lambda\, f_{S_a}(s)\, ds = \left| \frac{d\lambda_{S_a}(s)}{ds} \right| ds = \left| d\lambda_{S_a}(s) \right|$$

Limit State Probability (cont'd)

$$\lambda_f = \int P[D > C \mid s] \left| d\lambda_{S_a}(s) \right|$$

$$\lambda_f = \int\int F_C(x) f_{D|S_a}(x \mid s)\, ds \left| d\lambda_{S_a}(s) \right|$$

Limit State Probability (cont'd)

$$\lambda_f = \iint F_C(x) f_{D|S_a}(x \mid s)\, ds \; | d\lambda_{S_a}(s) |$$

$$= \iint F_C(x) \left| dG_{D|S_a}(x \mid s) \right| | d\lambda_{S_a}(s) |$$

Lim. State Prob.& Framing Equation

$$\lambda_f = \iint F_C(x) \left| dG_{D|S_a}(x \mid s) \right| \left| d\lambda_{S_a}(s) \right|$$

$$\lambda_{DV}(z) = \int_y \int_x G_{DV|DM}(z \mid y) \left| dG_{DM|IM}(y \mid x) \right| \left| d\lambda_{IM}(x) \right|$$

Lim. State Prob. & Framing Equation

$$\lambda_f = \iint F_C(x) \left| dG_{D|S_a}(x \mid s) \right| \left| d\lambda_{S_a}(s) \right|$$

$$\lambda_{DV}(z) = \int_y \int_x G_{DV|DM}(z \mid y) \left| dG_{DM|IM}(y \mid x) \right| \left| d\lambda_{IM}(x) \right|$$

Lim. State Prob. & Framing Equation

$$\lambda_f = \iint F_C(x) \left| dG_{D|S_a}(x \mid s) \right| \left| d\lambda_{S_a}(s) \right|$$

$$\lambda_{DV}(z) = \int_y \int_x G_{DV|DM}(z \mid y) \left| dG_{DM|IM}(y \mid x) \right| \left| d\lambda_{IM}(x) \right|$$

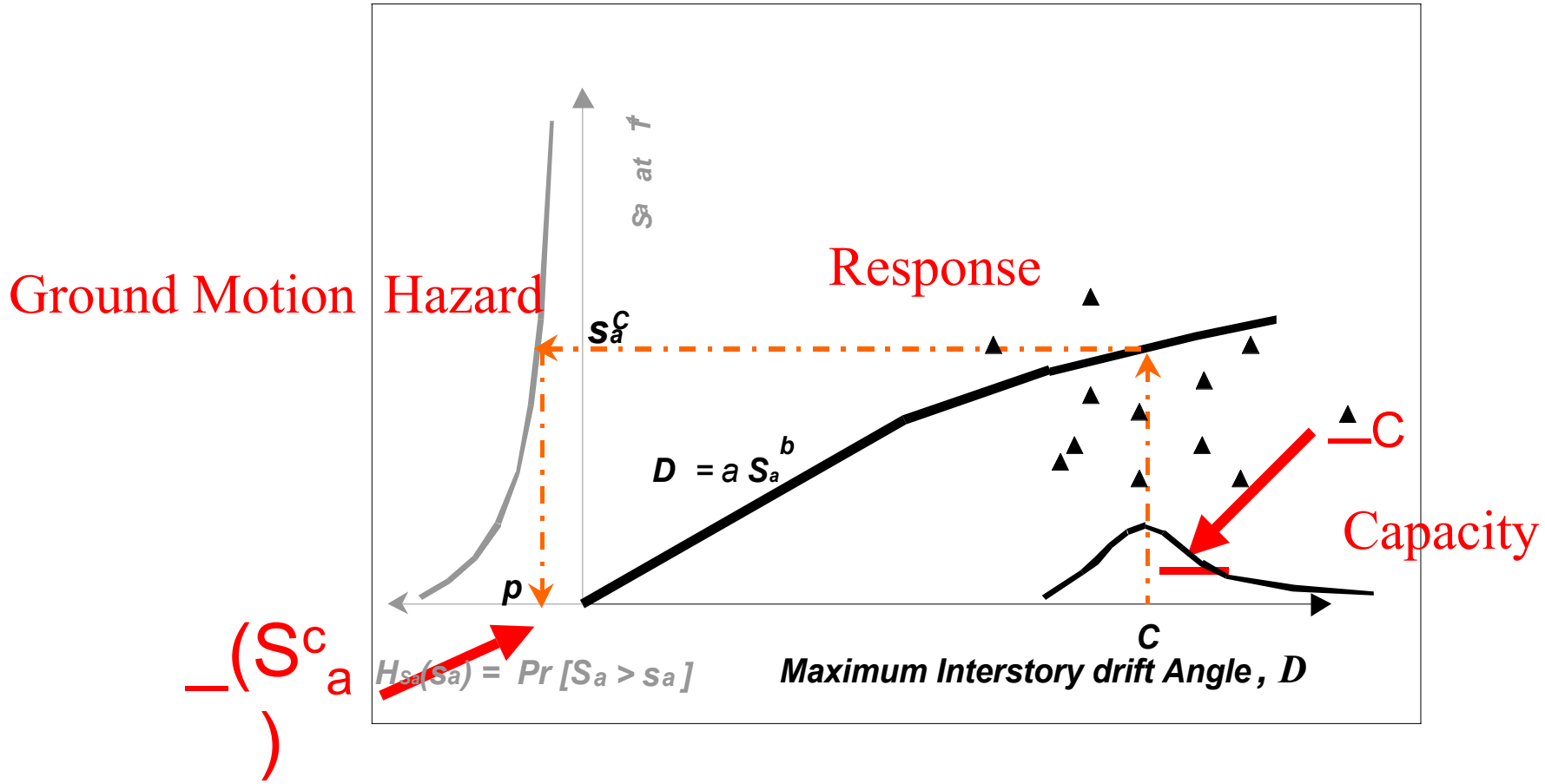
Lim. State Prob.: Closed Form

$$\lambda_f = \iint F_C(x) \left| dG_{D|S_a}(x \mid s) \right| \left| d\lambda_{S_a}(s) \right|$$

After fitting specific forms to these functions:

$$\lambda_f = \lambda_{S_a}(s_a^{\hat{C}}) \exp\left[\tfrac{1}{2} \frac{k^2}{b^2} (\beta_C^2 + \beta_{DM|S_a}^2)\right]$$

Lim. State Prob.: Estimation



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Lim. State Prob. >LRFD Format

$$\lambda_f = \lambda_{S_a}(s_a^{\hat{C}}) \exp[\tfrac{1}{2}\frac{k^2}{b^2}(\beta_C^2 + \beta_{DM|S_a}^2)]$$

Re-arranges to:

$$e^{-1/2(k/b)\beta_C^2} \cdot \hat{C} = e^{1/2(k/b)\beta_{D|Sa}^2} \hat{D}_{S_a^{\lambda_o}}$$

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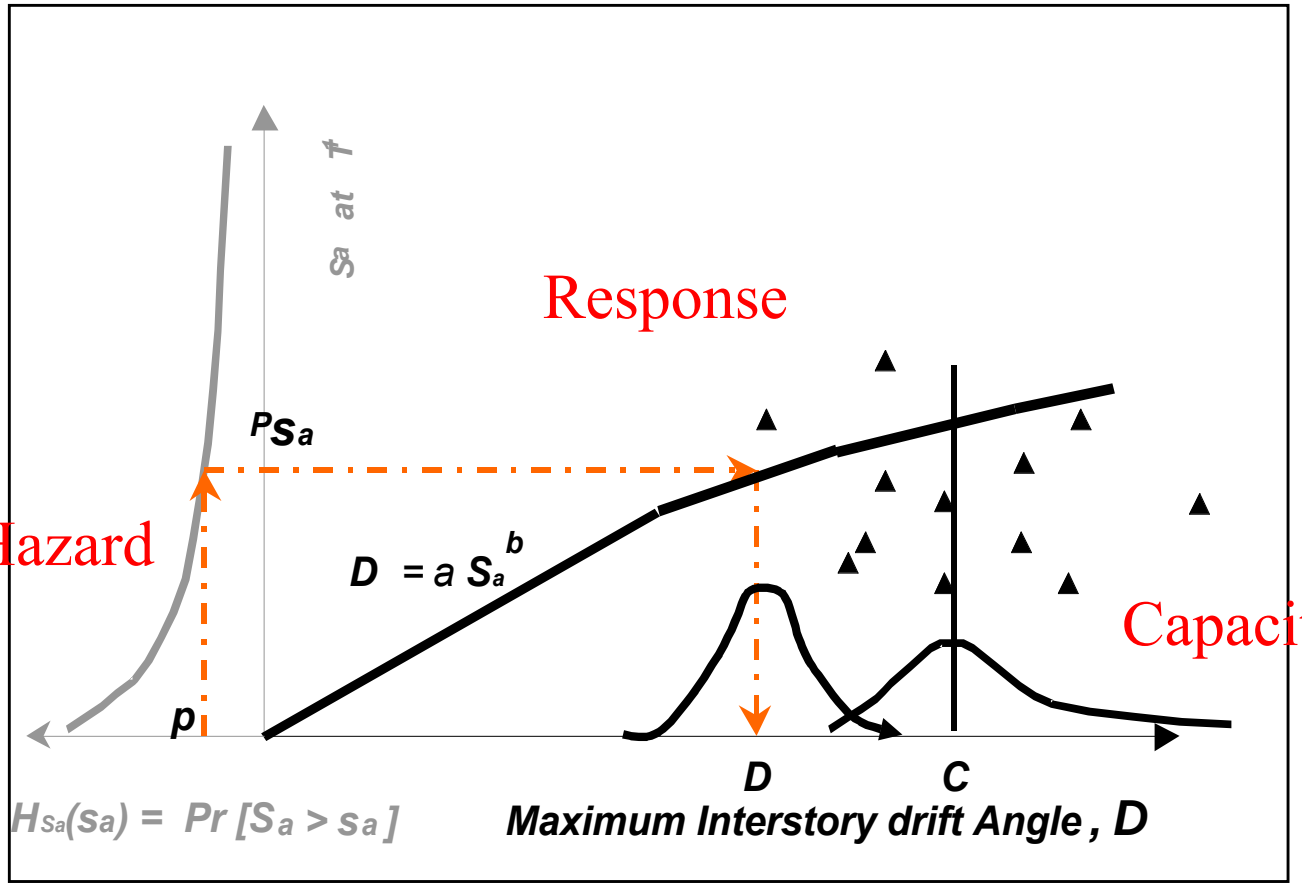
Lim. State Prob.: LRFD Check



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Displacement-Based "LRFD" Format

$$e^{-1/2(k/b)\beta_C^2} \cdot \hat{C} = e^{1/2(k/b)\beta_{D|Sa}^2} \hat{D}_{S_a^{\lambda_o}}$$

$$\phi \cdot C = \gamma \cdot D$$

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Economic Assessment Analysis

$$\lambda_f = \iint F_C(x) \left| dG_{D|S_a}(x \mid s) \right| \left| d\lambda_{S_a}(s) \right|$$

$$\lambda_{Dollars}(z) = \iint G_{Dlls|D}(z \mid x) \left| dG_{D|S_a}(x \mid s) \right| \left| d\lambda_{S_a}(s) \right|$$

Seismic Performance Assessment Analysis

- Provides guidance for integration of Ground Motion Hazard, Nonlinear Dynamic Response and Capacity
- Produces annual frequency of limit state "exceedance"
- In integral form, solution by simulation, numerical integration and approximate closed form approximations

Seismic Performance Assessment Analysis

- Closed from solutions lead also to familiar LRFD-like formats for the assessment
- Economic loss analysis falls into similar integral form.
- Both limit state and economic analysis can be represented by a common generic form