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Joint ICTP/IAEA Advanced Workshop on Earthquake Engineering for Nuclear Facilities

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PEGASOS / PRP Overview

(Presentation)

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PEGASOS / PRP Overview

Joint ICTP/IAEA Advanced Workshop on Earthquake Engineering for Nuclear Facilities

Dr. Philippe Renault

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Outline

- **History**
- **Overview PEGASOS and PEGASOS-Refinement**
- **“Lessons learned”**
- **Expected changes/improvements**

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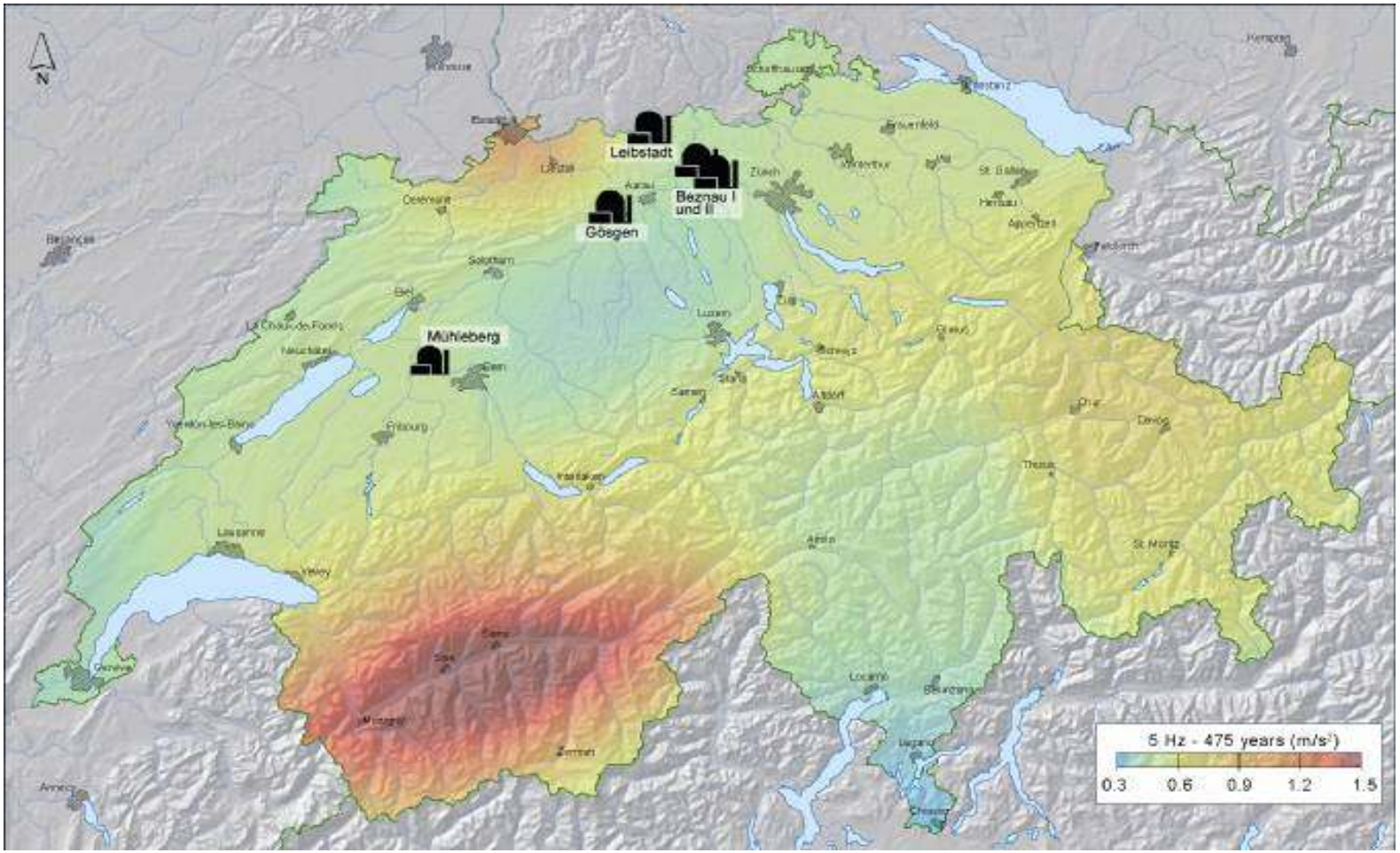
Initial Situation – Swiss NPP Sites



Seismic hazard map of Switzerland (Source: Schweizerischer Erdbebendienst ETH Zürich) and NPP locations

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Historical Background

1990-1997	Federal Nuclear Safety Inspectorate (HSK) identified the need to update the seismic hazard assessments for Swiss NPPs, as not compliant any more with the state-of-the-art (with reagard to progress in the US)
Dec. 1998	HSK started development of „PSHA Guidelines“ - Based on modern US recommendations - Beyond international state-of-the-art
June 1999	HSK requested Swiss NPP operators to perform a new PSHA that complies with SSHAC Level 4
March 2000	NPP operators submited first draft project plan: „Probabilistische Erdbebengefährdungsanalyse für die KKW-Standorte in der Schweiz“ (PEGASOS)
2001-2004	Project settlement - Project lead NAGRA - 13 Workshops, 17 „Elicitation Meetings“, … - Participatory peer review by HSK
Nov. 2004	PEGASOS review meeting: Specialists meeting, Baden
2004-2006	Review by the utilities and performance several additional studies
2007	Planning of a refinement study: PEGASOS Refinement
2008-2011	Realization PEGASOS Refinement Project

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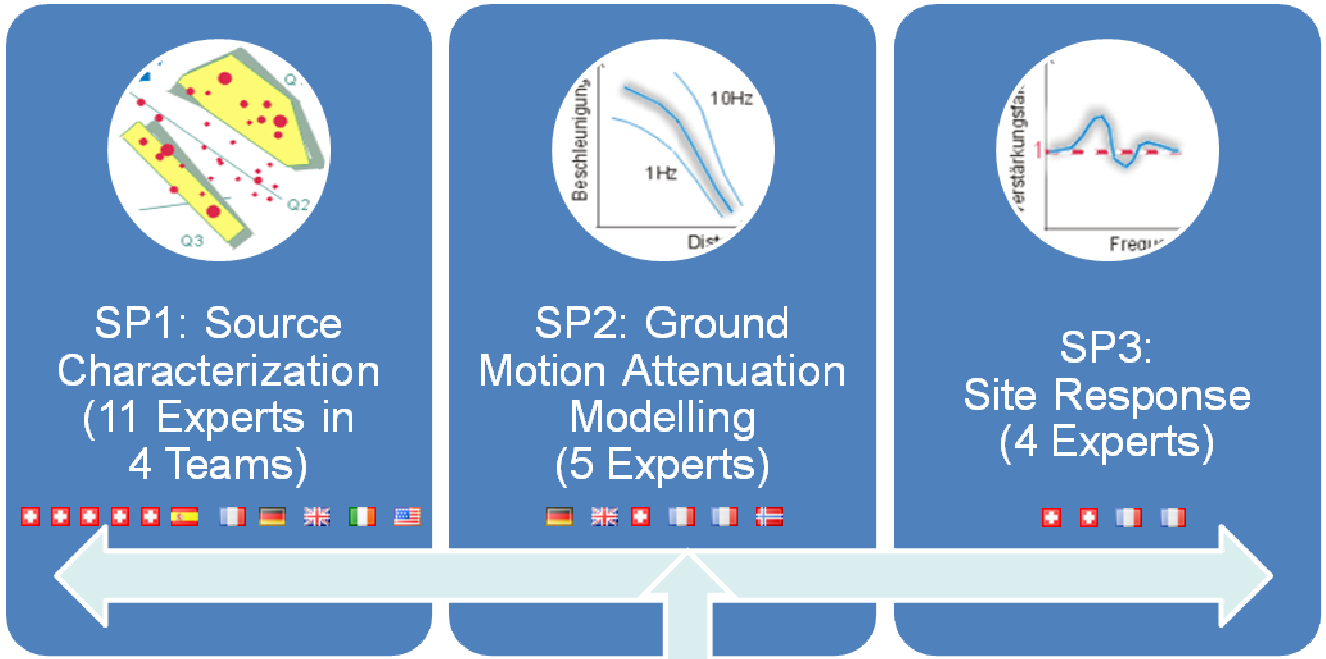
(PEGASOS/)PRP - Structure



International & interdisciplinary project with structured assessment of 21 experts of 7 European countries and the USA

Intensive cooperation with SED

„Lessons Learned“

SP1/SP2 interface:

- **SP1/SP2 convert to moment magnitude - Use consistent magnitude conversion for common earthquakes**
- **Avoid distance conversions - Keep native distance metric**

SP2:

- **A great deal of time and effort was spent solving very fundamental issues, many of which had only a small impact on the hazard results and some of which became redundant**
- **GM upper bounds had little impact on the hazard results**
- **The key issues were to constrain the best estimates of median ground motions in Switzerland, with their associated variability and the range of epistemic uncertainty**
- **Overestimated magnitude scaling of median ground motion at high fractiles (Mmax sensitivity)**

„Lessons Learned“ (continued)

SP2/SP3 Interface:

- **SP3 used a reference rock velocity of 2000 m/s** (higher than the rock velocity at any of the four sites; which avoided issue of deconvolving ground motions)
- **But, empirical rock GM models used by SP2 correspond to Vs 500 - 1000 m/s. Thus, SP2 applied scale factor to adjust the empirical models to Vs=2000 m/s**
- **Now, site-specific rock for each NPP based on Vs profile and $v_{S,30}$ based rock ground motion models**
- **Double counting of aleatory variability between SP2 and SP3**

SP4:

- **Pinching/tree trimming was necessary to achieve computational realization, required significant effort and verifications**

Post- PEGASOS:

- **Implementation of results was difficult for NPPs**

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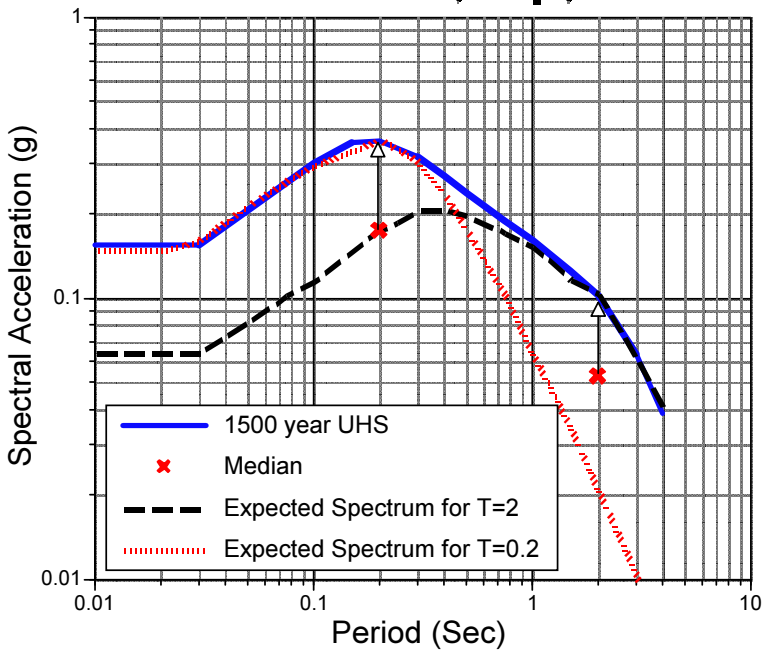
PRP Output SP4

- **Seismic hazard as H+V hazard curves and UHS on rock for annual exceedance probabilities of 10^{-2}/yr to 10^{-7}/yr (0.025 – 10 g)**
- **Deaggregation for: Magnitude, Distance, Epsilon**
- **Deaggregation in three distance bins: 0 - 16km, 16 - 40km, >40km**
  - Frequencies: 1 Hz, 5 Hz, 10 Hz, 100 Hz
  - Exceedance probabilities: 10^{-2}/yr, 2.1 10^{-3}/yr, 10^{-4}/yr, 10^{-5}/yr, 10^{-6}/yr, 10^{-7}/yr

  → **Deaggregregated UHS**
- **Investigated frequencies: 0.5, 1, 2.5, 5, 10, 20, 33, 50, 100 Hz (PGA)**

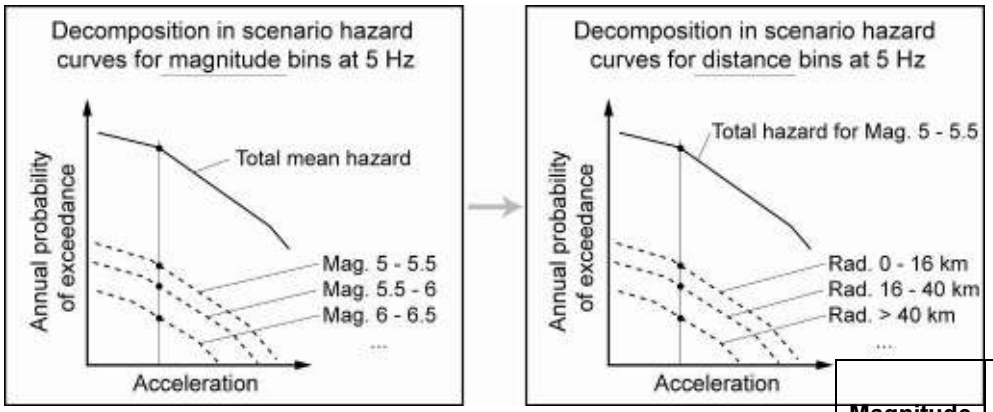
PRP - Output SP5

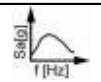
- **Development of scenario earthquakes: Conditional Mean Response Spectra** (min. 2) ~~and **corresponding times histories** (min. 7)~~ based on hazard curve for rock
- **Attribution of: Location of controlling earthquake (long., lat.), magnitude, source mechanisme, dip, focale depth, duration**



PRP - Output SP5 (continued)

- **Breaking down into szenario hazard curves for rock**
  - for following frequencies: 1 Hz, 5 Hz, 100 Hz
  - separate for magnitude and distance



Magnitude	Distance	Spectral accel. for 5 Hz OR UHS OR Scenario spectrum	Rate of occurrence
5.25	10 km	0.5 g OR Spectrum: 	0.8 (10^{-4})
6.5	10 km	0.4 g OR Spectrum: 	0.2 (10^{-4})
…	…	…	…
5.25	10 km	0.55 g OR Spectrum: 	0.8 (10^{-5})
…	…	…	…

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„Lessons Learned“ – Supporting Literature

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4. Klügel, J.-U., 2005: Alternative Aggregationsverfahren zur Integration der PEGASOS-Ergebnisse – Eine systematische Untersuchung, Report BER-D-17379, KKW Gösgen.
5. Klügel, J.-U., 2005: Problems in the application of the SSHAC probability method for assessing earthquake hazards at Swiss nuclear power plants, Engineering Geology 78, 285-307.
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12. Klügel, J.-U., 2006: Data analysis for the evaluation of parameters of the temporal and spatial frequency distributions of earthquake recurrence around the Gösgen site, Report BER-D-23274, KKW Gösgen.
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15. Klügel, J.-U., 2007: Comment on “Why Do Modern Probabilistic Seismic-Hazard Analyses Often Lead to Increased Hazard Estimates?” by Julian J. Bommer and Norman A. Abrahamson, Bulletin of the Seismological Society of America, vol. 97(6), p. 2198-2207.
16. Klügel, J.-U., 2008: Seismic hazard analysis - Quo vadis?, Earth Science Reviews, vol. 88(1-2), p. 1-32.
17. Budnitz, R. J., Cornell, C. A. & Morris, P. A., 2005: “Comment on J.U. Klügel's "Problems in the application of the SSHAC probability method for assessing earthquake hazards at Swiss nuclear power plants" in Engineering Geology, Engineering Geology 82, 76-78.
18. Lomnitz, C., 2005: Comment on J.U. Klügel's "Problems in the application of the SSHAC probability method for assessing earthquake hazards at Swiss nuclear power plants", in Engineering Geology, vol. 78, pp. 285–307, Engineering Geology 82, 71-73.
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23. HSK, 2007: Neubestimmung der Erdbebengefährdung an den Kernkraftwerkstandorten in der Schweiz (Projekt PEGASOS), HSK-AN-6252.

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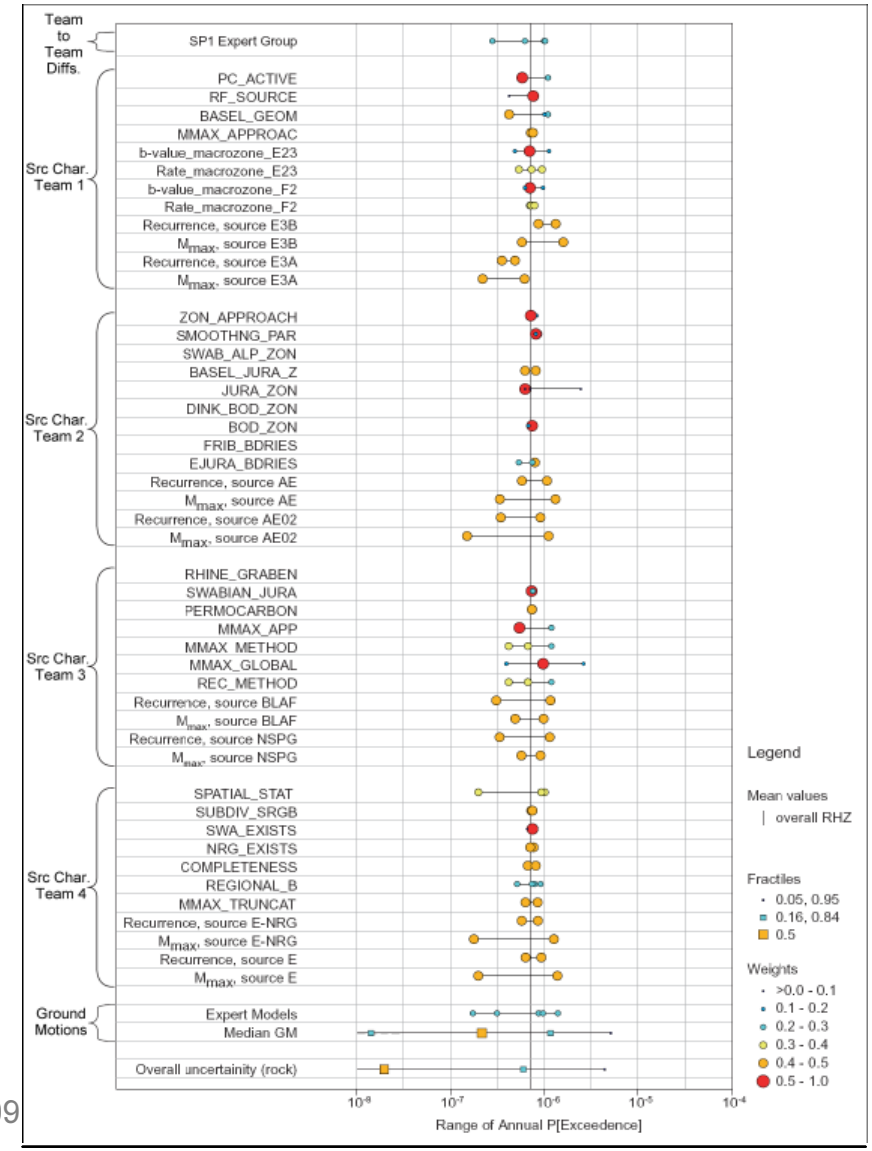
Uncertainty Contribution



Uncertainty in the median estimate of ground-motion parameters was the single greatest source of epistemic uncertainty

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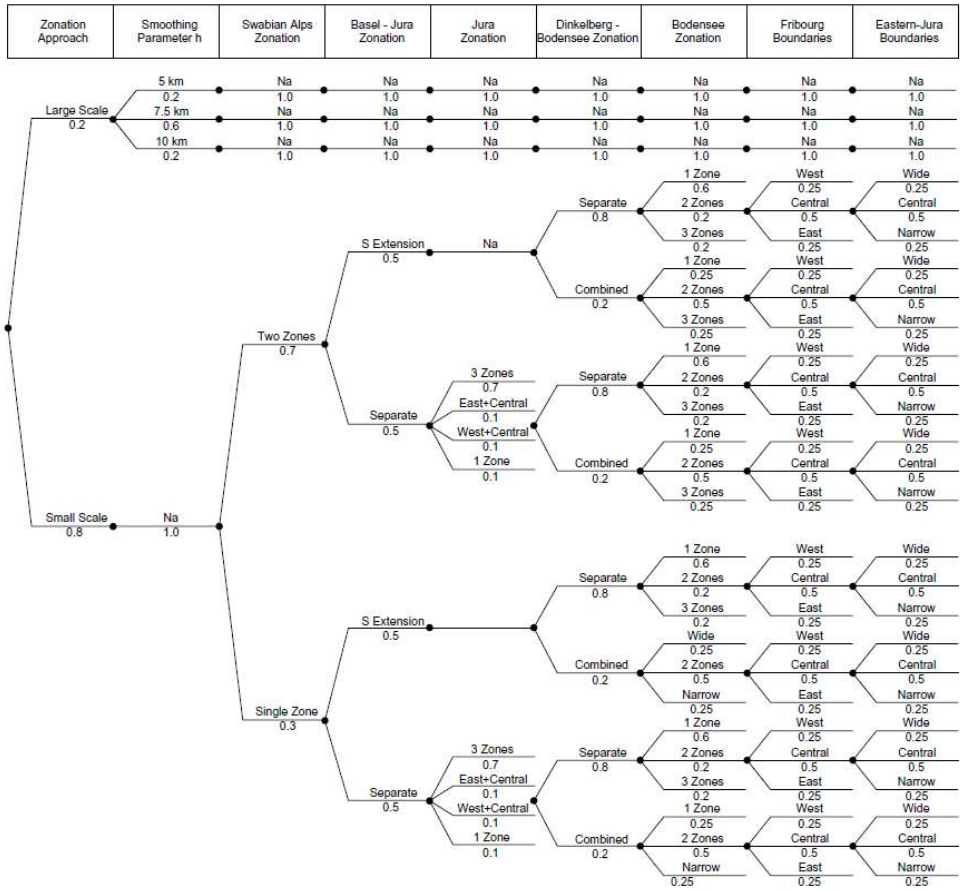
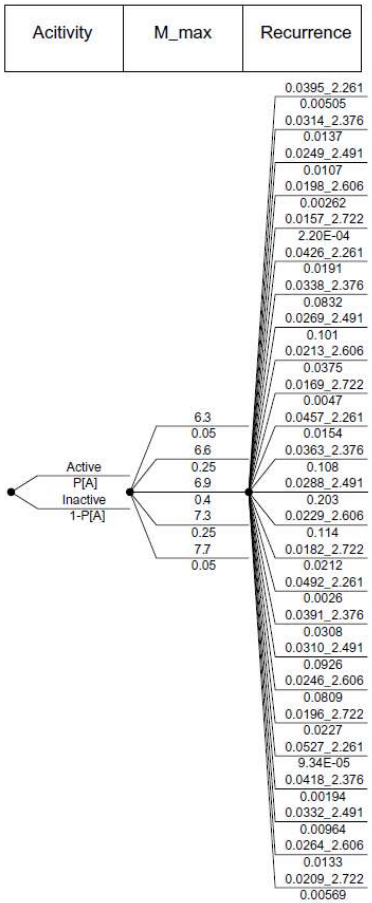
Hazard Computation - Logic Tree Approach

SP1 Global Logic Tree (EG1b)

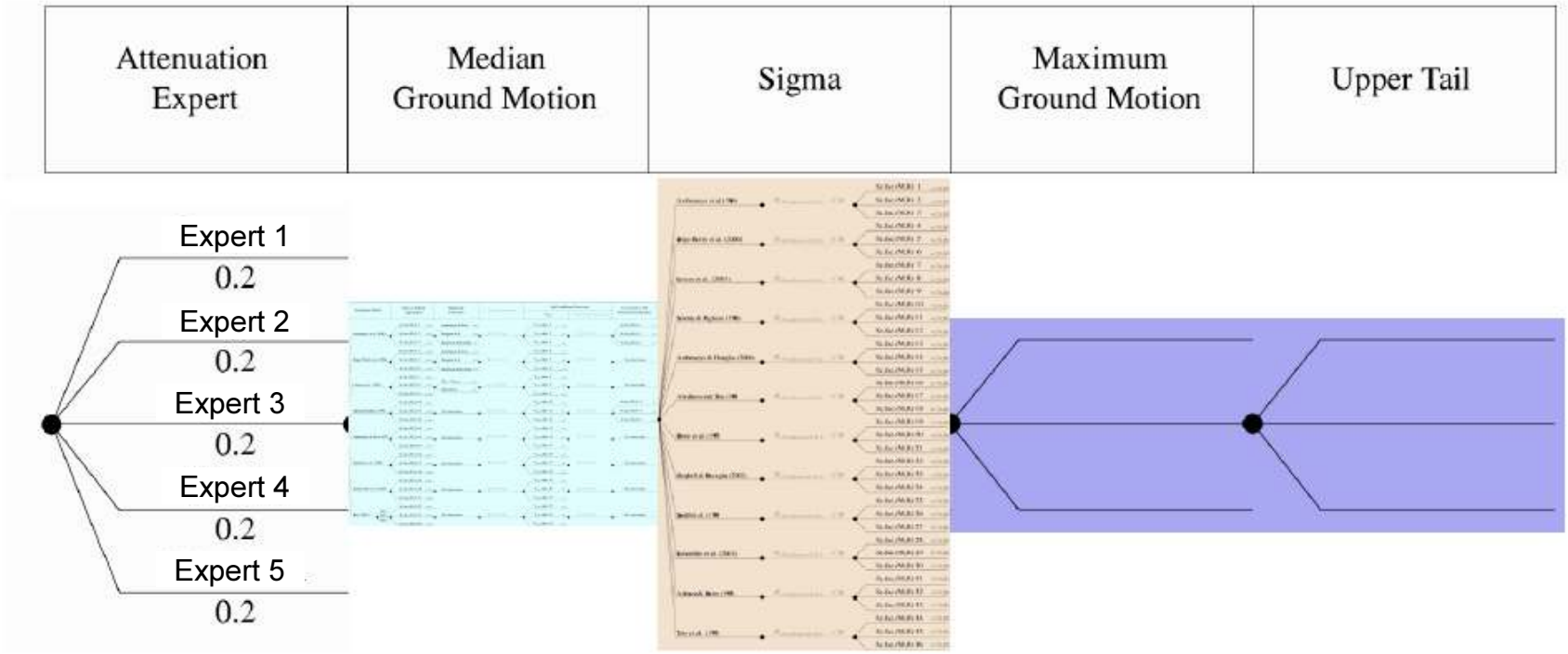


SP1 Source Tree

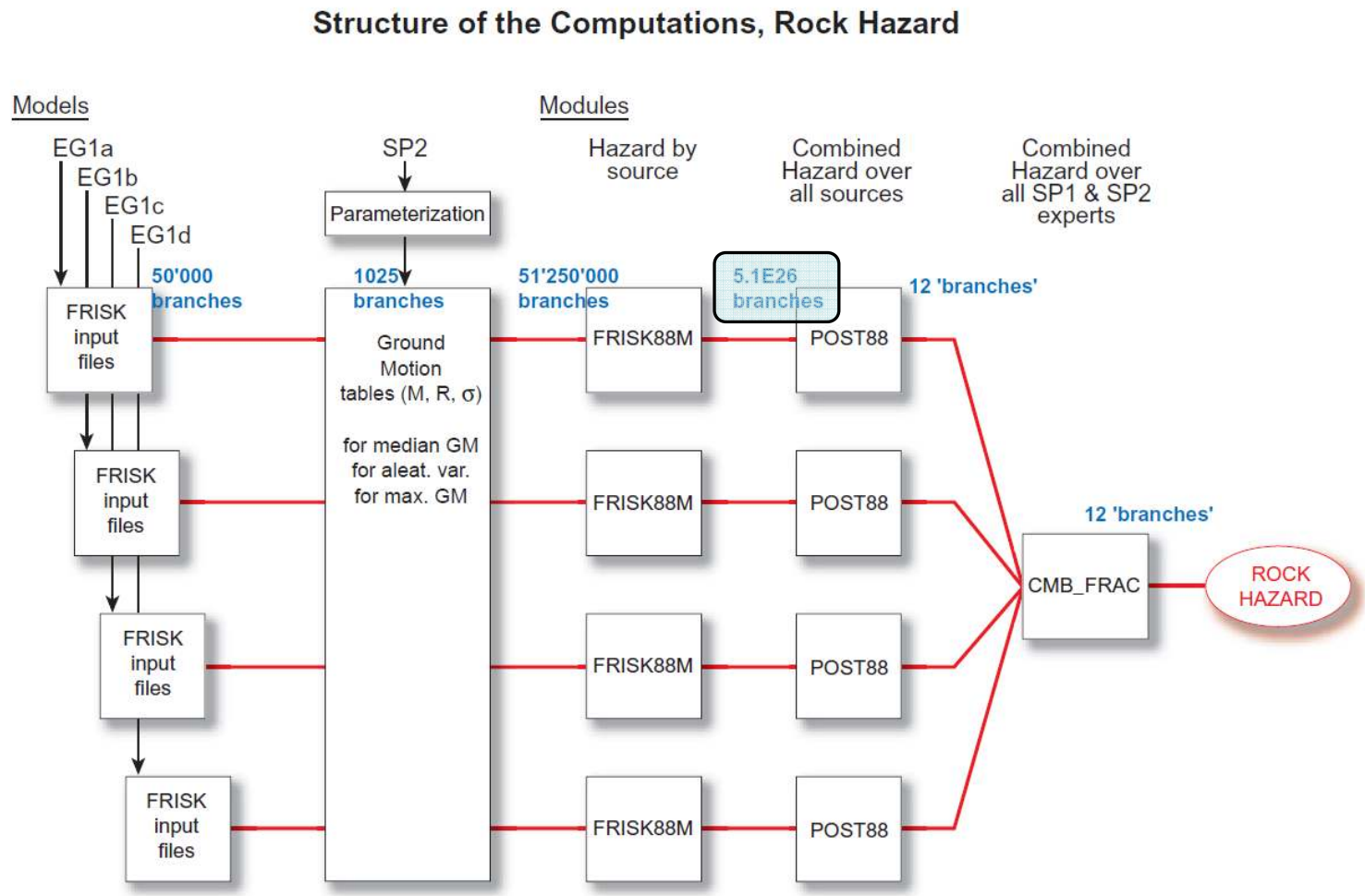


Hazard Computation - Logic Tree Approach

SP2: Combination of the Subtrees



Hazard Computation - Logic Tree Approach



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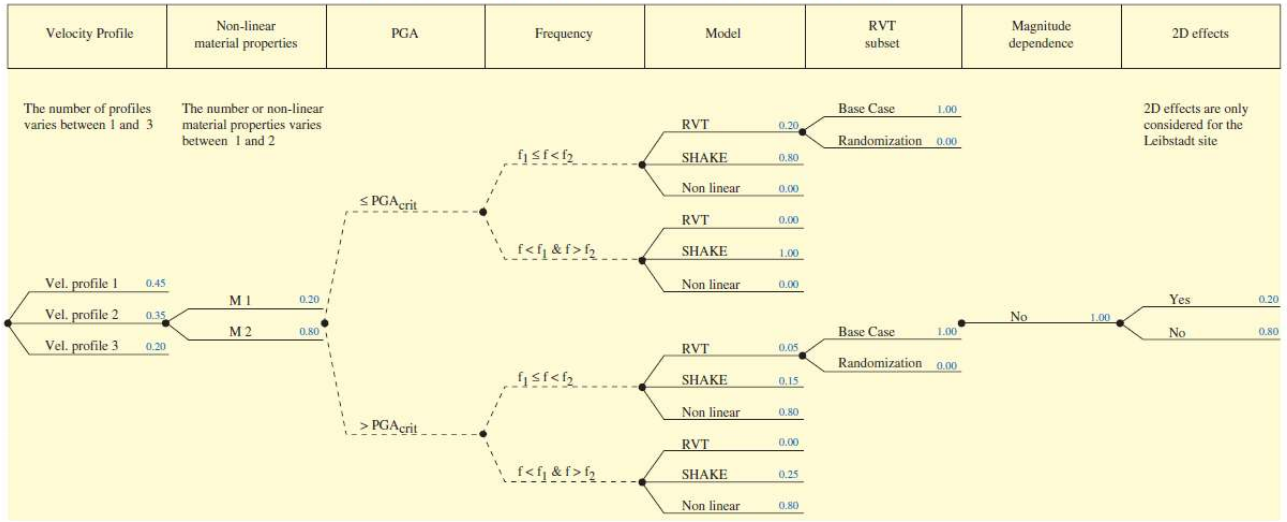
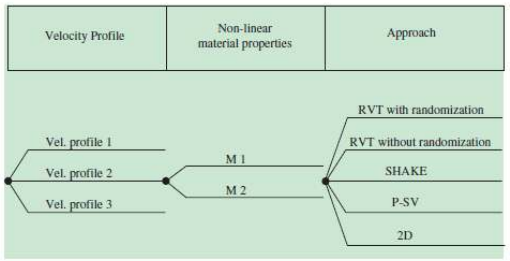
Hazard Computation - Logic Tree Approach

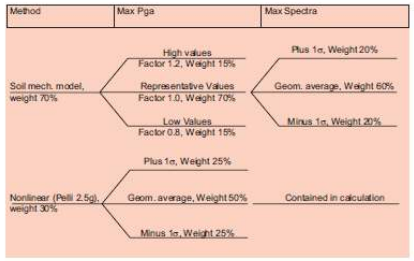
SP3: Logic Tree for the Median Site Amplification



SP3: Simplified Logic Tree for the Aleatory Variability



SP3: Logic Tree for the max. GM



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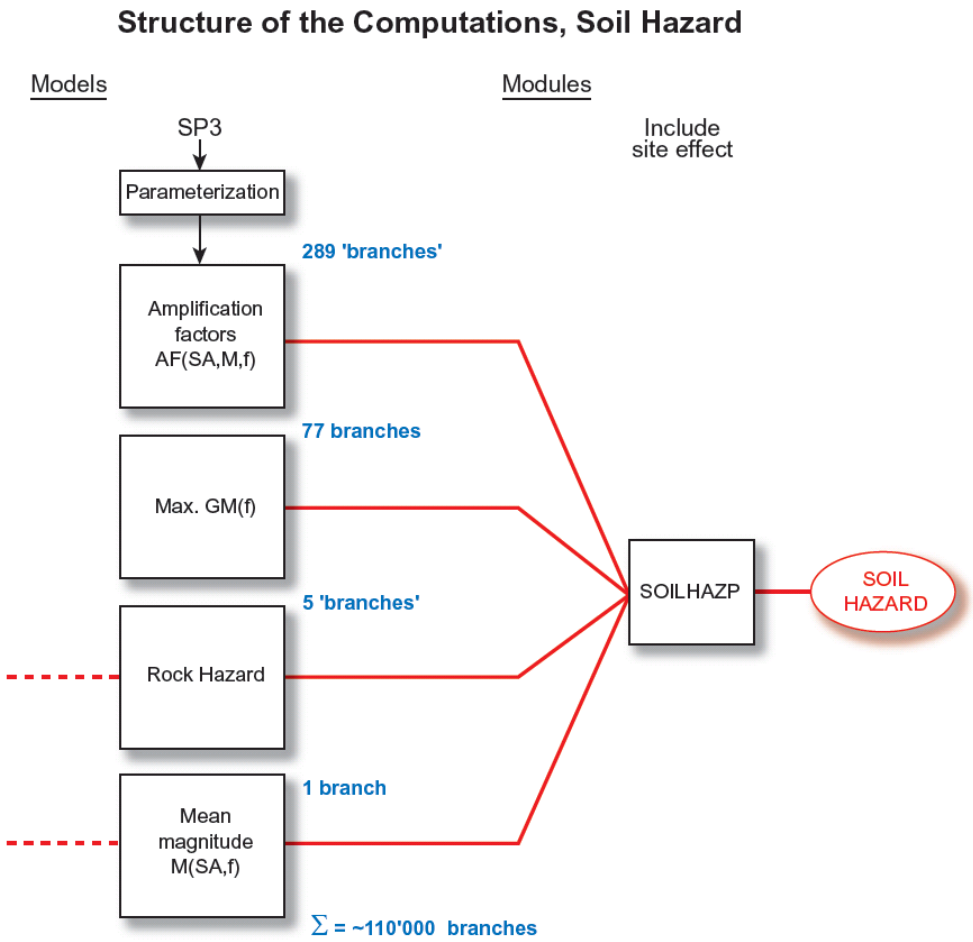
Hazard Computation - Logic Tree Approach



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PRP - Expected changes/improvements

- **Avoiding double counting of uncertainties**
- **Use of Swiss specific data for the model building**
- **Systematic reduction of magnitudes in earthquake catalogue**
  → Slight reduction of mean hazard
- **With new attenuation models (like NGA)**
  → Significant reduction of sigma and average reduction of mean hazard
- **With data collected during new site invesigation**
  → Reduction of uncertainties for site response (?)
- **Apply sampling techniques on logic tree**
  → Avoiding tree trimming/pinching

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Contact and Information Source

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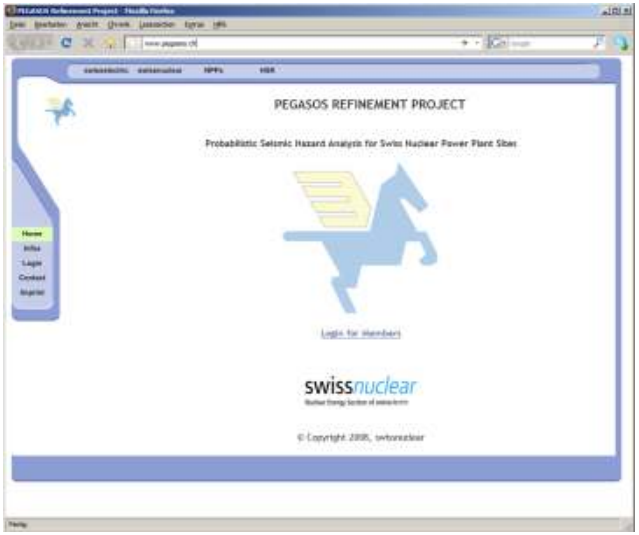

Thank you for your attention