Probabilistic Safety Assessment for internal and external events

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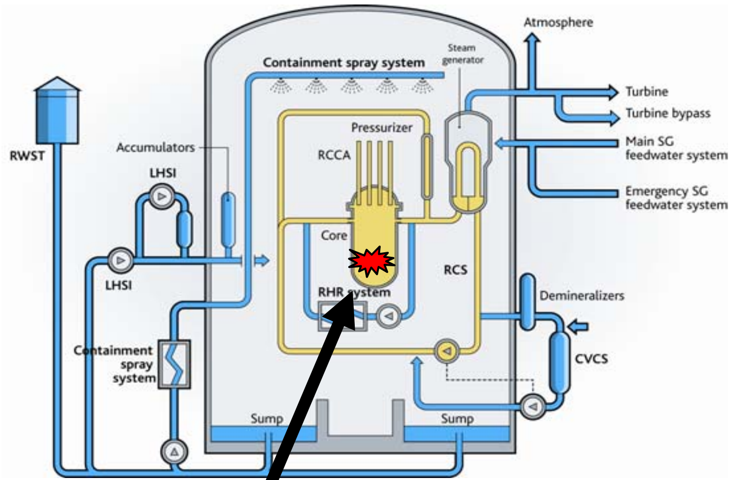
Probabilistic Safety Assessment (PSA) in Nuclear Safety

The design of NPPs is mostly based on **deterministic** safety rules and concepts (e.g. safety margins, design basis accidents), in relation with the defense-in-depth concept.

Nevertheless, vulnerabilities and residual risk exist, which can be determined and quantified by **Probabilistic** Safety Assessment (PSA).

Therefore PSA is an increasingly important supplement to the traditional deterministic approach.

THE 3 LEVELS OF PROBABILISTIC SAFETY ASSESSMENT (PSA)



PSA-2

Frequency, containment failure mode, release kinetics and amplitude

PSA-3

Frequency

Health, economical, environmental consequences

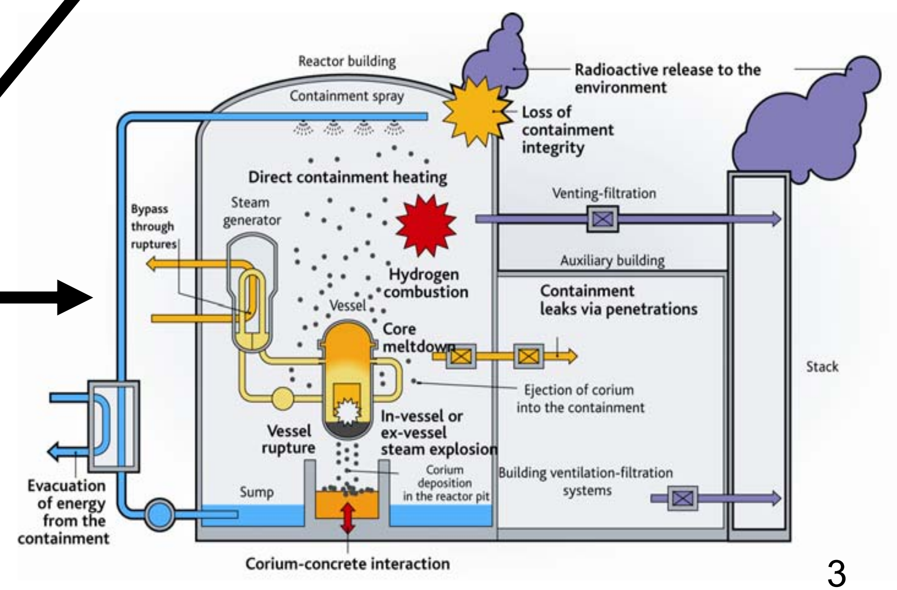
PSA-1

Frequency of core damage sequences

Core degradation

Containment failure

Severe accident



From WENRA Reference levels

- *“PSA shall be used to assess the overall risk from the plant, to demonstrate that a balanced design has been achieved, and to provide confidence that there are no "cliff-edge effects”*

- In other words, PSAs should provide a high level of confidence on the NPPs safety. But what is the reality in Europe ?

EC supports research on PSAs ...

- EC - FP6 2005-2007 – **SARNET** – L2 PSA Workpackage
  - Exchanges on L2 PSA methodology
  - Benchmark on dynamic PSA approach (Hydrogen combustion)
  - But need for guidance that can be used by industry

- EC - FP7 2008-2011 **ASAMPSA2**
  (22 partners in Europe - Regulator, TSO, R&D, Industry)
  - Guidance on application and development of L2 PSA
  - Extension to Gen IV reactors
  - But there is a need (final workshop, Helsinki, March 9th 2011)
    - for extension to the risks associated to external events
    - for a limited set of requirements to develop high quality L2 PSA.

- EC - FP7 20013-2016 ASAMPSA_E (28 partners in Europe)
  - Will be detailed in the following slides

ASAMPSA 2 guidelines

An extensive compilation of current practices …

ASAMPSA2 | Advanced Safety Assessment Methodologies: Level 2 PSA | EURATOM

"NUCLEAR FISSION"
Safety of Existing Nuclear Installations

Contract 211594

ASAMPSA2
BEST-PRACTICES GUIDELINES
FOR L2PSA DEVELOPMENT AND APPLICATIONS

Volume 1 - General

Reference ASAMPSA2
Technical report ASAMPSA2/ WP2-3-4/D3.3/2013-35

Rapport IRSN-PSN/RES/SAG 2013-0177

This document has been established through collaboration between

IRSN, GRS, NUBIKI, TRACTEBEL, IBERINCO, UJV, VTT, ERSE, AREVA NP GmbH, AMEC NNC, CEA, FKA, CCA, ENEA, NRG, VGB, PSI, FORTUM, STUK, AREVA NP SAS, SCANDPOWER

Period covered: from 01/01/2008 to 31/12/2011	Actual submission date:	
Start date of ASAMPSA2: 01/01/2008	Duration: 48 months	
WP No: 2&3&4	Lead topical coordinator : E. Raimond	His organisation name : IRSN

Project co-funded by the European Commission Within the Seventh Framework Programme (2008-2011)		
Dissemination Level		
PU	Public	Yes
RE	Restricted to a group specified by the partners of the ASAMPSA2 project	No
CO	Confidential, only for partners of the ASAMPSA2 project	No

ASAMPSA2 | Advanced Safety Assessment Methodologies: Level 2 PSA | EURATOM

"NUCLEAR FISSION"
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ASAMPSA2
BEST-PRACTICES GUIDELINES
FOR LEVEL 2 PSA DEVELOPMENT AND APPLICATIONS

Volume 2 - Best practices for the Gen II PWR, Gen II BWR L2PSAs. Extension to Gen III reactors

Reference ASAMPSA2
Technical report ASAMPSA2/WP2-3/D3.3/2013-35
Reference IRSN - Rapport PSN-RES/SAG/2013-0177

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ASAMPSA2
BEST-PRACTICES GUIDELINES
FOR L2 PSA DEVELOPMENT AND APPLICATIONS

Volume 3 - Extension to Gen IV reactors

Technical report ASAMPSA2/WP4/D3.3/2013-35

Reference IRSN - Rapport PSN-RES/SAG/2013-0177

This document has been established through collaboration between

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- www.asampsa2.eu

ASAMPSA_E - 7th FP - EC call – November 2012

- Research on best-practices for PSA external events and their combinations
- Identification of low probability events can lead to extreme consequences
- PSA use for decision making in the European context: to take appropriate decisions to reinforce the defence in depth of the plant.
- Nb. of participants : 28 + non EU members in an advisory board (e.g. JANSI (new utility TSO) from Japan, US-NRC, TEPCO)
- Nb. of deliverables (reports): ~35
- 2013 - 2016

Definition used for ASAMPSA_E

- An *extended PSA* (probabilistic safety assessment) applies to a site of one or several Nuclear Power Plant(s) (NPP(s)) and its environment.

- It intends to calculate the risk induced by the main sources of radioactivity (reactor core and spent fuel storages) on the site, taking into account all operating states for each main source and all possible accident initiating events affecting one NPP or the whole site.

ASAMPSA_E

- The ASAMPSA_E project is proposed with the objective to help European stakeholders to develop efficiently such *extended PSA* and verify that all *dominant risks* are identified and managed.

- The scope of the project is EXTREMELY LARGE and covers internal and external hazards. The idea is to have specialists from external hazards (earthquake, flooding …) and PSA working together …

- Comment : we have to recognize that is very ambitious … and develop reasonable approach.

ASAMPSA_E

ASAMPSA_E reflects many concerns which came up in the PSA field after the Fukushima Daïchi disaster:

- Identification of the initiating events (single and correlated), to be taken in consideration in an extended PSA,
- How to introduce hazards in Level 1 PSA and all possibilities of events combination?
- General issues regarding extended PSA scope and applications (e.g. risk metrics, evaluation of defense in depth)
- How to introduce hazards in Level 2 PSA and all possibilities of events combinations?
  (e.g. Impact on Human Reliability Assessment, on possible release)

ASAMPSA_E – Achievements so far

ASAMPSA_E started 2013-07-01, so that only few achievements can be reported:

- For the identification of the initiating events a partner outside the nuclear community takes the lead (University of Vienna):
  Particularly it provides knowledge in paleoseismic science (see next slides).
  Other organizations from non nuclear area will be contacted as far as possible.
- In order to identify all potential initiating events, a seed list with approx. 60 items has been drafted (see next slide).
- A report summarizing ASAMPSA2 experiences has been written in order to guide the activities in ASAMPSA_E.

ASAMPSA_E Hazard Lists

3/5 groups

Code	Hazard
Natural Hazards	
Seismotectonic (earthquake)	
N1	Vibratory ground motion (including aftershock effects)
N2	Vibratory ground motion induced or triggered by human activity (e.g., oil, gas or groundwater extraction, mine collapse)
N3	Surface faulting (fault capability)
N4	Liquefaction
N5	Dynamic compaction (seismically induced soil settlement)
N6	Permanent ground displacement subsequent to earthquake
Flooding and hydrological hazards	
N7	Tsunami (seismic, volcanic, submarine landsliding, meteorite impact)
N8	Local extreme rainfall (note links to other meteorological phenomena)
N9	Floods resulting from snow melt
N10	Flooding due to off-site precipitation with waters routed to the site (including river floods)
N11	High ground water
N12	Flood due to obstruction of a river channel (downstream or upstream) by landslides, ice, jams caused by logs or debris, or vlocanic activity)
N13	Floods resulting from changes in a river channel due to erosion or sedimentation, river diversion
N14	Flood resulting from large waves in inland waters induced by volcanoes, landslides, avalanches or aircraft crash in water basins

Code	Hazard
Natural Hazards	
N16	Flood and waves caused by failure of water control structures and watercourse containment failure (dam failure, dike failure) due to hydrological or seismic effects
N17	Seiche (fluctuation in water level of a lake, sea or any body of water)
N18	Bore (tide-induced and induced by water management)
N19	Seawater level: high tide, spring tide
N20	Seawater level, lake level or river: wind generated waves
N21	Seawater level: storm surge
N22	Seewater lavel: impact of human made structures such as tide breaks and jetteries
N23	Instability of the coastal area due to erosion or sedimentation (sea and river)
N24	Underwater debris

Meteorological events: Extreme values of meteorological phenomena	
N25	Precipitation (rain or snow)
N26	Extremes of air temperature (high and low)
N27	Extremes of ground temperature
N28	Extremes of water (sea, lake or river) temperature
N29	Humidity (high and low), extreme atmoshperic moisture
N30	Air pressure
N31	Extreme drought leading to low river or lake water levels
N32	Low ground water
N33	Snow pack
N34	Icing (including for power lines) (**)
N35	White frost
N36	Hail
N37	Permafrost
N38	Recurring soil frost
N39	Snow melt (see Flooding)
N40	Low seawater level

ASAMPSA_E – Hazard Lists

2/5 groups

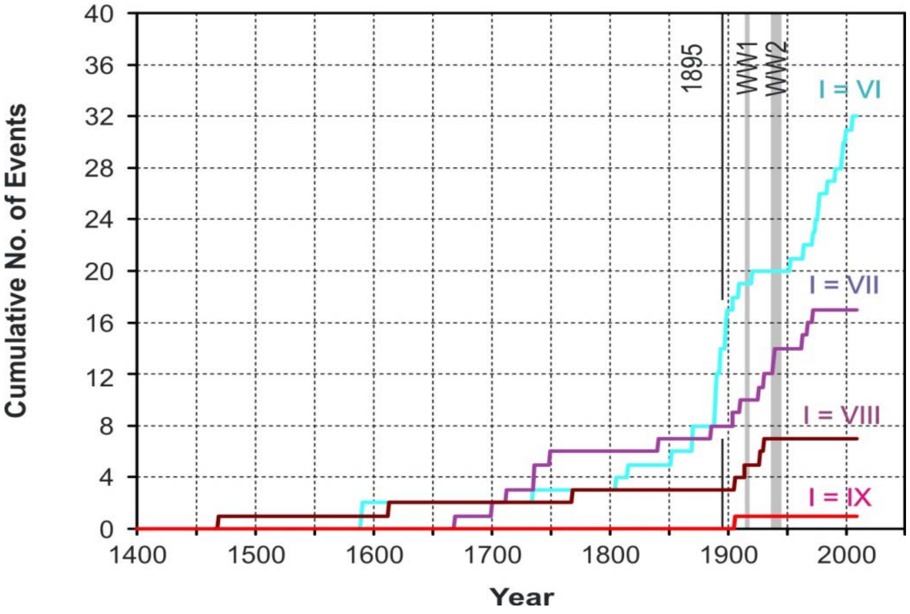
Meteorological events: Rare meteorological phenomena	
N40	Lightning including electromagnetic interference
N41	High wind, storm (including Hurricane, Tropical Cyclone, Typhoon)
N42	Tornado
N43	Blizzard / Snowstorm
N44	Wind blown debris (external missiles)
N45	Sandstorm, dust storm
N46	Saltspray / Saltstorm
N47	Waterspouts
N48	Snow avalanche
N49	Surface ice (rivers, lakes or sea)
N50	Ice flows
N51	Frazil
N52	Mist, fog and freezing fog
N53	Solar flares, solar storms, electromagnetifc interference

Biological / Infestation	
N54	Marine growth (seaweed, altgae), biological fouling
N55	Fish
N56	Jellyfish
N57	Crustaceans, molluscs (shrimps, clams, mussels, shells)
N58	Birds
N59	Airborne swarms (insects) or leaves
N60	Infestation by rodents and other animals

Remarks on Seismic Hazard (1)

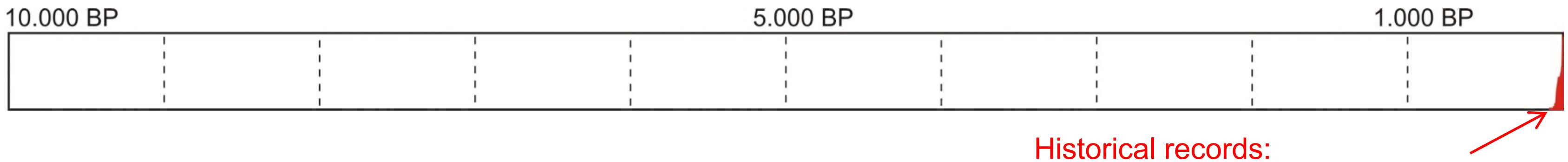
The earthquake record in the Vienna Basin

- First record 1468 AD
- Data not even complete for the 20th century (see world wars I & II impact)
- Many proven active faults did not generate earthquakes in historical times - but in the near future ?



Remarks on Seismic Hazard (2)

- Seismic hazard assessment for very low probabilities („once in 10.000 years“) is seriously challenged by limited and incomplete earthquake data.
- Seismic Hazard assessment needs to extrapolate 10 to 100 times over data coverage:



- Paleoseismological approach will support the assessment
- Observations in the soil provide information on:
  - faults which did not generate earthquakes in historical records
  - potential magnitude of earthquakes due to that fault

ASAMPSA_E – Example of challenges

- The seismic example (which even belongs to the more developed issues) shows the extreme difficulties in assessing external hazards.
- The number of potential hazards (60+) shows the size of the task
- The more impact (internal or external) is on a NPP, the more it will deviate from its normal status
  - Conditions of structures / components which may influence / prevent / mitigate an accident are difficult to evaluate
  - Human actions under extreme conditions difficult to predict
- Only little experience with extended PSA, in particular in PSA L2

ASAMPSA_E – Roadmap

- Early 2014: PSA end-user's opinions will be collected by a questionnaire and an open workshop (March 2014?). Contributions are expected from 50+ stakeholders
- Mid-2014: structure, table of contents and main contributors will be defined for the key reports
- End-2015: final draft of deliverables submitted to end-user's group
- Mid-2016: project ends.