Report of the Second Workshop on Seismic Observation in Deep Boreholes and Its Application

April 9, 2013

Yuichi UCHIYAMA
Japan Nuclear Energy Safety Organization (JNES)

36th Meeting of the Integrity and Aging of Components and Structures Working Group
18th WGIAGE Seismic Sub-group Meeting

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1. Background

Tsukuba WS: Nov. 2004
(Importance of deep borehole was emphasized)

NCO Earthquake: July 2007
(Forcusing effect from responses in each units)

First SODB WS in Kashiwazali: Nov. 2010

Initiation of JNES SODB project: 2009
- Soft rock site(kasiwazaki):2009~
- Hard rock site (Tottori):2011~

Off-Tohoku Earthquake/Tsunami: Mar 2011

Second SODB WS in Kashiwazali: Nov. 2012

Third SODB WS : 2014
(Final Summarization)

2. Objectives of the second WS

(i) International application and promotion of seismic observation technology in deep boreholes and technology for investigating underground structures.

(ii) Development of more practical, more reliable, more economical, and simpler technology for investigating underground structures

(iii) Utilization of this technology for the evaluation of uncertainty of 3D deep underground structures.

(iv) Application of deep seismic ground motion observation data for the seismic safety of nuclear facilities (usage to real-time automatic-scram, etc.), and promotion of international multi-purpose usage of such data.

3. Organizations

- Japan Nuclear Energy Safety Organization:
  K. Ebisawa, S. Horino, Y. Mamada, G. Kobayashi
- International Atomic Energy Agency/ISSC:
  S. Samaddar, Y. Fukushima
- OECD/NEA Working Group on Integrity and Aging of Components and Structures (IAGE): A. Huerta

4. Date and Venue

November 7-9, 2012
at the Niigata Institute of Technology, Kashiwazaki, Japan

5. Participants of the Second WS

79 persons in total, including **14** from overseas hailing from **8** countries and **2** international organizations, participated

(France, Germany, New Zealand, Sweden, Turkey, USA, Vietnam and Japan)

6. Outline of the Second WS(1/2)

- **Opening Session**
  - **IAEA, OECD and JNES**
- **Technical Session S1【Development of Deep Borehole Seismic Observation System】**
  - **Development of new Observation Technology (high temperature and high pressure resistant seismometer, multi-depth seismometer installation method) ………………… 8 presentations**
  - **Development of economical and realistic investigation method of deep underground structure…………………3 presentations**

Outline of the Second WS(2/2)

- **Technical Session S2【Deep Ground Motion Evaluation (Application to Seismic Design)】**
  - **Evaluation of attenuation characteristics at deep underground ……………………… 2 presentations**
  - **Evaluation of 3D underground structure………7 presentations**

- **Technical Session S3【Multi-usage of Deep Borehole Seismic Observation Technology and Data】**
  - **Proposal of simple underground structure exploration method for practical application at nuclear newcomer countries….. 2 presentations**
  - **International sharing of seismic ground motion observation data ………………… 1 presentation**
  - **Current status of application of seismic ground observation data, sharing and application (of data) for safety of nuclear facility ………………10 presentations**

7. Resolutions of the Second WS

(i) We participants of the WS acknowledge the value of the deep underground and multi-depth observation; we resolve to promote its international usage.

(ii) We promote the practical usage of simpler, more reliable, and more economical underground structure investigation technology. Such technology is available to the international nuclear power community, including newcomer countries.

(iii) We acknowledge the value of site effect evaluation by geophysical exploration and seismic observation data on seismic evaluation. We will examine the design method of the degree of uncertainty inherent in establishing reliable ground motion estimates.

(iv) JNES has proposed a possible application of seismic observation in deep boreholes in a real-time automatic-scram system to improve the seismic safety of nuclear plants. We also encourage future international multi-purpose usages of these achievements.

(v) We acknowledge the value of the Kashiwazaki Seismic Safety Center and the continuation of deep seismic observation at this facility for the international community.

Report of the Second WS

- The report is nearly completed and will be sent to the IAGE secretary in several weeks after native check is finished.

Thank you for your attention!

Group picture of the second SODB workshop

CAPS
Seismic Input Definition and its Control Point
Member States Regulations and Practices

Working Group: Integrity and Ageing of Components and Structures (IAGE WG)

Seismic Sub-Group

Paris, April 9th 2013

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- Scope
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- Newly gathered practices
- Updated practices
- Conclusions
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Introduction

- Spanish CSN in charge of CAPS "Seismic input definition and its control point"
- Work to be completed by Principia in conjunction with CSN

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Introduction

- SHA produces information on site GM parameters.
- This information is to be employed in the structural dynamic analyses (design and reevaluation).
- The characteristics of the SHA results must be consistent with the use being made, key points:
  - Soil characteristics: mechanical & geometrical
  - Control point: where are they obtained or will be applied (ground level, certain depth)

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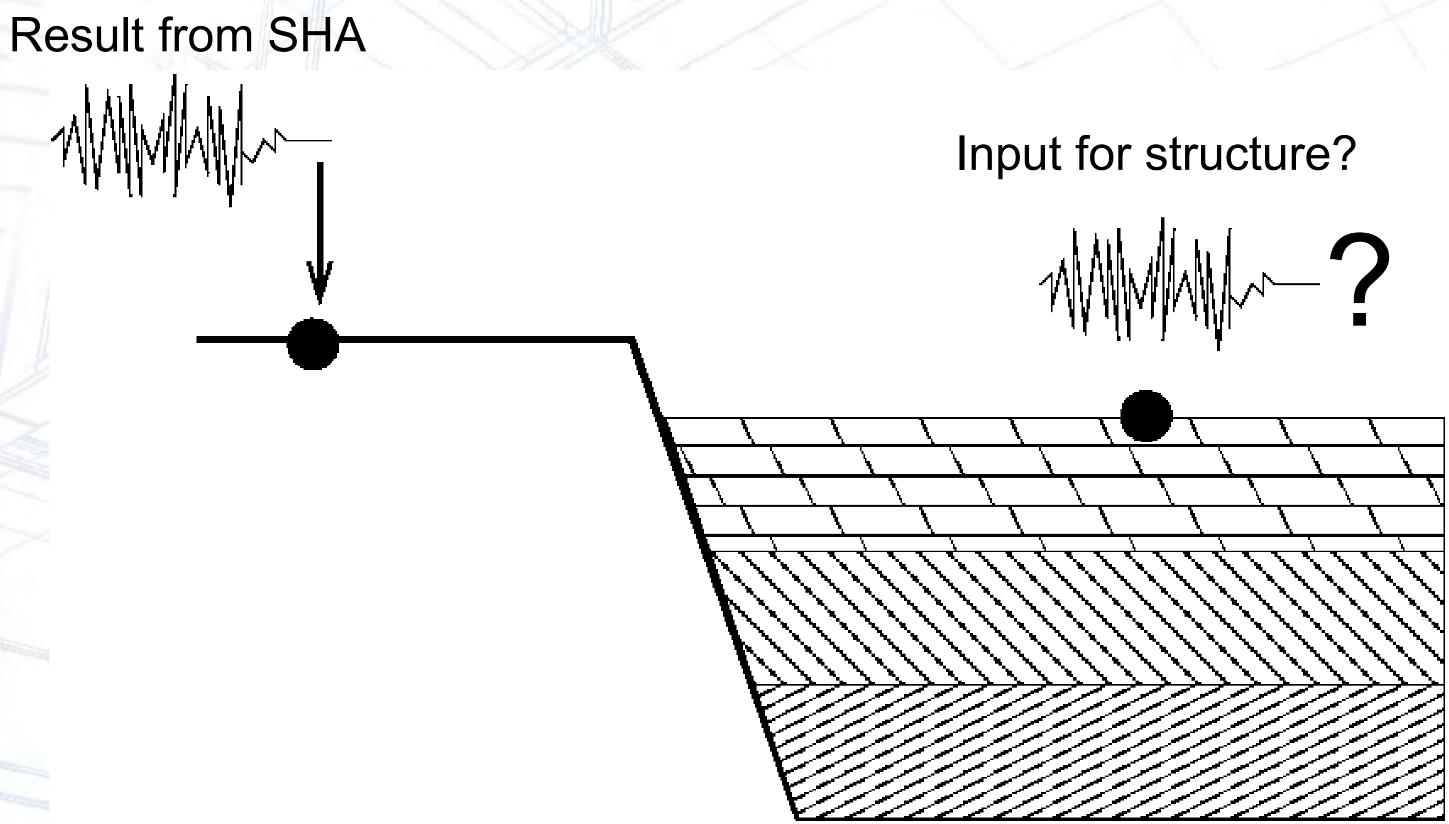
Introduction



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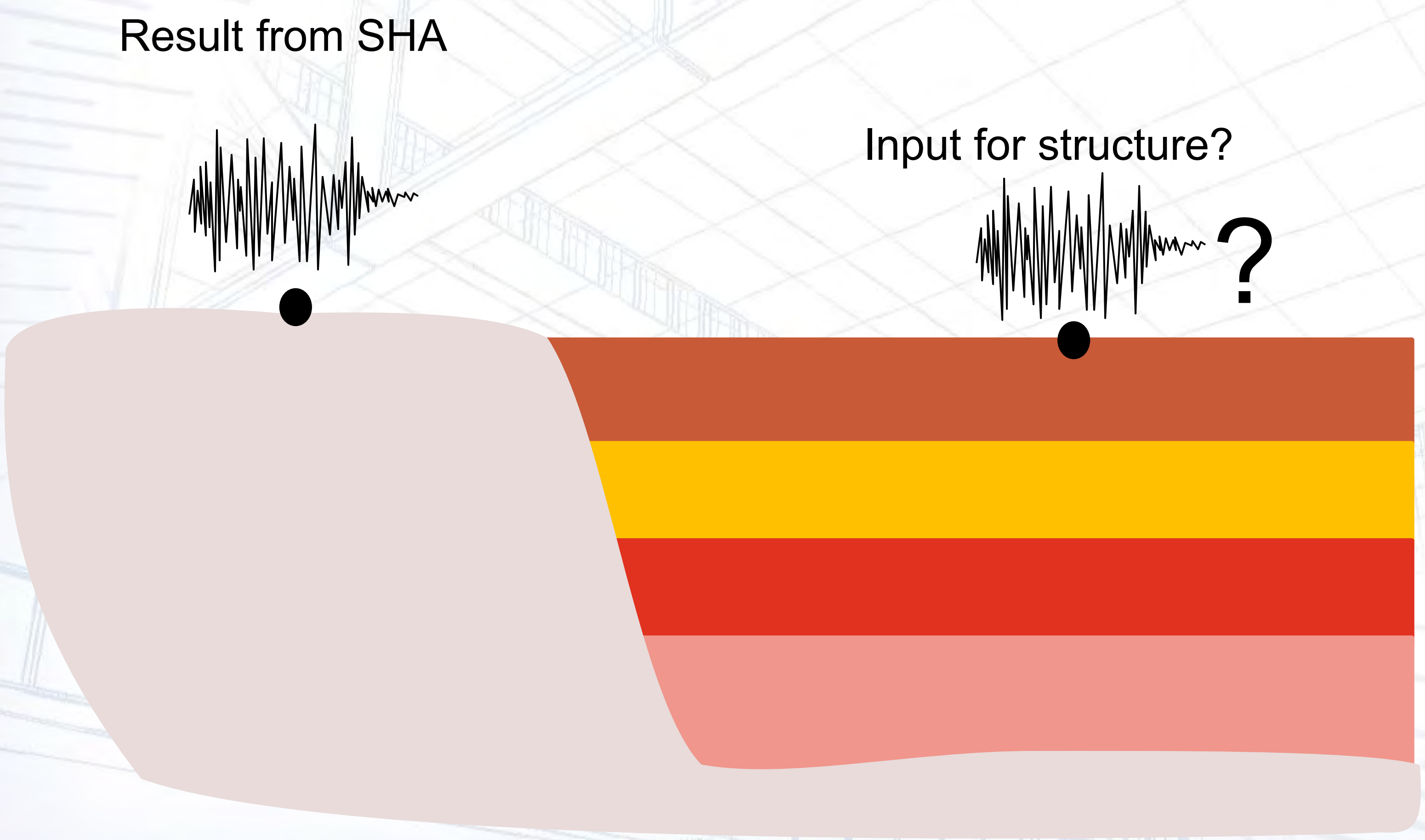

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Introduction

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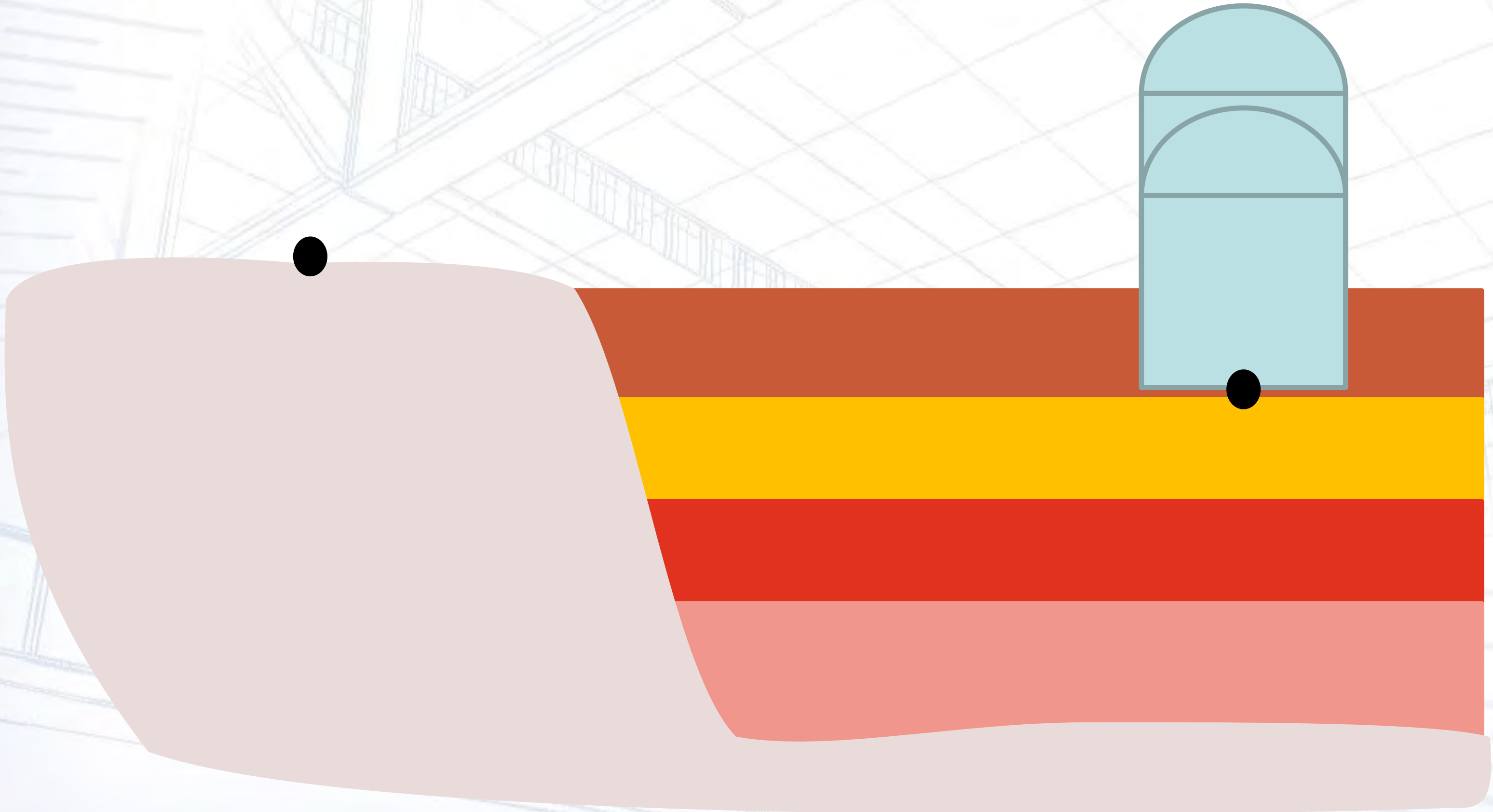

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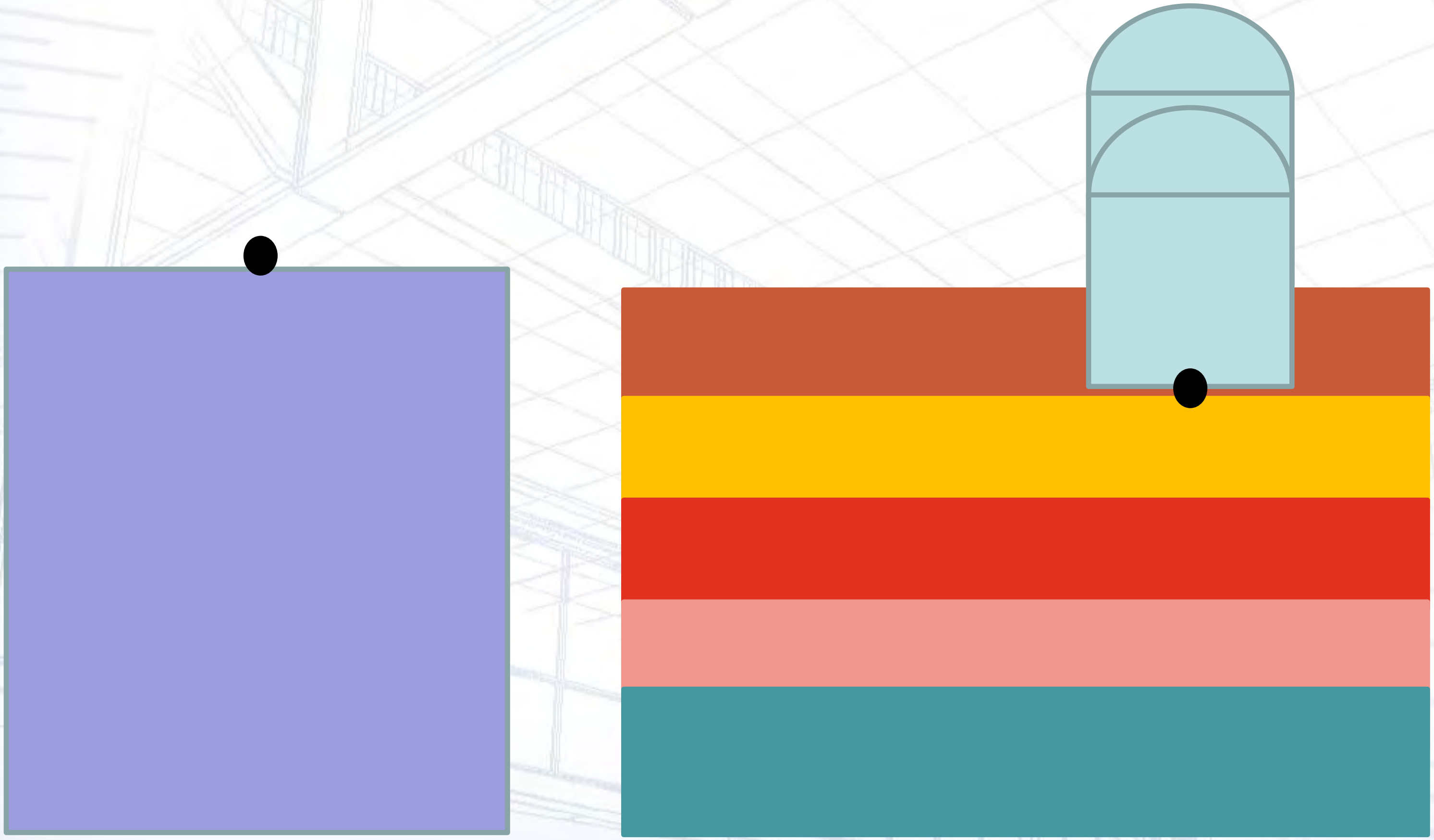
Introduction



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Objective

- Clarify current practices in Member States (MS) on the definition of seismic input out the SHA results

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Scope

- Gather MS information
- Produce a document presenting the information from MS → latest version sent last week

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Status

- Information has been received from:
  - Canada
  - USA
  - Japan
  - Finland
  - France
  - Germany
  - The Netherlands
  - Korea
  - Spain
  - Sweden
- A report has been issued
  - Open to suggestions/comments

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Newly gathered practices

- Canada
  - Relevant documents:
    - "Site Evaluation for New Nuclear Power Plants", Regulatory Document 346
    - "Design of New Nuclear Power Plants", Regulatory Document 337
    - "Ground Motion Determination for Seismic Qualification of Nuclear Power Plants", N289.2-10
    - "Design Procedures for Seismic Qualification of Nuclear Power Plants", N289.3-10

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Newly gathered practices

- Canada
  - PSHA to be performed reporting the results for a 10^{-2} to 10^{-5} range of annual probability of exceedance
  - Reference ground condition associated with the PSHA results to be given (i.e. in terms of shear wave velocity).
  - DBE shall have at least 10^{-4} annual probability of exceedance at the mean confidence level.
  - Spectral shape, based on Newmark and Hall (1978).

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Newly gathered practices

- Canada
  - CSA N289.3-10 requires convolving the response spectra to account for overburden above the elevation associated with it ➔ result to be used as input for SSI, allowed to be at top surface or at foundation level.
  - No specific guidance on how to convolve.

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Newly gathered practices

- Sweden
  - Relevant documents:
    - "Characterization of seismic ground motions for probabilistic safety analyses of nuclear facilities in Sweden" SKI Technical Report 92:3
    - Swedish Safety Guide, still in a draft status, which refers to SKI Technical Report 92:3
  - No regulation on how to handle site effects.
  - SKI TR 92:3 is the reference document.

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Newly gathered practices

- Sweden
  - Annual exceedance probabilities of interest: 10^{-5} - 10^{-6}.
  - SKI TR 92:3 presents a complete approach for the generation of the seismic input for two NPPs including:
    - construction of site specific design response spectra with the modelling of specific site conditions (i.e. soil layers).
    - sedimentary bedrock and soil strata overlying the basement rock modelled with finite elements.
    - basement rock where the finite element model starts has a shear wave velocitiy of 3400 m/s.

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Updated practices

- France
  - Relevant document:
    - "Règle fondamentale de sûreté no. 2001-01 relatives aux installations nucléaires de base"
  - Deterministic seismic hazard assesment
  - It deals with the consideration of site effects:
    - two possible site conditions as a function of shear wave velocity.
    - if the site does fit into any of the two categories, a specific site analysis is needed.

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Updated practices

- The Netherlands
  - Relevant documents:
    - “Guidelines for the Protection against External Hazards”, known as NVR3.1
      - Never became official.
  - Ongoing process of evaluation of existing Dutch Safety Requirements and of updating existing guidance.

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Updated practices

- The Netherlands
  - Recent stress test aknowledged that the RG 1.60 spectra employed for the Borssele NPP site were inadequate.
    - In one of the safety evaluations new ground response spectra are defined using the Hosser (1987) methodology.

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Conclusions

- Answers from 10 MS
- US and Japanese practices are the most complete
- Within Europe, Sweden has the most guided approach, although not within the regulations, however, it is the reference document for the definition of the seismic input at the Swedish NPPs.

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Conclusions

- Canada, France and South Korea explicitly recognise the need to account for site effects although no guidelines are provided

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Conclusions

- General remarks:
  - Definition of bedrock is heterogeneous: should not be a problem if the information is known and adequately incorporated to the soil column response
  - Probabilities are different from one country to another, more difficult to homogenise
  - In absence of local guidelines, US practice is frequently employed (The Netherlands, Spain, Sweden)

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Proposed future work

- Additional version of the report if further comments or suggestions are received.
- In the proposal it was said:

  "Another CAPS will be proposed upon completion of this work to provide recommendations for developing a harmonised approach to define the seismic input and its control point".

Status of Methodology Development for Probabilistic Tsunami Hazard Analysis

April 9, 2013

Yuichi UCHIYAMA

Japan Nuclear Energy Safety Organization (JNES)

36th Meeting of the Integrity and Aging of Components and Structures Working Group
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   3.5 JNES Recipe of TPSA
4. Summary

1. Study Reports and Relating Events

Timeline of the events relating tsunami hazard evaluation in Japan

(1) 2001/06 Long-term evaluation of EQ probability by the Headquarter for Earthquake Research Promotion

(2) 2002/02 Tsunami Assessment Method for Nuclear Power Plants in Japan, Feb. 2002, JSCE

(3) 2004/12 The 2004 Indian Ocean earthquake and Tsunami

(4) 2006/07 Development of a Probabilistic Tsunami Hazard Analysis in Japan, July, 2006, T.Sakai et.al. , ICONE14 (Basic idea of JSCE2011)

(5) 2008/02 IAEA initiated works of tsunami (external flooding) guide development (DS417, published in 2011 as SSG-18, (JSCE2002 methodology was introduced in its attachment.)

(6) 2011/03 The 3.11 Earthquake and Tsunami in off-Tohoku Japan and Fukushima Accident

(7) 2011/09 Methodology for Probabilistic Tsunami Hazard Analysis, Sept. 2011, JSCE (in Japanese)

(8) 2012/02 Standard for Procedure of Tsunami Probabilistic Risk Assessment(PRA) for nuclear power plants 2011, Feb.2012, AESJ (in Japanese)

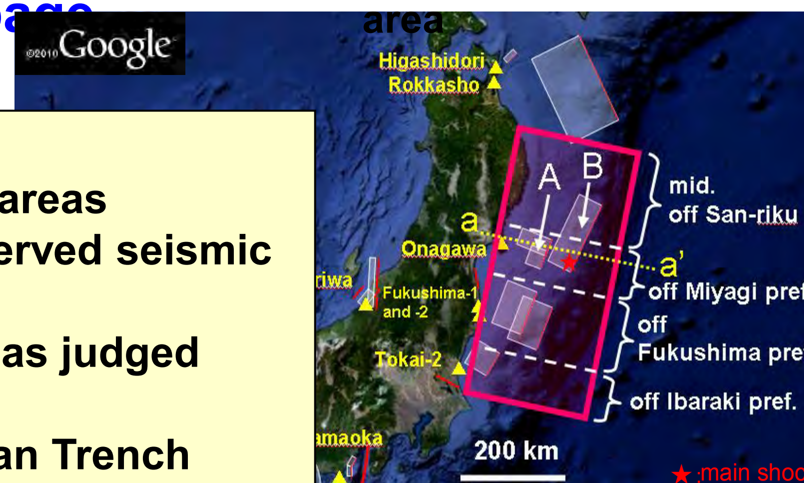
(9) 2012/09 Recipe for Assessing Design Tsunami Height in Light of the 2011 Tohoku Earthquake and Tsunami, Sept.5 2012, Yoko Iawabuchi, JNES

2. Characteristics of 2011 Tohoku EQ. and Tsunami

Characteristics of the source, observed ground motions and tsunami waveforms, slippage distribution

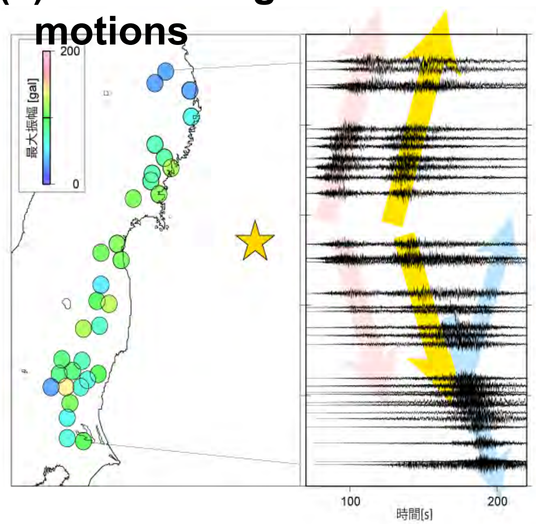
(1) Great earthquake with the scale of Mw 9.0
(2) Spatial conjunction among multiple source areas
(3) Tendency of time lags has seen among observed seismic ground motions
(4) Overlapping of waves different in character as judged from observed tsunami waveforms
(5) Distribution of large slippages near the Japan Trench

(1),(2) Source area



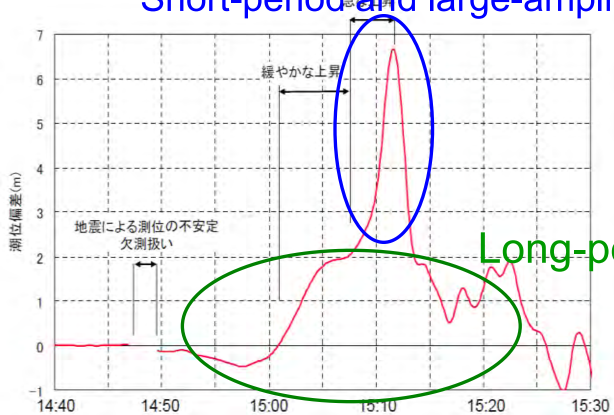
Google

(3) Observed ground motions



Quot. From NIED

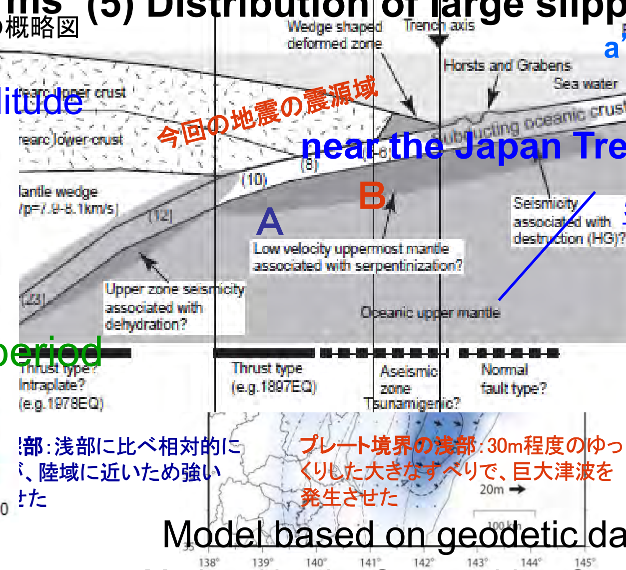
(4) Observed tsunami waveforms



Quot. From PARI

GPS wave gauge record off southern Iwate Pref.

(5) Distribution of large slippages near the Japan Trench

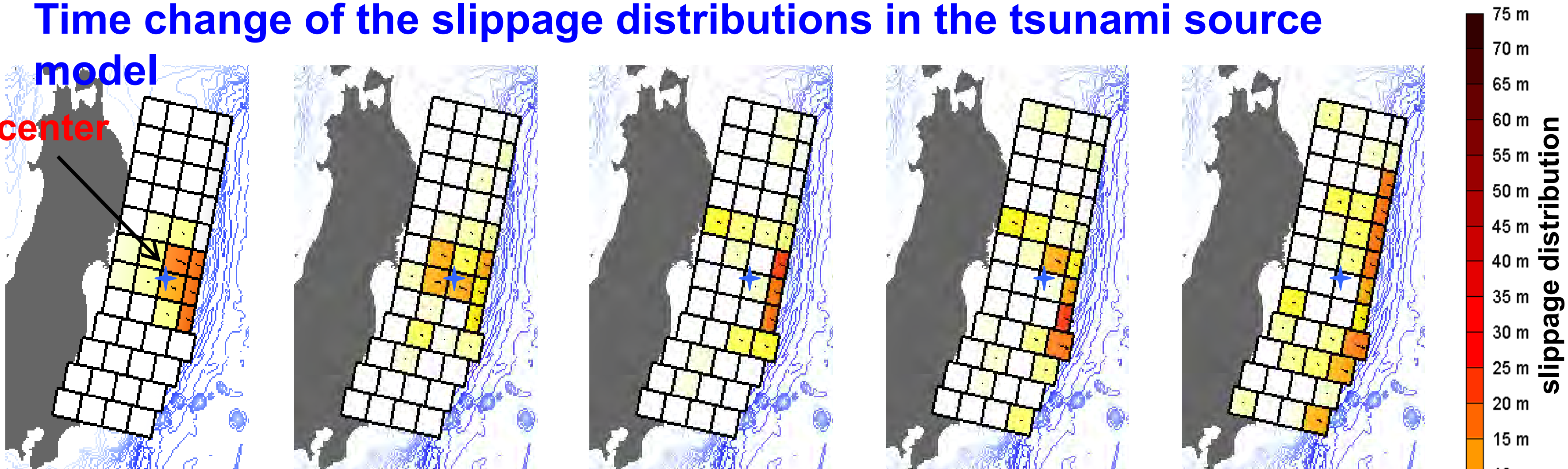


Model based on geodetic data

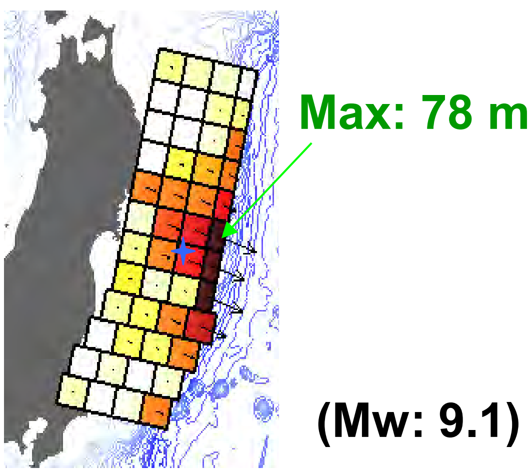
Modeled by the Geographical Survey Institute and the Japan Coast Guard

Estimated tsunami source model

- Time change of the slippage distributions in the tsunami source model



a) 0-60 sec. b) 60-120 sec. c) 120-180 sec. d) 180-240 sec. e) 240-300 sec.

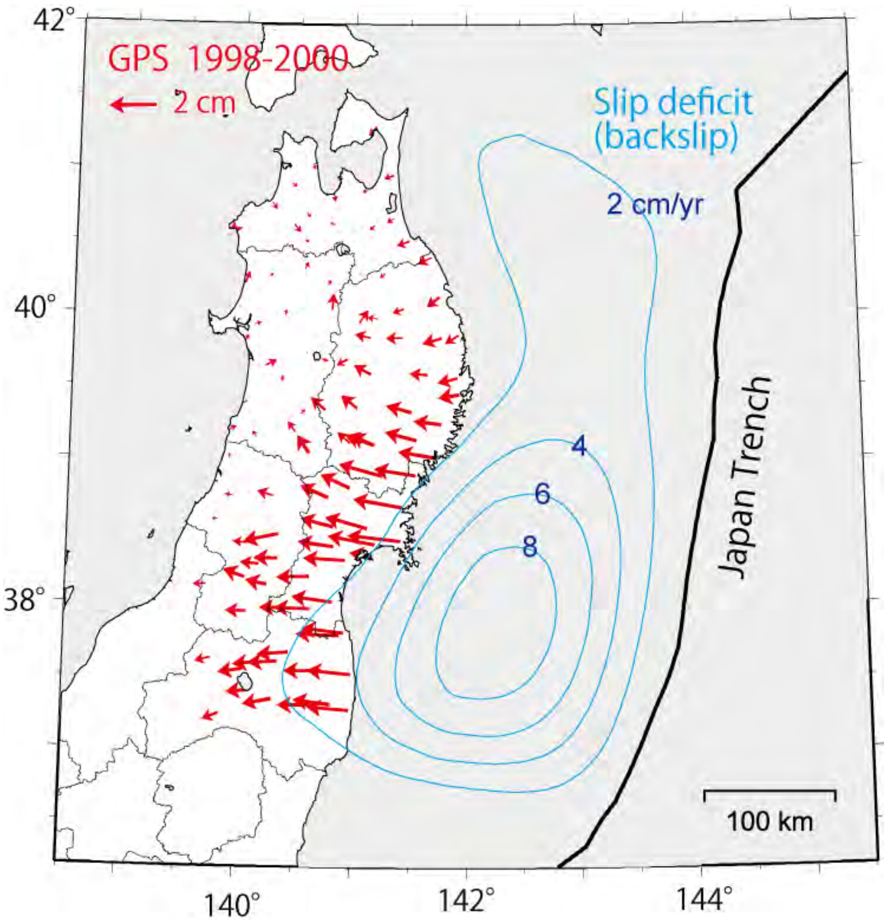


f) Total slippage

- Slip (fault displacement) starts to spread after the initial break point, and then spreads to relatively deep areas, finally moving toward shallow areas along the Japan Trench and continues further.
- This result match with the estimation of Geographical Survey Institute of Japan (characteristic no.5 of tsunami source) .

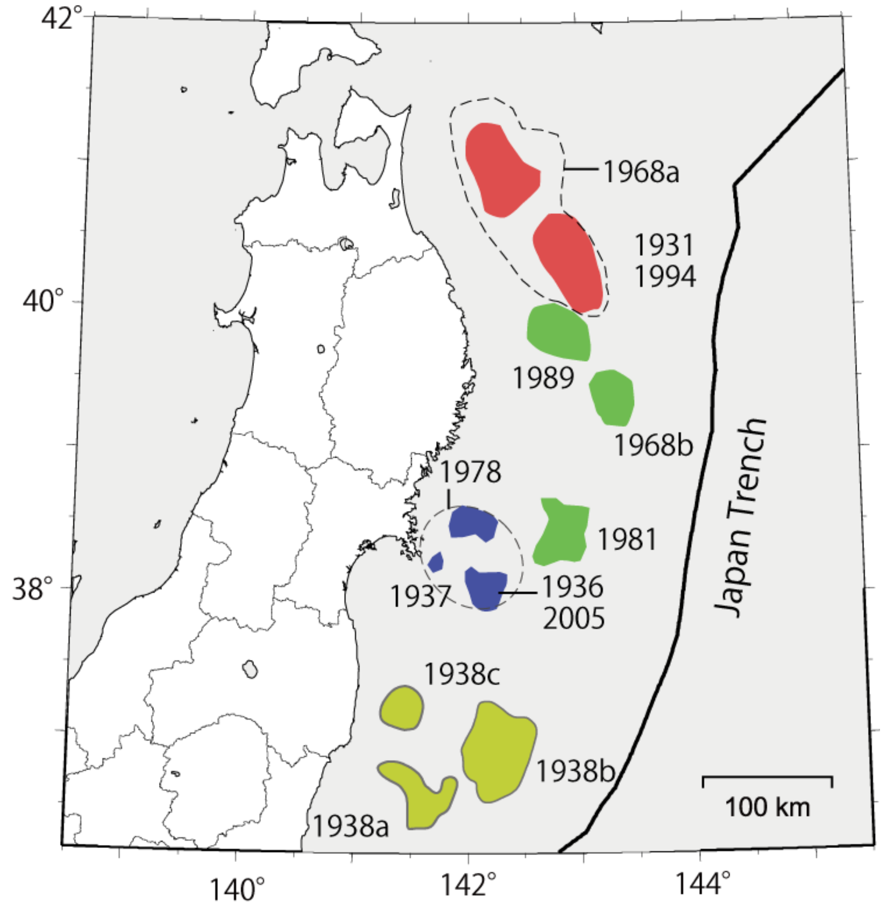
GPS data and past earthquakes

1998-2000



GSI (2010, 2011)

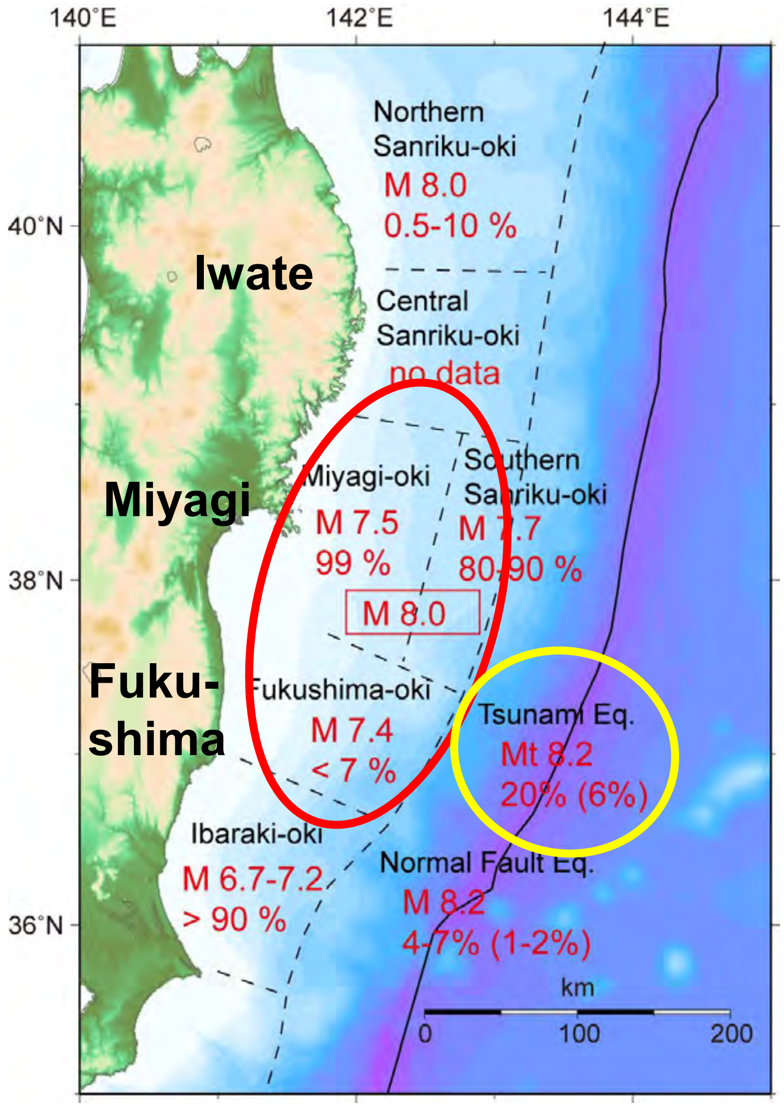
Large earthquakes since 1900



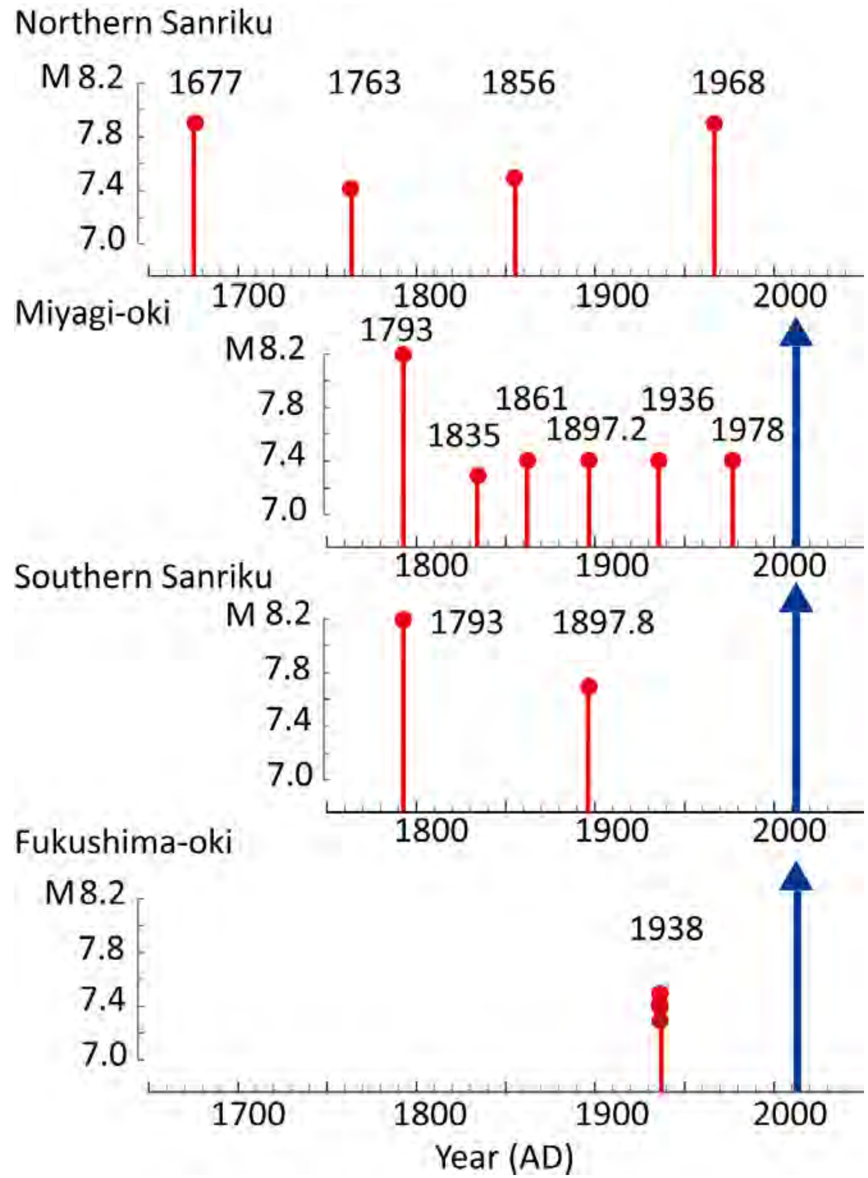
Yamanaka and Kikuchi (2004)

From Prof. Satake's presentation at the Regional Workshop on Site Evaluation, IAEA, June 13 2012

Long-term forecast of earthquakes before 2011 eq.

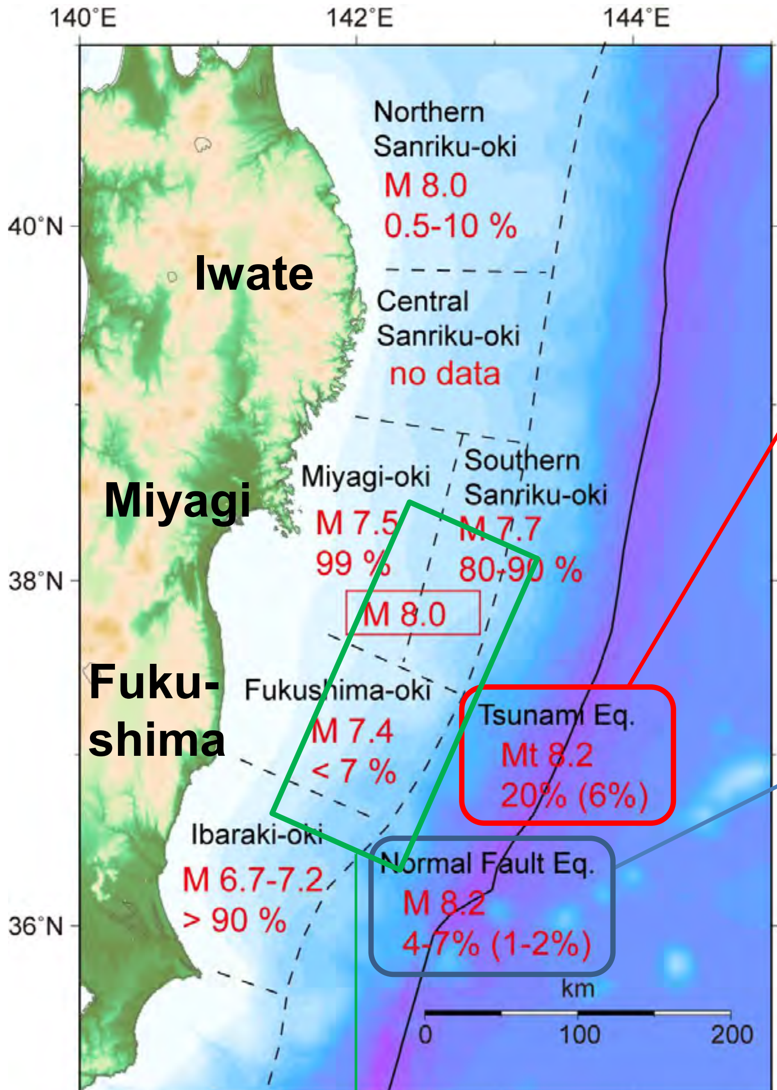


Long term forecast by ERC (2003)



From Prof. Satake's presentation

Long-term forecast of earthquakes before 3.11 eq.



Long term forecast by ERC

Along Japan trench

Tsunami earthquakes
- 3 events in last 400 years
- once in 133 years somewhere in the 800 km region
- at particular place once in 533 yrs
- (fault length: 200 km)

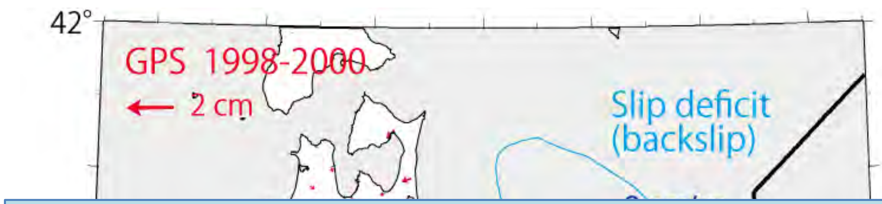
Outer-rise normal fault eq.
- 1 event in 400 yrs
- once in 400 – 750 yrs somewhere
- at particular place, once in 1600-3000 yrs

869 Jogan earthquake model

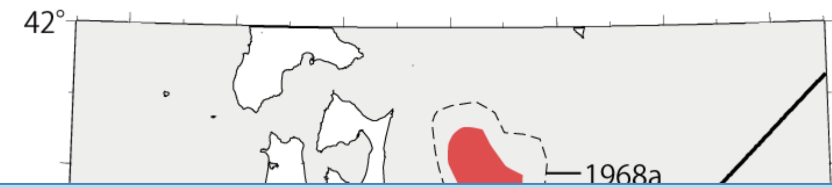
From Prof. Satake's presentation

GPS data and past earthquakes

1998-2000



Large earthquakes since 1900



(Slip deficit) = (Plate convergence speed) – (Coseismic slip)

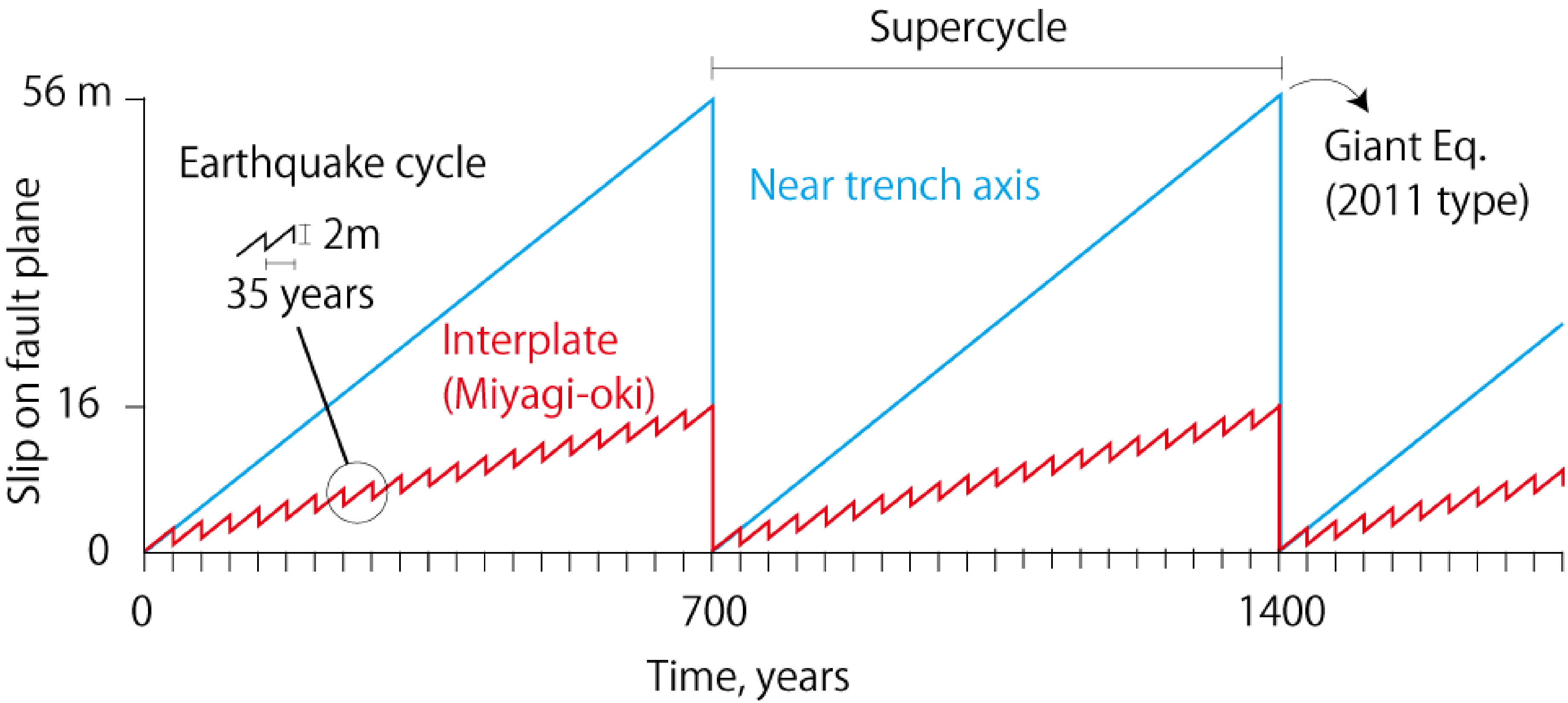
modified from "Supercycles of Great Earthquakes along Japan Trench", Prof. Satake (In Japanese)

Miyagi-oki Earthquakes

- **Interval of specific eq (R) : 37 year**
- **Coseismic slip/eq (d) : 2 m**
- **Coseismic slip speed (2m/37year): 5.4 cm/yr**
- **Plate convergence speed : 8 cm/yr**
- **Slip deficit speed : 8- 5.4 = 2.6 cm/year**
- **Coseismic slip in the 2011 eq : 17m**
- **Interval of 2011 type eq : 1700/2.6=660 year ⇨ Super cycle**

Slip deficit is thought to be dissipated by interseismic slow slip before the 2011 eq.

Supercycle of earthquakes



Seismologists assumed earthquake cycle (~35 years) from past records of two centuries and made forecast (99% in 30 years), but there seems to be a supercycle (~700 years) on top of it.

From Prof. Satake's presentation at IAEA/ANSN Regional WS

3. Outline of PTHA Relating Studies

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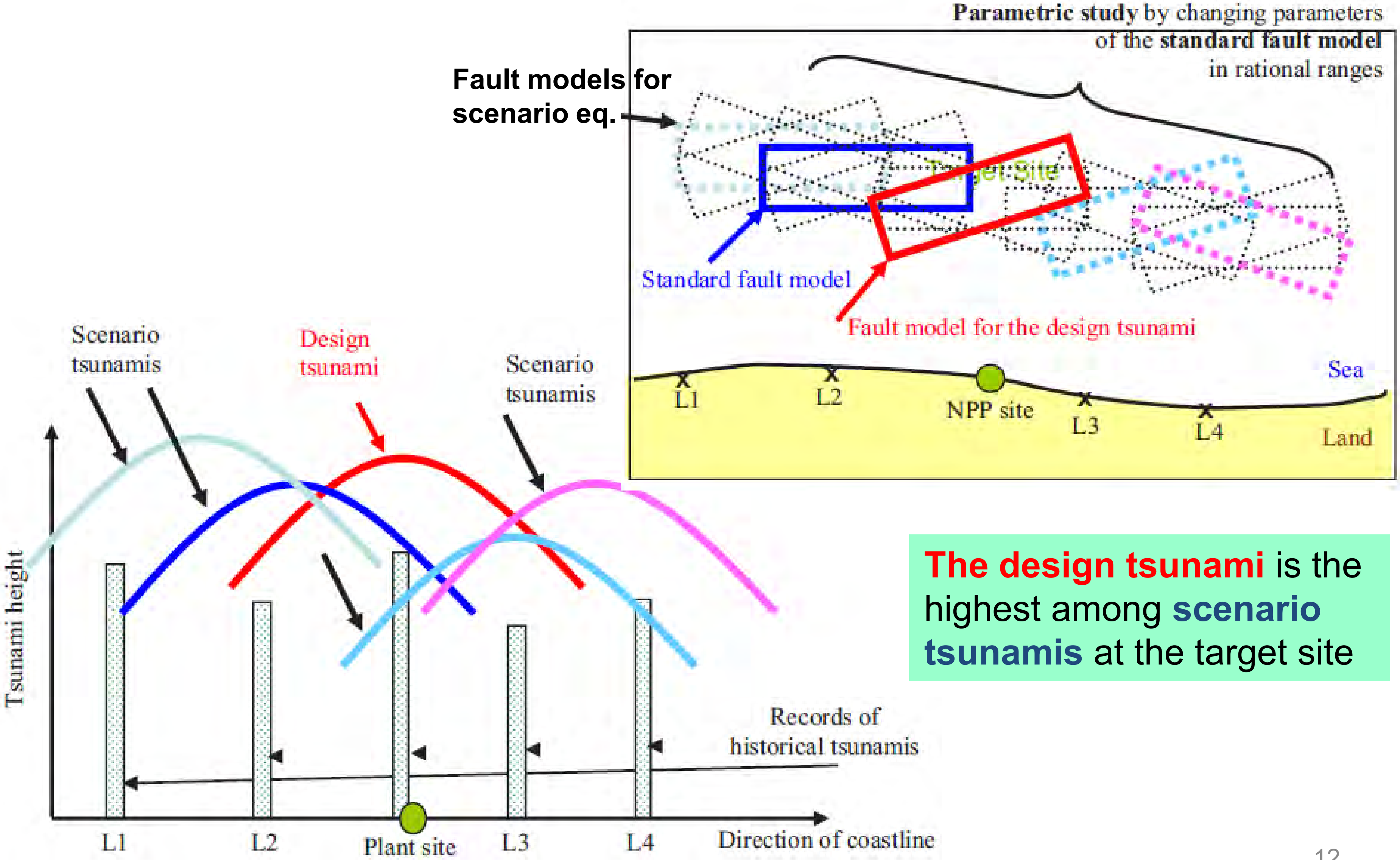
3.5 JNES Recipe of TPSA

3.1 Deterministic method : JSCE 2002

Concept of setting up source fault and parametric studies

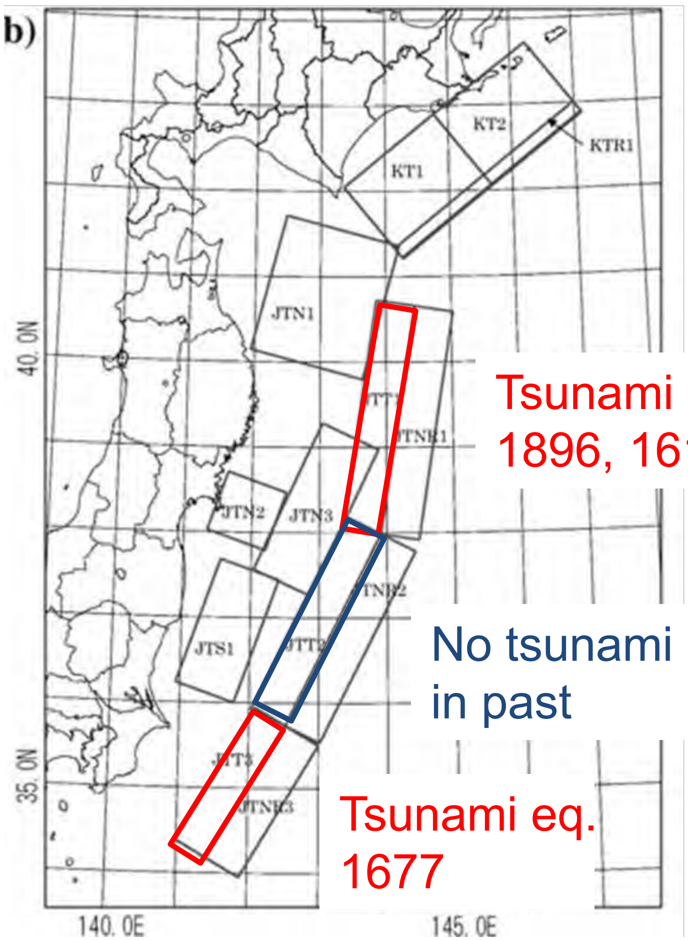


The design tsunami is the highest among **scenario tsunamis** at the target site

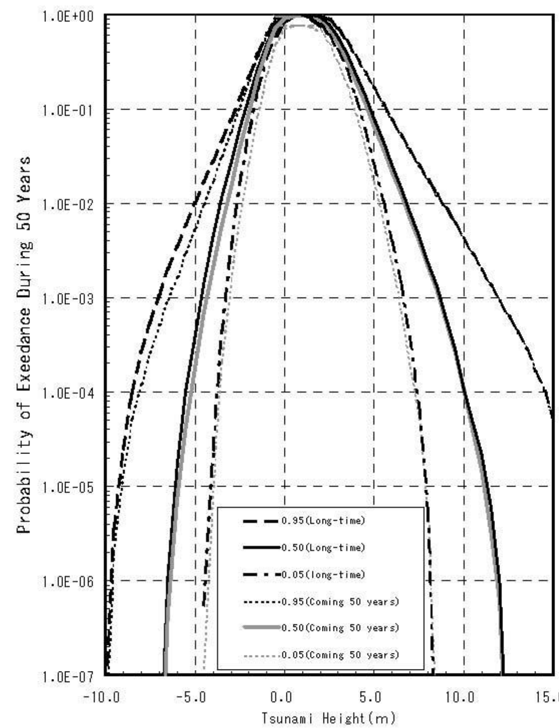
From IAEA SSG-18 Attachment 2

3.2 Trial Study of PTHA in 2006

Annaka et al. (2007) Pure Applied Geophysics vol. 164 pp. 577-592,
Sakai et al. ICONE14 (2006)



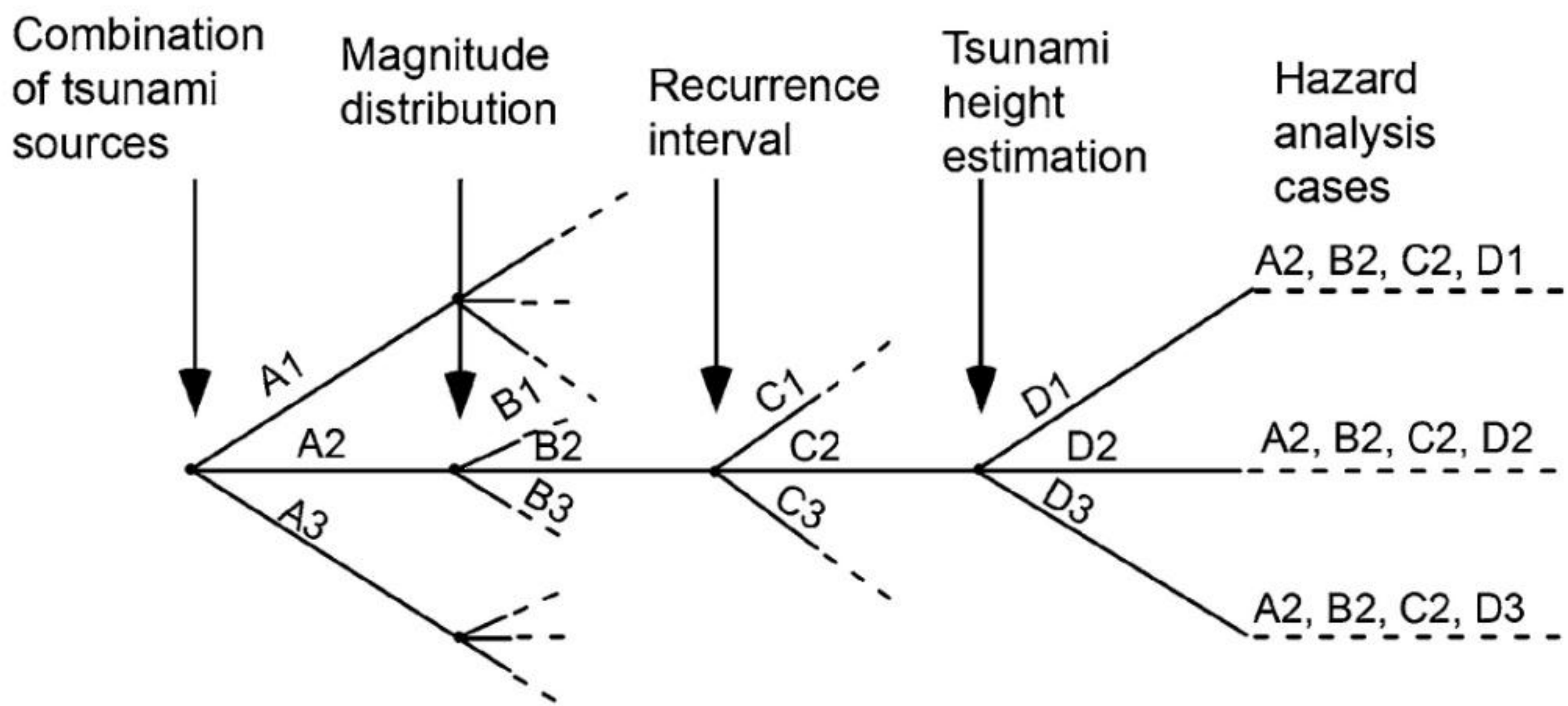
Fukushima NPP



Probability of > 10 m tsunami:
50yr probability ~ 5 x 10-3
Annual probability ~ 1 x 10-4
(recurrence: ~10,000 yrs)

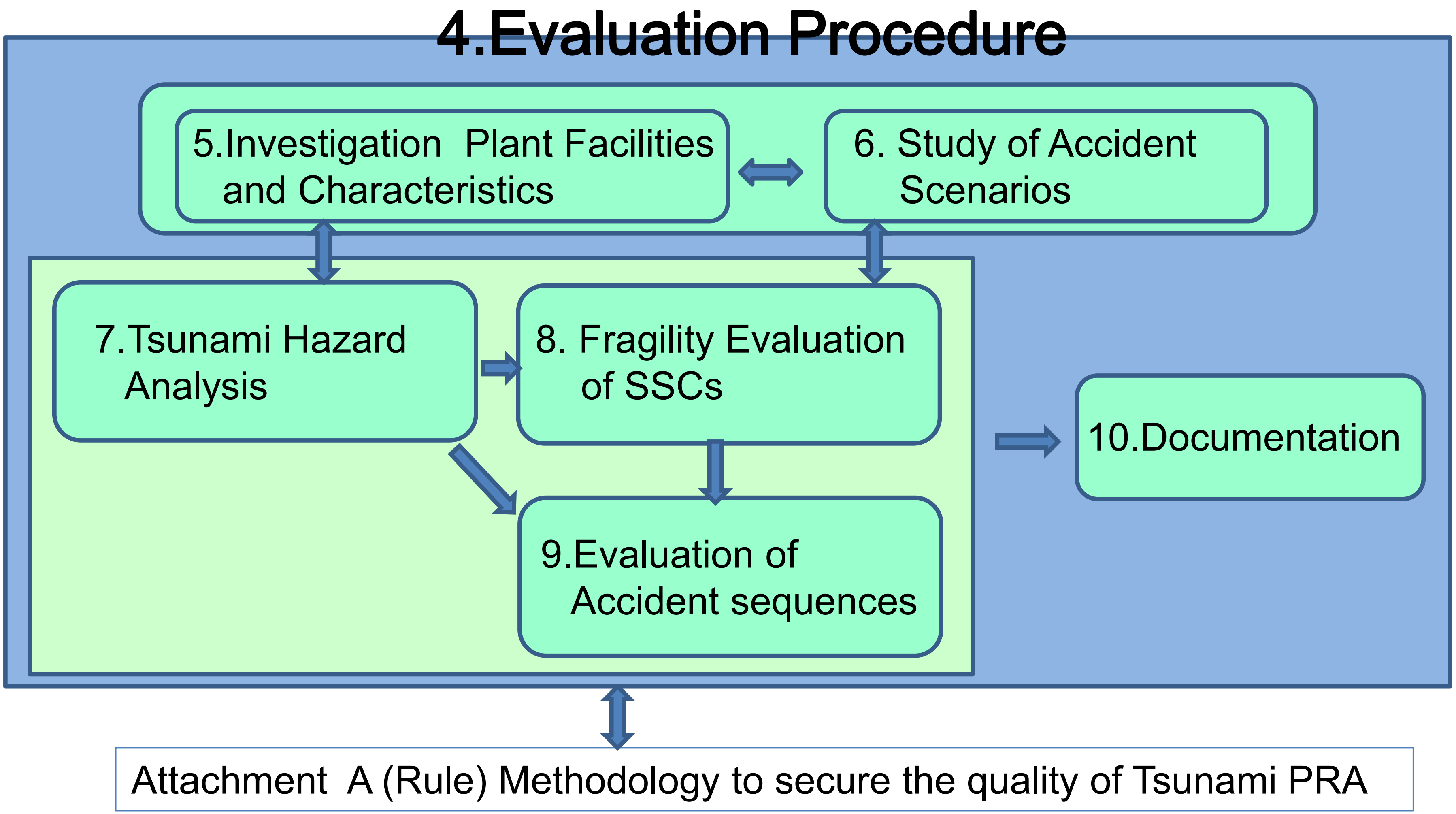
3.3 Methodology for Probabilistic Tsunami Hazard Analysis, Sept. 2011, JSCE (in Japanese)

Logic tree representation of Uncertain Parameters



Each path of logic tree generates a tsunami hazard curve

3.4 A Standard for Procedure of Tsunami Risk Assessment for NPPs 2011, Atomic Energy Society of Japan (in Japanese)



3.4 JNES Recipe of TPSA

This part is extract from "Recipe for Assessing Design Tsunami Height in Light of the 2011 Tohoku Earthquake and Tsunami" , Toko IWABUCHI, JNES, for IAEA experts' meeting on protection against extreme earthquakes and tsunamis on September 5, 2012.

(1) Concept of Recipe on the basis of probabilistic tsunami hazard assessment

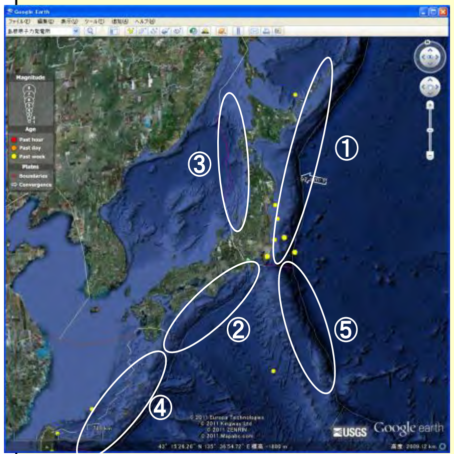
which reflects information on the 2011 Tohoku EQ tsunami

Prioritized items

Target tsunami source area

■ **Near-field tsunami**

(1) Interplate earthquake
- a) Tsunami earthquake
- b) Deep earthquake



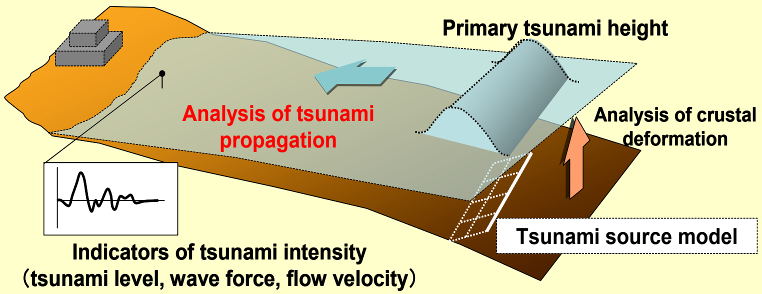
(2) EQ in the oceanic plate
(3) Crustal EQ caused by offshore active fault
(4) Others (landslide, volcano)

■ **Far-field tsunami**

Assessment of level and waveform of tsunami

■ **Determination of tsunami source model**
- (1) Macroscopic features
- (2) Microscopic features
- (3) Features related to disruption

■ **Calculation of the tsunami level and waveform**



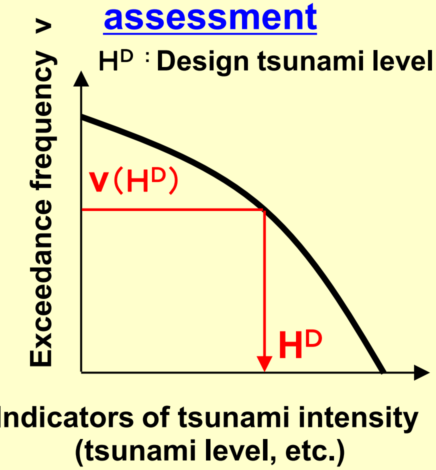
Assessment of the frequency of occurrence

■ **Modeling of EQ activities involving tsunami**
- (1) Past activity history (historical earthquakes and tsunami deposits)
- (2) Periodicity (Poisson process, Renewal process)

Assessment of uncertainty

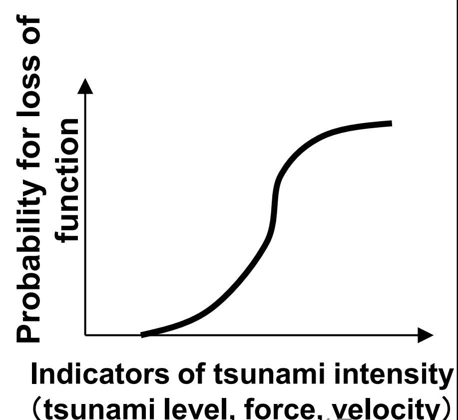
- (1) Accidental uncertainty
- (2) Epistemological uncertainty (logic tree method)

Tsunami hazard assessment



Linking

Fragility assessment

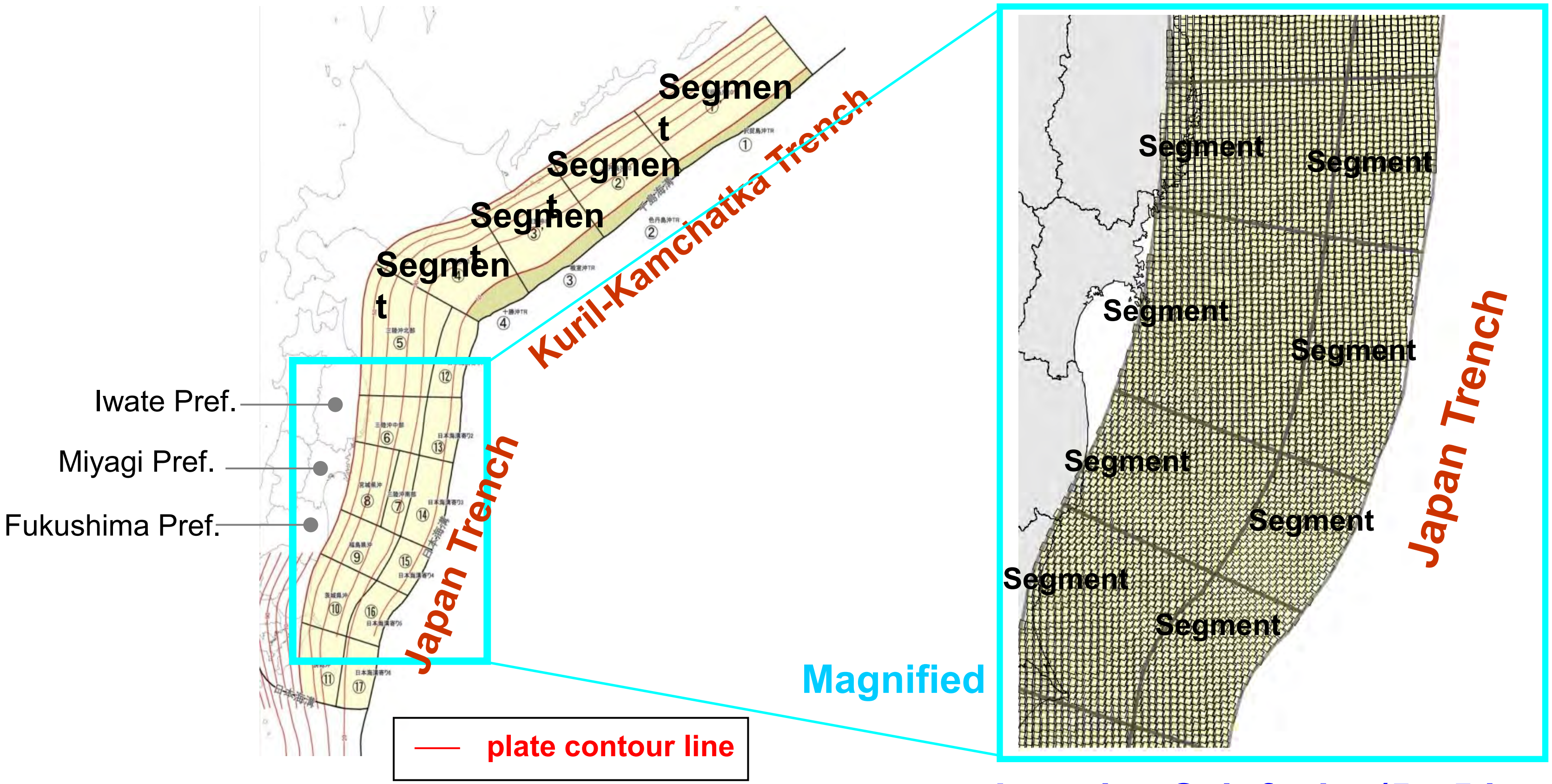


(2) Macroscopic features of tsunami source

in the case regarded as one earthquake

■**Establishing tsunami source** <u>**free from consideration of the largest tsunami in the past**</u>

- **Setting plate boundary surface and segment divisions**
- **Setting the combination of segments, and then setting the scale of earthquake Mw from gross area of faults**



In the above example, the range is Mw 8.1–9.5.

Locating Sub-faults (5×5 km) on the plate boundary surface

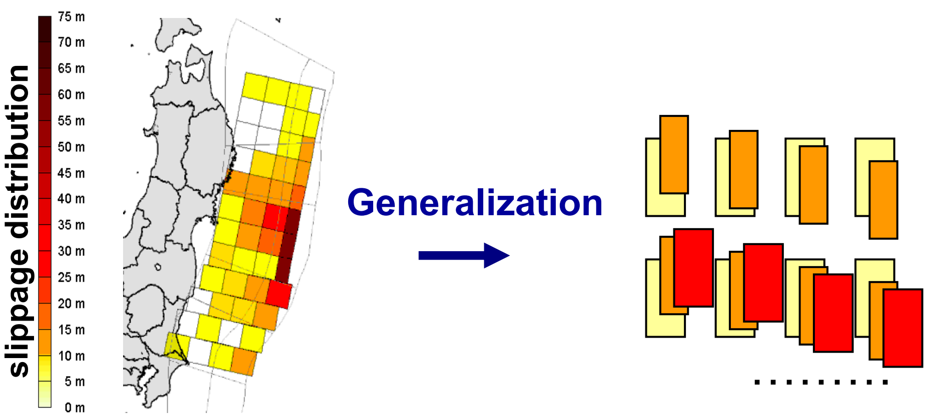
Setup method for "Features of rupture time" in the case regarded as one earthquake (A-1)

(3) Microscopic features of tsunami source

- Setting multiple patterns of large slippage areas and very large slippage areas based on the knowledge of the 2011 Tohoku EQ tsunami
- To facilitate use for future prediction, the tsunami source model used for future prediction is created by generalizing the detailed tsunami source model.

■Detailed model

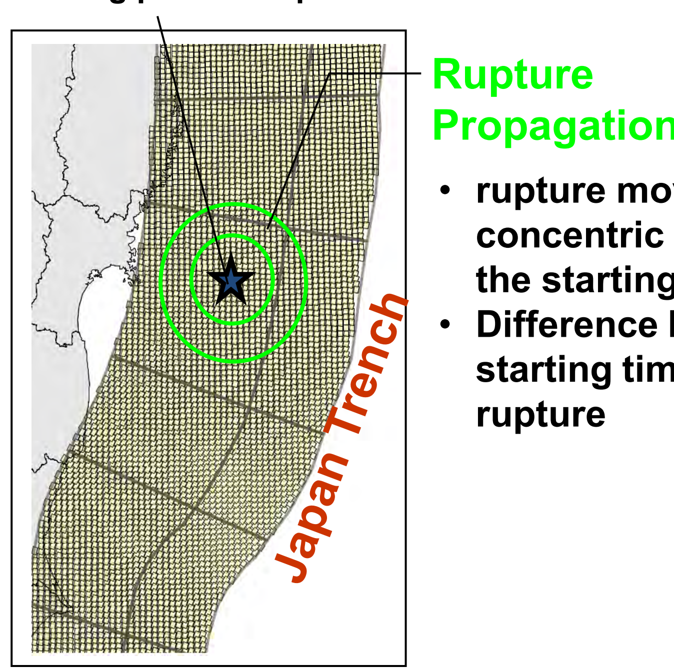
■Model for future prediction



(Reproduction of the 2011 Tohoku EQ tsunami)

(4) Features of rupture time

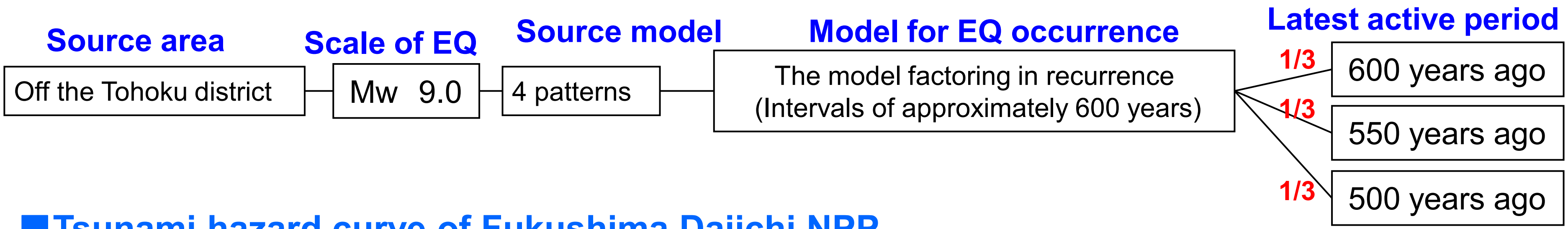
- Tsunami sources by which the scale of the earthquake (ex. Mw8.5) that would exceed a certain amount are considered with delay of starting time for rupture based on the rupture propagation.
- Rupture duration: several minutes



- rupture moves out as a concentric circle from the starting point
- Difference between the starting times of rupture

(4) Verification of frequency of occurrence of the tsunami level for the 2011 Tohoku EQ at Fukushima Daiichi NPP

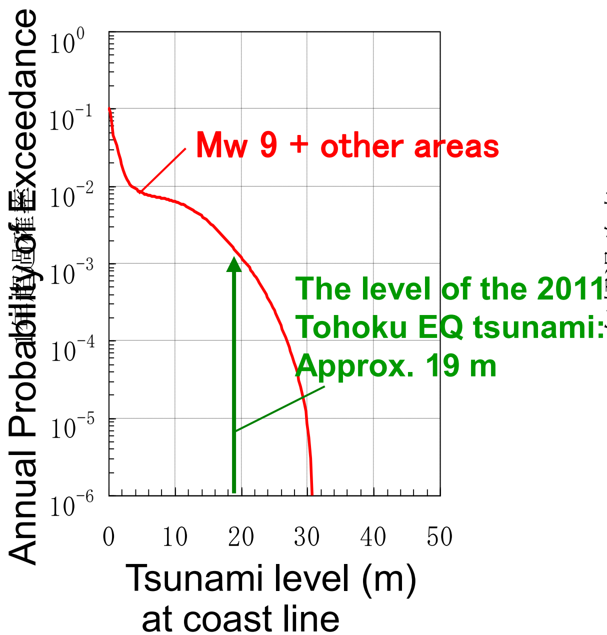
■Scheme of logic tree for the 2011 Tohoku earthquake (Mw 9)



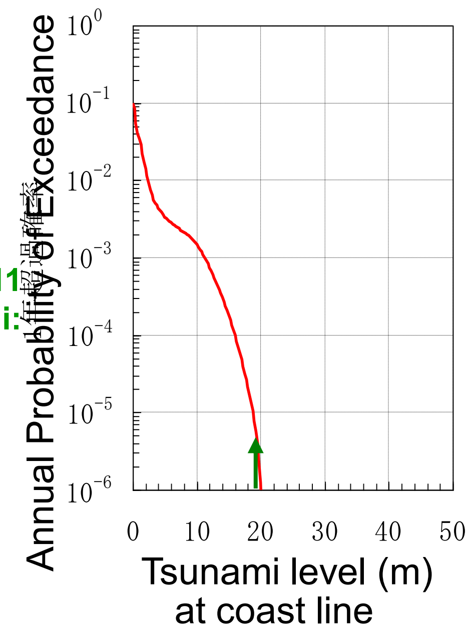
* Red letters represent the weight of each term

■Tsunami hazard curve of Fukushima Daiichi NPP

With knowledge of the 2011 Tohoku EQ tsunami



Without knowledge of the 2011 Tohoku EQ tsunami
(Based on the information before 2011)



- **The frequency at which the level of the tsunami estimated with hazard knowledge gained from the 2011 tsunami taken into consideration exceeds the level achieved by reproducibility analysis (approx. 19 m) is about 1.5 × 10^{-3} (about once every 670 years).**
- **The frequency at which the level achieved without the knowledge gained from the 2011 tsunami taken into consideration exceeds the same analyzed level (approx. 19 m) is about 10^{-5} (about once every 100,000 years).**

6. Summary

(1) The clarification of the mechanism of the massive earthquake and tsunami is advanced since the Off-Tohoku earthquake.

(2) The super cycle and simultaneous movement of the segments looks to be the cause of this tsunami.

(3) Development of PTHA and PTSA were under way before the 3.11 Eq.

(4) The tsunami high evaluations at the Fukushima site were implemented in several organizations after the 3.11 Eq.
The probability of 19m at the Fukushima site with/without Fukushima insight by JNES:
- with Fukushima insight:1.5x10-3 (about once every 670 years)
- without Fukushima insight; 1x10-5 (about once every 100,000 years)

(5) The difference of tsunami probabilities looks coming from tsunami source evaluation, not from probabilistic/deterministic.

Thank you for your kind attention

Probabilistic Seismic Hazard Assessment in Belgium

OECD Nuclear Energy Agency

Committee on the Safety of Nuclear Installations

IAGE – Seismic subgroup

09-10 April 2013

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Safety Analysis - Structural Mechanics
Bel V, Technical Safety Organization
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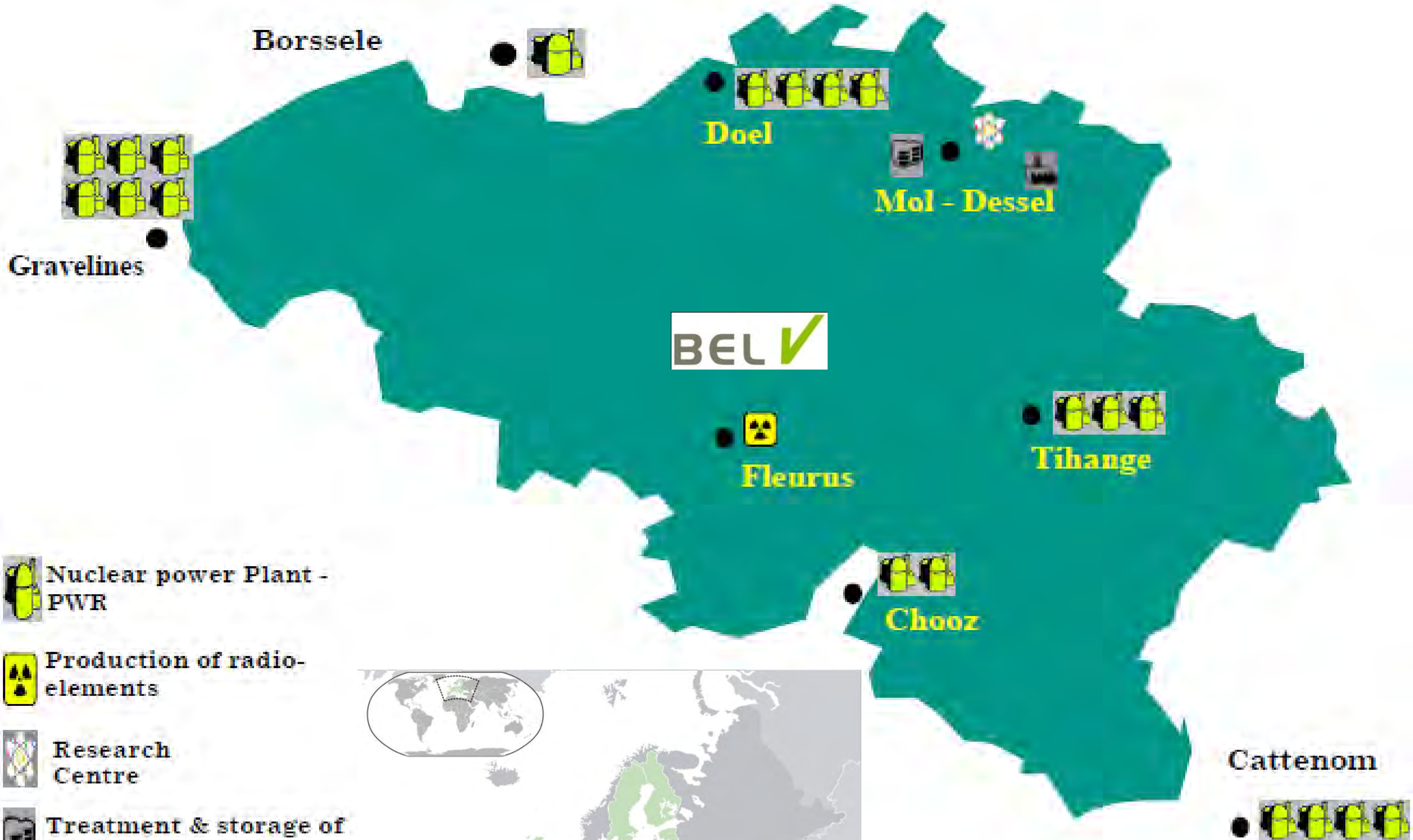
Outline

- Introduction and definition of PSHA
- Presentation of the methodology
  - Logic Tree
  - Sensitivity analysis
- Preliminary results as of June 2012



Nuclear power Plant - PWR

Production of radio-elements

Research Centre

Treatment & storage of waste

Fuel fabrication (UO_2 / MOX)

Definition

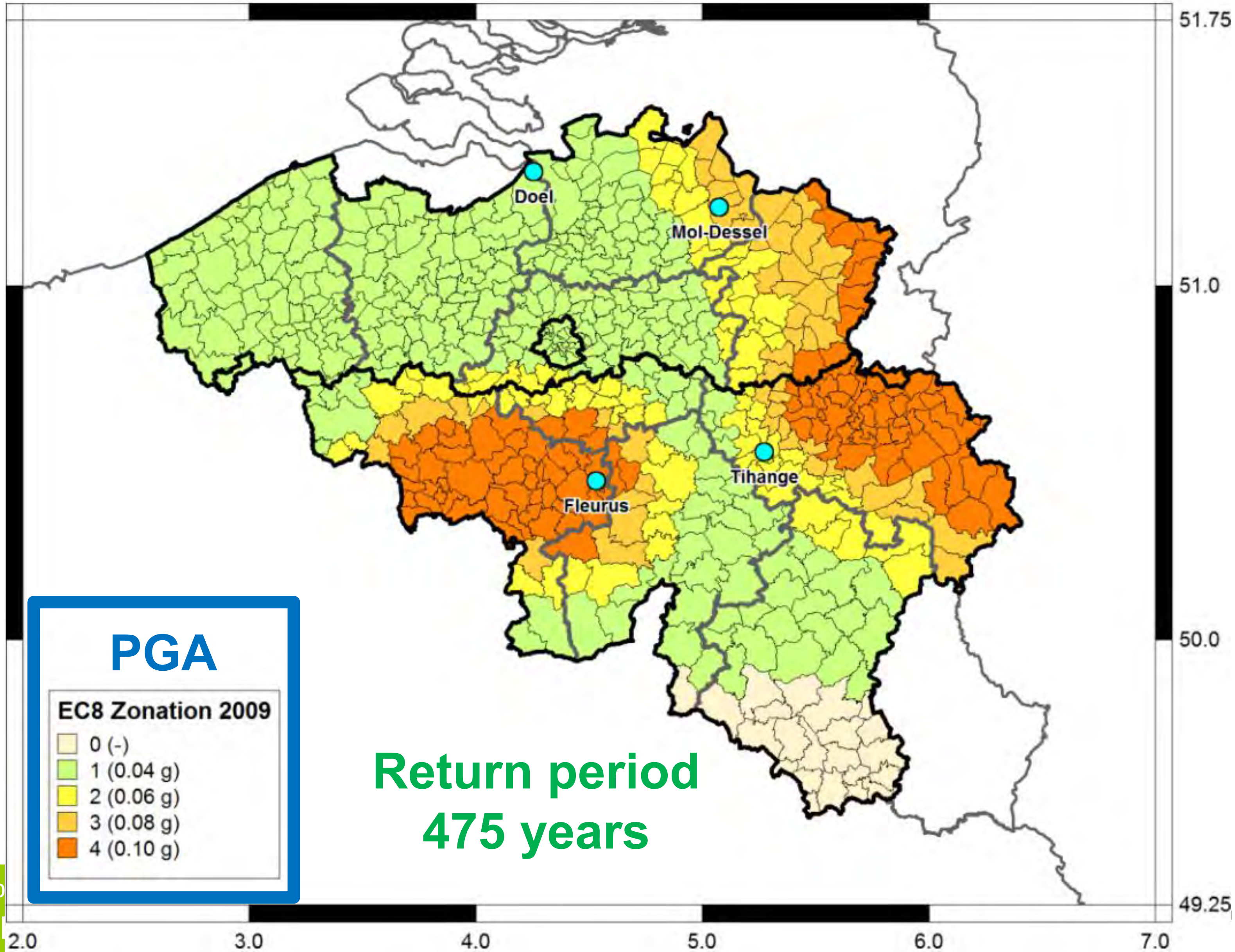
Probabilistic Seismic Hazard Analysis (PSHA) quantifies the probability of exceeding ground-motion levels at a site based on a selection of earthquakes.

PSHA gives the PGA in function of:

- the exceedance rate or return period
- the location

Example : Seismic zonation map according to Eurocode 8

Seismic zonation map according to Eurocode 8



New PSHA

In the framework of the Nuclear Stress Test exercice, the Authority asks for a **new PSHA** to be performed on the four nuclear sites:

- Doel : Doel NPP
- Tihange: Tihange NPP
- Mol/Dessel: Nuclear Research Center and Waste facilities
- Fleurus: Isotope production facility

New PSHA

Necessary data for a PSHA:

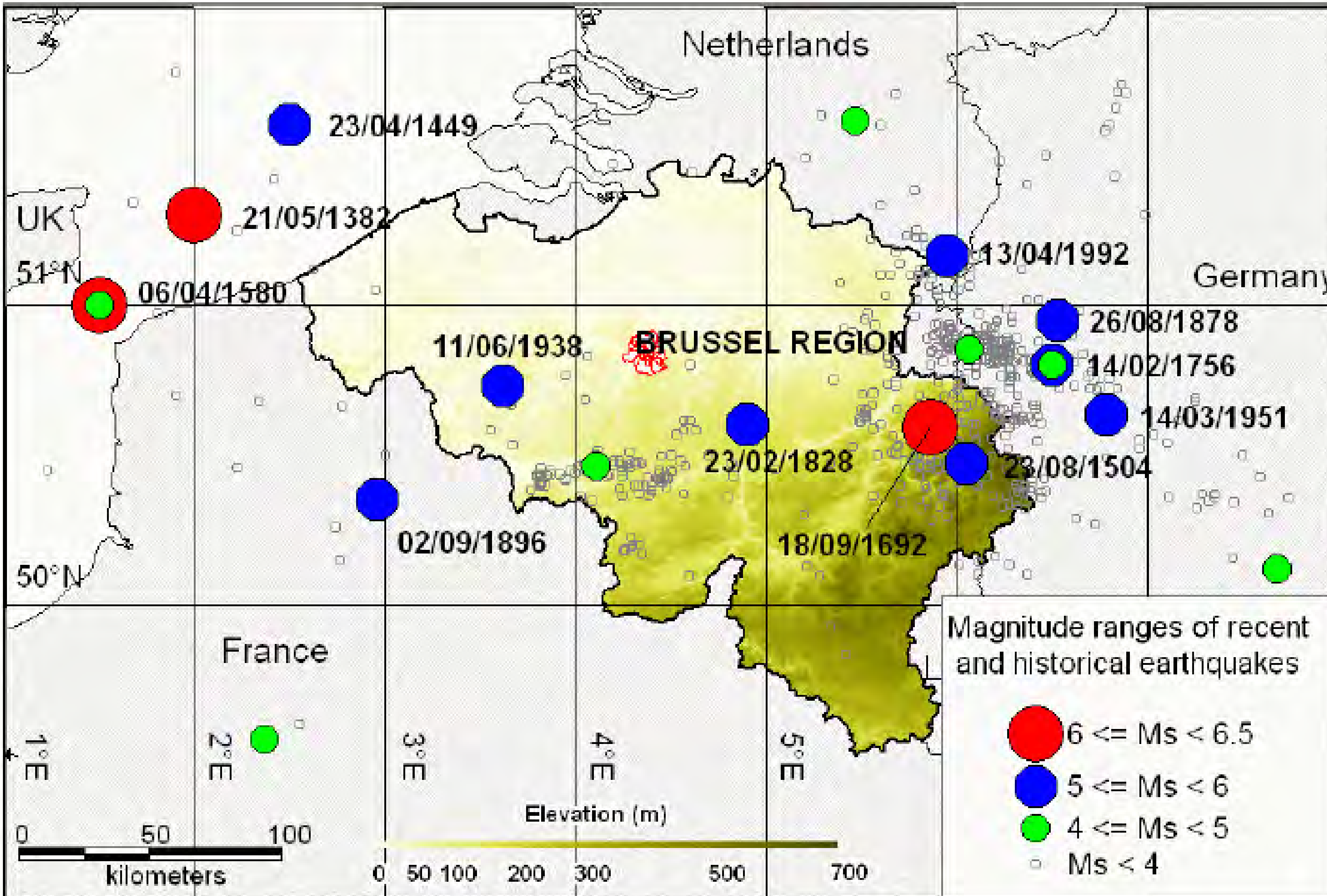
1. Characterization of seismic activity
2. Seismotectonic zones based on seismic sources
3. Ground-motion attenuation relationships

Characterization of seismic activity

Seismic data are provided by the Royal Observatory of Belgium:

- Historical data: from 1350 to 1910
  - Chronicles, annotations, parochial registers, accountancy registers with details about local effects
  - Precise enough to allow estimating the epicentral area and the maximum intensity
- Instrumental data: from 1911, continuous seismic recordings started

Historical and recent earthquakes in Belgium



Characterization of seismic activity

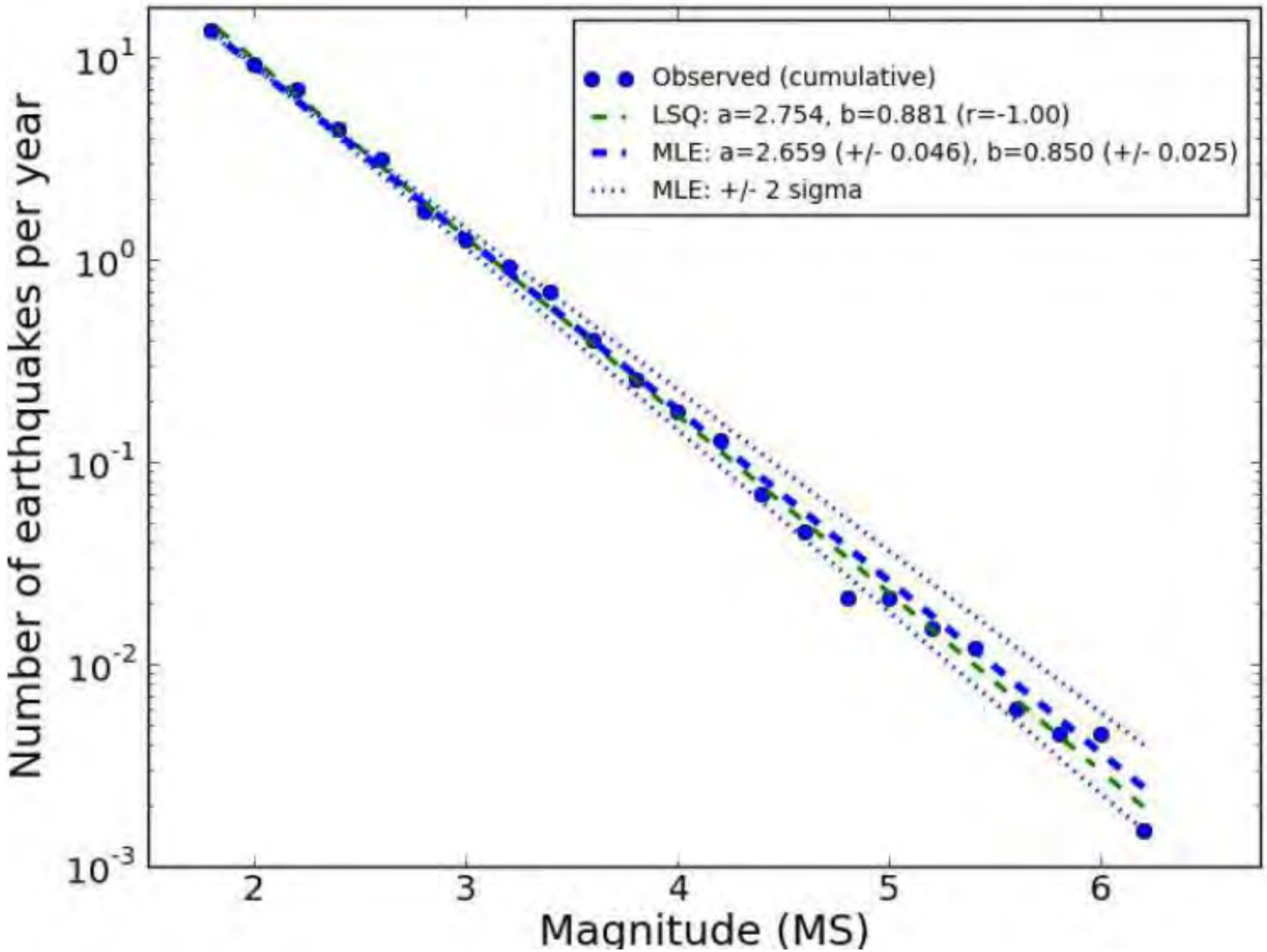
Frequency-magnitude relation, aka Gutenberg-Richter law:

$$\log N = a - bM$$

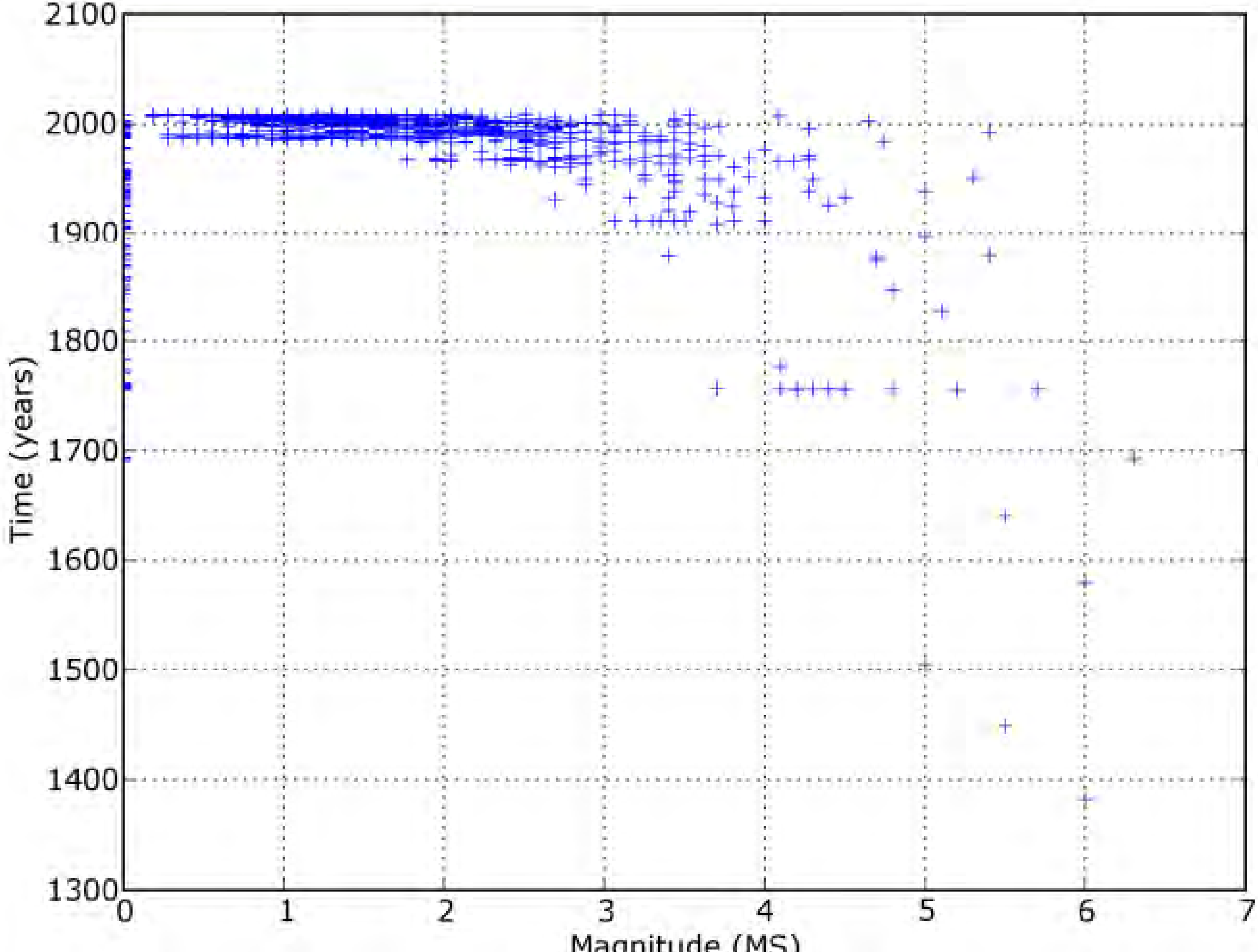
N: annual number of earthquakes with magnitude > M

a: intercept with the y axis, indicates how seismically active the area is

b: slope of the curve, corresponding to the ratio of small to large earthquakes

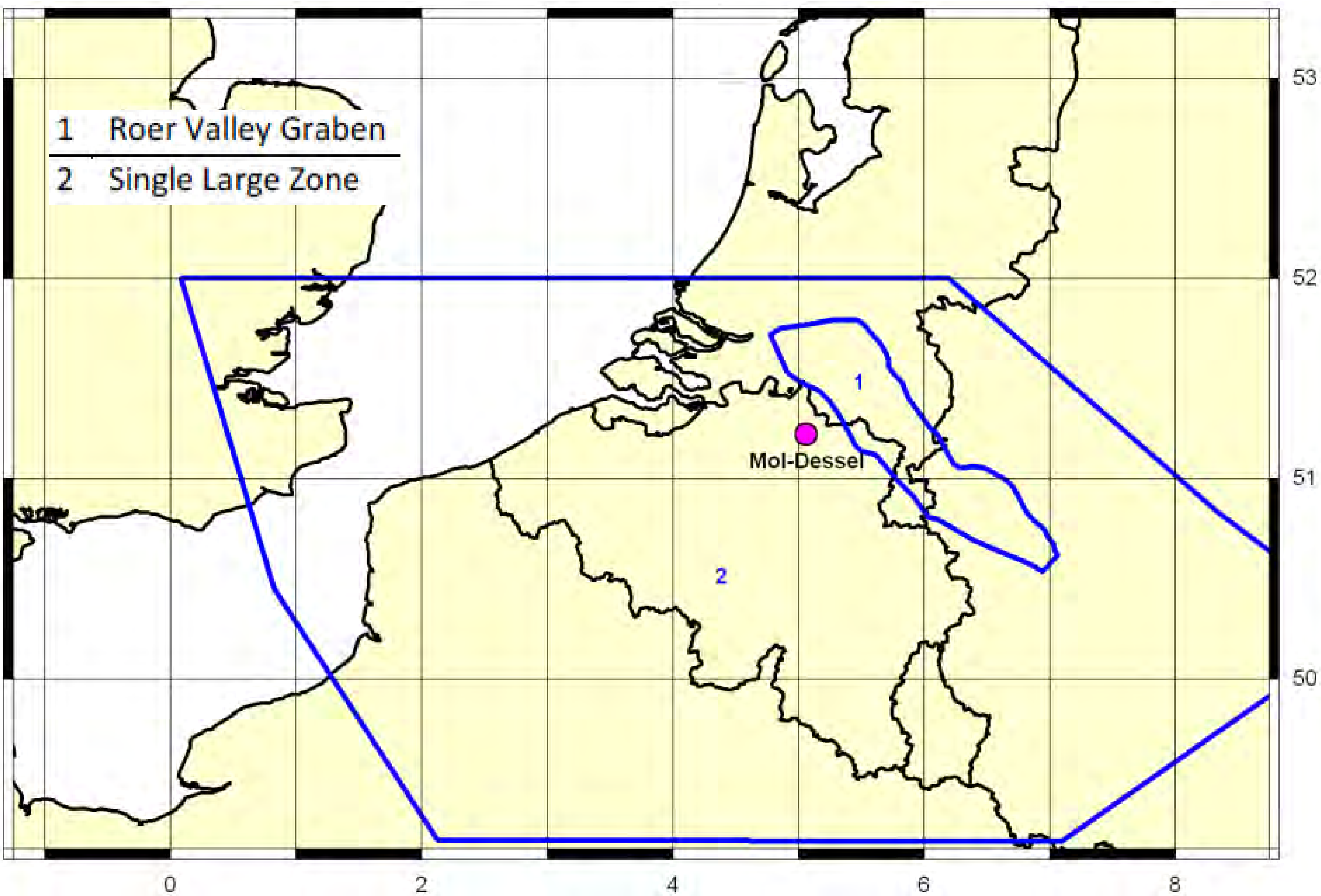

Number of earthquakes per year
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
2
3
4
5
6
Magnitude (MS)
Observed (cumulative)
LSQ: a=2.754, b=0.881 (r=-1.00)
MLE: a=2.659 (+/- 0.046), b=0.850 (+/- 0.025)
MLE: +/- 2 sigma

Catalog completeness



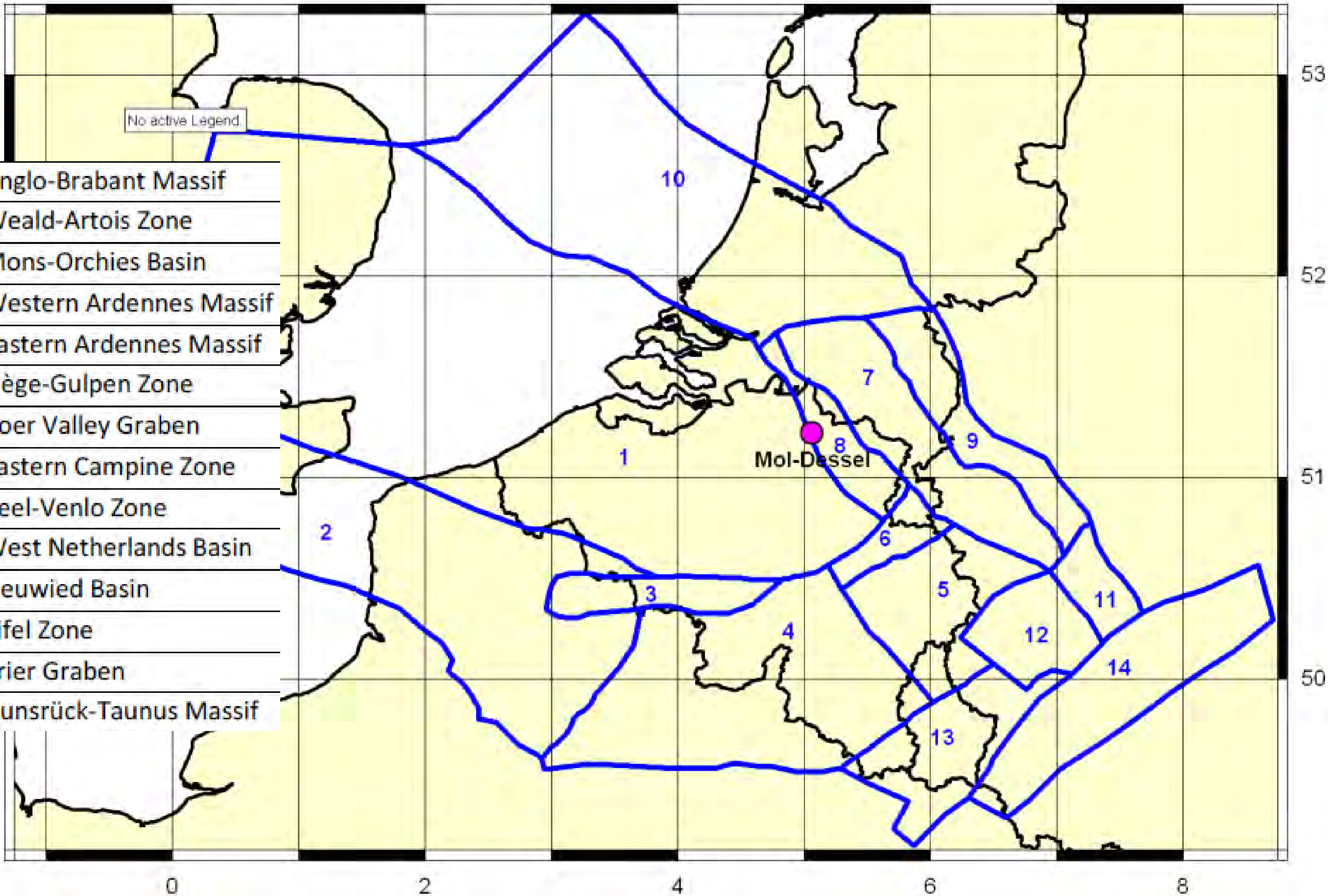
Seismotectonic zones

Two zones model



Seismotectonic zones

Seismic Source-zone model



1	Anglo-Brabant Massif
2	Weald-Artois Zone
3	Mons-Orchies Basin
4	Western Ardennes Massif
5	Eastern Ardennes Massif
6	Liège-Gulpen Zone
7	Roer Valley Graben
8	Eastern Campine Zone
9	Peel-Venlo Zone
10	West Netherlands Basin
11	Neuwied Basin
12	Eifel Zone
13	Trier Graben
14	Hunsrück-Taunus Massif

Zone name	M 1.8-2.0	M 2.0-2.5	M 2.5-3.0	M 3.0-3.5	M 3.5-4.0	M 4.0-4.5	M 4.5-5.0	M 5.0-5.5	M 5.5-6.0	M 6.0-6.5	Tot.
Anglo-Brabant Massif	4	6	3	5	0	2	0	2	1	1	24
Weald-Artois Zone	0	2	1	3	0	1	0	1	0	1	9
Mons-Orchies Basin	9	7	4	8	6	4	0	0	0	0	38
Western Ardennes Massif	3	4	2	1	0	0	0	0	0	0	10
Eastern Ardennes Massif	13	16	4	2	1	0	0	0	0	1	37
Liège-Gulpen Zone	4	7	6	2	0	1	1	0	0	0	21
Roer Valley Graben	41	57	31	5	6	1	2	5	2	0	150
Eastern Campine Zone	3	0	1	3	0	1	0	0	0	0	8
Peel-Venlo Zone	2	0	2	1	0	0	0	0	0	0	5
Neuwied Basin	12	17	3	2	2	0	0	0	0	0	36
Hunsrück-Taunus Massif	14	11	5	2	3	0	0	0	0	0	35

Table 5 - Number of earthquakes per magnitude interval for the zones in the seismotectonic source-zone model

Zone name	a (LSQ)	b (LSQ)	a (MLE, fixed b)	b (fixed)	a (MLE)	b (MLE)	λ_0 (MLE)	β (MLE)
Anglo-Brabant Massif	1.006	0.664	1.456 ± 0.190	0.851	0.947 ± 0.129	0.620 ± 0.072	0.060 ± 0.050	1.429 ± 0.165
Weald-Artois Zone	0.461	0.604	1.030 ± 0.310		0.252 ± 0.191	0.516 ± 0.106	0.028 ± 0.056	1.188 ± 0.244
Mons-Orchies Basin	1.166	0.598	1.673 ± 0.203		1.038 ± 0.152	0.533 ± 0.085	0.149 ± 0.063	1.228 ± 0.195
Western Ardennes Massif	1.183	0.884	1.103 ± 0.483		1.133 ± 0.488	0.867 ± 0.271	0.013 ± 0.035	1.995 ± 0.625
Eastern Ardennes Massif	0.973	0.729	1.644 ± 0.151		1.918 ± 0.195	0.989 ± 0.108	0.029 ± 0.028	2.277 ± 0.250
Liège-Gulpen Zone	1.154	0.719	1.405 ± 0.229		1.252 ± 0.204	0.775 ± 0.113	0.035 ± 0.041	1.785 ± 0.261
Roer Valley Graben	2.192	0.851	2.251 ± 0.074		2.310 ± 0.078	0.880 ± 0.043	0.170 ± 0.034	2.026 ± 0.100
Eastern Campine Zone	0.452	0.597	0.996 ± 0.443		0.370 ± 0.333	0.537 ± 0.185	0.031 ± 0.062	1.237 ± 0.426
Peel-Venlo Zone	0.461	0.669	0.802 ± 0.683		0.339 ± 0.594	0.608 ± 0.330	0.016 ± 0.057	1.399 ± 0.760
Neuwied Basin	1.729	0.926	1.656 ± 0.238		2.001 ± 0.277	1.035 ± 0.154	0.024 ± 0.026	2.383 ± 0.354
Hunsrück-Taunus Massif	1.518	0.808	1.627 ± 0.177		1.878 ± 0.215	0.980 ± 0.119	0.028 ± 0.028	2.256 ± 0.275

Table 6 - Seismicity parameters for zones in the seismotectonic model, calculated with least-squares regression (LSQ), and maximum-likelihood estimation (MLE), with and without imposing "b" value of entire catalog

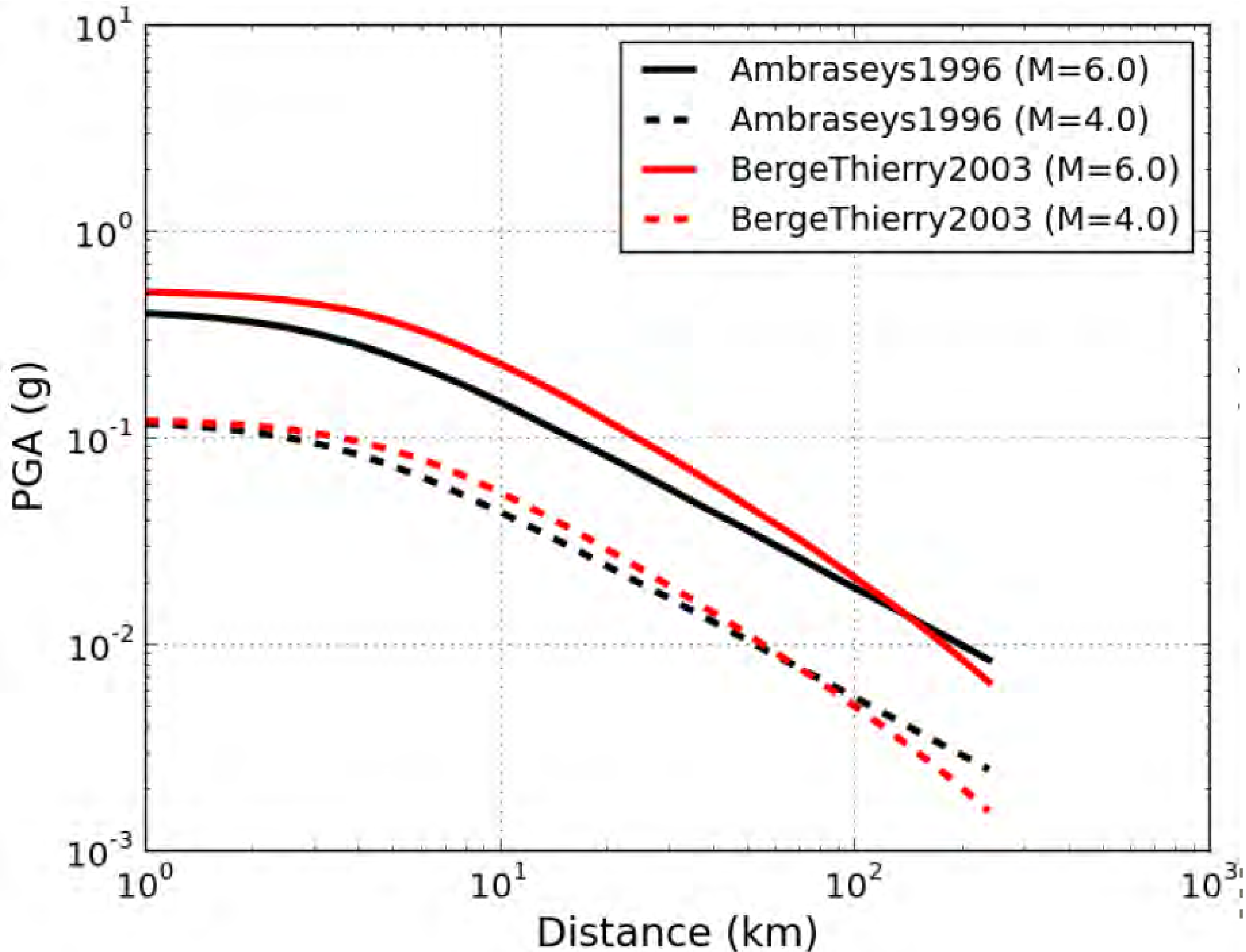
Ground-motion attenuation relationships

Attenuation law gives the acceleration response spectrum versus earthquake magnitude and distance.

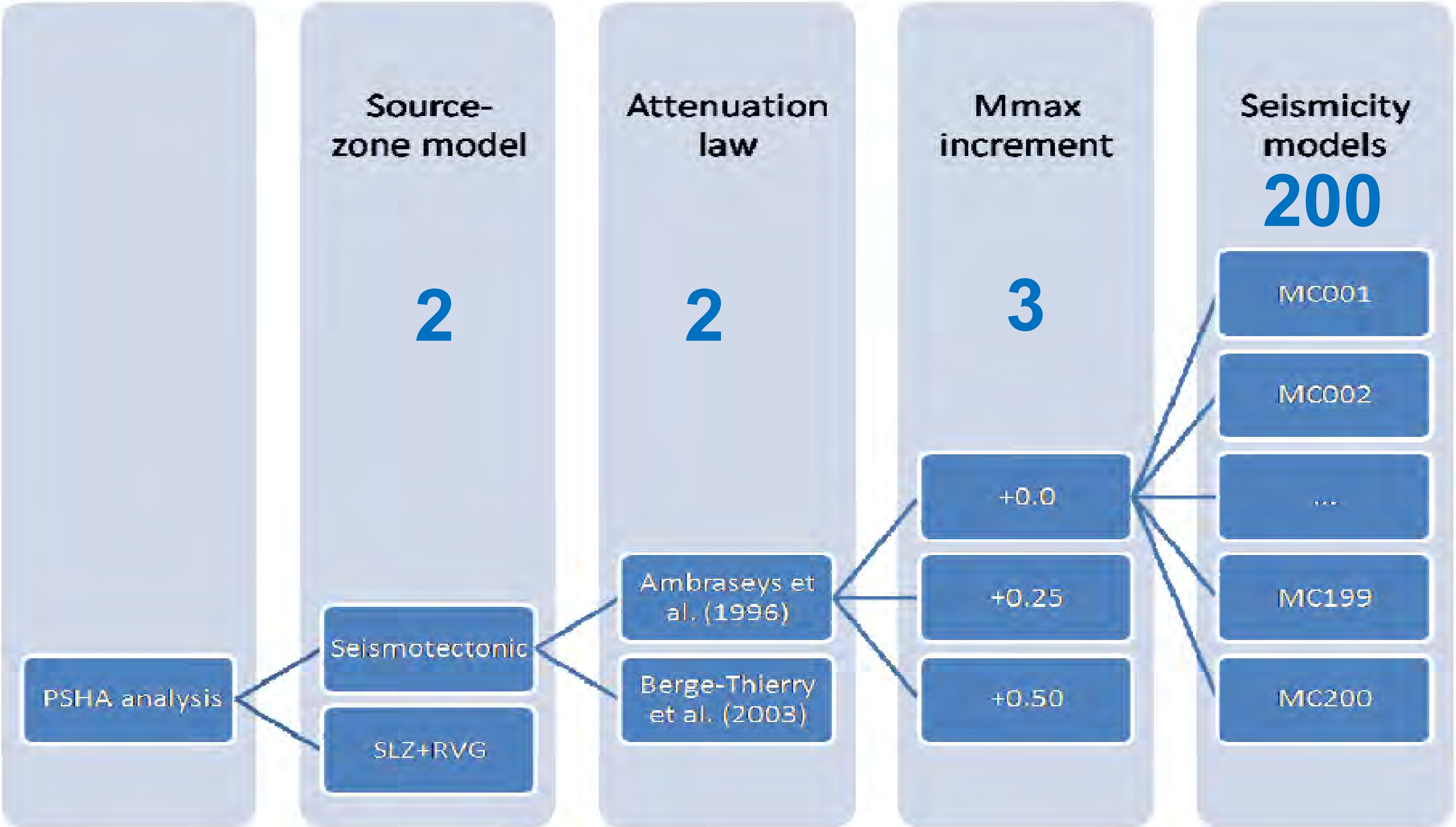
Two applicable attenuation laws

- Ambraseys et al. (1996), also been evaluated by Leynaud et al. (2000)
- Berge-Thierry et al. (2003), has been adopted as a reference for the nuclear regulation in France

Attenuation law

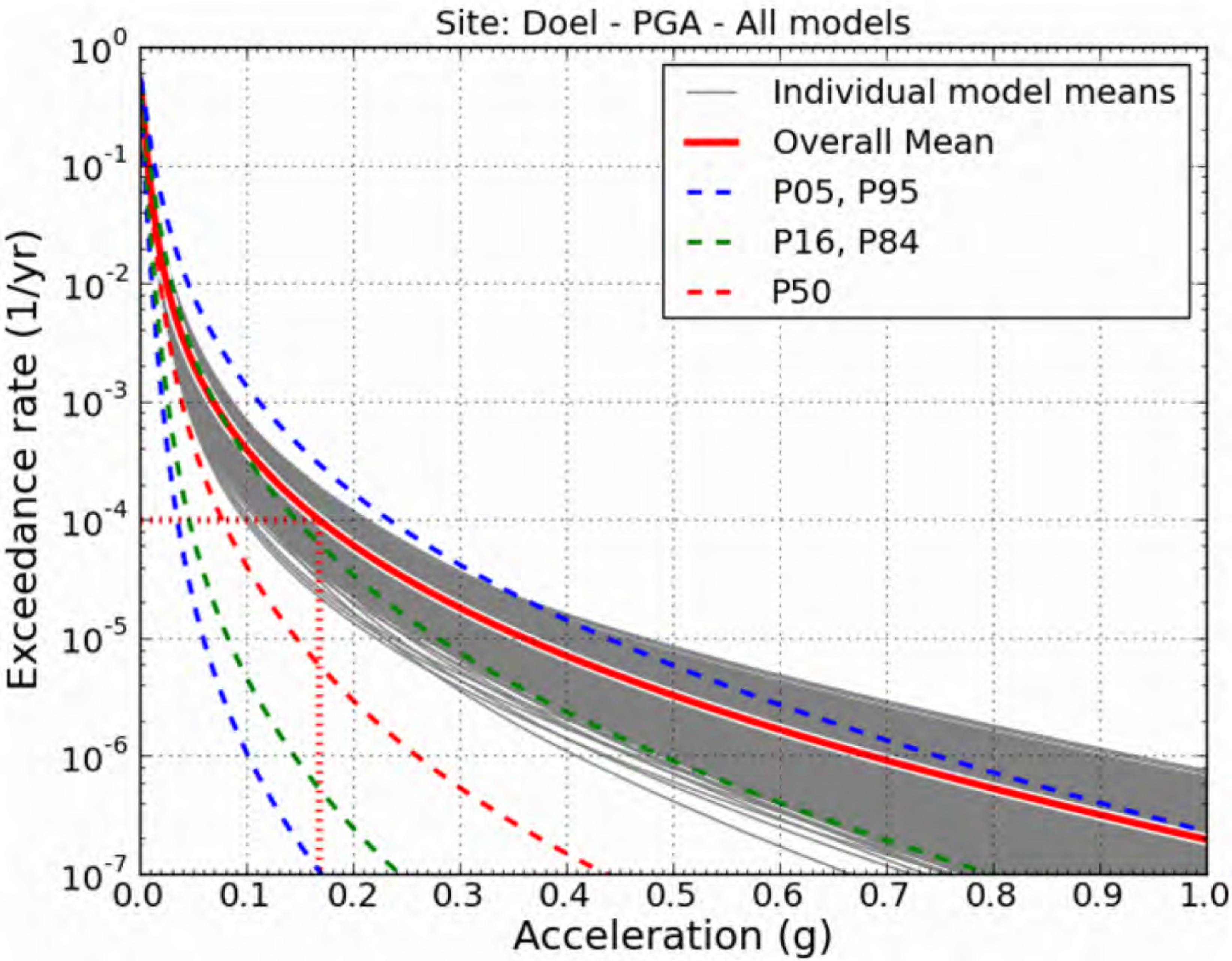


Logic-tree procedure

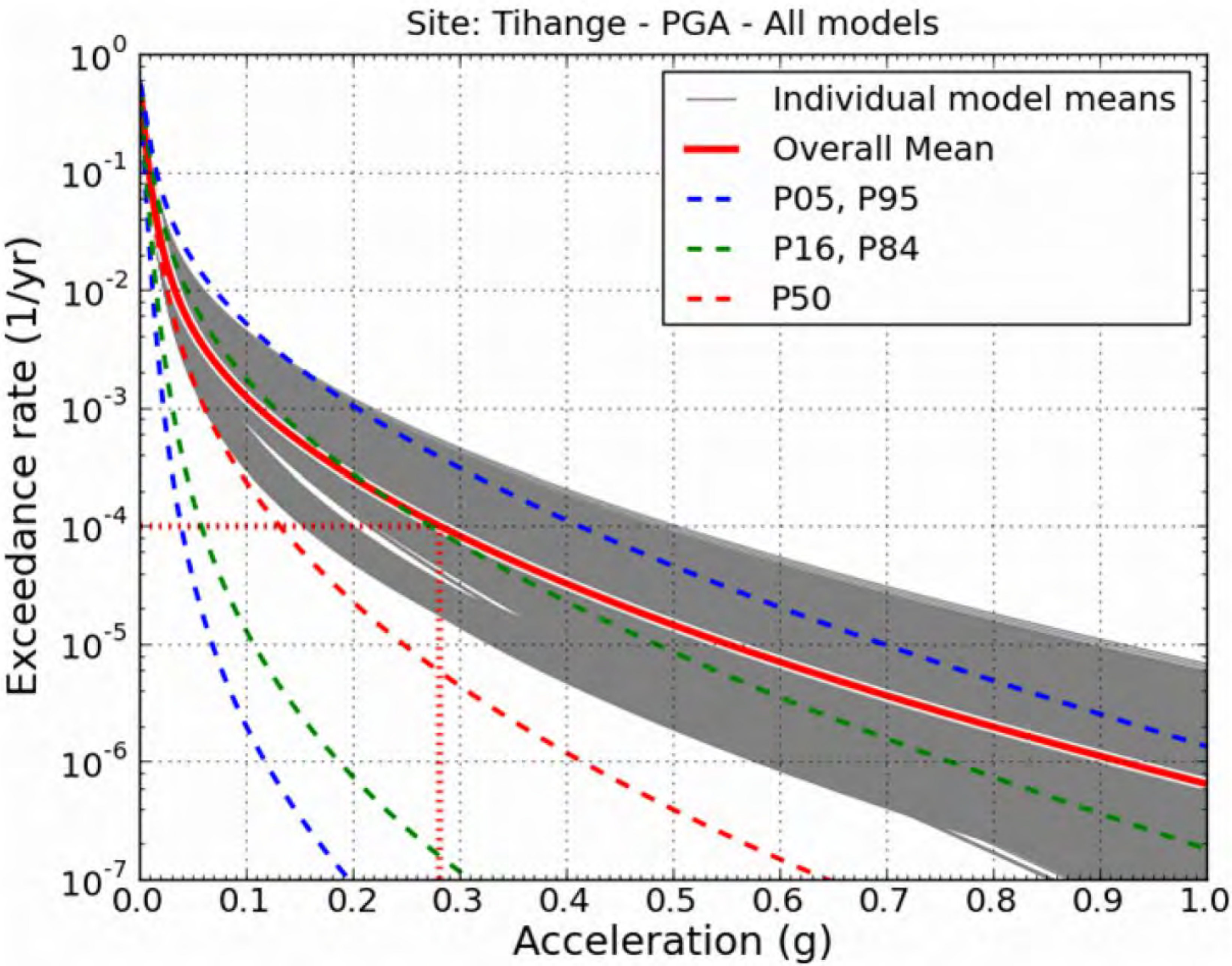


Epistemic uncertainties → 2400 branches

Doel

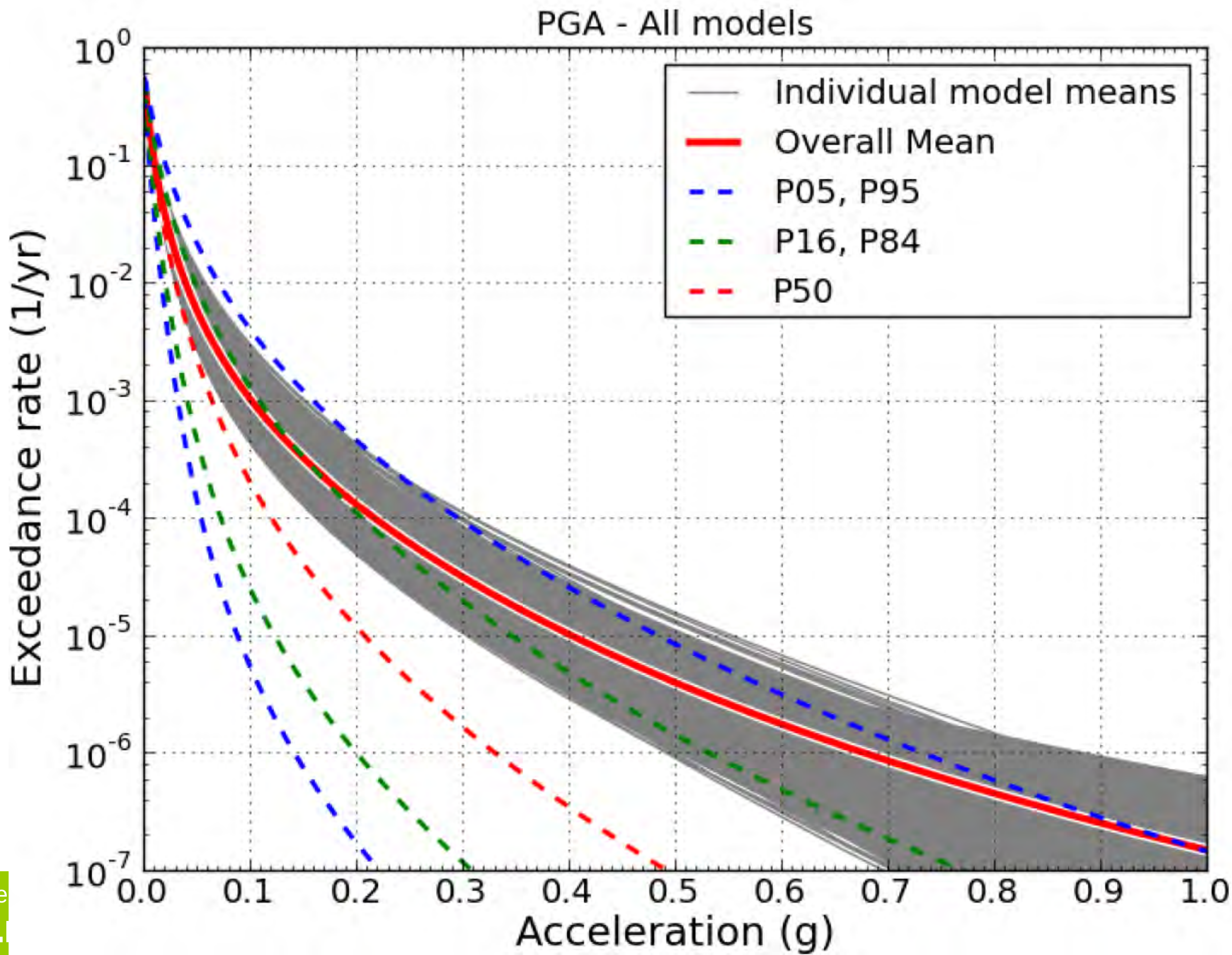

Site: Doel - PGA - All models
Exceedance rate (1/yr)
Acceleration (g)
Individual model means
Overall Mean
P05, P95
P16, P84
P50
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

Tihange

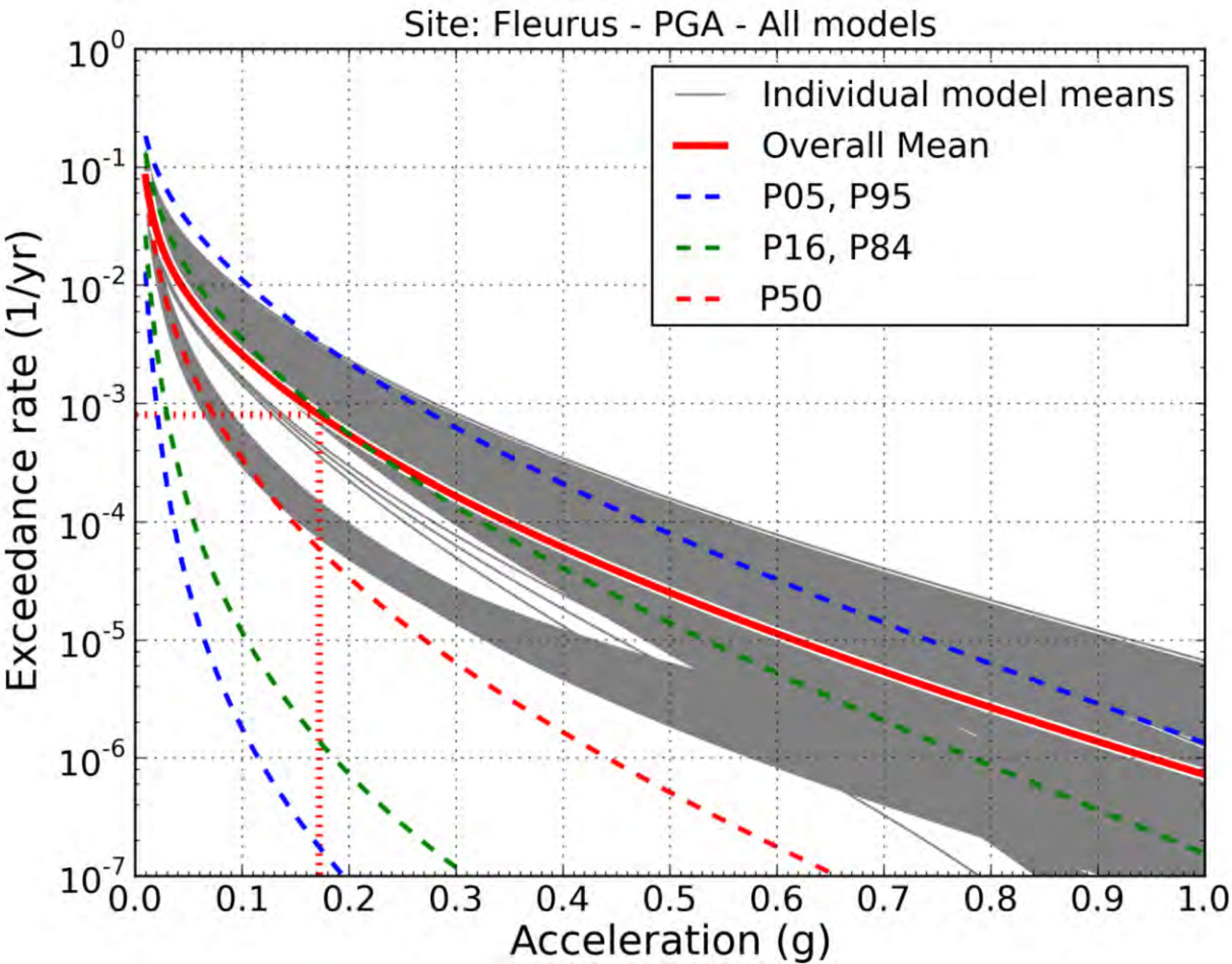


Site: Tihange - PGA - All models
Individual model means
Overall Mean
P05, P95
P16, P84
P50
Exceedance rate (1/yr)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Acceleration (g)

Mol/Dessel


PGA - All models
Individual model means
Overall Mean
P05, P95
P16, P84
P50
Exceedance rate (1/yr)
Acceleration (g)
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

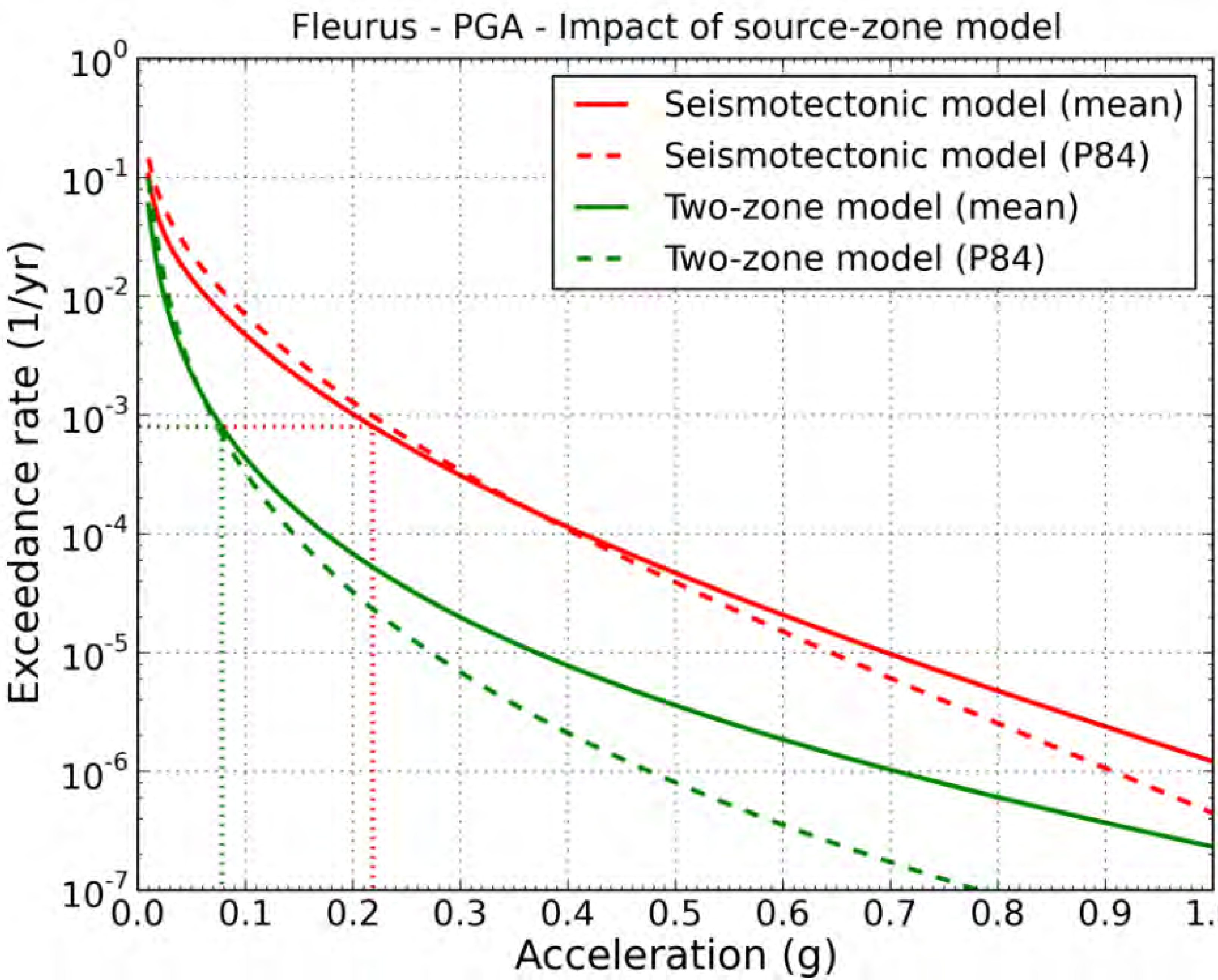
Fleurus

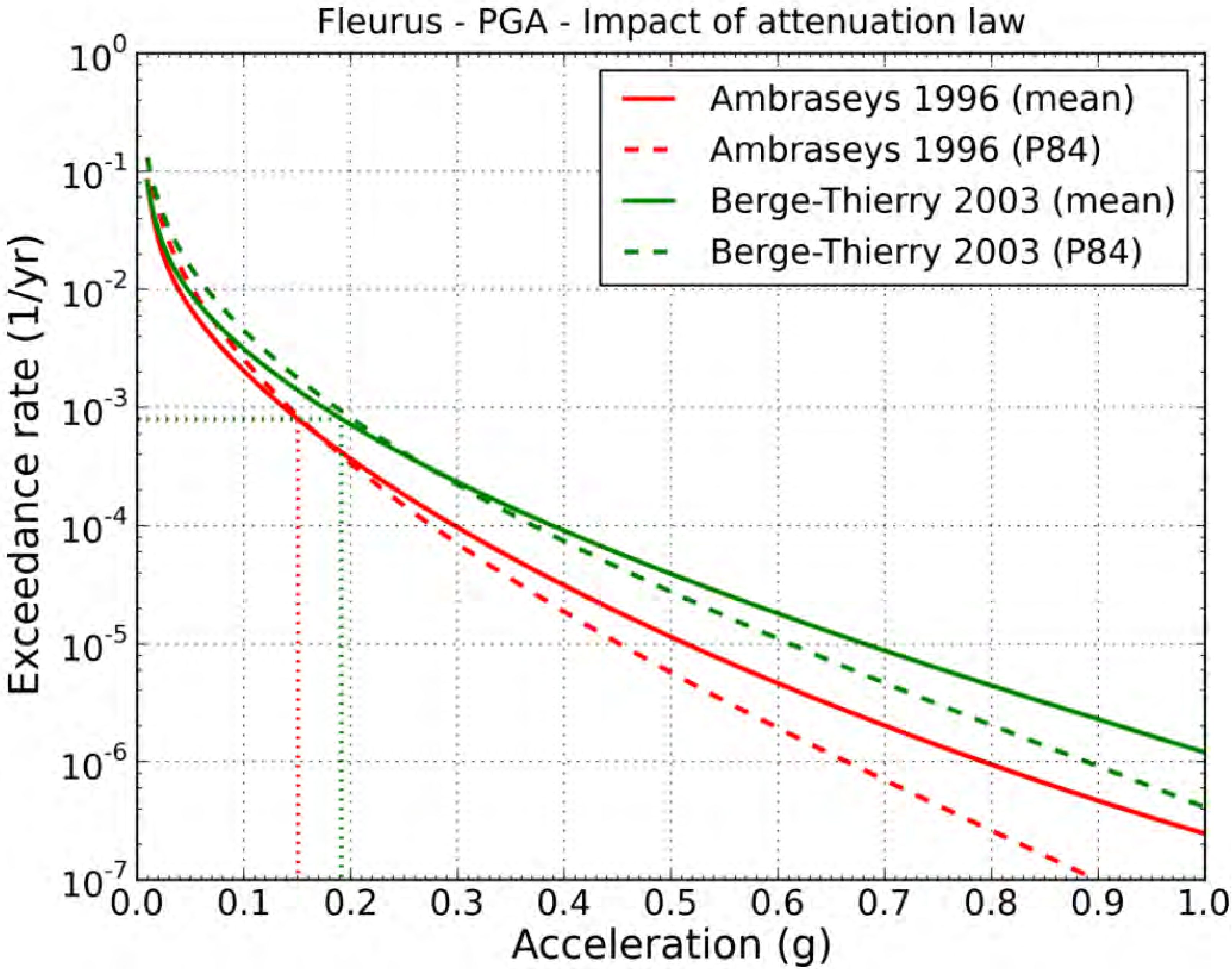


Site: Fleurus - PGA - All models
Exceedance rate (1/yr)
Acceleration (g)
Individual model means
Overall Mean
P05, P95
P16, P84
P50
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

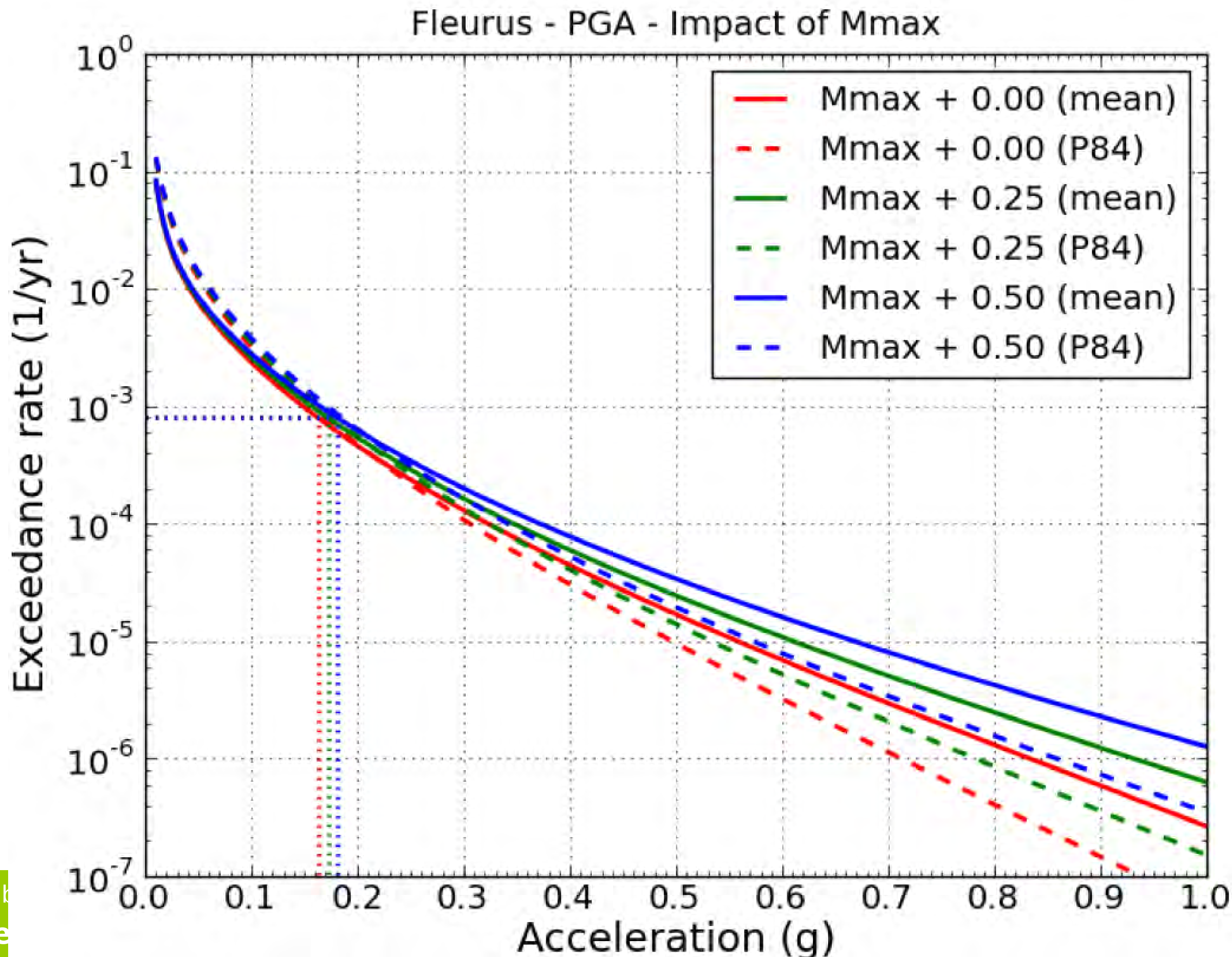
Sensitivity analysis

- Impact of source-zone model
  - Two zone or 14 seismic zone
- Impact of the attenuation law
  - Ambraseys or Berge-Thierry
- Impact of the Mmax + increment
  - Mmax +0 ; +0.25 ; +0.5
- Impact of the cutoff magnitude Mmin
  - Mmin = 3.5 ; 4.0 ; 4.5 ; 5.0

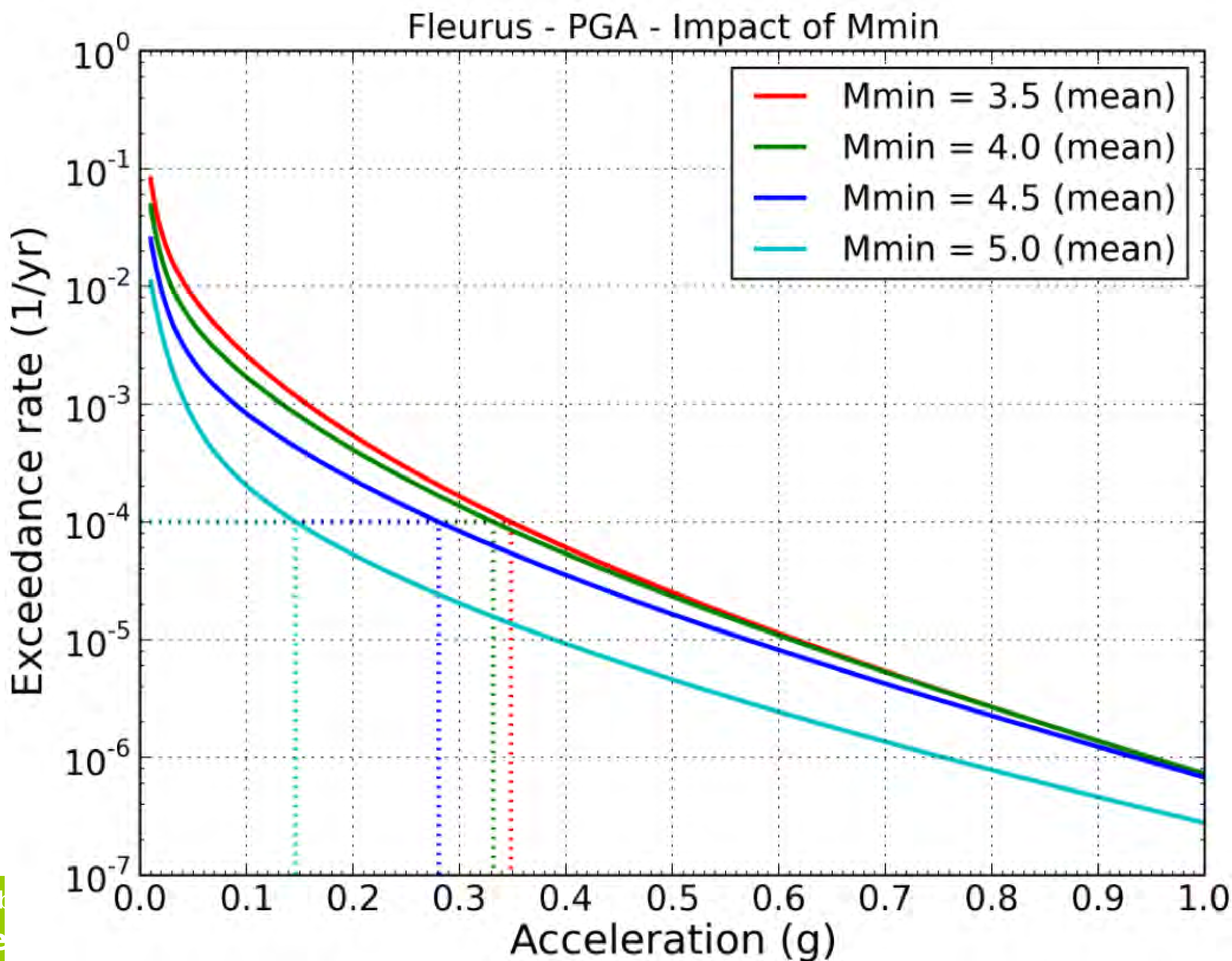

Fleurus - PGA - Impact of source-zone model
Seismotectonic model (mean)
Seismotectonic model (P84)
Two-zone model (mean)
Two-zone model (P84)
Exceedance rate (1/yr)
Acceleration (g)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0



Fleurus - PGA - Impact of attenuation law
Ambraseys 1996 (mean)
Ambraseys 1996 (P84)
Berge-Thierry 2003 (mean)
Berge-Thierry 2003 (P84)
Exceedance rate (1/yr)
Acceleration (g)


Fleurus - PGA - Impact of Mmax
Exceedance rate (1/yr)
Acceleration (g)
Mmax + 0.00 (mean)
Mmax + 0.00 (P84)
Mmax + 0.25 (mean)
Mmax + 0.25 (P84)
Mmax + 0.50 (mean)
Mmax + 0.50 (P84)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0

Fleurus


Fleurus - PGA - Impact of Mmin
Mmin = 3.5 (mean)
Mmin = 4.0 (mean)
Mmin = 4.5 (mean)
Mmin = 5.0 (mean)
Exceedance rate (1/yr)
Acceleration (g)
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
10^-6
10^-7
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

How to use such data?

- New seismic hazard assessment:

  Comparison between probabilistic and deterministic approach

- New guidance from the Authority:

  The probability of occurrence of the Design Basis Earthquake should not exceed **a few percent during the lifetime of the installation**

  - **Few percent**
  - **Lifetime of the installation**

  → **Return period**

Return period

Return period estimates of the likelihood of an event like earthquake. It is the inversed of the exceedance rate (1/y).

Earthquake occurrence considered by a Poissonian distribution:

$$T_R = \frac{-T_L}{\ln(1-P)}$$

Tr: Return period of the earthquake

TL: Life expectancy

P: Probability of exceedance of the event

Return period

Eurocode 8 **Near surface disposal**

P (%)	Return periods (yr)			
	T_L=50 yr	T_L=70 yr	T_L=100 yr	T_L=350yr
0.5	9 975	13 965	19 950	69 825
1	4 975	6 965	9 950	34 825
2	2 475	3 465	4 950	17 324
3	1 642	2 298	3 283	11 491
4	1 225	1 715	2 450	8 574
5	975	1 365	1 950	6 824
6	808	1 131	1 616	5 657
7	689	965	1 378	4 823
8	600	840	1 199	4 198
9	530	742	1 060	3 711
10	475	664	949	3 322

Further investigations

- P84 or mean
- Large sensitivities with the different paths in the logic tree
- Site effect: transfer function
- Next generation attenuation ground motion
- Cumulative Absolute Velocity filtering
- Application of a logic tree for each source zone separately

Acknowledgment

Data and technical information have been provided by the **Royal Observatory of Belgium:**

- Kris Vanneste
- Bart Vleminckx
- Thierry Camelbeeck

Thank you for your attention.

Any questions?

I am looking forward to hearing any Operating Experience Feedback about PSHA.

Related PSHA:

- Pegasos Project in Switzerland
- EC-project SHARE Seismic Hazard Harmonization in Europe
- Regulatory Guide 1.208 (March 2007)
- NUREG/CR-6372
- NUREG/CR-6728

Status of the nuclear energy in Belgium

In principle, no limit in time in the licence of Belgian NPP.

Periodic Safety Reviews every 10 years.

However in 2003, a phase-out law limits the life of NPPs to 40 years except in case of force majeure.

By government's decision in 2012, phase-out of nuclear energy is confirmed with scheduled shutdown of:

- Doel 1&2 in 2015
- Doel 3 in 2022
- Tihange 2 in 2023
- Tihange 1, Tihange 3 and Doel 4 in 2025
  - Extension of operation of Tihange 1 by 10 years

Doel			Tihange		
#	MWe	Connected	#	MWe	Connected
1	433	02/1975	1	962	10/1975
2	433	12/1975	2	1008	02/1983
3	1006	10/1982	3	1046	09/1985
4	1039	07/1985	**TOTAL : 5930 MWe**		

Currently 55% of the electricity is produced through nuclear power

ENEL Nuclear Technical Area

WGIAGE Seismic Sub-group meeting

Paris, 9-10 April 2013

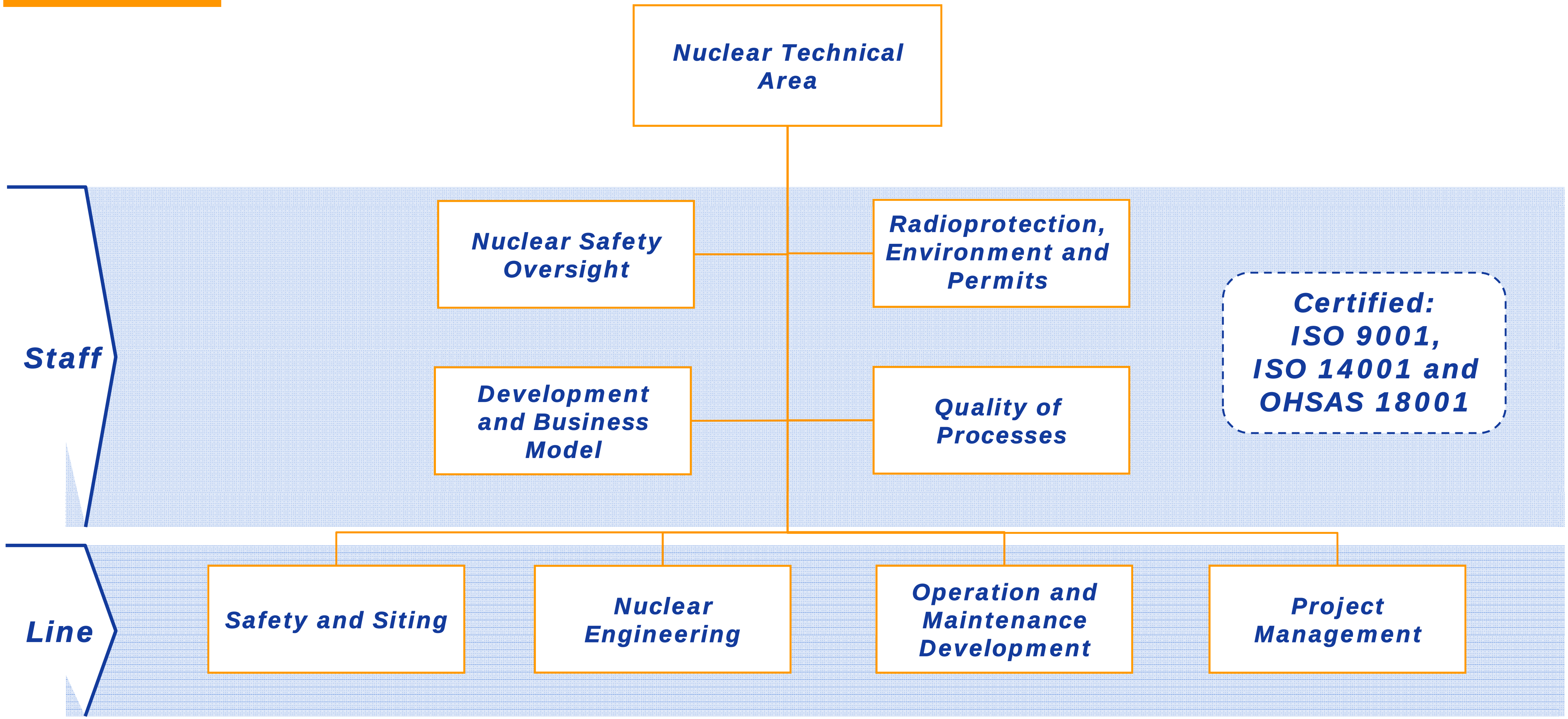
mariacristina.bramati@enel.com

Contents

- ATN division
- Experiences and current projects of ATN
- Identified issues

Nuclear Technical Area

Organizational Structure



Nuclear Technical Area

Current Projects

	Projects	Activities
Development	▪ Baltic NPP ▪ Cernavoda ▪ AP -1000 technology ▪ Polish Nuclear Project ▪ Turkish Nuclear Project	Assessment of ▪ Siting (safety criteria, environmental issues, licensing) ▪ Design (safety, technology, licensing issues) ▪ Cost Estimate ▪ Schedule ▪ Project Management and Organization
Engineering & Construction	▪ Mochovce 3&4 (Nuclear & Conventional Island, together with SRI) ▪ Flamanville3	▪ Engineering and Project Management Integrated Team with SE and EDF ▪ The Architect Engineer model is applied in both Projects (multi-contract approach with overall Project management and interface coordination by Owner)
Support to Operation & Maintenance	▪ Best Practices Sharing among operating NPPs of Enel Group	▪ Technical support to the Operating organizations ▪ Promote and support improvement projects of the Operating organizations ▪ Coordinate and participate to the Best Practice Sharing project
Nuclear Safety Oversight & Radioprotection Survey Network	▪ Endesa-ANAV NPPs ▪ Slovenské Elektràrne NPPs	▪ Independent monitoring and reporting of Nuclear Safety and radiation exposure within ENEL Group ▪ Representatives of ENEL in Nuclear International Associations (WANO, ENISS, IAEA)

Main operation areas of ATN

- Safety assessment of new and existing plants, both probabilistic and deterministic
- Safety assessment of plant changes and improvement programs
- Plant Life extension programs: ageing management, testing and monitoring program, integrity assessment – Program development and review
- Site specific hazard development and review – Seismic, Hydrological, Meteorological and Man-induced
- Security assessment: sabotage scenarios (aircraft crash, explosions, etc.) and plant safety assessment

Site-specific Seismic Hazard update

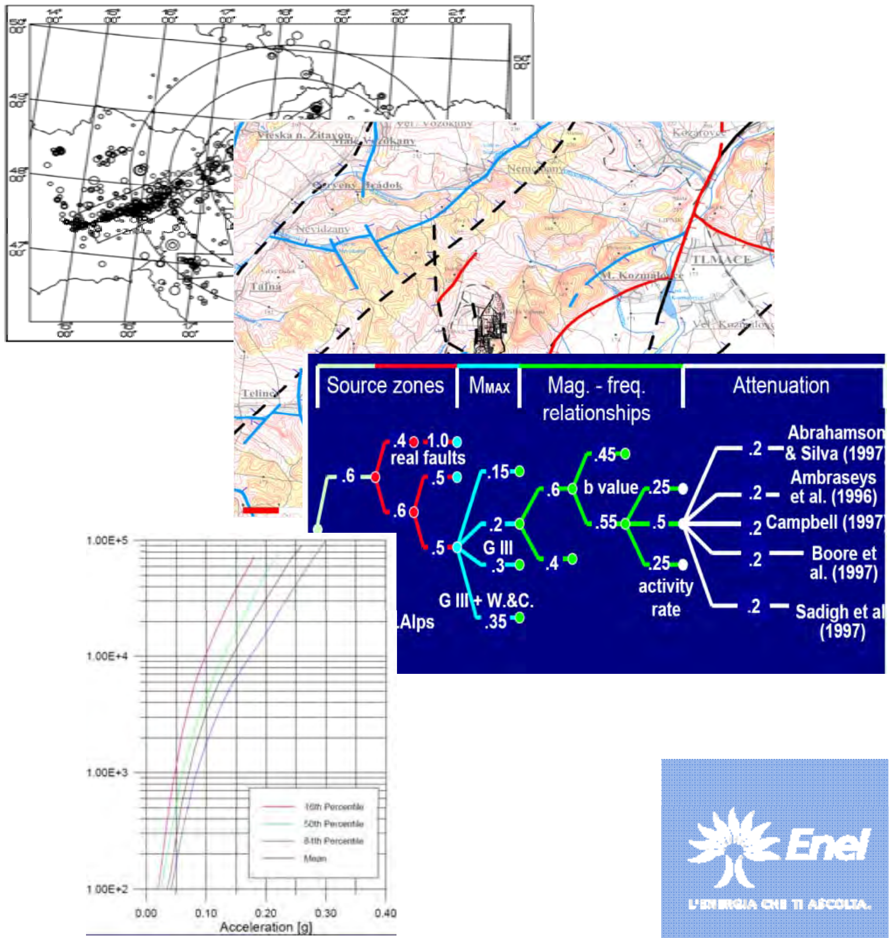
Seismic re-assessment of EMO12 after Stress Tests

Sensitivity study of the site specific seismic hazard for the Mochovce NPP

- **Analysis of the existing PSHA:**
  - Suitability of the geological and seismological database
  - Validity of the technical assumptions (zoning, Mmax, magnitude-frequency relationships, GMPEs) with reference to the current practice

- **New evidences in the geological, seismological and seismotectonic field**

- **Sensitivity analysis:** suitability of the seismic input to be used for the seismic re-assessment of EMO12 NPP



Seismic Hazard and Fault Capability Analysis

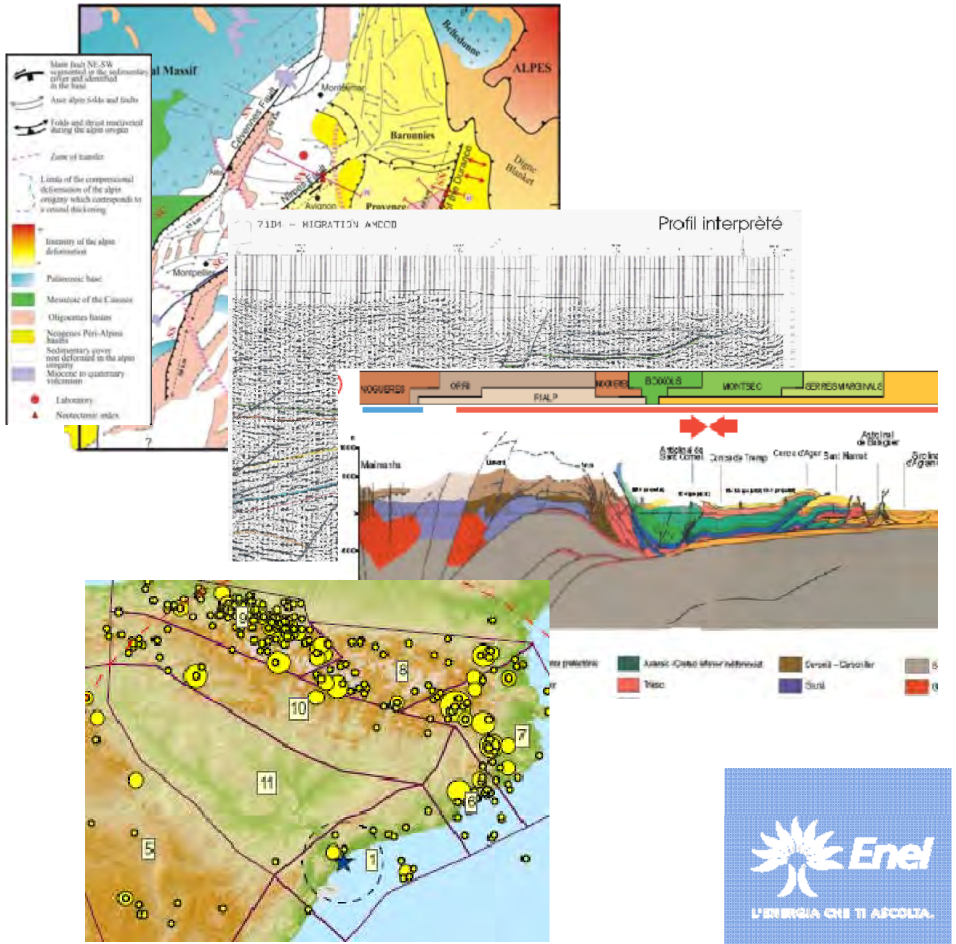
Post Stress Tests activity in Spain

Evaluation of the fault capability potential and re-assessment of the site specific seismic hazard of Endesa-ANAV NPPs in Spain

- **Analysis of the geological context:**
  - Collection of geological, geotechnical and geophysical information
  - Development of the local geological model

- **Field investigation in the site vicinity**

- **Seismic hazard and fault capability analysis:**
  - Collection of seismological data
  - Development of the seismotectonic model
  - Evaluation of the potential for surface faulting in the site vicinity
  - Re-assessment of the site-specific seismic hazard

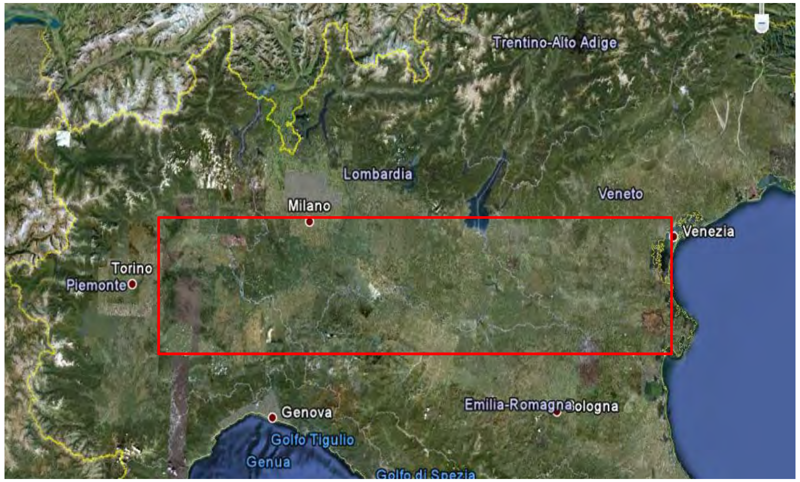


Participation in SIGMA project

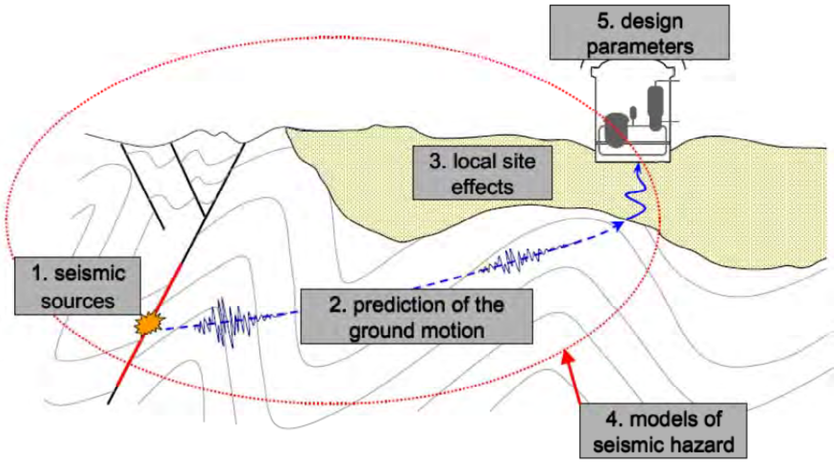
Italian contextualization

Uncertainty reduction in PSHA studies - specific issues for low seismicity zones, in absence of superficial morphological evidences

- **Region of interest for the study: Po Plain**



1. **Seismogenic sources characterization (problem of blind thrusts)**
2. **Selection of adequate attenuation relationships (regionalization of existing attenuation laws)**
3. **Site effect evaluation (sites on thick alluvial sediments)**



Identified issues for potential coverage by the scientific community

- **Hazard for fault capability**

  (despite of the international guidelines provided by the IAEA, NRC, etc., still large uncertainty survives in the application of the relevant criteria and methodologies for assessment)

- **Reduction of uncertainties in PSHA; sharing of data for tuning of region specific methods/laws**

18TH WGIAGE Seismic Sub-Group Meeting
09 & 10 April 2013
OECD Headquarters Paris

Presented by John P McFarlane
Chief Civil Engineer
EDF-Nuclear Generation UK

welcome

london
official partner

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18TH WGIAGE Seismic Sub-Group Meeting

09 & 10 April 2013

18TH WGIAGE Seismic Sub-Group Meeting
09 & 10 April 2013

STF-2: *The nuclear industry should establish a research programme to review the Seismic Hazard Working Party (SHWP) methodology against the latest approaches. This should include a gap analysis comparing the SHWP methodology with more recent approaches such as those developed by the Senior Seismic Hazard Analysis Committee (SSHAC).*

Solution Proposal: *The scope shall comprise two elements of work: (i) a review the SHWP methodology against the latest approaches used to evaluate the seismic hazard and (ii) a gap analysis comparing the SHWP methodology with more recent approaches such as those developed by the SSHAC..*

The review shall consider the following:

- Any deficiencies in the original SHWP models that have not been addressed in detail.
- Any required corrections or updates to the source models from the original SHWP studies (which could lower or raise the hazard results).
- Establish how uncertainty is dealt with in the SHWP work.
- Establish how uncertainty would be dealt with using the SSHAC process.
- Identify any gaps that may require further work.
- Relevant guidance in the IAEA guidelines.

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09 & 10 April 2013

STF-4: *Licensees should undertake a further systematic review of the potential for seismically-induced fire which may disrupt the availability of safety-significant structures, systems and components (SSC) in the seismic safety case and access to plant areas.*

Solution Proposal: *The scope of work shall comprise a systematic review of the potential for seismically-induced fire to affect Bottom Line plant, or to challenge the ability to undertake necessary post-event operator actions at EDF-NG Nuclear Power Stations.*

The review shall consider the following:

- Potential causes and sources of fire following a seismic event.
- Potential for fire spread as a result of damage to fire barriers.
- Potential for Operator action to be compromised.
- Potential for consequential damage to Bottom Line structures, systems and components as a result of fire;
- Availability of fire detection, suppression and fire fighting systems.
- Options for plant enhancements to mitigate the risks identified.

The work shall consist of background research, reviewing the fire and seismic safety cases and severe accident guidelines, as well as performing
seismic walk-downs on all EDF-NG sites. The walk-downs shall be carried out by experienced Seismic Qualification Utility Group (SQUG) engineers and will include:

- Review all available information on fire safety barriers and suppression systems for all sites, and engagement with the appropriate EDF-NG fire hazard experts.
- Check of the Equipment Qualification Schedule for seismic qualification.
- On a station-by-station basis conduct seismic walk-downs of potential vulnerable areas, particularly those areas close to vulnerable essential plant. Carefully check for interactions in proximity to essential plant.
- List areas visited and highlight potential areas for further investigation.
- Compare practices across sites to identify any learning issues for the fleet.
- Preparation of a final report with recommendations.

18TH WGIAGE Seismic Sub-Group Meeting
09 & 10 April 2013

STF-5: *Licensees should further review the margins for all safety-significant structures, systems and components (SSC), including cooling ponds, in a structured systematic and comprehensive manner to understand the beyond design basis sequence of failure, and any cliff-edges that apply for all external hazards.*

Solution Proposal: *This scope of work shall comprise a programme of formal seismic walk-down assessments carried out in accordance with*

the Seismic Qualification Utility Group guidelines, and shall cover:

- Reactor pressure boundary and post-trip reactor cooling
- Post-trip reactor monitoring plant and equipment.
- Cooling pond pipework and equipment

It is proposed to apply a walk-down method to civil engineering structures to identify potential vulnerabilities, taking cognisance of worldwide seismic OPEX. Walk-downs shall be carried out by experienced Seismic Qualification Utility Group (SQUG) engineers and shall comprise:

- A review of Nuclear Power Plant seismically attributed structural failure OPEX from international earthquake events. Determine when and how the structures were designed (e.g. elastic or energy absorbing). Identify features which were susceptible and failed under seismic loading.
- A desk study review of the EDF-NG civil engineering structures and identification of areas of vulnerability under seismic loading (e.g. irregular layout, plan eccentricities, soft storey collapse mechanisms etc).
- A seismic walk-down of civil engineering structures and identification of any features which have been observed to have failed based on OPEX. Review the condition of the buildings and identify if there are any perceived vulnerabilities in the seismic robustness of the structures.
- If there are any identified features which are suspected to be seismically vulnerable, review the existing quantitative seismic assessments and check how the structures have been assessed and what margins are presented.
- Using all of the above, form an expert judgement on the perceived robustness of the fleet civil engineering structures. Expert judgement is essential as the credible UK seismic events will be much shorter duration than international OPEX and therefore would cause less damage.
- Identify areas which are not robust and not well substantiated by the historic assessments, and present recommendations to re-evaluate using up-to-date best practices.

18TH WGIAGE Seismic Sub-Group Meeting
09 & 10 April 2013

STF-6: *Licensees should review further the margin to failure of the containment boundary, and the point at which containment pressure boundary integrity is lost should be clearly established for the advanced gas-cooled reactors (AGR) and Magnox stations*.

Solution Proposal: *The scope of work shall comprise a review of each AGR station to determine whether the reactor coolant pressure boundary has appropriate integrity and margin to failure for relevant scenarios and will consider:*

- All components required to assure pressure boundary integrity (e.g. the Pre-stressed Concrete Pressure Vessel as well as non-isolatable penetrations into the vessel such as feed & steam penetrations, fuel & control standpipes, gas bypass lines, gas circulators, and small bore service pipes.
- The seismic capability and available margins of the surrounding civil structures.
- Identification of any potential cliff edges in the capability of the plant to withstand extreme hazards, and practical enhancements to the sites' resilience in responding to such hazards
- A formal bounding beyond design basis seismic margin assessment for the plant and equipment, with the scope of the walk-downs relevant to reactor pressure boundary integrity giving due consideration to this.

The work will consist of initial background research reviewing existing safety cases, Periodic Safety Review reports, previous SQUG walk-downs and other detailed seismic analysis. Walk-downs will be carried out ensuring a 'once through' pass i.e. combining STF-4 and STF-5. The walk-downs shall be carried out by experienced Seismic Qualification Utility Group (SQUG) engineers, and shall cover:

- Review all available information from existing work / analysis carried out on the pressure boundary.
- Identify any gaps that need to be addressed to identify margins.
- Liaise with EDF-NG Subject Matter Experts on the pressure boundary / containment (penetrations, reactor internals etc).
- Review results from combined walk-downs identified from the Equipment Qualification Schedule for each site and discuss with the EDF-NG teams responsible for carrying out resilience modifications.
- List any gaps that require further analytical investigation or propose resilience modifications.
- Prepare final report with recommendations.

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Japan Earthquake Response Programme Workscope

Design Basis Issues

- Although the approach focussed on the most severe situation of loss of all cooling and services, there are a number of design basis issues which have been considered in the JER response
- If possible, the proposed JER solution would also address these known issues for Design Basis events
- However, care must be taken to avoid slowing down the JER response by protracted discussions of design basis issues
  - Otherwise these issues will be left to "Business As Usual"

Design Basis Issues (1)

Ref	Specific Area	Question/Issue	Comment	JER	SRD	ONR
1	FLOODING: Design Basis (Ongoing Consideration)	The design basis flooding assessments are being re-evaluated on a consistent basis for the fleet	See Further review and Assessment			
2	SEISMIC: Safety Case claims on Operator Action (Ongoing Consideration)	The existing safety case assumes a number of operator actions The totality of the operator actions is subject to review under a consideration However, a specific issue has arisen during the resilience walkdowns; *Is there a claim on accessing the pile cap and, if so, are any of the stairwells claimed to be seismically qualified?*	Sites have been surveyed and no work is planned			
3	SEISMIC: Safety Case and Claims on the AICs (or equivalent)	The AICs were installed for a number of specific hazards *Note that flooding upgrades are being planned separately*	All AICs have been identified as Seismically qualified. No work planned			
4	SEISMIC: Safety Case and Claims on the Emergency Facilities on the Site	The emergency arrangements would be invoked following a design basis seismic event The majority of ECCs (and their Back Up Facilities) are not seismically qualified The safety cases make claims (explicit or implicit) that emergency management would be " adequate" *These alternative (post seismic event) arrangements may be subject to challenge given the proposals for BDB i.e. the moving to site of a portable ECC*	Minor modifications to ECC wall/ceiling mounted furniture to improve seismic properties			
5	AGR Cooling Ponds - Plant System Faults	Pond wall cracking, and thus pond water loss, at water temperatures below boiling point are a live issue	Back-up pond water coolers are to be provided by the JER Programme			

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Design Basis Issues (2)

Ref	Specific Area	Question/Issue	Comment	JER	SRD	ONR
6	FIRE/FLOODING	The HRA fire pumps are located in the turbine hall basement and are therefore prone to flooding themselves if responding to a turbine hall fire	No longer doing this work.			
7	EMERGENCY MANAGEMENT	The HYA and HYB ECCs are recognised to be limited in size and this may limit their effectiveness. There have been proposals to address this for some time including a combined ECC (whether it is the main ECC or the back up is a secondary issue)	The proposal is to build a Heysham Emergency Facility which will combine a multisite ECC and BUE store			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

- The Summary

The Main Assumptions which Shape the Work

- It is difficult to bound the impact of an external hazard as the uncertainties are high
  - Using the highly uncertain results of beyond design basis hazard analysis is therefore potentially misleading
- It is considered more likely that a severe storm will provide the UK BDB challenge than say an earthquake or earthquake induced Tsunami
- Although there is a focus on the effects of flooding from the ground level because of Fukushima, the consideration of a severe storm with its high winds, flying debris and rain can result in water damage of plant systems (esp electrical systems) at any height
  - Ground level protection from floods will not therefore stop the effects of water on the functioning of plant systems, but will significantly reduce the risk
- The additional consideration of a 911 “hazard” means that the main assumption is that all power and cooling is lost and there is major physical disruption to any facility on site
  - This would include the emergency management facilities and equipment on the site
- Electrical systems are particularly prone to the effects of a hazard and can take significant time to re-commission as shown in Fukushima
  - The proposal bases the fundamental cooling provision on portable direct drive diesel pumps
  - This allows for timely and well controlled re-commissioning of the installed electrical systems
- So there is a fundamental requirement to control the Emergency Arrangements from off site and bring the necessary equipment onto site
  - This also allows for controlled movement of people onto the hazardous site and therefore keeping most people at a safe distance
  - The emergency arrangements at Fukushima were, and still are, being hampered by the emergency centre being too close to the source of high radiation

Plant Buildings (1)

Ref	Building	Approach	Specific Issues	JER	SRD	ONR
1	Reactor Buildings	Flooding: Very difficult to protect with confidence Enhanced flood protection will be provided for key vulnerable areas will be protected at specific sites, e.g. Ponds, Battery rooms. Seismic: The AGRs will have a seismically qualified Stair access to the pile cap via one targeted Stairwell	Dewatering equipment will be provided. Note that if ponds are lower relative to the ground, consideration is being given to better flood protection (HPB and HNB). However, note that the reactor building level compared to the sea will influence the final decision			
2	Turbine Hall Buildings	Flooding: Very difficult to protect with confidence. No resilience measures planned.	The back up equipment will have de-watering capability to assist in removing flood water but the turbine hall basements will not be a priority activity			
3	Cooling Water Pumphouse	Flooding: Very difficult to protect with confidence The essential cooling water pumps would be interdependent on essential electrical supplies and, in any case, the recovery is not dependent on essential cooling water supplies No resilience measures planned.				
4	Emergency Back Up Boiler Feed Buildings	Flooding: Very difficult to protect with confidence However, for the standalone buildings, even though it is recognised that this offers limited protection, door openings will be fitted with dam boards, and penetrations sealed as far as reasonably practicable.	The HRA HYA HPBUCS and LPBUCS direct drive diesel water pump houses will be subject to a further review given the sensitivity of these reactor designs to loss of either boiler feed or PVCW			
5	Essential Electrical Buildings	Flooding/Water Ingress: Very difficult to protect with confidence However, for the standalone buildings, even though it is recognised that this offers limited protection, door openings will be fitted with dam boards, and penetrations sealed as far as reasonably practicable.	Further Review Required to identify site specific enhancements. To include flood protection of HYB/TOR ESBs, SZB aux shutdown building.			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Plant Buildings (2)

Ref	Building	Approach	Specific Issues	JER	SRD	ONR
6	Essential Electrical Generation	Flooding: Very difficult to protect with confidence However, for the standalone buildings, even though it is recognised that this offers limited protection, door openings will be fitted with dam boards, and penetrations sealed as far as reasonably practicable.				
7	Fire Fighting Facilities/Systems	Seismic: Upgrades to ensure the entire installed fire fighting system survives seismic events are not planned as the systems are extensive and would require significant work to upgrade. Reliance will therefore be placed (as currently) on protection and provision of portable fire fighting capability and fire hazard reduction. Seismic: The fuel tanks for Engine Driven fire pumps and their large water supply tanks will be anchored	Note the detail scope of modifications will be site specific, however it will include, where appropriate: Fire Stations Enhanced seismic resilience of the fire stations to withstand a 10-4 p.a. infrequent event and increase the survivability of fire fighting equipment that would be necessary to combat outbreak of fires following a seismic event. Dry Risers Seismic qualification of a certain dry riser to withstand a 10-4 p.a. infrequent event to enable delivery of water to the charge face to provide water for cooling purposes to the Buffer store. FJFP Tanks Installation of restraints to ensure that the tanks do not dislodge in a BDB seismic event and damage the ad adjacent fire fighting pumps.			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Plant Buildings (3)

Ref	Building	Approach	Specific Issues	JER	SRD	ONR
8	Sea Barrier Defences	Flooding: The re-assessment of the Design Basis flooding levels on a consistent basis may require some local changes. No significant work is planned on Sea Barrier Defences	DNB Impractical to improve – Localised flood protection installed around critical plant HRA Reviewing the potentail to increase the existing defences – although any work will be limited HY1/2 No work planned			

Not happy with Principle	Happy with Principle But want to see detail	Happy with Principle Know enough to be happy

Plant Systems – AGRs (1)

Ref	System	Approach	Connection Points	Back Up Equipment	JER	SRD	ONR
1	Pressure Vessel Cooling (also see Reactor Blow Down and LPBUCS)	AGR PVCW will vapour lock fairly quickly once the water flow has stopped so even getting the pumps going again (closed loop and open loop) is not enough to ensure water flow to all the key areas No modifications planned.	No	No			
2	Boiler Water Feed	The priority for a " hot" pressurised AGR Engineered connection points will be provided where appropriate.	Yes – Site specific locations agreed for all stations Plan B will be " Hot Tap In"	Yes – Variable high pressure direct drive diesel water pumps			
3	Gas Circulator Operation	Re-commission in a systematic way to avoid damage and loss This approach would preserve the gas circulators for later use	No	No			
4	Reactor Re-Sealing Capability	The Plan A for reactors shutdown and in air with circuits open Useful approach given a severe storm would build hence give time for action (36hrs notice)	Yes Permanent plug-in points to enable prompt connection of pre-deployed generators to energise appropriate crane systems.	Yes – Portable 415v generators to support crane moves pre-deployed in advance of the outage Re-sealing equipment will be site based. Note HYB/TOR will require a resealing capability			
5	Gas Pressure Support	The Plan A for reactors shutdown and de-pressurised	Yes Permanent and non permanent modifications to CO2 systems facilitating the introduction of gas to maintain minimum pressure required for natural circulation post BDB event. Non permanent modification kits to facilitate the use of on-site gas supplies should they survive the BDB event - limited to TOR & HYB	Yes – Nitrogen gas and make-up pipework			

Not happy with Principle

Happy with Principle But want to see detail

Happy with Principle Know enough to be happy

Plant Systems – AGRs (2)

Ref	System	Approach	Connection Points	Back Up Equipment	JER	SRD	ONR
6	Reactor Blowdown	Required to control/reduce reactor pressure following loss of PVCW whilst in natural circulation. Protection to the LPBUCS at HRA/HYA is being considered.	No Manual valves have been identified	No			
7	Fuelling Machine	Generally nothing The HYB/TOR MUS booms will be seismically qualified	No	No			
8	Buffer Store Cooling	Time available to reinstate water jacket cooling (by water or possibly air). Gas pressure not essential	Yes – Site specific locations agreed Note: Some dry risers may be seismically qualified where practicable to support the connection points proposed. A seismically qualified access route will be provided at all sites. Plan B will be " Hot Tap In"	Yes – Low pressure direct drive diesel water pump			
9	Fuel Pond Cooling	Time available for action to top up Coolers will also be provided	Yes HYB/TOR Only - Permanent modifications where it is practical to establish simple route and connection to add water to the fuel pond No - All other sites- hoses will be laid to the ponds for top up and cooling	Yes – Low pressure direct drive diesel water pump Yes – Portable Coolers			
10	LPBUCS	Due to the vulnerability of the BCU's and the issues around flood protection for the LPBUC's facility – a LP tie in is being considered for HYA/HRA	If flood protection of LPBUCS is not feasible consider the implementation of connection point to allow additional cooling to LPBUCS.	If required will use low pressure direct drive diesel water pump			

Not happy with Principle

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But want to see detail

Happy with Principle
Know enough to be happy

Plant Systems – AGRs (3)

Ref	System	Approach	Connection Points	Back Up Equipment	JER	SRD	ONR
11	C&I	Provision of an Event Response Reactor Monitoring (ERRM) to allow the condition of the reactor to be monitored during and even up to the point where proposed BUE can be deployed An station instruction will be prepared to instruct how to initiate a reactor trip by initiating a shutdown of a secondary system	A system is to be permanently installed that will be capable of monitoring and remotely displaying essential reactor parameters for a period of at least 8 hrs prior to and for at least 8 hrs after a BDB event. No	Yes – Command and control POD No			
12	Other	Flooding: The Tritiated Water Tanks in the HRA HYA Reactor Basements will have improved anchoring where practicable to stop them breaking free in a flood and compounding the recovery	No	No			

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Plant Systems – SZB (1)

Ref	System	Approach	Connection Points	Back Up Equipment	JER	SRD	ONR
1	Reactor Cooling Pump Seal Charging System	The charging system is inter-dependent on other systems hence limited benefit Preferred approach is to fit a later seal pack which is less prone to causing a small LOCA in the event of system failure	No	No			
2	Steam Generator Water Feed	Prolong the use of the steam driven system by topping up the water supply and the CATS N2 supply	Yes – to the relevant water tanks Yes – to the CAT N_2 tank Yes – to Aux Cooling	Yes – Low pressure direct drive diesel water pump Yes – Nitrogen supply			
3	Steam Generator Water Tie	Provision of a tie in to allow direct injection of water to auxiliary system, as a back up	Yes - to Auxiliary cooling line Yes – to the CATS tank	Yes – High pressure direct drive diesel water pump Yes – Nitrogen supply			
4	Hydrogen Re-combination in the Containment	Supplement the existing electric design basis ARs with BDB Passive ARs (more in number to cope with a full core melt)	No	No			
5	Containment Venting	Significantly enhance the current approach with a Filtered Vented Containment System - Electric and manual means of opening	Permanently installed new plant system may have a connection point to assist in electrical actuation of the vent valves All subject to feasibility being confirmed	No			

Not happy with Principle

Happy with Principle But want to see detail

Happy with Principle Know enough to be happy

Plant Systems – SZB (2)

Ref	System	Approach	Connection Points	Back Up Equipment	JER	SRD	ONR
6	Debris cooling at the bottom of the containment	Provide a means of topping up the water flooding of the corium by pumping via a portable pump to provide debris cooling.	Yes – Via existing penetration, detail to be agreed,	Yes – Low pressure direct drive diesel water pump			
7	Fuel Pond Cooling Make Up	Provide a means of topping up the cooling ponds to offset evaporation - Note this is not to prevent boiling No Modifications planned	Use installed dry riser if available post event or run hoses from the water pump/cooling unit into the cooling pond if unavailable.	Yes – Low pressure direct drive diesel water pump			
8	Hydrogen Re-Combination in the pond cooling buildings	If the cooling pond water falls to the point where Hydrogen is produced, the greater problem would be dose levels The recovery focus will therefore be to maintain adequate water levels. No Modifications planned	No	No			
9	Primary Coolant	Provision of a low pressure boronated feed into the primary circuit to provide support for the removal of decay heat from the SZB reactor core whilst in a Station Blackout at Mode 6	Yes - Permanent modification to provide connection of high pressure BUE pumps to feed water into Primary cooling circuit to provide cooling in Mode 6 condition.	Yes – Low pressure direct drive diesel water pump Water to come from RWST			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Plant Systems - Generic

Ref	System	Approach	Connection Points	Back Up Equipment	JER	SRD	ONR
1	Essential Water Stocks	Use on Site water tanks. 48hr capability for seismically qualified water tanks (HNB, HPB and TOR will require work to meet this requirement) unless further review of water usage allows this.	Yes – To top up the tanks during use Yes – To take water supplies to the portable water pumps	Yes – Use Reverse Osmosis units to clean the sea water (post-48hrs) Yes – Low pressure direct drive diesel water pumps Yes – Filter units to filter the sea water for the RO plants Yes – A portable submersible sea water pump will be provided (mainly for fire fighting purposes but could be used as "last resort" water feed for essential cooling			
2	Essential Electrical Generation Units	Very difficult to protect with confidence, although practical protection will be provided to the buildings. SZB: The Battery Charging Diesel Generators will be qualified for Seismic and Flooding hazards. It will also be fitted with the additional connection points	Yes – For the high voltage 3.3kV Yes – For 415V to underpin essential indication and DPS Yes – For 415V to energise the box-up cranes. Yes – 415V connector to SZB battery charging Diesel Generators	Yes – 3.3kV portable generators Yes – 415v portable generators Yes – 415v portable generators Yes – 415v portable generators			
3	Essential Electrical Systems	Very difficult to protect with confidence . The approach is to plan to systematically repair and re-commission the electrical system No modifications planned.	No	Yes – dewatering and drying out equipment Yes – cable repair equipment			
4	Essential Fuel Stocks	Day tanks are generally sufficient to provide ~24 hours supply, bulk tanks are not seismically qualified with ~2m high. Back up equipment will have its own fuel. No modifications planned.	No	Note all back up equipment will have its own fuel tank which will be topped up hence Yes – portable bowser			

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But want to see detail

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Emergency Management Facilities (1)

Ref	Facility	Approach	Specific Issues	JER	SRD	ONR
1	CCR/MCR	These have limited hazard resilience No proposals to enhance them	Will have Satellite Phones provided			
2	AIC	These are seismically qualified but will be site specific enhanced to increase their resilience to flooding/ other external hazards (e.g. wind blown missiles) The plant control functionality is subject to review to assess the reasonable practicality to provide limited plant control for the essential functions for the reactor type	This scope will cover the resilience of the back up electrics and the H&V Note the SZB AIC (ASR) has quite good existing plant control but will need to be fitted with the FVC valve control if that is implemented			
3	ECC	These have limited hazard resilience Site specific enhancements will be made on a best endeavours basis to increase resilience to Hazards	This scope will cover where appropriate minor Civil modifications, flood protection, the provision of back up diesel generators and a standalone suitable H&V system. This includes the CESC in Barnwood as well as all stations. For the Station ECC's installation of HEPA Filtration will be considered on a case by case basis Note the proposal to build a combined ECC for HYA and HYB Enhance backup facility for CESC			
4	Back Up ECC	These have limited hazard resilience No proposals to enhance them	The AGRs will be provided with portable Ultimate Back Up ECCs and these have the advantage of flexibility of location and therefore are less prone to the hazard affecting their tenability SZB will be provided with a permanent Ultimate Back Up ECC some 1 mile from the site The portable Ultimate Back Up ECC will be a back up to the SZB " ERC" should that location not be tenable			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Emergency Management Facilities (2)

Ref	Facility	Approach	Specific Issues	JER	SRD	ONR
5	Damage Repair Team/Incident Response Team Facilities	Seismic: The Breathing Air arrangements on site will be hardened Seismic: Fire Station buildings will be seismically qualified.				
6	Access Control Point	These have limited hazard resilience No proposals to enhance them				
7	Forward Control Point	This is a flexible location and therefore cannot be hazard qualified				
8	Emergency Lighting	Provide portable 'grab' torches around the plans **This is no longer being implemented**	The Back Up Equipment portfolio will include its own generator, cabling and lighting			
9	Enhance the resilience and diversification of communication systems	Identify the vulnerabilities and limitations of EDF Energy's current communication systems and enhance their resilience where possible and appropriate.	Provision of Satellite phones into key facilities on site; upgrade of TIMMS; review of the resilience of existing telephone exchanges			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Emergency Arrangements

Ref	Facility	Approach	Specific Issues	JER	SRD	ONR
1	SBERGs and SAGs	Review, extend (where appropriate) and update SBERGs & SAGs, also taking into account Fuel Route and new back-up equipment.	The aims of the work are: improved awareness of severe accident management, embedding guidelines into emergency arrangements, sharing best practice across fleet, provides confidence to staff, identifies gaps in procedures			
2	BDB Deployment Response	Undertake the necessary assessments and produce the necessary documentation to provide a BUE handbook which will provide input information to all emergency arrangements documentation to allow the effective deployment of the BUE equipment. Other equipment delivery is also included e.g. Sat Phones and Enhance the Resilience of Central facilities (ERC) equipment provision.	Review current emergency documentation, establish resource requirements, produce generic BUE deployment handbook and site specific appendices. Other supporting information / equipment is provided e.g. Staging post location, notification process, sat phone delivery and ERC equipment requirements, supply chain resilience			
3	EP People and Organisation	Identify the impact on EDF's Energy Nuclear Generation of the Japanese Earthquake Response Programme enhancements. Focusing on managing the integration and impact on people and organisation.	Role of JER to provide information and briefing to EPG on people and organisation issues to ensure alignment with BAU approach and the customers view is represented			
4	BDB Training	To meet the needs of a possible BDB event, JER will ensure that EDF personnel and others supporting the response have sufficient training to provide the required capability	JER Training activity is designed to integrate with EDF NG emergency arrangements and operational training and will conform in design and delivery to company training policy			
5	NG Exercise strategy	To review the existing regime and recommend changes to improve both its effectiveness and efficiency.	To develop and implement the exercising requirements for a beyond design basis event, which includes incorporating it within a coherent strategy.			
6	BDB Proof of Concept	To demonstrate the enhanced resilience capabilities provided through Final Proof of Concept Demonstration Exercises 2013/14	Plan, design and deliver the Proof of Concept Exercises to demonstrate that the JER provided enhanced capabilities to respond to a Beyond Design Basis (BDB) initiating event and subsequent nuclear emergency have reached an Initial Operational Capability			

Not happy with Principle

Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Back-Up Equipment

- AGR Development
  - AGR High Pressure Pump
  - Low Pressure Pump
  - Pond Cooler Package
  - Nitrogen Stillages (15t)
  - Nitrogen Generation
  - Make Up Route
  - Box Up
  - Reverse Osmosis (excl. Seawater extraction)
  - Seawater Extraction
  - Flood Management (inc. Small Dewatering pumps)
  - Large Dewatering
  - Waste Water Management Small Storage
  - Waste Water Management Large Storage
  - Waste Water Treatment
  - Electrical Generation Low Power
  - Electrical Generation High Power
  - Response Monitoring Equipment
  - Lighting Towers
  - Fuel Tanks
  - Damage Repair Team Equipment
  - Logistics / Ancillaries
  - PPE
  - Electrical Re-commissioning
  - Gas circ static seal hydraulic oil pump (DNB)
  - Temporary Buildings
- PWR Development
  - SZB High Pressure Pump
  - Low Pressure Pump
  - Nitrogen Stillages (CATS)
  - SZB Flood Management (inc. Small Dewatering pumps)
  - " Waste Water Management- Small Storage"
  - " Electrical Generation- Low Power"
  - Response Monitoring Equipment
  - Lighting Towers
  - Fuel Tanks
  - Damage Repair Team Equipment
  - Logistics / Ancillaries
  - PPE
  - Electrical Re-commissioning
  - Temporary Buildings

Further Review and Assessment (Design Authority)

Principles

1. Rather than the DA JER programme being designed specifically to address the STFs, IRs and FRs, the following principles have been adopted for DA JER work.

2. We will focus our efforts during the duration of the JER programme (i.e. to March 2014) on those hazard events where we judge that there is the most potential nuclear safety benefit to be derived from the work. Implicit in this principle is the focus on underpinning the design basis for the stations.

3. The work will focus on examining hazards prioritised as per principle #1 above, and on examining the plant and operator capability to withstand them. The objective is to reassess our confidence in the capability for hazard magnitudes at or beyond the design basis (10-4 per year frequency).

4. We will in general address work on a pilot basis (i.e. do the work for a lead station). Depending on the learning obtained from the pilots, we will make a decision as to whether to extend the work to other stations. **Such extension, if appropriate, may be beyond the scope and timescales of the JER programme, and will be pursued as part of Business As Usual (BAU).**

Further Review and Assessment (Design Authority)

Principles (cont.)

5. Any nuclear safety benefit resulting from the work will derive only from physical modifications to increase the resilience of the plant or modifications to the recommended operational response (e.g. procedures, training, ancillary equipment and emergency arrangements). The analytical work, of itself, just serves to inform recommendations for such modifications.

6. The work must therefore take cognisance of related JER workstreams, and how they are also acting to deliver nuclear safety improvements.

7. It is expected that each IR, FR and STF will need a coherent and appropriate response before it will be possible to reach agreement that the recommendation/finding may be considered closed. Those responses will take account of all the above principles #1 - #5 in describing the output from the DA JER work on external hazards.

Further Review and Assessment (Design Authority)

External hazards	DA JER Work and Commentary	JER	SRD	ONR
Seismic	Generic reassessment of the seismic analysis methodology. Confirmation that qualification approach implicitly leads to significant margin because qualification against a given earthquake equates to very low failure likelihood. Pilot study for HPB incorporating a desktop review of previous work to underwrite withstand to the bottom line 10^{-4} earthquake. This will be supplemented by 'expert' walkdowns to confirm that the desktop review is based on accurate assumptions about the plant configuration, condition and qualification status.			
External flooding	Following safety assessments to support the Stress Test report, a complete new set of assessments based on modern standards and a consistent approach for all sites has been completed. Deterministic shortfall identified at DNB – being addressed and transferred to BAU because it represents an operational safety case shortfall. Options for safety enhancement are being explored for HYA/B and HRA. No increased threat at other sites. Other than for DNB – which is being addressed as a priority - the safety cases are intended to be updated to incorporate the revised assessments, but this will be part of future BAU.			
Extreme wind	Revised assessment of 10^{-4} hazard.			
Extreme Ambient Temperatures (EATs)	Revised assessment of 10^{-4} hazard.			
Lightning	No further assessment of hazard magnitude planned for JER work. Hazard added to the NSP schedule by PSR2 and new explicit safety cases in preparation or planned for the AGR fleet.			

Further Review and Assessment (Design Authority)

External hazards (con)	DA JER Work and Commentary	JER	SRD	ONR
Aircraft Impact	No further assessment of hazard magnitude planned for JER work. Scope of JER centred upon natural hazards.			
Industrial Hazards	No further assessment of hazard magnitude planned for JER work. Scope of JER centred upon natural hazards.			
Drought	No further assessment of hazard magnitude planned for JER work. Hazard added to the NSP schedule by PSR2 and new explicit safety cases in preparation/planned.			
Bio-fouling	No further assessment of hazard magnitude planned for JER work. Hazard added to the NSP schedule by PSR2 and new explicit safety case in preparation/planned.			
External EMI/RFI	No further assessment of hazard magnitude planned for JER work. Hazard added to the NSP schedule by PSR2 and new explicit safety case in preparation/planned.			
Combined weather hazards	Flooding, wind, EATs, lightning etc. are potentially causally linked hazards which would be expected to coincide as a result of a single severe weather event. Combined hazard severities being assessed, and reliability of operational response being addressed. This approach has been piloted at HRA/HYA, but will be rolled out across fleet within JER programme timescales because the workshop discussions are of significant benefit in raising hazards awareness. Identified follow-on actions will be in BAU. VisualEyes and Safesee (weather and coastal flooding alert systems which directly access Met Office predictions in "real time") are being procured for all stations to improve forecasting of severe hazard events. This will be completed within JER programme timescales.			

Not happy with Principle

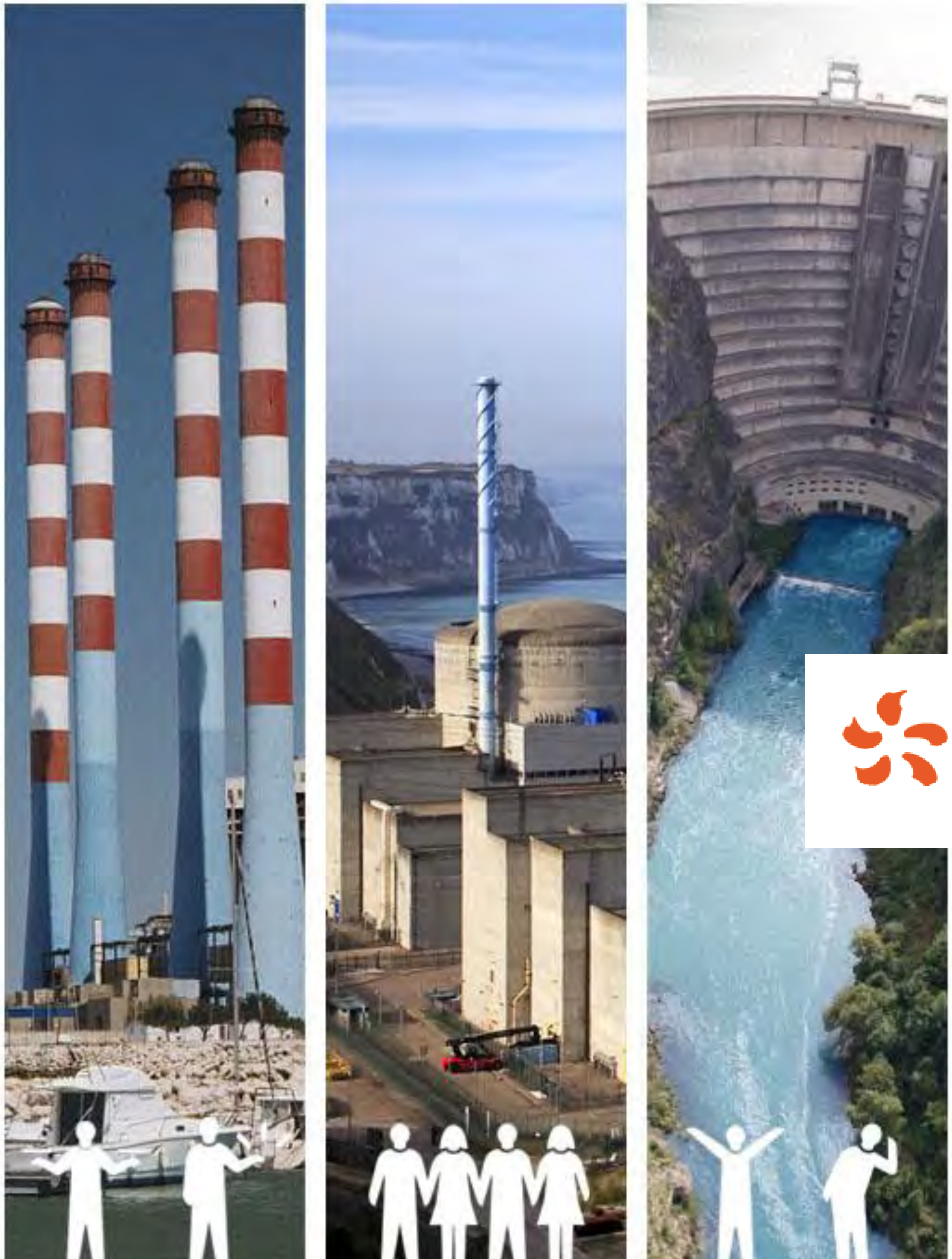
Happy with Principle
But want to see detail

Happy with Principle
Know enough to be happy

Further Review and Assessment (Design Authority)

Other workstreams	DA JER Work and Commentary	JER	SRD	ONR
Hazards Governance	Not strongly linked to JER work: already effectively being pursued as BAU			
L2 PSA	Pilot for HNB to be completed: any resulting inputs to SBERGs and/or SAGs identified, captured and made available to CCR/ECC/CESC. Full implementation in SBERGs and/or SAGs as "final" updates not required within JER scope because these documents are to be managed on a fleet-wide basis, so any follow-on BAU work will influence how this aspect is to be handled.			
SBO	Pilot for HNB to be completed. Any learning identified and implemented e.g. via updates to SOIs. Any follow-on BAU work for other sites specified.			
Human Factors	Not a work stream in its own right, but an area of activity which supports others. No scope closure criteria therefore required. However, DA do "own" STF3. The approach to this is to pilot studies of operator actions required during seismic and severe weather events for HRA/HYA, and implement any learning identified. Any follow-on work for other sites will be BAU.			

thank you



Σigma

Seismic Ground Motion Assessment

Progress of SIGMA project

EDF cea Enel AREVA

L'ENERGIA CHE TI ASCOLTA.

OECD/NEA/CSNI/IAGE annual meeting
Paris, 10 April 2013

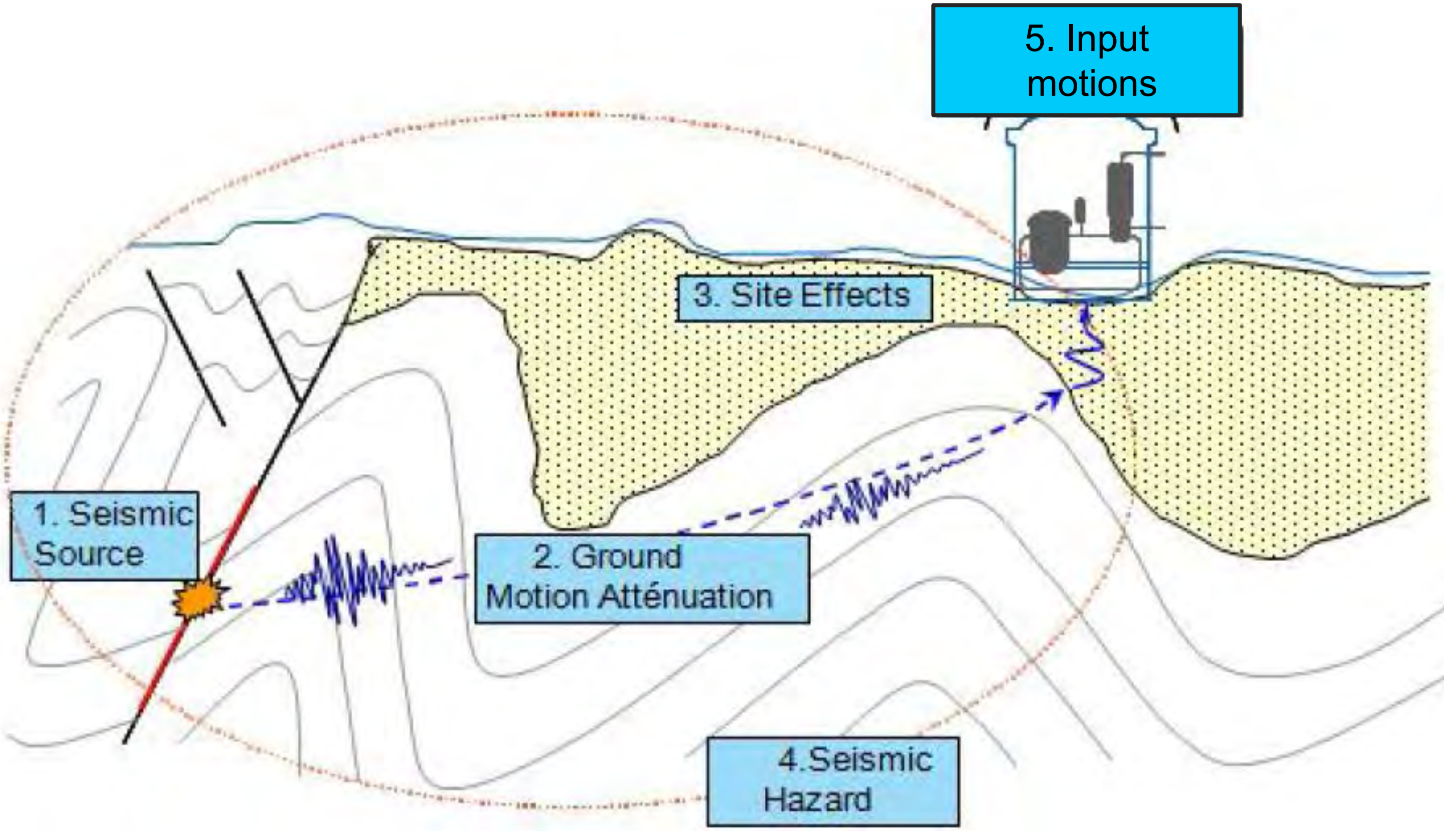
EDF

CHANGER L'ÉNERGIE ENSEMBLE

The SIGMA Objective

To a large extent SHA outputs are controled by uncertainties.
The SIGMA objective is to reduce or better account for uncertainties in SHA

The SIGMA five Work Packages



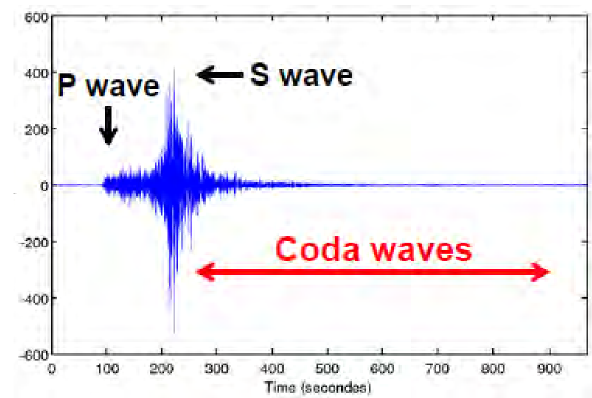
WP1 Improve the knowledge of seismic sources

Σigma
Seismic Ground Motion Assessment

Towards a unique and homogeneous seismicity catalogue at both historical and instrumental scales

- Instrumental period (1962-2009) 100 000 events
  Instrumental catalogue with identified/homogeneous procedure and uncertainties estimate: August 2013

R&D on use of coda waves for a better estimate of Mw.

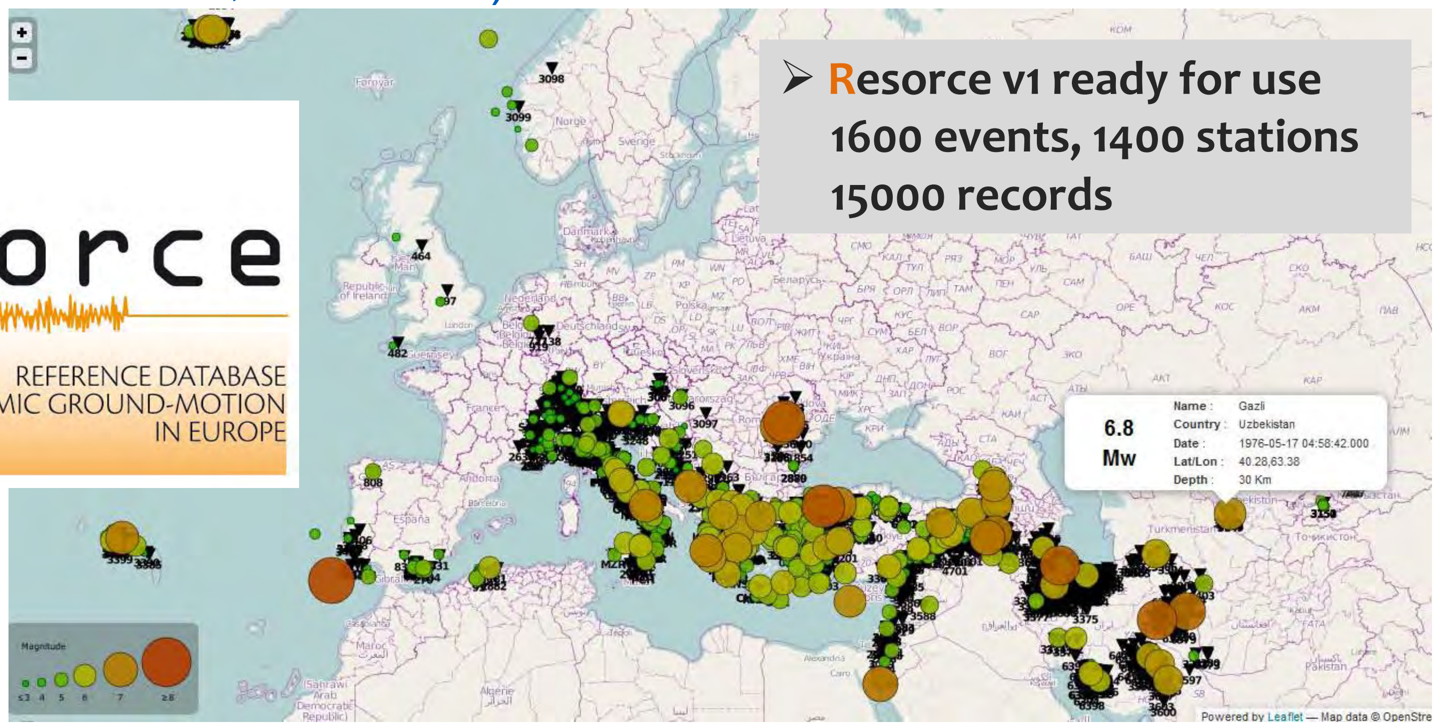


- Intermediate period (1905-1972)
  Magnitude location and focal mechanism reestimated for 15 earthquakes : June 2013

- Historical period (400 -) 1000 events
  Historical catalogue with uncertainties: 2014

WP2 Improve ground motion prediction

- **Resorce**: a well documented and homogeneous european database of strong motions (earthquake, station, waveform)

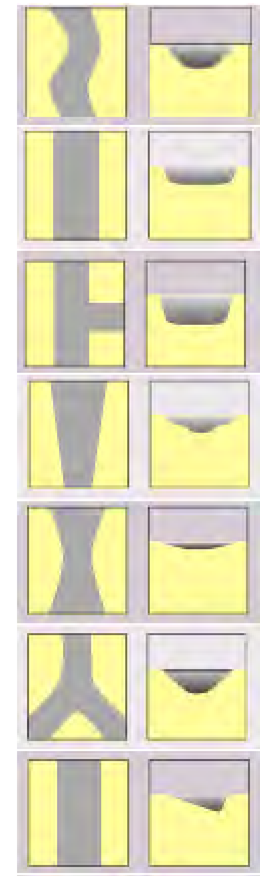


- **Resorce v1 ready for use**
  1600 events, 1400 stations
  15000 records

- Work on single site σ

WP3 Better accounting for local site effects

- ❑ How to ‘clean’ databases from site effects ?
- ❑ How to account for site effects in PSHA ? (uncertainty double counting issue)
- ❑ Why site specific studies (almost) always lead to higher seismic levels than regional approach ? e.g. PEGASOS



- ➢Guidelines on how to address site effects issue
- ➢Parametric studies on some representative 2D and 3D cases

WP4 Improve seismic hazard models

- Investigate influence on SHA of epistemic uncertainties relating to
  - Source models, Catalogue, Mmax …
  - Recurence models,
  - GMPEs,
  - Site conditions.

Preliminary PSHA at sites in the Po Plain region 2012
Preliminary PSHA of South-East of France 2012

- To be updated according to developments of WP1-3

- To be updated on the basis of **Bayesian updating technique**
  - against instrumental seismicity,
  - against historical seismicity.

Ref: Conclusions of the 2008 OEDC Workshop on « Recent developments in PSHA methodologies »

WP5 *Selecting or generating safety relevant input motions*

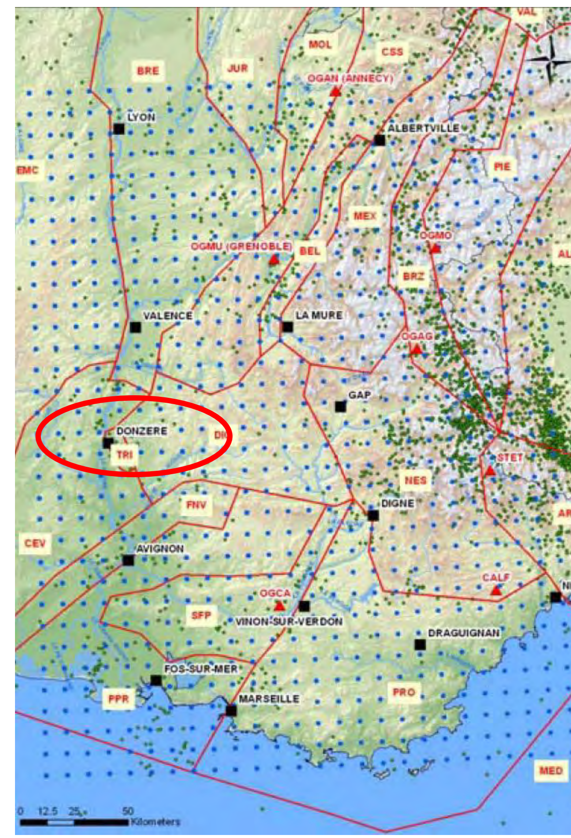
- Development of Conditional Spectrum method
- Application to a site in South'East of France, Valence

Conditional Spectrum

- breaks the Uniform Hazard Spectrum down into realistic earthquakes

- can be used for selection of time-history inputs

- can be used for risk analysis of multi-modal structures



Memo on the Consideration of “Risk Approach” or “Worst Consideration Approach”

Heki Shibata,
Professor Emeritus,
University of Tokyo

About the Situations in Japan related to the PSA study for the Risk Analysis on Natural Events , and Short Discussion Today

- Since the new Regulatory Commission was establishing, we should follow their Policy; last July.

- However, still we have never caught how we,

  the member of the sub-committee in JEA for Seismic related codes like JEAC/G 4601 & similar, should follow their policy.
- They have been asking to us, nuclear power plant operators, to follow their policy.
- There have been two major points there.

  1) Design Condition regarding to Design-Base Tsunami Height for the Prevention Wall.

  2) Identifying the Fault Structure in the Plant Area.

  The item 1), we, Japanese have been discussing with publics since the 3.11 events, but we have not reached our, in the public, yet.

- **I received the following mail from Dr. Alejandro Huerta** OECD Nuclear Energy Agency (NEA), last Feb. Regarding for the subject in this? Meeting.

Mails from **Dr. Alejandro Huerta** OECD Nuclear Energy Agency (NEA)

- *From* **Dr. Alejandro Huerta,** OECD Nuclear Energy Agency (NEA); regarding to the one Workshop regardin the Use of "Probabilisti Method for the Hazard Analysis. "Please find attached the flyer of a Public Workshop on Probabilistic Flooding Hazard Analysis that might be of interest.
- *This workshop may be of interest for some WGIAGE members; if it is the case, can you distribute the flyer to the members?* This mail came from Dr. Siu, Nathan, USNRC; [mailto:Nathan.Siu@nrc.gov]
- Then, we concluded that we would have a chance to discuss one this subject as follow;
- I AM SURE WE COULD FIND TIME DURING THE APRIL WEEK MEETINGS TO DISCUSS ABOUT THE RISK APPROACHES FOR NATURAL HAZARDS.

- As I, Shibata, mentioned previously, we have had the discussions regarding to the probabilistic or risk approach to define the loading condition against natural hazards. This Situation in Japan is coming from the Opinion of Publics.as following;

Short Report on the Situation in Japan

- Entry -Restricted Area Surrounding Fukushima NPP are kept, and many people, near to million, have been living out-side of Fukushima-pref..
- Current electric supply has been made from other power source except only one NPP; Ohi, KEPCo. at this moment.
- Most of Power Companies are proposing to increasing their rate of power more 10～20% up currently.
- The Democratic Party; they took the Government at the time of the 3.11 event, is insisting "No NPP policy" at this moment towards the Voting in this June.
- The Conservative; the Government have been declaring the restarting of NPPs after the severer survey on their safety.

Short Report on the Situation in Japan (2)

- The new organization; Nuclear Regulatory Commission was organized, and has been operating since last July.
- They have been strongly insisting the following two points to be considered for restarting of all NPPs in the view points related to safety from the natural hazard, mainly seismological events, that is, considerations on Tsunami height and the activity assumption of faults in the plant area.
- One of the commissioners of NRC; Dr. Shimazaki, Professor Emeritus, Seismologist, has been insisting as follows:
- No any trace of the event should be proven ever on Tsunami activity.
- No any trace of slipping of the fault should be proven on any structure in the plant area and near-by since 400,000 year ago.

Short Report on the Situation in Japan (3)

- The Government have been accepting it as their policy, and they have been working for those criteria with the specialists related to these requirements to restarting some of these NPPs.
- Most of the Japanese people accept this policy of the Government in general as the safety culture in the Society, even with some power shortage in Summer.
- One of the big News Paper Company Asahi is supporting this judgment; non-logical way.
- Another one Yomiuri has been insisting the necessity of power supply from nuclear energy source, but this opinion has been supported by limited populations.
- This is the situation about restarting the study on the risk-type evaluation approach on the design conditions for the safety relating to natural hazard-type events in Japan.

PSM meeting in Tokyo

- I talked to Professor T. Takada; Univ. of Tokyo for attending in this WAIAGE to talk about the situation on Risk Analysis related to Tsunami hazard, however, he should talk about the same subject in the following meeting.
- Also, in Tokyo, this week; The PSM meeting; WS, covering all engineering areas for discussing on Probabilistic Safety Management has been going on as usual year.

- The Risk Assessment Approach has been very significant subject for related engineers and some scientists in Japan.

END

Regulatory System Change after Fukushima Accident

April 8, 2013

Yuichi UCHIYAMA
Japan Nuclear Energy Safety Organization (JNES)

36th Meeting of the Integrity and Aging of Components and Structures Working Group
18th WGIAGE Concrete Sub-group Meeting

Reform of Nuclear Regulatory Organization

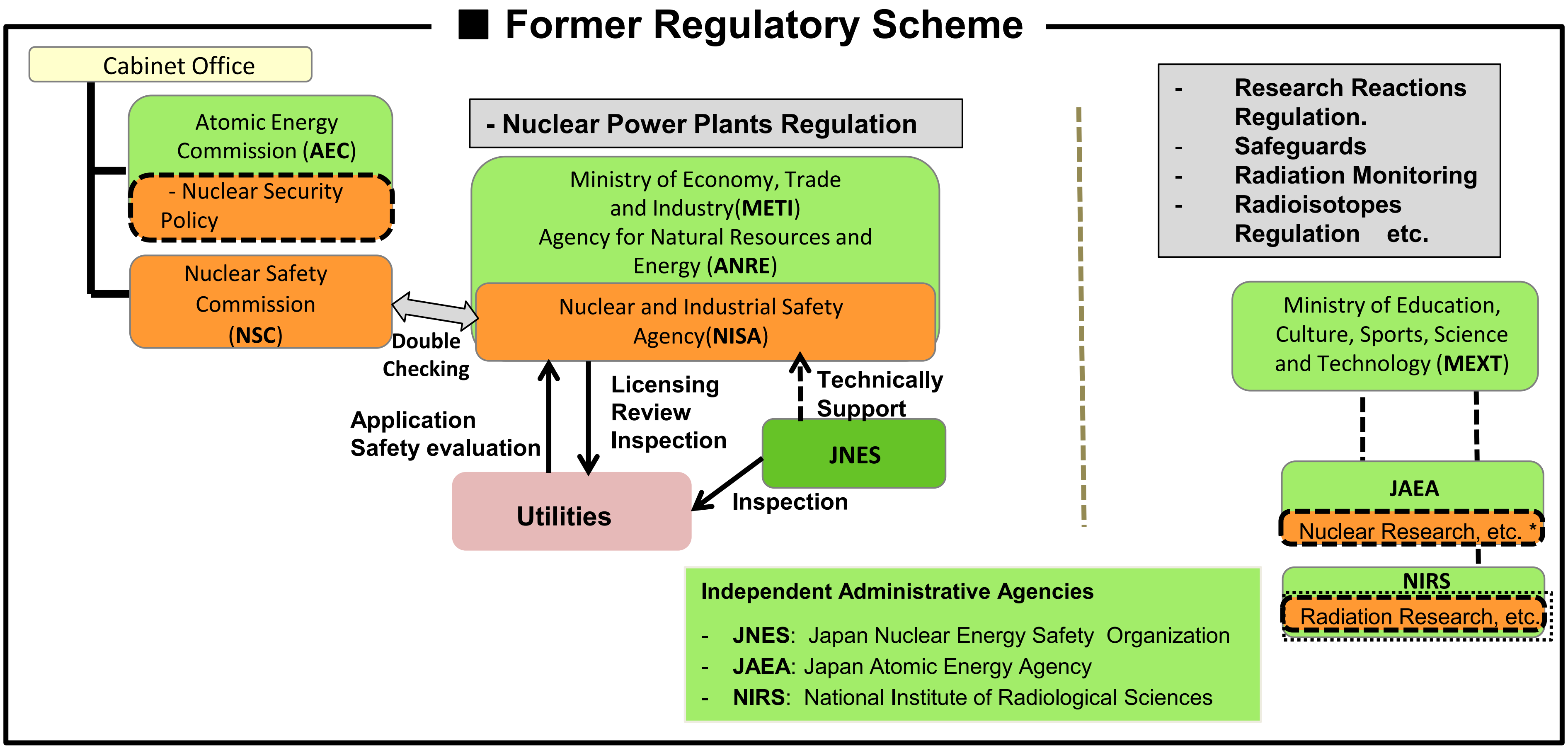
- Independence
  Separate the functions for nuclear regulation and nuclear promotion, and establish the Nuclear Regulation Authority (NRA) as an independent commission body.

- Integration
  Integrate nuclear regulation functions regarding safety, security, safeguards, radiation monitoring and radioisotopes regulation into the NRA.

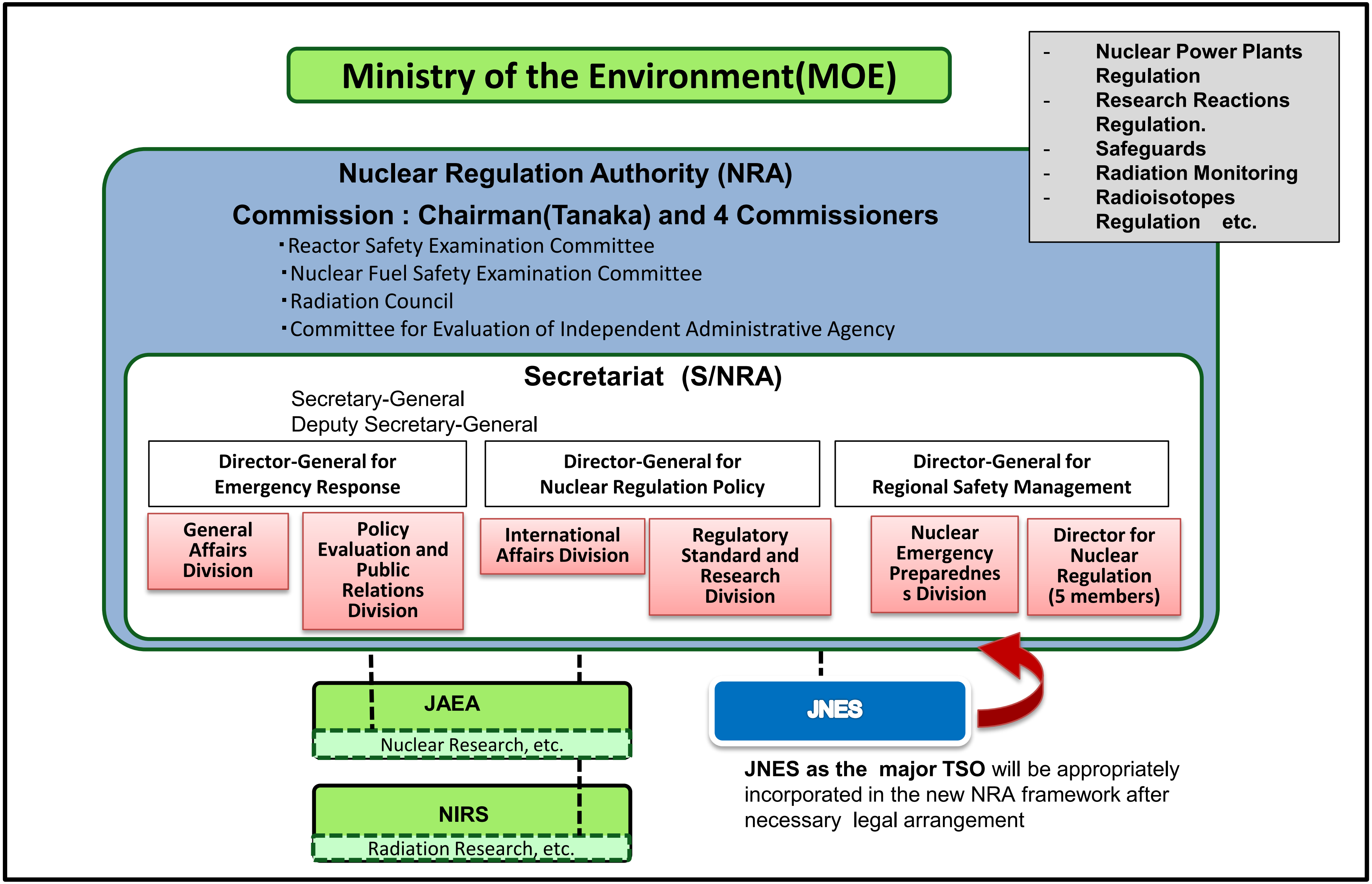
Nuclear safety regulation system change in Japan

New System started at Sept.2012 for Independence, Integration and Transparency of nuclear safety regulation.

- **NSC** and **NISA** merged in new **NRA**
- **NRA** is **now revising nuclear safety guidelines by July 2013**.



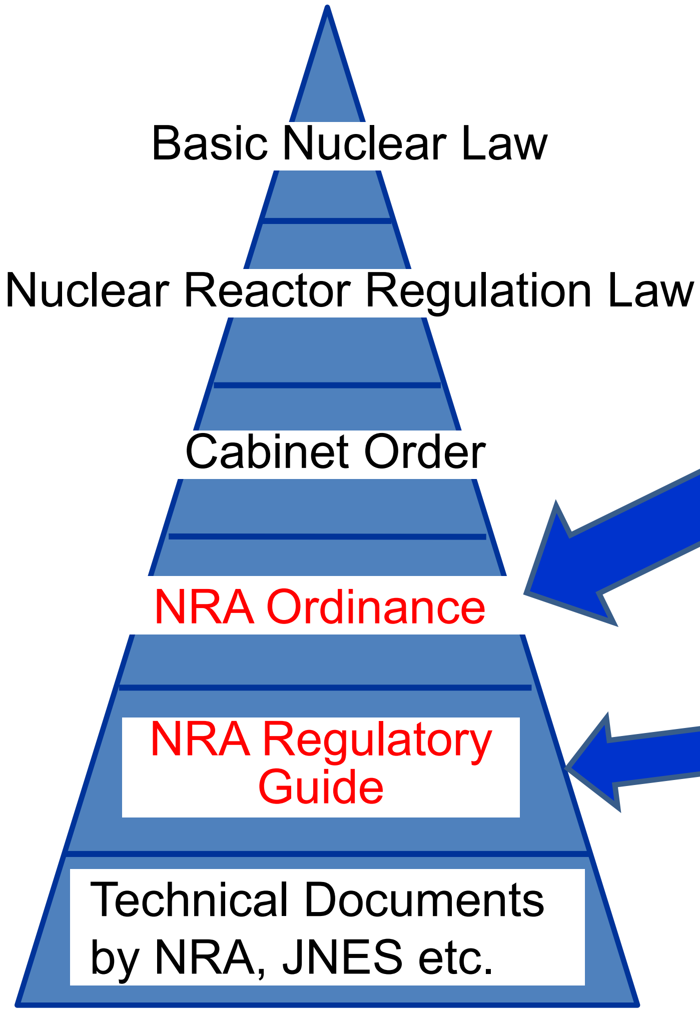
■ New Regulatory Scheme



Newly Proposed Regulatory Requirements for Light-Water Nuclear Power Plants

- Strengthening of Design Basis
- Severe Accident Measures
- Enhanced Measures for Earthquake/Tsunami

Structure of NPP Regulation Legislation



Requirements

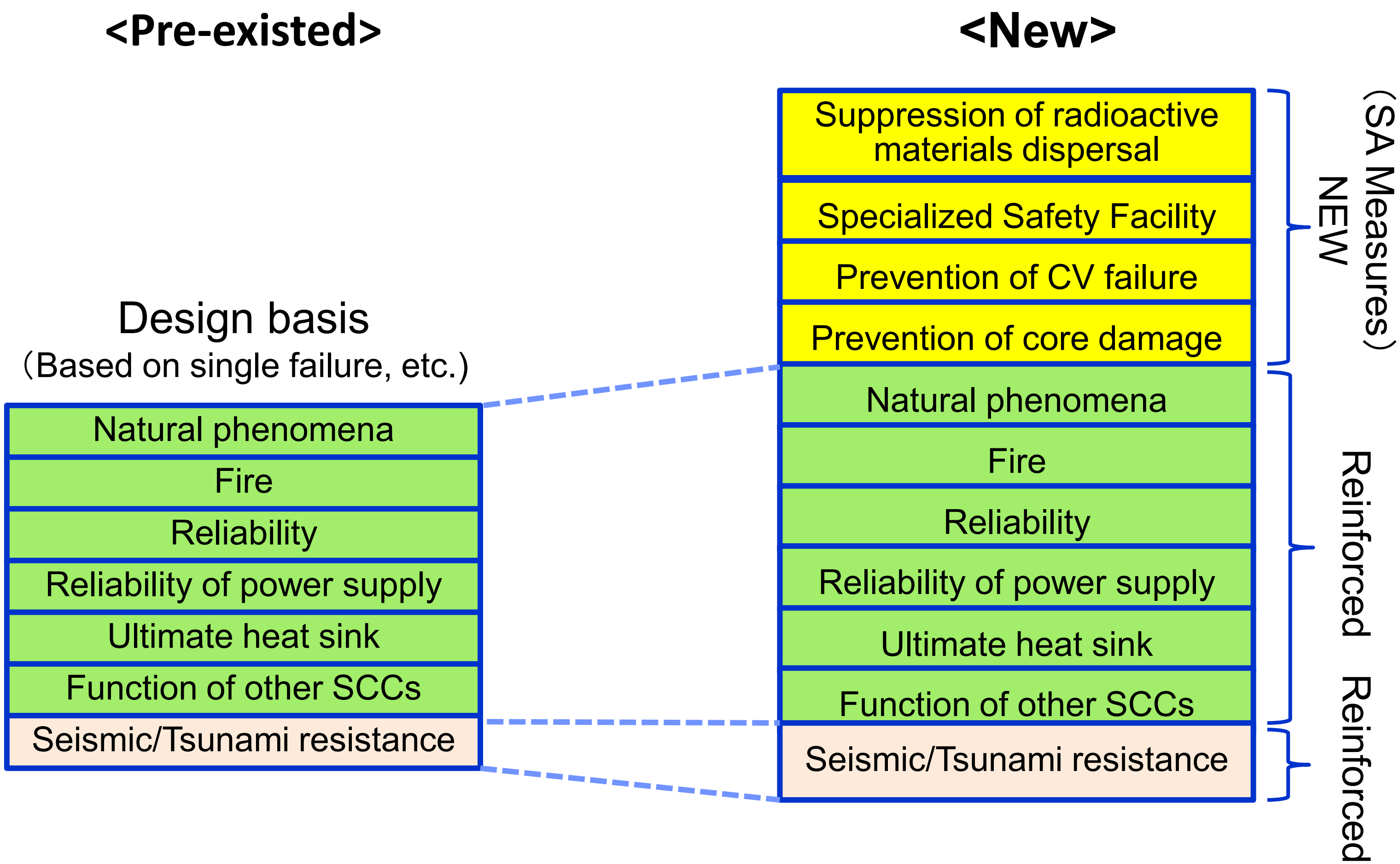
Define the level of capacity of equipment and/or procedures for each function, e.g. depressurization of primary coolant system.

Requirement details

Show examples to achieve the level of capacity.

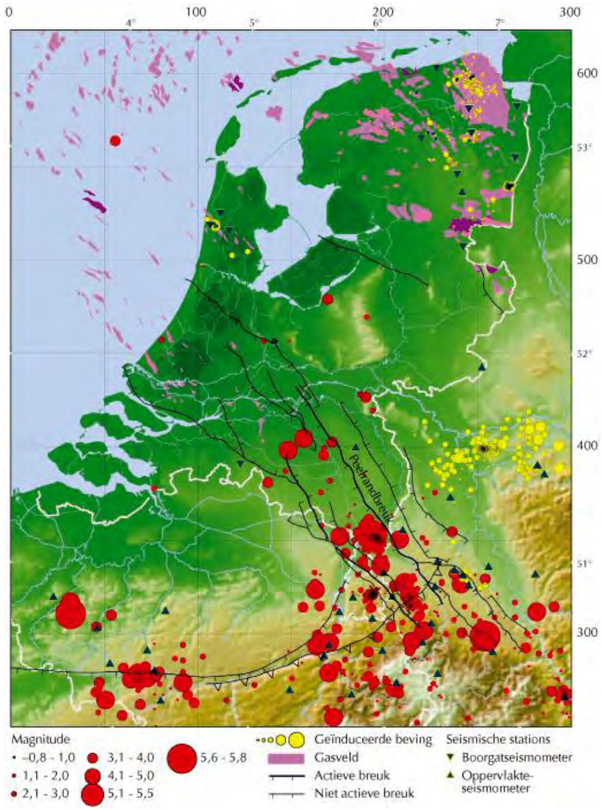
e.g., Evaluation method of habitability of control rooms

Structure of proposed requirements



Inspectie Leefomgeving en Transport
Ministerie van Infrastructuur en Milieu

Seismic developments in The Netherlands



Wouter van Lonkhuyzen

Department of Nuclear Safety, Security and Safeguards (KFD)

4/17/2013

Contents

- Activities at nuclear installations
- Discussion on seismic hazard
- Developments in regulatory framework

Activities nuclear installations

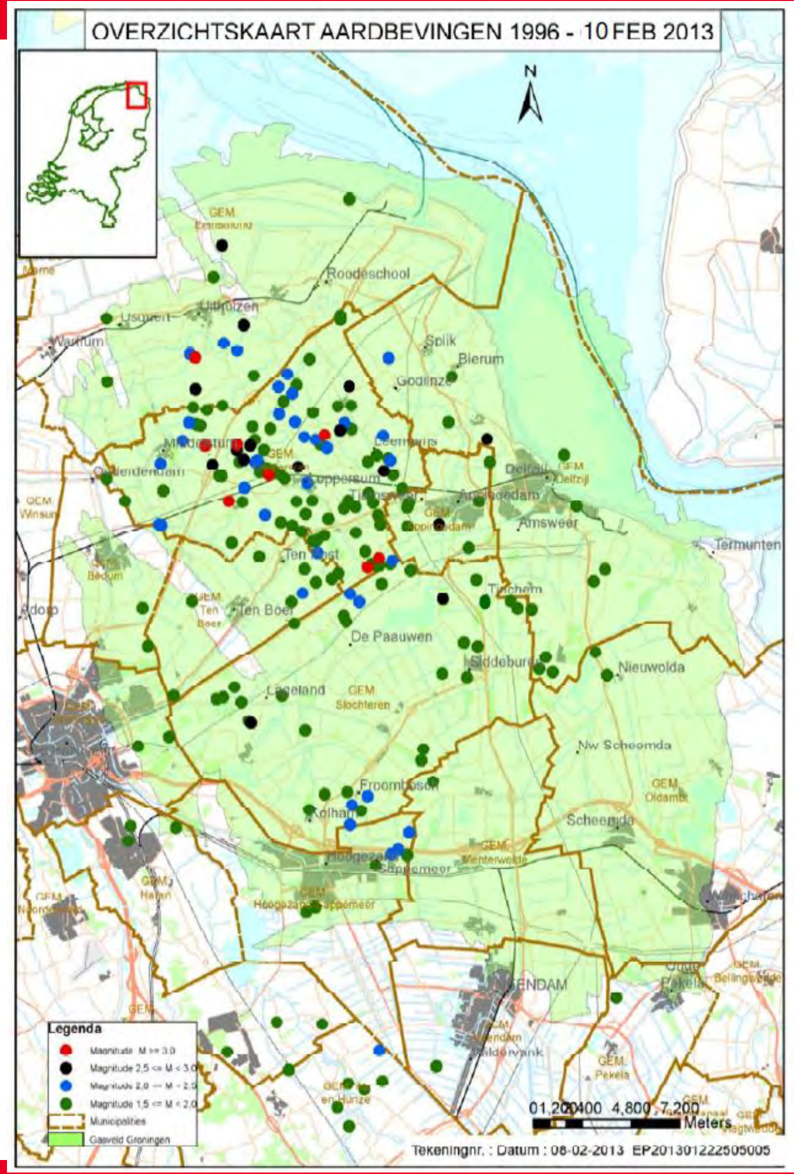
- Seismic Margin Assessment (SMA) NPP Borssele
  - Seismic hazard re-evaluation
  - Plant walkdown

- Difficulties with SMA:
  - Zone with low seismic activity
  - Few seismic data
  - Modelling issues

- Stresstest performed at non-NPP’s
  - Enrichment facility and interim storage facility
  - Including seismic hazards/seimic margins

Discussion on seismic hazard:

Induced earthquakes in northern part The Netherlands (due to gas exploration)



Discussion on seismic hazard

- Induced eathquakes due to gasexploration
- Northern part of The Netherlands; no nuclear installations nearby
- Depth earthquakes about 3 km
- Discussion on seismic hazard
  - Severity (higher magnitudes than 3.9 Richter to be expected)
  - Occurence freqency
  - Large uncertainties
- Several studies ongoing

Developments in Regulatory Framework

- Update of Regulatory framework
  - Initiatives for a new nuclear power plant are cancelled
  - Plans for building new research reactor (about 50 MW)
- Framework is aimed at nuclear power plants as well as research reactors (graded approach)
- Framework is aimed at new build. Discussion on how to apply for existing installations is ongoing.

- With respect to earthquakes
  - Minimum value of 0.1 g as design basis will be adopted
  - Developments at IAEA and WENRA are followed

Slovenian Stress Test, Safety Upgrades Program and National Action Plan

The SNSA, dr. Leopold Vrankar

36th WGIAGE Meeting, 8-12 April 2013, Paris

Stress tests in Slovenia

- In May 2011 SNSA issued a decision for Krško NPP to perform a special safety review – in line with ENSREG "Stress Tests" specifications
- The Krško NPP fulfilled its commitment and sent both the Stress Test progress report as well as the Final report in time
- The plant performed some additional analyses:
  - evaluations of seismic and flooding margins,
  - additional station blackout analyses to support the newest severe accident strategies,
  - drain cycle of the batteries supplying power to the instrumentation of safety systems,
  - water heat-up and evaporation rate in the spent fuel pool,
  - evaluation of spent fuel pool criticality

Stress tests in Slovenia

- These analyses were reviewed and approved by the technical support organizations with additional calculations (with different codes) done where appropriate
- All these analyses and technical support organization reports were also reviewed by the SNSA
- The final report concluded that the plant is well designed and built, and with additional SAM equipment available onsite, well prepared even for most rare and severe events

Stress tests in Slovenia

- This conclusion was again confirmed in the country report prepared by the Stress tests' peer review mission in Slovenia
- Taking into consideration all (already at that time) planned modifications (coming out of the SNSA' 2nd decision) the peer review mission identified no major recommendations
- The only recommendation identified in the report was to use extended seismic design basis for future modifications, which was already provisioned in the plant's Safety upgrades program approved by the SNSA

The Krško NPP's "Safety Upgrades Program"

- In September 2011 the SNSA issued the 2nd decision for Krško NPP to reassess:
  - the severe accident management strategy,
  - existing design measures and procedures and
  - to implement necessary safety improvements for prevention of severe accidents and mitigation of its consequences
- The evaluation was finished in January 2012
- Action plan was reviewed and approved by the SNSA
- It shall be completely implemented by the end of 2016

The Krško NPP's "Safety Upgrades Program"

- Additional systems, structures and components, which will be implemented within the SUP, will be designed and structured in accordance with the design extension conditions (DEC) requirements

- A set of DEC is derived on the basis of engineering judgment, deterministic assessment and probabilistic assessment based on the IAEA methodology defined in SSR-2/1, Safety of Nuclear Power Plants: Design Specific Safety Requirements, Krško NPP's Individual Plan Examination and the Krško NPP Analyses of Potential Safety Improvements

The Krško NPP's "Safety Upgrades Program"

- The DEC are described by:
  - **earthquake**, extended design condition seismic value is 2xSSE (0.6 g PGA),
  - **flooding**, new maximum flood level is 157.53 m (above sea level) (existing flood protection dikes are at 157.10 m),
  - **earthquake + flooding**, flood due to dikes damaged by earthquake with the river flow at current maximum PMF flow,
  - **earthquake + fire**, fire caused by DEC earthquake,
  - **external low and high temperatures**, air temperatures with a return period of 10,000 years,
  - **aircraft crash accident**, crash of large commercial aircraft at the maximum landing velocity,
  - **fire**, fire due to DEC aircraft crash.

The Krško NPP's "Safety Upgrades Program"

- All other combinations of events/accidents are considered as Beyond Design Basis Accidents (BDBA) and will be addressed by mobile equipment (procedures are also in place; SAMGs).
- The assumed time duration of the above-mentioned conditions are:
  - loss of off-site power (LOOP) for 7 days,
  - station black-out (SBO) for 72 hours,
  - loss of ultimate heat sink (UHS) for 30 days,
  - loss of UHS combined with SBO for 72 hours,
  - flooding water (from Sava river) retains for 7 days.

The Krško NPP's "Safety Upgrades Program"

- DEC systems, structures and components will be located in two new bunkered buildings, one already built and the other one to be built until 2015
- The new DEC equipment can be separated into the prevention and mitigation part. The prevention part of the equipment serves to preserve adequate fuel cooling in case of DEC events, taking into account prolonged duration of these events
- For the mitigation part it is assumed that preventive DEC equipment will not be available for 24 hours and that core will be melted and corium relocated into containment. This is the basic assumption for DEC containment filtered vent system and passive autocatalytic recombiners. This assumption also led to the requirement that batteries for DEC equipment and emergency control room shall have a 24 hour capacity

The Krško NPP's "Safety Upgrades Program"

Modification or equipment procurement	Description	Scheduled finish
Filtered venting system	Filtered venting system capable of depressurizing containment and filtering over 99.9% of volatile fission products and particulates (not including noble gasses)	2013
Installation of passive auto-catalytic recombiners in the containment	Replacement of electric DBA recombiners with passive BDBA auto-catalytic recombiners in the containment	2013
Additional high pressure pump for RCS injection	Additional high pressure pump for RCS injection in the separated bunkered (2×SSE and PMF flood protected) building with dedicated source of borated water for 8 hours with provisions to refill by mobile equipment from different water sources	2015
Additional high pressure pump for feeding SGs	Additional high pressure pump for feeding SGs in the separated bunkered (2×SSE and PMF flood protected) building with dedicated source of water for 8 hours with provisions to refill by mobile equipment from different water sources	2015
Additional low pressure pump for spraying and flooding the containment	Additional low pressure pump for spraying (pressure control) and flooding the containment (preventing core concrete interaction in case of failed reactor pressure vessel). This pump will also be located in the separated bunkered (2×SSE and PMF flood protected) building with dedicated source of water for 8 hours with provisions to refill by mobile equipment from different water sources	2015

Preparation of NAcP

- For the preparation of the National Action Plan (NAcP) the SNSA reviewed several reports, reviews and analyses including:
  - ENSREG Compilation of recommendations and suggestions,
  - 2nd Extraordinary Meeting of the Contracting Parties to the Convention of Nuclear Safety, topic and summary report (CNS EOM),
  - IAEA Action Plan on Nuclear Safety
  - US Nuclear Regulatory Commission's (US NRC) "Recommendations for Enhancing Reactor Safety in the 21st Century", The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident,
  - "Forging a New Nuclear Safety Construct", a report from the American Society of Mechanical Engineers (ASME),
  - and other

Preparation of NAcP

- Each recommendation was reviewed how it concerns Slovenia and/or its NPP
- Each recommendation was commented
- For recommendations that were evaluated as relevant for Slovenia or the Krško NPP, possible actions were identified
- Based on the set of actions resulting from the Krško NPP's SUP and proposed actions resulting from the review of additional recommendations, the NAcP was compiled
- The NAcP was published in December 2012 on the SNSA's web page and was sent to the ENSREG for peer review
- NAcP previsions the implementation of all actions until the end of 2018

The Slovenian NAcP

No.	Future action / activity	Area	Status	Finalization	Level
1	SUP SUP comprises of a set of modifications/ improvements (see numbers 1.1 to 1.10) that will be implemented in steps until the end of 2016. Some of the discussed recommendations (see related recommendations) are to be verified within the licensing and implementation of the SUP. (for SUP details see chapter 2 in Part IV)	SUP	in progress	2016	site
1.1	Safety upgrade of AC power supply	SUP	in progress	2015	site
1.2	New pump for supplying SGs; in a bunkered building, with a dedicated water supply	SUP	in progress	2015	site
1.3	Installation of alternative ultimate heat sink	SUP	in progress	2015	site
1.4	Additional pumps (low and high pressure, as well as a special pump for seal injection) in a bunkered building, with a dedicated water supply	SUP	in progress	2015	site
1.5	Containment integrity safety upgrades including containment filtered vent systems and PARs	SUP	in progress	2013	site
1.6	Establishment of emergency control room	SUP	in progress	2016	site
1.7	Installation of fixed spray system around the SFP with provisions for quick connection from different sources of water.	SUP	in progress	2015	site
1.8	Mobile heat exchanger with provisions to quick connect to SFP, containment sump or reactor coolant system	SUP	in progress	2015	site
1.9	Flood protection upgrade (additional protection of nuclear island and bunkered buildings)	SUP	in progress	2015	site
1.10	Establishment of new technical support center and upgrade of existing operational support center (emergency operating facilities)	SUP	in progress	2015	site
2.1	SNSA shall amend its legislation to include: • requirements regarding the use of advanced deteriorating weather warning systems • requirements regarding the use of seismic monitoring systems • PSA Level 3 requirements (at least for new NPPs) • requirements for Beyond Design Basis Accidents I&C for Spent Fuel Pool • emergency planning requirements for prolonged SBO in the areas of communications capability (onsite, e.g., radios for response teams and between facilities, and offsite, e.g., cellular telephones, satellite telephones), ERDS capability, training and exercises, and equipment and facilities	legislation	planned	2014	national
2.2	The SNSA shall consider amending its regulation for the design basis by more stringent safety objectives for: • Prevention and mitigation of core-melt accident in reactor and in spent fuel storage to avoid off-site long term contamination • Large or early release to be practically eliminated (for new NPPs) • Increase robustness of NPPs to be able to face natural hazards more severe than the ones considered in the design basis (DEC); this should also include requirements for test and maintenance of equipment, training,... This will be done mainly by following WENRA/ENSREG new initiatives, updated RL... The SNSA shall also examine whether more detailed requirements are needed regarding LOOP, SBO and loss of UHS	legislation	to consider	2014	national

Conclusion

- The SNSA as well as the Krško NPP responded quickly and proactively to the Fukushima event
- The plant performed immediate steps to increase its robustness and preparedness
- The stress tests were performed with several additional analyses and calculations reviewed and approved also by TSOs
- The final conclusion could be based on the results of stress test and peer review processes:

  → **the Krško NPP is well designed against all credible and even some very unlikely external threats at the site**

Conclusion

- The SNSA ordered the plant to perform additional analysis and to implement measures capable of coping with extreme external hazards and severe accidents
- The Krško NPP prepared the Safety upgrades program, which was reviewed and approved by SNSA
- The SUP represents radical improvement of the Krško NPP and its nuclear safety
- Takes into account all the key Fukushima lessons learned, as well as the results from the cliff-edge effects analysis prepared for the process of stress tests

Conclusion

- In addition the SNSA reviewed recommendations of many international organizations (IAEA, ENSREG, NRC, KJV,...)
- The NAcP was adopted envisioning additional actions and improvements in the NPP, legislation, regulatory body processes, international cooperation and Slovenian nuclear safety infrastructure in general
- Actions of the NAcP will be implemented until end of 2018
- The implementation of the NAcP will further increase nuclear and radiation safety of the Krško NPP and general public

In the Wake of the Stress Tests

Further Seismic Assessments for Plants in Spain

Francisco Beltrán

36th Meeting of the IAGE WG – CSNI, NEA

Paris, April 2013

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1 Background

2 Methodology for further assessments

3 Overview of results

4 Concluding remarks

BACKGROUND

Spanish NPPs & Seismicity:

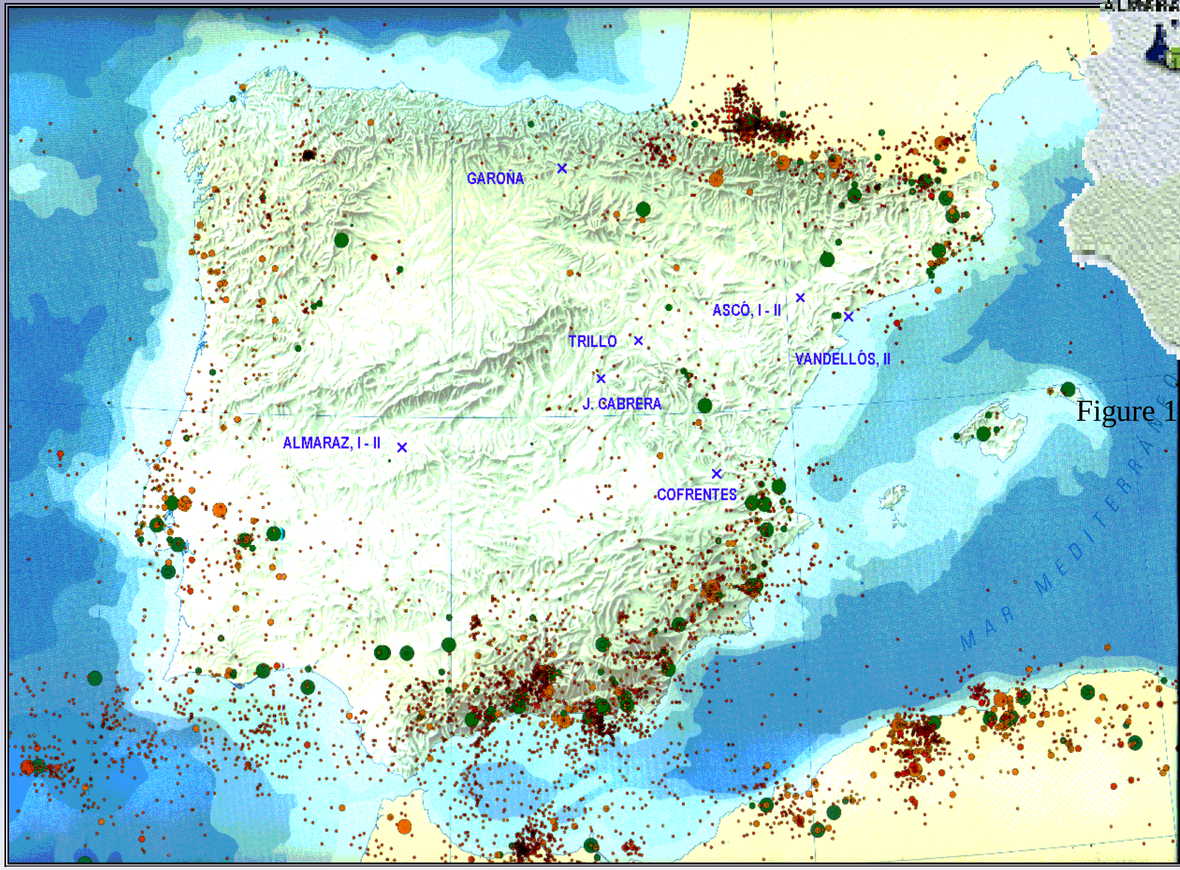

Figure 1.- The seven Spanish npp`s sites.

BACKGROUND

Site	Reactor type	Power (MWe)	Operation since	SSE	Comments
José Cabrera	Westinghouse-PWR	160	1968	0.07 g	Under decomissioning
Sta. Mª Garoña	GE-BWR	466	1971	0.10 g	Indefinite shutdown (since December 2012)
Almaraz I, II	Westinghouse-PWR	974, 983	1981, 1983	0.10 g	
Ascó I, II	Westinghouse-PWR	1028, 1024	1982, 1985	0.13 g	
Cofrentes	GE-BWR	994	1984	0.17 g	
Vandellós II	Westinghouse-PWR	1004	1988	0.20 g	
Trillo	Siemens/KWU-PWR	1066	1988	0.12 g	

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BACKGROUND

The wake of the stress tests:

- ***Utilities submitted final reports in October 2011***
- ***Commitments by utilities:***
  - Short term: by 31/Dec/2012
  - Medium term: 2013-14
  - Long term: by 31/Dec/2016
- ***Commitments made "official" by regulator in letter (January 2012)***
- ***Commitments have to include new procedures or adaptation of current procedures***

BACKGROUND

The wake of the stress tests:

- ***Commitments related to earthquake capacity:***
  - Seismic margin (including spent fuel pool):

    Plant level HCLPF ≥ 0.3 g

    Analysis → short term

    Implementation → medium term

  - Assessment of "indirect" effects:
    - Assume rupture of seismic class II piping

      Internal flood study giving credit only to seismic class I elements

    - Assess capacity of seismic class II piping whose rupture could cause significant flood or fire

METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 1 - Assume rupture of seismic class II piping:

- ***Criteria in US-NRC Branch Technical Position BTP 3-3***

  (“Protection against postulated piping failures in fluid systems outside containment”, March 2007)

- ***Credit only to seismic class I flood barriers***

  Drains, check valves, doors, instrumentation, alarms, etc.

- ***Identify potentially affected equipment (short term)***

- ***Implementation of suggested action (medium term)***

METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

- ***Some of the scope, already covered during IPEEE program***

  Piping able to produce spray, flooding or flammable material spillage near SSEL equipment already identified during SMA plant walkdowns.

- ***Focus is now on piping whose rupture could lead to an initiating event and loss of mitigation systems***

  Piping could be far away from the SSEL equipment.

- ***Effort to make a more systematic and thoroughly documented assessment***

  Not just visual inspection during plant walkdown.

METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

- ***Methodology of US-DoE EH-0545 (Chapter 10)***

  Based on seismic experience + simple analyses.

  Developed in the mid 1990s by Antaki *et al*.

  Tested in US-DoE facilities (Savannah River, Rocky Flats).

  Very cost-effective to identify seismic vulnerabilities.

METHODOLOGY FOR FURTHER ASSESSMENTS

Seismic experience about piping performance (NUREG/CR-6358, 1995)

Large sample (200 facilities), mostly without seismic design.

PGA between 0.10 and 0.85 g

More than one million supports

Only 0.1% of total length suffered from seismic damage

Table A1.2 - Piping Damage in Power Plants and Other Facilities

Category	Total Pipe Damage Cases	Power Plants	Other Facilities
Seismic Anchor Movement	142	15	127
Corrosion	8	7	1
System/Spatial Interaction	72	62	10
Non-welded Joints	153	46	107
Supports	74	40	34
Internal Equipment	34	34	0
Buried	450	5	445
Miscellaneous	87	10	77
Total	1,020	219	801

No damage due to exceedance of stress allowables (i.e. stresses given by flexibility analysis)

METHODOLOGY FOR FURTHER ASSESSMENTS

Seismic experience about piping performance

(Onagawa NPP, IAEA Mission, Aug 2012)

PGA (at basemat) ~ 0.60 g

No damage

(no matter whether it has or not "seismic design")

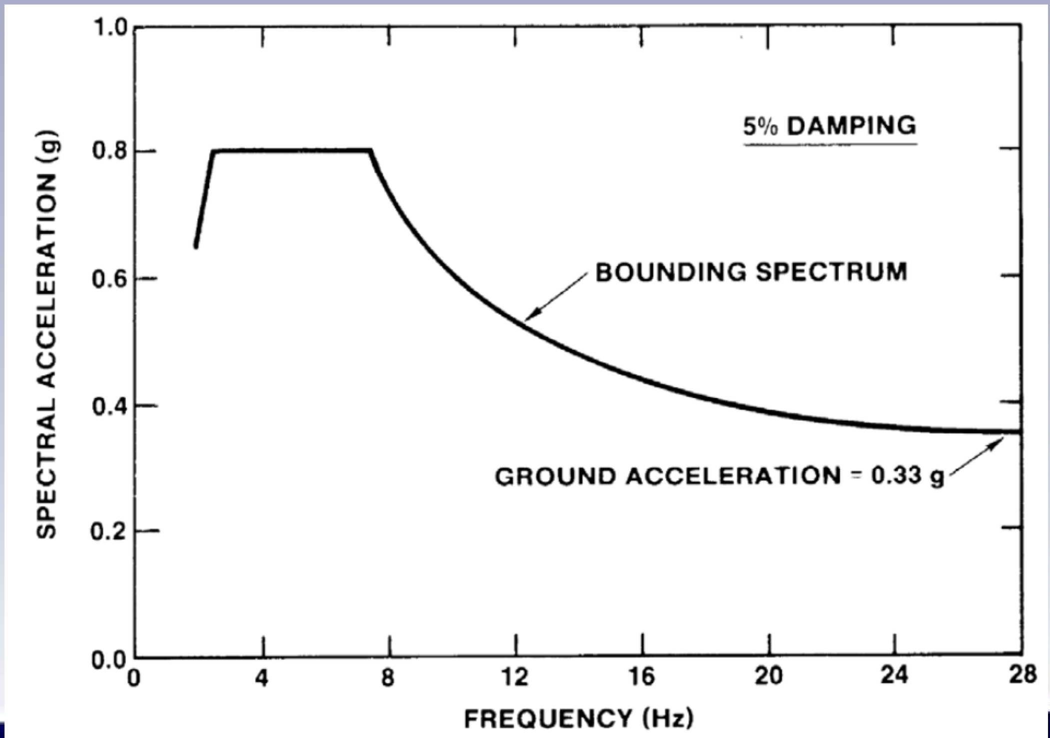
METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

- ***Methodology of US-DoE EH-0545 (Chapter 10)***

  Based on 13 screens, to check good seismic practice

  If the 13 screens are passed, seismic capacity is defined by *bounding spectrum*



METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

List of potential flood sources

↓

Gather information

→

- *Seismic class and rating*
- *Material (stainless steel, carbon steel…)*
- *Dimensions (diameter & thickness)*
- *Pressure & temperature at normal operation*
- *Type of joints (welded, flanged, threaded, etc.)*
- *Isometric diagrams & Support drawings*
- *Operating experience (leakage, rupture, thickness reduction)*

↓

Preliminary Assessment

↓

Walkdown

↓

Capacity checks
***Outlier* resolution**

↓

Documentation

In older plants, it is sometimes easier to get the information straight from the field.

METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

List of potential flood sources

↓

Gather information

↓

Preliminary Assessment →

a. Range of applicability.
b. Screen 1: Construction quality.
c. Screen 2: Internal degradation. Operating experience
d. Screen 4: Distance between vertical supports
e. Screen 5: Distance between lateral supports
f. Screen 7: Absence of mechanical joints
g. Screen 8: Parameters of flanged joints
h. Screen 11: Flexible expansion joints (bellows)
i. Screen 12: Check capacity of supports (10% sample)

↓

Walkdown

↓

Capacity checks
***Outlier* resolution**

↓

Documentation

METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

List of potential flood sources

↓

Gather information

↓

Preliminary Assessment

↓

Walkdown →

- a. *Screen 1: Confirm quality of construction*
- b. *Screen 3: Absence of external corrosion*
- c. *Screen 4: Distance between vertical supports (account for wall penetrations)*
- d. *Screen 5: Distance between lateral supports (account for wall penetrations)*
- e. *Screen 6: Seismic anchor motion → adequate flexibility*
- f. *Screen 9: Nozzle loads (distances to line supports)*
- g. *Screen 10: Unsupported eccentric masses*
- h. *Screen 12: Confirm support configuration*
- i. *Screen 13: Spatial Systems Interaction*

↓

Capacity checks
***Outlier* resolution**

↓

Documentation

METHODOLOGY FOR FURTHER ASSESSMENTS

Assessment 2 – Assess capacity of seismic class II piping:

List of potential flood sources

↓

Gather information

↓

Preliminary Assessment

↓

Walkdown

↓

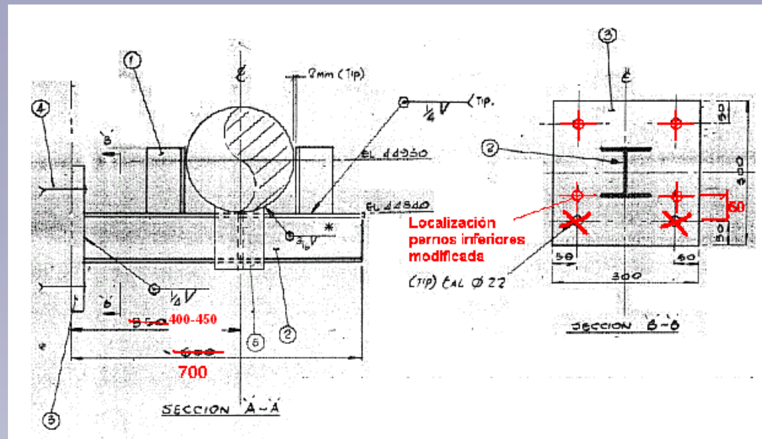
Capacity checks
***Outlier* resolution**

→

- *a. Update input data with field information*
- *b. Update support loads*
- *c. Additional support capacity checks*
- *d. Outlier resolution + Retrofit recommendations*

↓

Documentation



OVERVIEW OF RESULTS

Average scope per plant:

- ***3000 m of piping***
  - Fire protection system
  - Non-essential service water
  - Non-essential chilled water

- ***500 supports***
  - Many different types
  - Extensive use of expansion anchors
  - Simplified capacity checks for about 75 supports
  - Floor RS from IPEEE (0.3 g) were used

OVERVIEW OF RESULTS

Typical findings:

- ***Most of "non-seismic" piping complies with the 13 screens***
  - Steel piping, with welded or flanged joints
  - Good construction standards & well maintained
  - Adequate support distances and configuration
- ***Ductile response will take place***
  - Large seismic capacity, consistent with seismic experience
- ***Few outliers***
  - Most of them related with expansion anchors at supports or weak axis bending
  - Some maintenance issues

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OVERVIEW OF RESULTS

Typical outliers:

Excessive gap at base plate

Weak axis bending

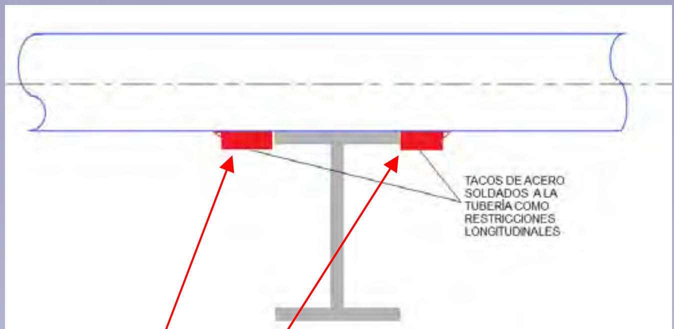
Missing nuts

Leaking flange (potential low bolt pre-stress)

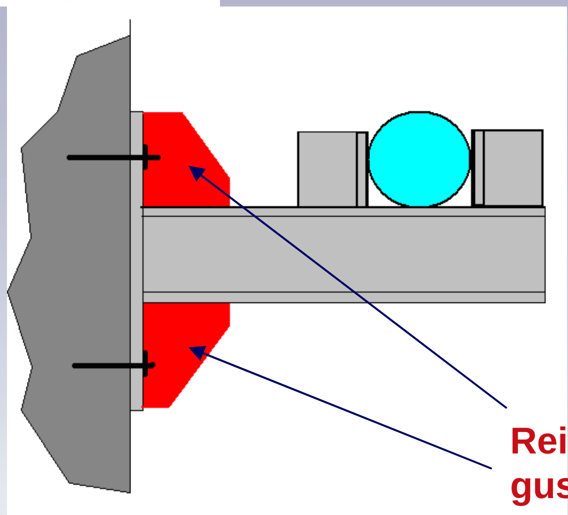
OVERVIEW OF RESULTS

Typical recommendations for retrofit:

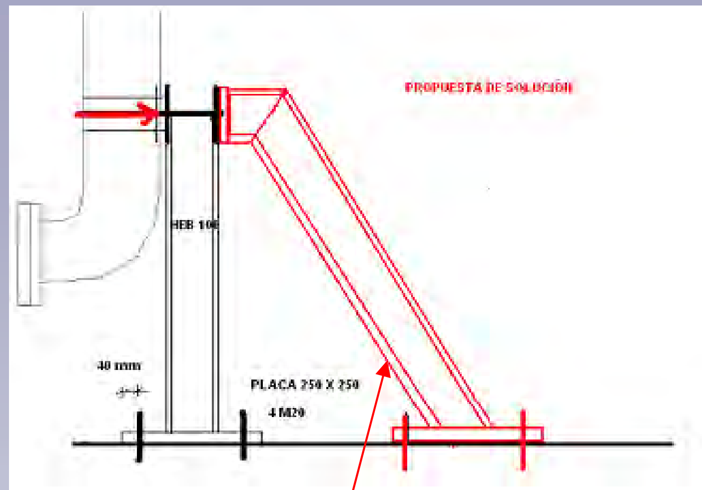
- *Retrofit usually implies only minor modifications at supports*



Restrictors welded to pipe



Reinforcing gussets



Member added to existing support

CONCLUDING REMARKS

After the Stress Tests, Spanish plants committed to a series of additional assessments and upgrades:

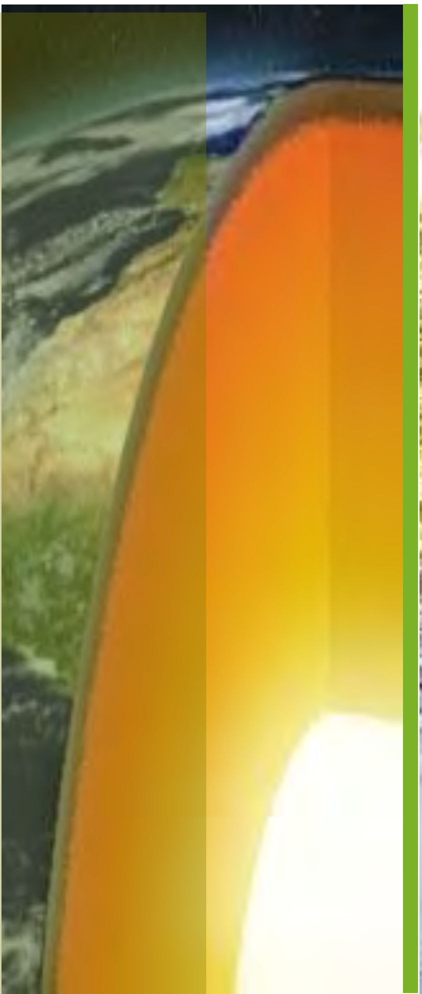
- ***Target plant-level HCLPF capacity is 0.3 g for all plants***
- ***Potential for seismically induced internal floods and fires has been re-assessed in 2012***
- ***Seismic experience based methodology has been used for the capacity assessments***
- ***As a result, minor retrofit modifications are going to be implemented***
- ***Modifications affect a small number of non-seismic class supports***

CSN CONSEJO DE SEGURIDAD NUCLEAR

IAGE/Seismic (Paris) 9 - 10 April, 2013

www.csn.es

SPANISH STRESS TESTS: RESULTS ON EXTERNAL EVENTS



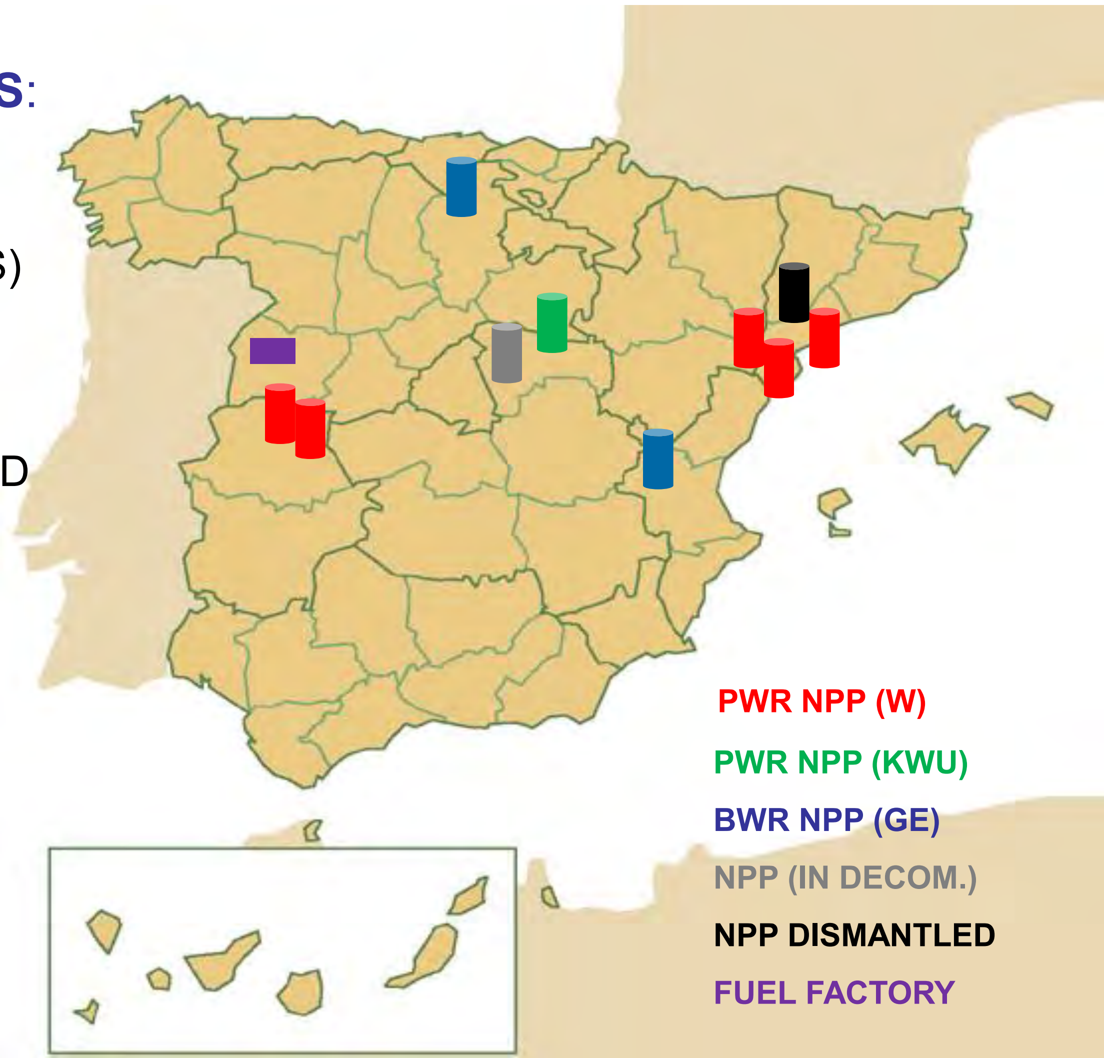
INDEX

1. NUCLEAR FLEET IN SPAIN UNDER "STRESS TESTS"
2. SPANISH RESULTS: MAIN ISSUES
3. ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

01 SPANISH RESULTS ON PLANTS SEISMIC SAFETY

NPPs & FUEL FACTORY FACILITIES:

- 8 REACTORS IN OPERATION (6 SITES)
  - 2 TECHNOLOGIES (PWR & BWR)
  - 3 SUPPLIERS (W, GE, KWU)
- 1 REACTOR BEING DECOMMISSIONED
- 1 REACTOR DISMANTLED
- 1 FUEL FABRICATION PLANT



02 SPANISH RESULTS: MAIN ISSUES

SPANISH NPPs SEISMIC DESIGN BASES

- ✓ The DBE of Spanish NPPs ranges from PGA 0.1 g to 0.2 g (0.25 g in cases of Spent Fuel Storage Facilities, ATIs).
- ✓ The Iberian Peninsula has showed low to moderate seismicity.
- ✓ Licensees have verified the fulfillment of these design bases and their appropriateness (according to the original standards).

02 SPANISH RESULTS: MAIN ISSUES

SEISMIC MARGIN ANALYSIS

✓ Seismic margin beyond DBE was analyzed for all Spanish plants in the nineties, according with USA SM methodologies (EPRI and NRC). It was obtained by comparing the seismic margin of each SSC needed for safe plant shutdown, against a RLE spectra anchored by 0.3 g.

✓ Results and process details were presented in past meetings:

- OECD - NEA Workshops on “Seismic Risk” (Tokyo, August 1999) and “Seismic Re-evaluation of NPPs” (Ispra, March 2001).
- IAEA, International Symposium on Seismic Evaluation of Existing Nuclear Facilities; Vienna, August 2003.

02 SPANISH RESULTS: MAIN ISSUES

SEISMIC MARGIN ANALYSIS

SITE	DBE (SSE)	SAFE SHUTDOWN SAFETY FUNCTIONS	CONTAINMENT ISOLATION AND INTEGRITY	SPENT FUEL POOL INTEGRITY (SFP)
	PGA	HCLPF PGA VALUE OF PLANT SEISMC CAPACITY		
Trillo	0.12 g	0.20 g	0.30 g	0.24 g Temp. Stor. Buildg. 0.30g
Vandellós 2	0.20	0.30 g	0.30 g	0.30 g
Cofrentes	0.17 g	0.28 g	0.50 g	0.30 g
Ascó I-II	0.13 g	0.30 g	0.30 g	0.30 g
Almaraz I-II	0.10 g	0.21 g Unit I 0.24 g Unit II	0.30 g	0.30 g
Garoña	0.10 g	0.17 g	0.30 g	0.30 g

EARTHQUAKES INDIRECT EFFECTS

- ✓ Internal Flooding. Enhancing robustness beyond design basis.
- ✓ Fires and Explosions. Identification of combustible/explosive materials.
- ✓ Sloshing in Spent Fuel Pools & UHS. Loss of water inventory analysis.
- ✓ Earthquake Effects on Nearby Industries. Revisiting previous analysis.
- ✓ Dam rupture analysis.

02 SPANISH RESULTS: MAIN ISSUES

DAMS RUPTURE ANALYSIS

- ✓ Dam structural resistance analysis:
  - All the dams are able to withstand the DBE of affected plants.
  - Different margins has been verified for each case.
- ✓ Dam break analysis have been performed (extreme worst case)
  - Break conditions assumptions (dam type specific)
  - Flooding analysis based on specific models: flooding timing & level

DAMS RUPTURE ANALYSIS (Cont.)

- ✓ Trillo (Dry site).
- ✓ Vandellós II (Dry site).
- ✓ Cofrentes (DBE: 0.17 g)
  - SM: Alarcón dam (0.26 g) and Contreras dam (0.44 g)
  - Grading level/flooding level: 372 m / 363.49 m
- ✓ Ascó I & II (DBE: 0.13 g)
  - SM: Mequinenza dam (0.16 g) and Ribarroja dam (0.14 g)
  - Grading level/flooding level: 50 m / 49.85 m

02 SPANISH RESULTS: MAIN ISSUES

DAMS RUPTURE ANALYSIS (Cont.)

✓ Almaraz I & II (DBE: 0.10 g)

- Seismic margin: Valdecañas dam (> 0.3 g)
- Grading level/flooding level: 257.5 m / 255.4 m

✓ Garoña (DBE: 0.10 g)

- Seismic margin: Arroyo (Ebro) dam (0.378 g)
- Grading level/flooding level: 518 m / 516 m

✓ José Cabrera (Spent Fuel Temporary Storage Facility, DBE: 0.25 g)

- Grading level/flooding level: 628 m / 626 m

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

- Was not identified by the CSN's evaluation any aspect that involves a safety-relevant weakness which could require the urgent adoption of measures.

- Relevant improvements were identified as:
  - ✓ Increase seismic capacity of relevant SSCs.
  - ✓ Increase plant capacities to withstand internal events, which could been produced by earthquakes such as internal floods.
  - ✓ Implementation of appropriate measures to cope with extreme external events as flooding or weather conditions.

- After his evaluation, the CSN has issued to the licensees new orders (ITCs) requesting the implementation of the different improvements that were considered appropriate.

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

- The CSN has requested licensees to conduct additional studies and to proceed with the detailed specification of the design modifications.
- All the identified improvements will be implemented in several stages up to ending 2016 year (long term).
- Improvements implementation schedule based on a triple scheme: short (Dec.12), medium (Dec.14) and long-term (Dec.16).
- Any new information about what happened in Fukushima, or coming from other international experience, may give rise to new safety requirements.

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

SHORT TERM, up to Dec. 2012

✓ Upgrading the Spanish PSHA:

- A new PSHA Level 2 (July 2012) not yet validated, has been used by considering two alternative seismotectonic zonations and adopting maximum magnitudes values from current faults palaeosismic data.
- Preliminary results matching with 10^{-4}/yr, as mean probability of exceedance value, shows a discrete increasing above the DBE values in all plant sites, except in the Cofrentes site.

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

SHORT TERM, up to Dec. 2012 (Cont.)

- ✓ Analysis (based on the most updated regulation in the USA of internal flooding produced by circumferential breaks on pipes no designed as Seismic Category I.
- ✓ Analysis of failures in other components which can produce big releases of fluids, with the objective of verifying the existence of effective detection capacity, or physical barriers, appropriate for these scenarios (derived improvements up to December 2014).
- ✓ Definition of the characteristics of the future Emergency Alternative Center (EAC), and compensatory measures to be adopted up to its final implementation at December 2015.

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

SHORT TERM, up to Dec. 2012 (Cont.)

- ✓ Reassessment of the dam break analysis included in the UE Stress Tests in order to compare with the ones supporting the corresponding dams' emergency plans and to resolve any inconsistency that could appear.
- ✓ Implementation of additional plant-specific actions to increase the plant protection against external floods.
- ✓ Analysis of potential combinations of natural external events being credible at the site.
- ✓ To complete the studies already carried out of site accessibility in case of extreme natural events (earthquakes or flooding).

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

MEDIUM TERM (Dec. 2014)

- ✓ All spanish NPPs under operation with a seismic margin lower than 0.3 g, must be upgraded up to reach a HCLPF mean seismic capacity of 0.3 g, and strengthen their seismic design for:
  - The two *safe shutdown paths* defined on the plant-specific IPEEE.
  - Containment integrity.
  - Mitigation of situations with loss of electric supply (SBO).
  - Severe accident management.
  - SFP integrity and cooling (including liner & racks).
- ✓ Analysis of extreme temperatures at the site with identification of existing margins and possibilities to improve the robustness of the facility against these phenomena.

03 ADOPTED IMPROVEMENTS OR TO BE IMPLEMENTED

LONG TERM (Dec. 2016)

✓ The CSN is developing a programme to perform up to December 2016, a new level 3 of the Spanish PSHA according with the most recent IAEA standards, international experience, and using paleoseismological data to characterize relevant active faults.

VERY LONG TERM (further than Dec. 2016)

✓ Screening seismic criteria of Spanish sites to require every plant the proper seismic risk analysis.

THANK YOU FOR YOUR ATTENTION !

Current Topics of Interest concerning Swiss NPP

1. **Political Situation of Nuclear Energy Program in Switzerland**
2. **Current Legal Issues (unlimited operating permit for the Mühleberg Power Plant)**
3. **Ongoing seismic hazard study (PEGASOS Refinement Project)**
4. **Verifications of the Swiss NPPs after the Fukushima Accident**
5. **New guidelines and regulations**
6. **Ongoing projects**

Tadeusz Szczesiak, Ph.D. Structural Engineer MSc ETHZ,

Civil Engineering Section, Swiss Federal Nuclear Safety Inspectorate

1. Political Situation of Nuclear Energy Program in Switzerland

- Swiss Federal Council decided after the Fukushima Accident in 2011 to phase out gradually nuclear energy program. Swiss parliament (National Council and Council of States) approved this decision. Permits for new plants are no more possible. Research in the Nuclear Energy field is still possible.

- The 5 NPPs in Switzerland have unlimited operating permit (as long as the safety requirements are fulfilled).

1. Political Situation of Nuclear Energy in Switzerland (cont.)

- The Federal Council started the transition project Energy Strategy 2050.

- Some experts doubt that is possible to replace nuclear energy (currently 40% by NPPs) with expansion of hydropower a. s. o. without big drawbacks for private people and industry. The situation in Germany shows that there are unsolved issues.

- There will be 2 public votings next year:
  - Canton of Berne concerning the NPP Mühleberg
  - Swiss voting for 45 year lifetime limitation of existing NPP and abandoning of nuclear energy

2. Current Legal Issues: unlimited operating Permit for the Mühleberg Power Plant

- The Mühleberg NPP got the unlimited operating permit from environment ministry (DETEC – Federal Department of Environment, Transport, Energy and Communications) in 2009. Several persons living near the plant made a complaint against the unlimited permit.

- Switzerland's Federal Administrative Court (FAC) decided on 1. March that the Mühleberg plant can only operate until 28. June 2013, and overruled the decision of DETEC.

- According to FAC the unlimited operating permit given by DETEC should not be based only on the safety review reports by Swiss Federal Nuclear Safety Inspectorate ENSI. DETEC should have done own safety reviews. FAC questioned the regulatory function of ENSI.

- The operator of the Mühleberg Plant (BKW FMB Energy Company) and DETEC appealed against the FACs ruling.

2. Current Legal Issues: unlimited operating Permit for the Mühleberg Power Plant (cont.)

- Just before Easter the Swiss Federal Court has judged the case and has overruled the decision of FAC. The conclusions are:
  - ENSI is the responsible authority to ensure nuclear safety in Switzerland.
  - The operating permit for Mühleberg NPP is unlimited now, as for the other Swiss NPPs.

- Unlike the FAC the Swiss federal Court didn't deal with any safety aspect [Core Shroud, Earthquake, Cooling Systems].

- Opponents of Mühleberg are not satisfied and they still demand a another "independent" authority to ensure nuclear safety.

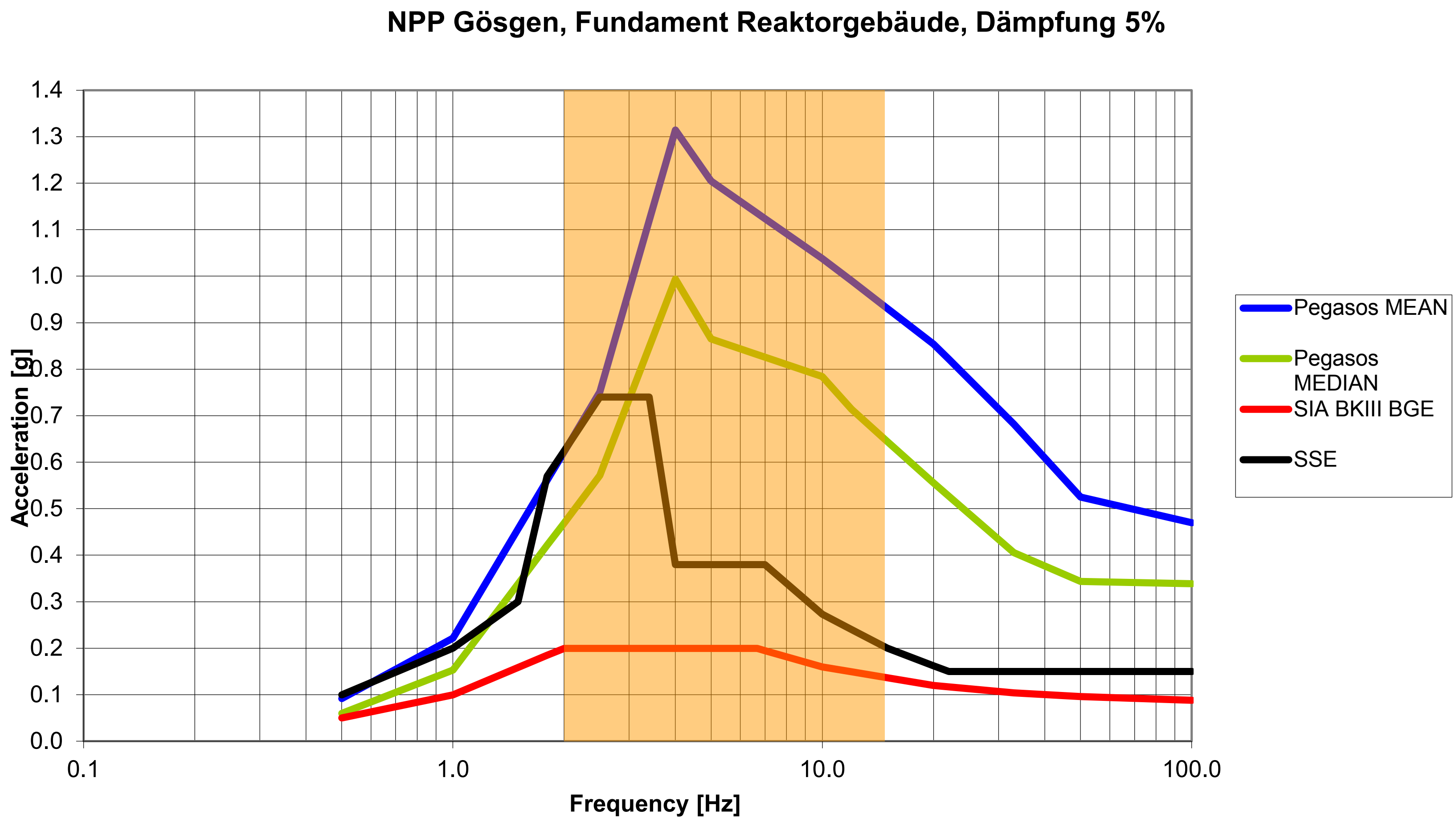
- DETEC, ENSI and the operator of the Mühleberg NPP (BKW) are glad that the legal issues are finally clarified.

3. PEGASOS Refinement Project

- 1999 ENSI (formerly HSK) required from the operators new Probabilistic Seismic Hazard Analysis. According to the requirements of ENSI the SSHAC 4 Level procedure should be used.
- Operators launches the PEGASOS project with the following four subprojects:
  SP1: Seismic Source Characterization
  SP2: Ground Motion Characterization
  SP3: Site Response Characterization
  SP4: Seismic Hazard Computation
- PEGASOS project was finished with the Final Report in 2004
- With the objective to reduce epistemic uncertainties in 2007 PEGASOS Refinement Project (PRP) was started. PRP included a new Subproject: *SP5 Earthquake Scenarios*
- In May 2011 Swissnuclear published PRP Intermediate Hazards for all plants. The PRP IH were used to run Swiss Fukushima Stress Test.
- Final report of PRP was delayed many times. Currently it’s expected in the middle of 2013.

4. PEGASOS Refinement Project (cont.)

- Basemat of reactor building (-9 m) / 10^{-4}



4. Verifications of Swiss NPPs after the Fukushima Accident

- EU stress test

  Switzerland participated voluntarily in the EU stress test.

- Swiss stress test (not only for the NPPs but also for the ENSI)

  After the Fukushima accident ENSI demanded by operators a safety proof for 10^{-4} earthquake and earthquake-induced failure of the dams in the area of influence of the power plant (orders of 18. March 2011, 1. April, 2011 and 5. May 2011

  The safety proofs were submitted by the operators by the deadline of 31. March 2012. On 9. July 2012 ENSI accepted all four safety proofs.

  Swiss NPPs fulfill the safety requirements in case of a 10^{-4} earthquake and earthquake-induced failure of the dams in the area of influence of the power plant.

5. New Guidelines and Regulations

- New Guideline G02 “Design bases for existing Swiss NPPs”.

  We started to work on G02 Guideline for new NPPs before the Fukushima Accident. The work was interrupted due to political situation. We decided now to continue, but the focus of the guideline had to be changed (from new to existing NPPs).

- Definition of methodology of the deterministic seismic verification of the Swiss NPPs.

  We have learnt from Swiss Stress Test last year that we need to define clear requirements for all steps of the seismic verification in order to make our review procedure efficient.

  Since the new definition of the seismic Hazard (PRP) is coming soon, we can expect next year another Stress Test. We want to be prepared well.

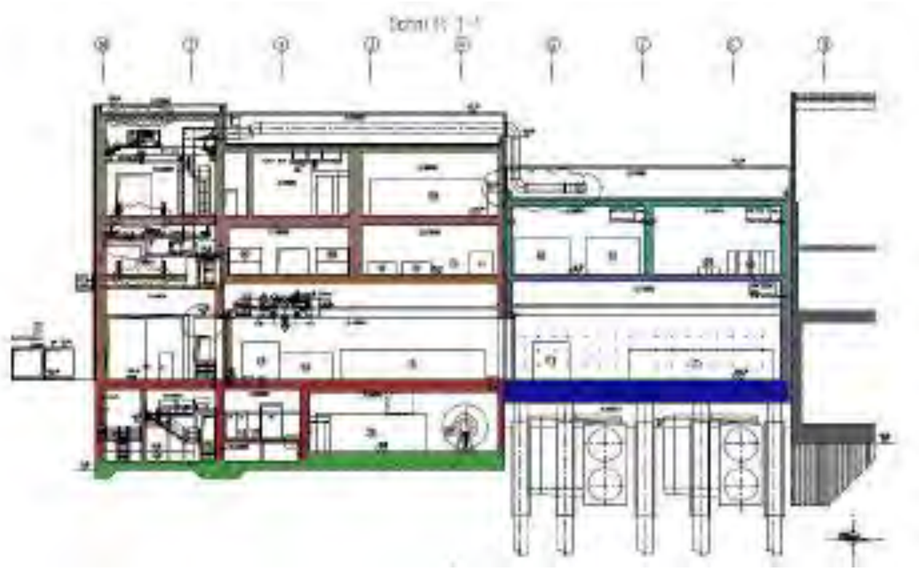
6. Ongoing Projects (cont.)

- Civil Engineering Section of ENSI participates in the Benchmark-projects a new edition of SMART (2013) and is Partner in the IMPACT III Project (Impact tests performed in Finland by VTT).

- Three new buildings are currently under construction in Swiss NPPs. Two emergency diesel buildings in Beznau and a building to store big nuclear components in Leibstadt.

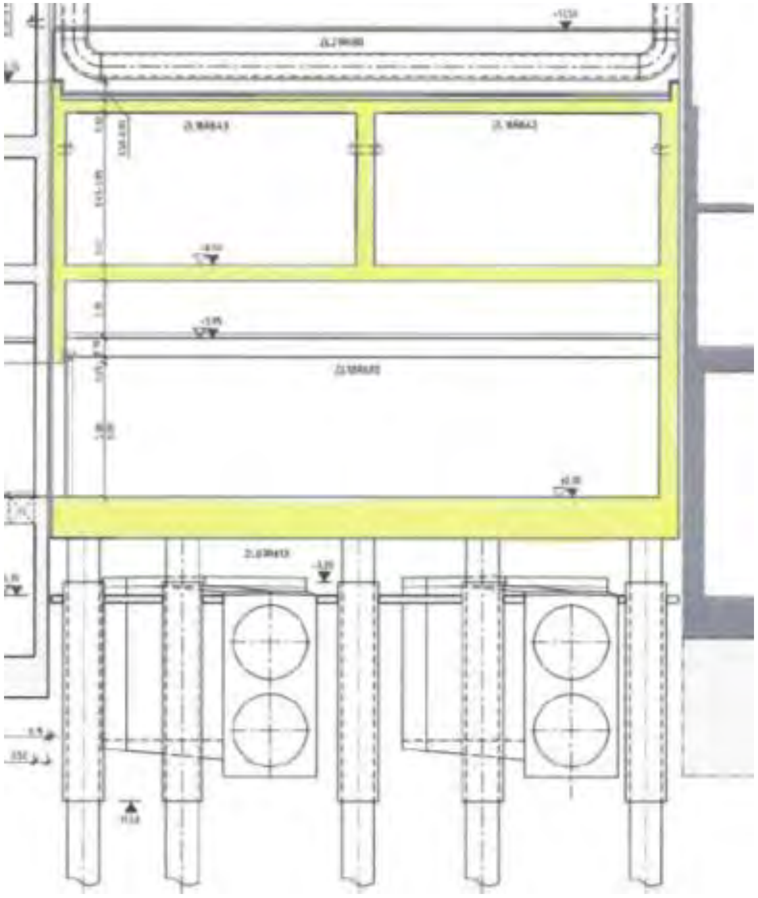
6. Ongoing Projects – ZENT

- ZENT building in Leibstadt is a new facility to store the big nuclear components. The south part of the building has an unusual pile foundation
- 30 Piles D1.25m are free standing in the upper part of about 10m. In the case of SSE the horizontal forces do to not affect the main water supply below the south part of the building.



6. Ongoing Projects – ZENT (cont.)

- Displacement based design, Capacity design of the piles
- Two Papers are submitted for SMiRT 2013 (ENSI) and for SEdIF2013 (operator)



THANK YOU FOR YOUR ATTENTION

Tadeusz Szczesiak, Ph.D. Structural Engineer MSc ETHZ,

Civil Engineering Section, Swiss Federal Nuclear Safety Inspectorate

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Annual Report of Seismic Activities at the USNRC

Andrew J. Murphy
Office of Nuclear Regulatory Research
US Nuclear Regulatory Commission

18th Annual Meeting
Seismic Subgroup of Working Group IAGE
OECD Headquarters
Paris, France
April 9 & 10, 2013

Status of US Nuclear Power Plant Licensing

- Early Site Permits
  - Four Permits Issued
  - One expected to be issued in 2014 & One withdrawn
- Combined Construction/Operating Licenses (COLs)
  - Initially 18 Applications for 28 Plants
  - Two COLs issued for Four Units - 2 @ Plant Vogtle and 2 @ VC Summer

    Summer and Plant Vogtle have completed 1St Nuclear Concrete Pour – March 2013 – about 1 week apart
  - Six Applications (8 Plants) Have Been Suspended at Applicant's Request

Status of US Nuclear Power Plant Licensing(cont'd)

- Design Certifications – four expected to be in review in 2013
- mPower's Team for a Small Modular Reactors will receive matching funds from DOE
- A competition for matching funding for 2nd SMR has been announced by DOE
- NRC staff is developing a new waste confidence policy

Seismic Activities from NRC Fukushima Near-Term Task Force Report

- NRC Issued Three Orders with Commission Approval
  - All Reactor Licensees are to increase mitigation capabilities for beyond-design-basis external hazards
  - All Reactor Licensees are to enhance instrumentation for monitoring spent fuel pools
  - All Reactor Licensees with Mark I or II containments are to have "a reliable hardened vent to remove decay heat and maintain control of containment pressure within acceptable limits"

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Seismic- Activities from NRC Fukushima Near-Term Task Force Report (cont'd)

- NRC Issued the following requests for information (RIs):
  - Information related to operators' ability to respond to external hazards – effectively seismic and flooding walkdowns per EPRI guidance document approved by NRC staff
    - Seismic – due November 2012 – currently under review by NRC
      - Anchorage
      - Seismic Interactions
      - Condition of Equipment
    - Flooding – due November 2012 – currently under review by NRC
    - June 2013 - Technical Evaluation Reports finalized
    - October 2013 – Seismic Lessons Learned Report finalized

US NRC Research Ongoing Activities

PSHA Research Effort

- General Guidance - completed
  - Updated SSHAC & R.G. 1.208
- Sources - completed
  - Collaborative Project with DOE, Industry, & NRC with USGS
  - Published in January 2012 - http://www.ceus-ssc.com
- Ground Motion - ongoing
- Analysis Code - ongoing

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US NRC Research Ongoing Activities

PSHA Research (Ground Motion)

- Next Generation Attenuation Relationship Development for the CEUS
  - Development of a Time-History Database
  - Examine Controlling Parameters
    - Uncertainty – epistemic & aleatory
    - Stress Drop
    - Spectral Shape
  - Strong Motion Simulation for Finite Sources
  - Next Generation Attenuation-East Program Plan with Multiple Participating Organizations: DOE, EPRI, USGS & others
  - NGA-East Program is on-going
  - Results Expected in 2014/15

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US NRC Research Ongoing Activities

PSHA Research (Analysis Code)

- Develop an independent PSHA computational code
  - Beta Version expected in 2013
    - Will test with new CEUS tectonic model and existing EPRI ground motion model (2004)
    - Will apply when NGA-East ground motion models available
    - Will be used for new reactor licensing and for Recommendation 2.1 of the Fukushima NTTF

US NRC Research Activities & Plans

- Improvements to Seismic Design & Risk Evaluation
  - Instrumentation for Independent Monitoring of Seismic Activity in the CEUS
    - Revision of R.G. 1.12
  - Multi-Dimensional Loading in Site Response Analyses
    - Initiated 2013 with development of elemental constitutive models
    - Testing in 2013 -14
    - Results in 2015
  - SSI – Earth Pressures on Deeply Embedded Foundations
    - Ongoing – Confirmation and Development of Analytical Tools
    - Results expected by 2014

Seismic Engineering Topics

- Soil Structure Interaction – Technical Basis for Regulatory Guidance
  - Small Modular Reactors on Individual Foundations
  - Multidimensional Soil Model Development
- Methods, Computational Platform & Case Studies for Non-Traditional SSI Modeling
- Engineering Evaluation of Post-Liquefaction Residual Strength
- Paleoliquifaction Features – Standards for Evaluation

Seismic Engineering Topics (cont'd)

- Seismic Base Isolation Techniques
  - State of Knowledge Report being prepared by NRC Staff based on data/analysis by Lawrence Berkeley National Laboratory & State University of New York at Buffalo – expected mid-2013
  - Testing of Specific Model thru University of Nevada expected mid-2013
- Seismic Analysis for Advanced Reactor Designs
- Development of Seismic Fragilities for PRA – Level 3
  - Expected in 2014 - 2015
  - Overall ~2016

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Seismic Engineering Topics (cont'd)

- Testing of Specific Hybrid Lead Rubber Isolation System thru University of Nevada

Tsunami Research Goals

- Better Understanding of Tsunamigenic Hazards with Current Emphasis on East and Gulf Coasts
- Development of Source Base & Analysis Techniques for In-House Capabilities with Emphasis on Probabilistic Approaches
- Integration of Landslide Modeling with Hazard Model
- Provide the Basis for Development of Probabilistic Tsunami Hazard Assessments (where appropriate)
- Incorporation into Regulatory Guidance
  - Support Staff in Licensing Reviews of New US NPPs
  - Develop Probabilistic Techniques
  - NRC Staff Training planned to Transfer Database and Computational Tools

CAPS

Workshop on Benefit of Bayesian updating techniques for seismic hazard assessment

OECD/NEA/CSNI/IAGE
annual meeting
Paris, 10 April 2013

CHANGER L'ÉNERGIE ENSEMBLE

CAPS :
Workshop on "Benefit of Bayesian updating techniques for seismic hazard assessment"

- In continuation of the series of WS aiming at promoting exchanges between seismologists and engineers

- Recommeded as a conclusion of the 2008 WS on Recent developments in SHA and applications:

"... using Bayesian updating methods can be of important value and further work (both research work and applications) in this area is to be encouraged."

- Recent papers on the subject:

  Stirling & Petersen 2006
  Albarello & D'Amico 2007
  Wang & Takada 2007
  Le Goff & al. 2009
  Musson & Winter, 2011 & 2012
  Baker & al. 2013

CAPS : Workshop on “Benefit of Bayesian updating techniques for seismic hazard assessment”

- Implementation: Autumn 2014
- Lead organization: EDF
- Coordination with the IAEA/ISSC WA1 activities

CASH

Benchmark on the seismic CApacity of reinforced concrete SHear walls

10 April 2013

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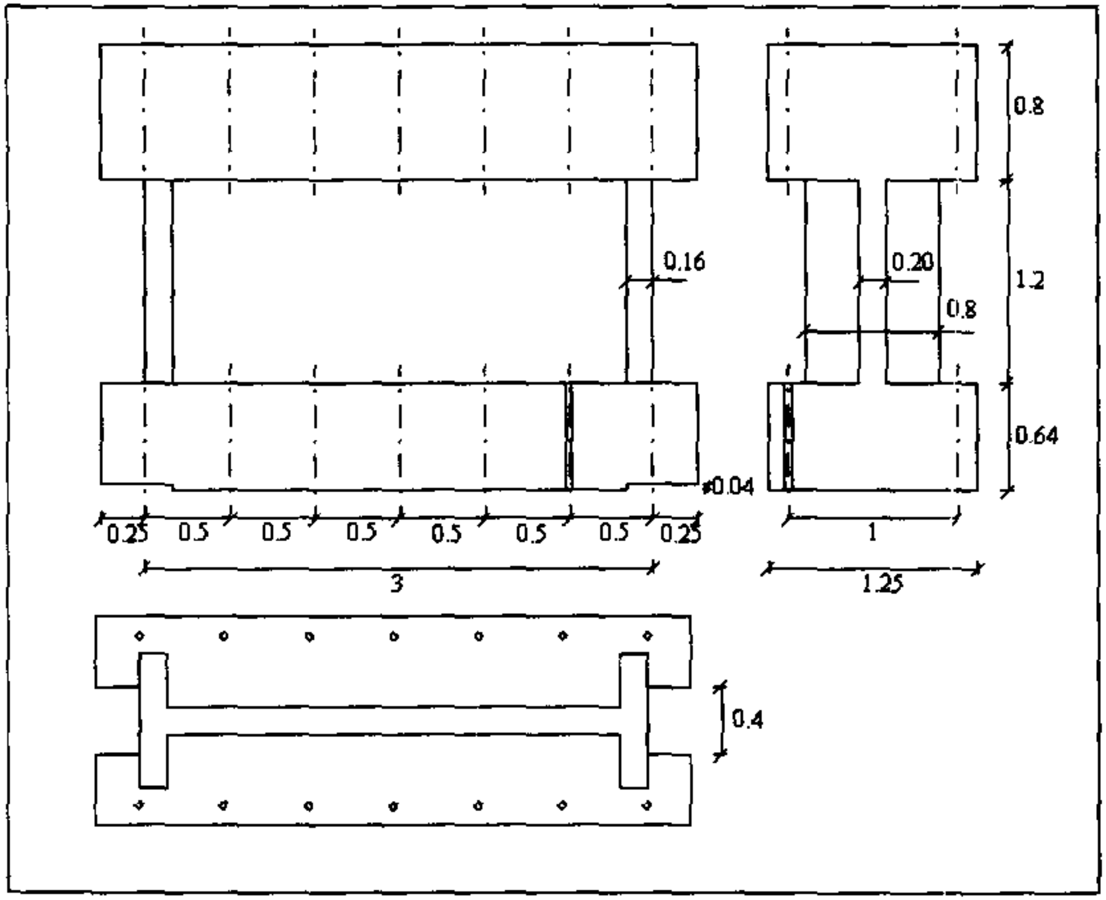
Objective

- Quantify the existing margins in seismic analysis of shear walls (for beyond design assessment)
- Validation (qualification) of analysis methods suitable for the use of regular design offices for the margin analysis of the existing NPP
  - Post elastic behavior
  - SMA HCLPF – deterministic type
  - Seismic PSA – fragility curve, probabilistic

Experimental data – SAFE – JRC 2000
3m x 1.2 m x 0.2   13 specimens



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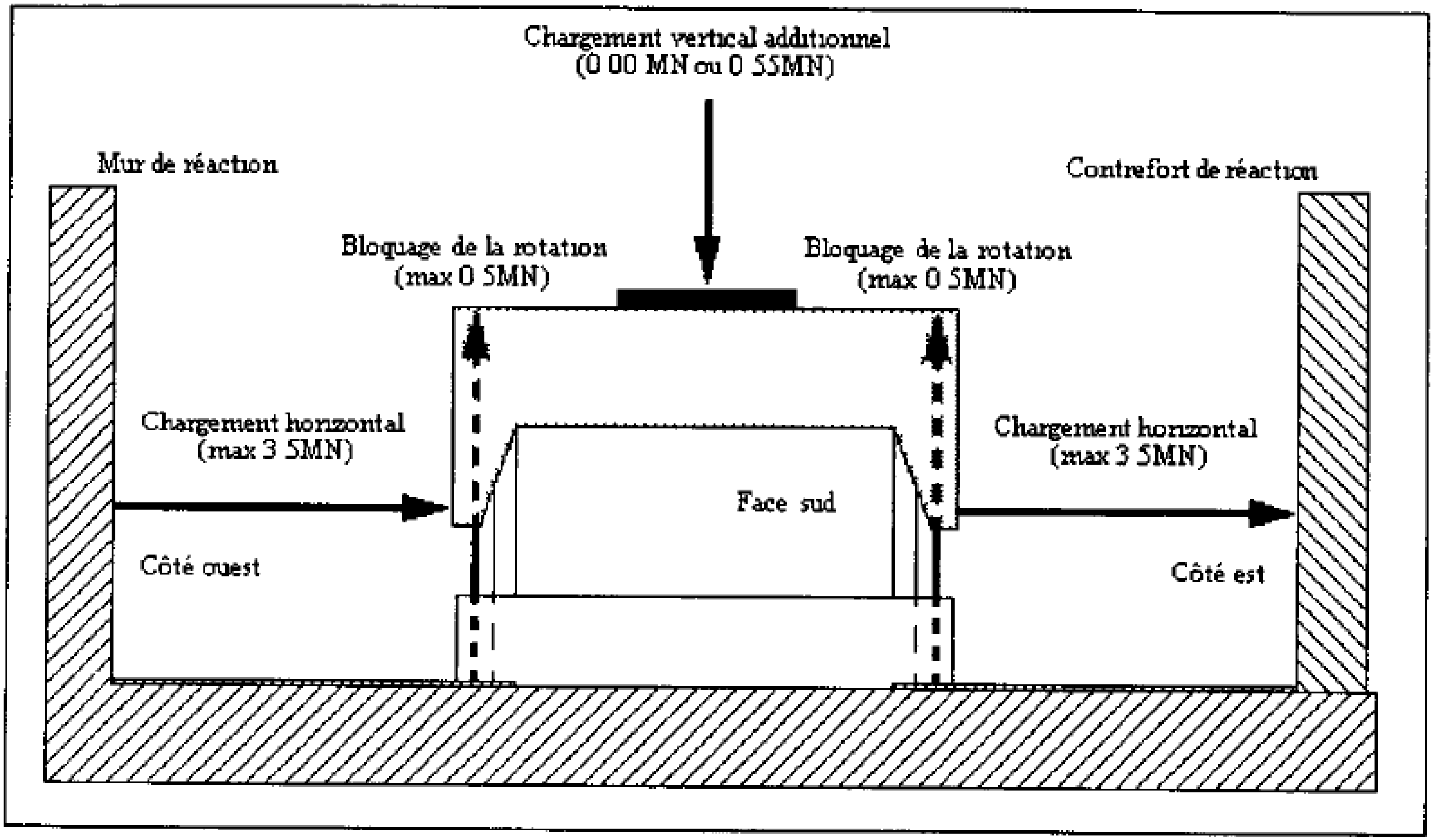
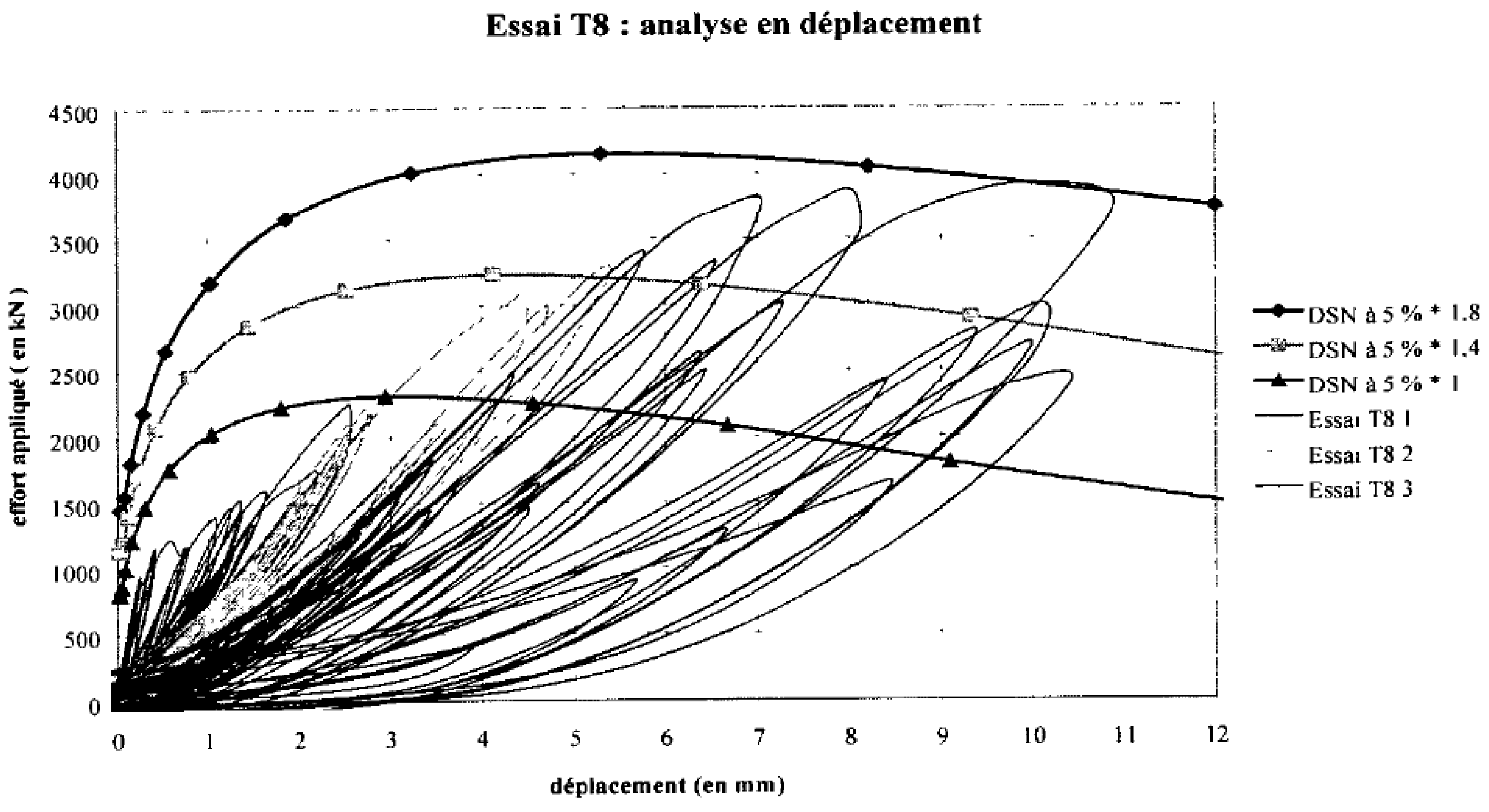


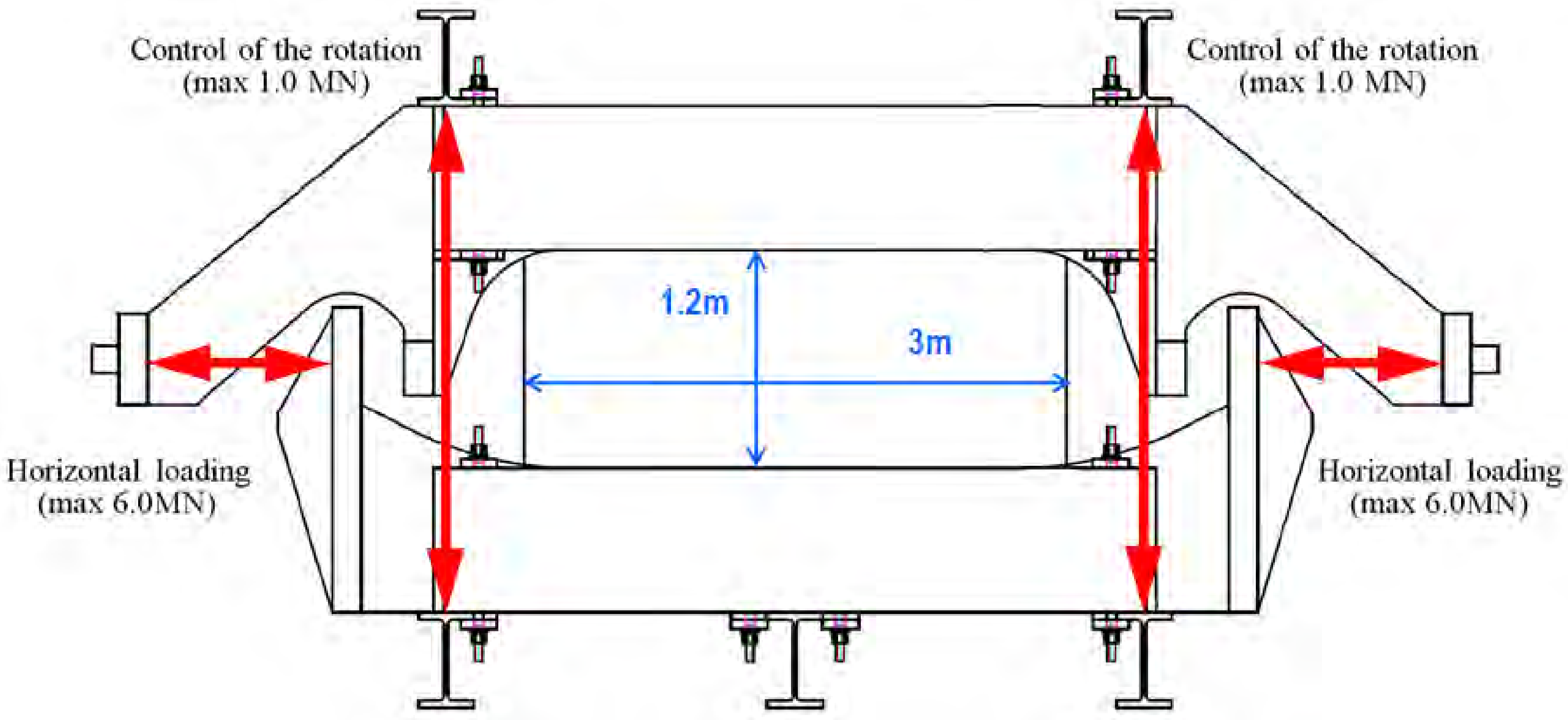
Chargement vertical additionnel
(0 00 MN ou 0 55MN)
Mur de réaction
Contrefort de réaction
Bloquage de la rotation
(max 0 5MN)
Bloquage de la rotation
(max 0 5MN)
Chargement horizontal
(max 3 5MN)
Chargement horizontal
(max 3 5MN)
Face sud
Côté ouest
Côté est

Result type : shear - displacement

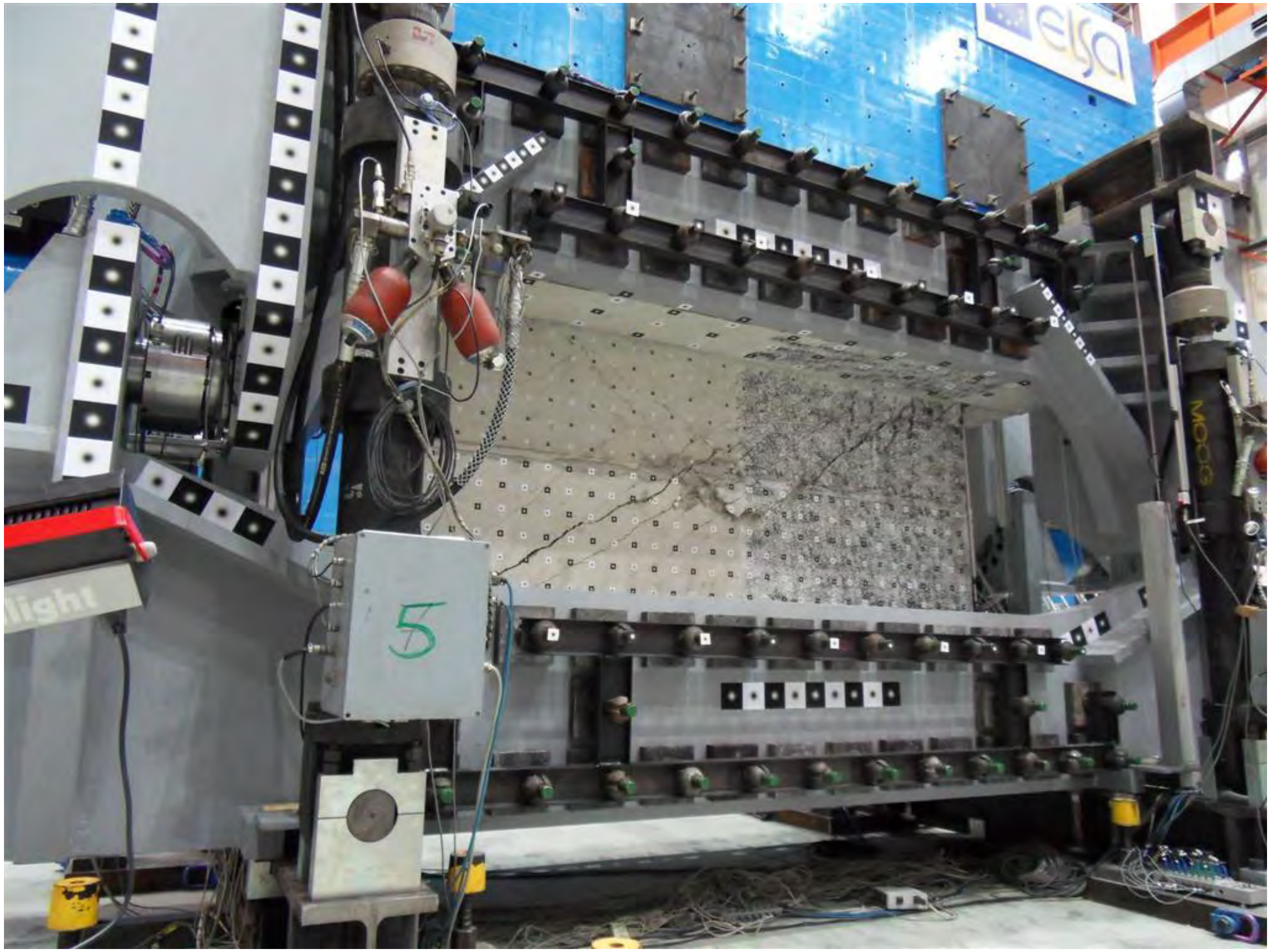


IRIS tests – 2012 – 3m x 1.2 m x 0.4 m

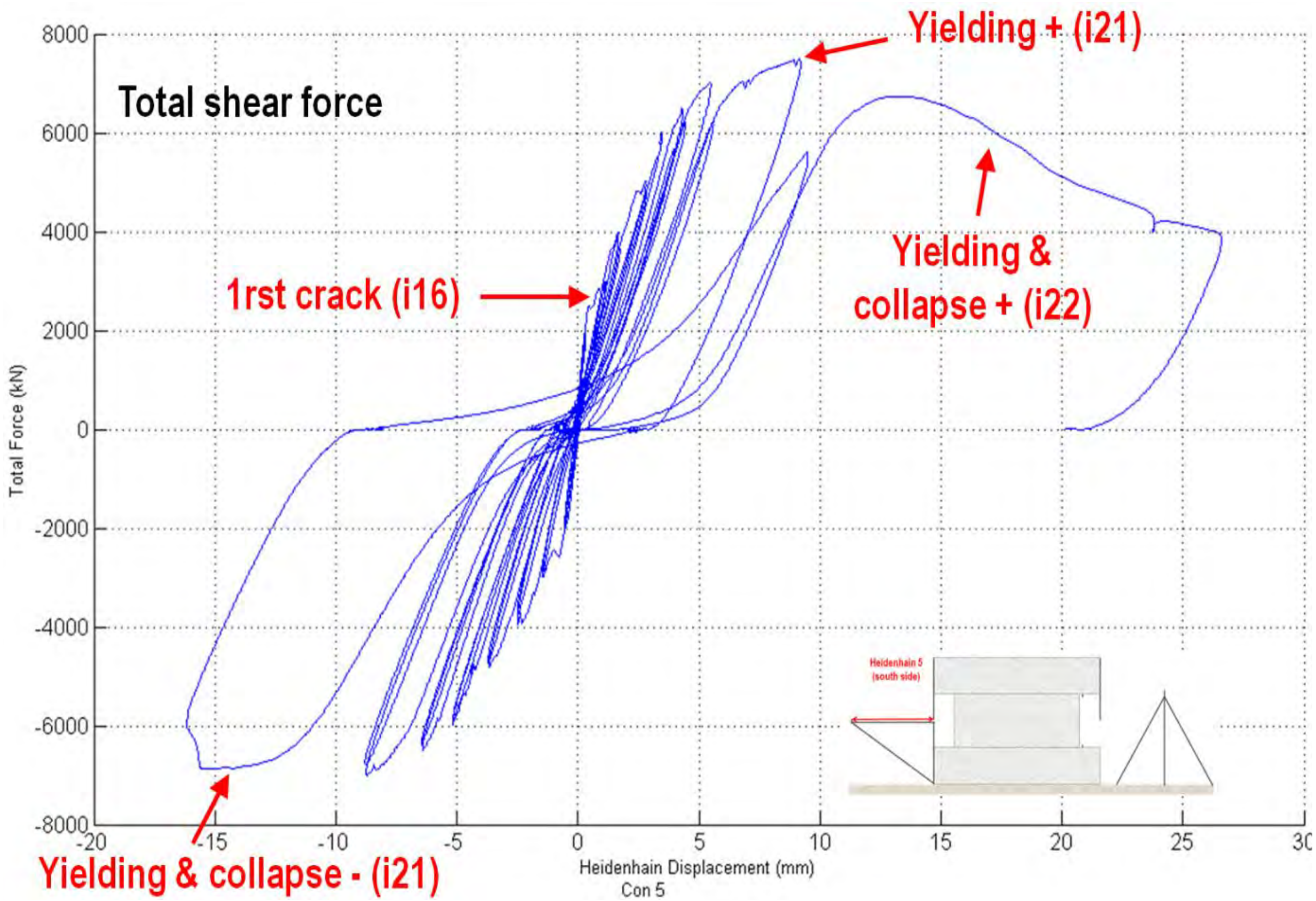
Principle of the loading devive



Wall after the WP1 demonstration test



Shear force vs shear displacement for the whole test campaign



Other interesting data ?

- NUPEC ?

Planning : October 2013 – February 2015

- Review of the shear walls types and performances for interest
  - January – June 2014
- Selection of experimental data and collaboration frame to access to them (NUPEC, SAFE, IRIS)
  - October 2013 – June 2014
- Benchmark specifications
  - Shear capacity evaluation (deterministic, HCLPF)
  - Fragility curves
  - Supporting capacity
  - June 2014
- Benchmark work : June 2014 – February 2015
- Final benchmark workshop - February 2015